GEORGETOWN COUNTY SHOREFRONT MANAGEMENT PLAN

From Garden City to North Inlet

Prepared for:

SOUTH CAROLINA COASTAL COUNCIL

Prepared by:

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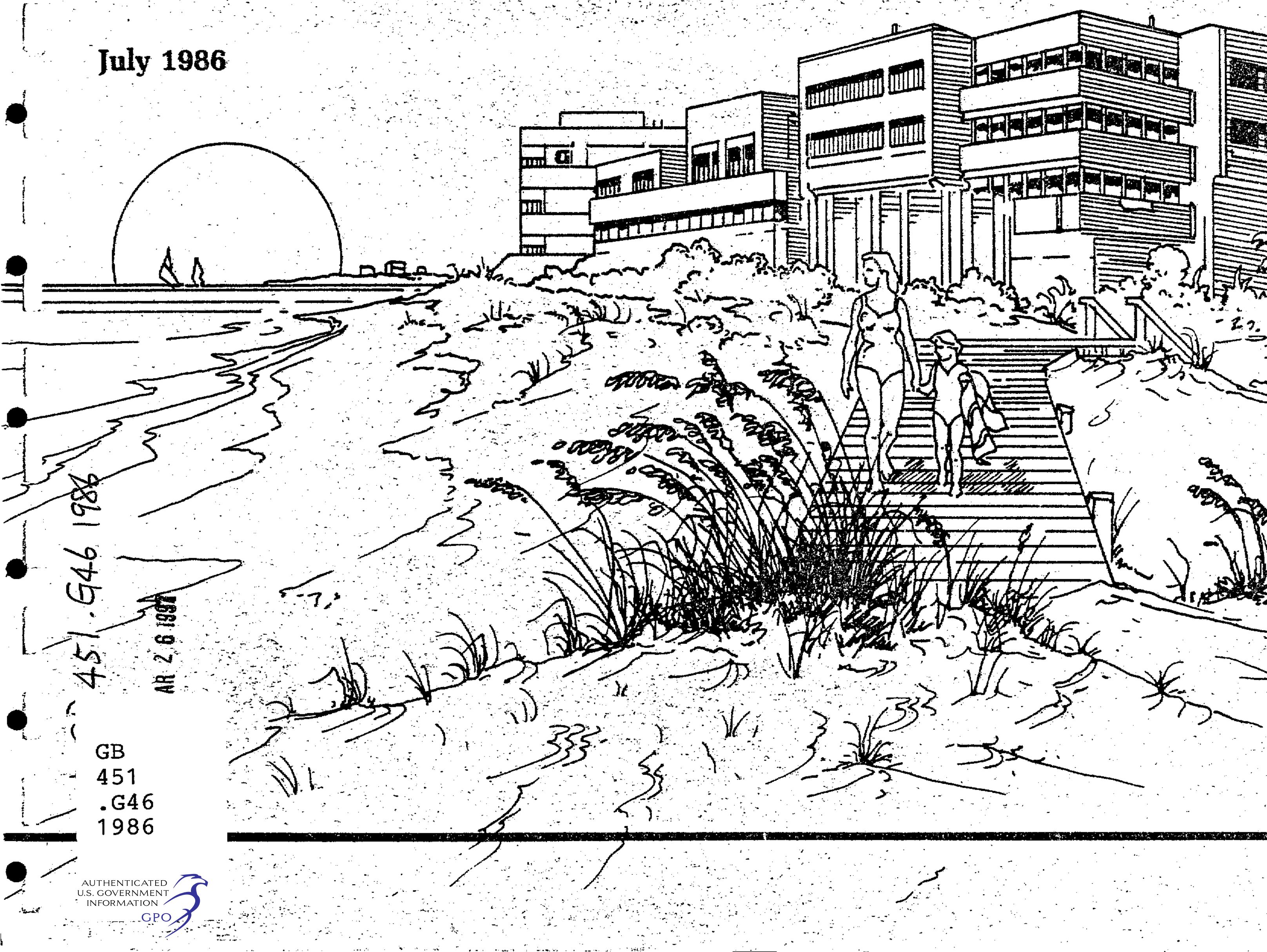


1.0 INTRODUCTION

1.1 PURPOSE

In 1979, the South Carolina Coastal Council completed a comprehensive management program for the eight-county coastal zone within the State. The program was approved by the General Assembly on February 14, 1979 and by the Federal government on September 29, 1979.

Accordingly, the Shorefront Management Plan included within this report specifically addresses the following two major goals formulated in the State plan:

1. The development of a program that will achieve a rational balance between economic development and environmental conservation of natural resources within the shorefront portion of the coastal zone of South Carolina.

2. The development of a permitting system for activities within the dynamic shorefront portion of the coastal zone that will serve to implement the goals and objectives of the management program and promote the best interest of all citizens of South Carolina.

The purpose of the Shorefront Management Plan is to make recommendations suitable for adoption by local government necessary for the protection of beach/dune resources, as well as both future and existing adjacent upland development. Accordingly, this study will address the following three major areas of coastal regulation:

1. Setbacks or similar controls necessary to both insure the long-term integrity of the dynamic beach/dune system and to prevent future development from ultimately being located on the active beach

face as a result of chronic or persistent beach erosion and shoreline recession. In addition, setbacks associated with storm related impacts to the beach/dune system will be discussed.

2. Coastal construction zones within which minimum building standards should be implemented to insure that future major habitable structures are designed to properly accommodate the impacts associated with a 100-year storm event.

3. General erosion control policy guidelines dealing with the consideration of future permits requesting armoring, groins, beach restoration, bulkheads, and other coastal protection structures.

Within the Garden City section of the Georgetown County coastline, the methodologies utilized by this study to recommend building setbacks were similar to the formats developed for comparable studies performed by previous investigators for both Myrtle Beach and North Myrtle Beach. The methodology involves the determination of the ideal present shoreline (IPS) and the identification of the 25- and 50-year future dune crest based upon both the IPS and known rates of erosion or accretion (Kana, et al). This technique is based upon the long-term extrapolation of average annual rates of volume change in the beach face. South of Murrells Inlet within the remainder of the study area, long-term recession predictions were made on the basis of comparisons of historical beach profile surveys and/or shoreline and inlet change maps available from reliable sources.

Neither of these two approaches, however, account for short-term and typically more severe erosional effects associated with low-frequency storm events (i.e. severe northeasters, tropical storms and hurricanes). For that reason, a separate computer analysis has been included which simulates the erosion of the ideal present profile (IPP) during the occurrence of the 25- and 50-year storm. The latter can be expected to have an annual probability of occurrence of .04 and .02, respectively. A 25-year storm, for example, is an event that statistically would be expected to occur once in 25 years, on the average.

1.2 STUDY AREA

Located within the Grand Strand, the study area along the Georgetown County Coastline extends from a point 3.4 miles north of Murrells Inlet south to North Inlet, a total shoreline length of approximately 18 miles. From north to south, the areas investigated include a portion of Garden City, all of Litchfield Beach and Huntington Beach State Park, Pawley's Island and Debidue Beach. These four areas are each separated by a tidal inlet. Figure 1.2-1 shows the general location of the study area. Located between Garden City and Huntington Beach State Park, Murrells Inlet was structurally stabilized by the COE in 1979. Midway Inlet, Pawley's Inlet and North Inlet are located along the southern limits of Litchfield Beach, Pawley's Island and Debidue Beach, respectively. From Little River Inlet, the Grand Strand coastline follows a general arc to North Inlet at the southernmost point.

Extreme variability in development pressures, including both development patterns and density, exists between Garden City and Debidue Island. As the coastline population has grown, the worth of South Carolina's beaches to the local and state economy has become considerable. It should continue to increase as long as adequate sandy beaches suitable for recreation are preserved and maintained.

Specific stretches of Georgetown County's shoreline are

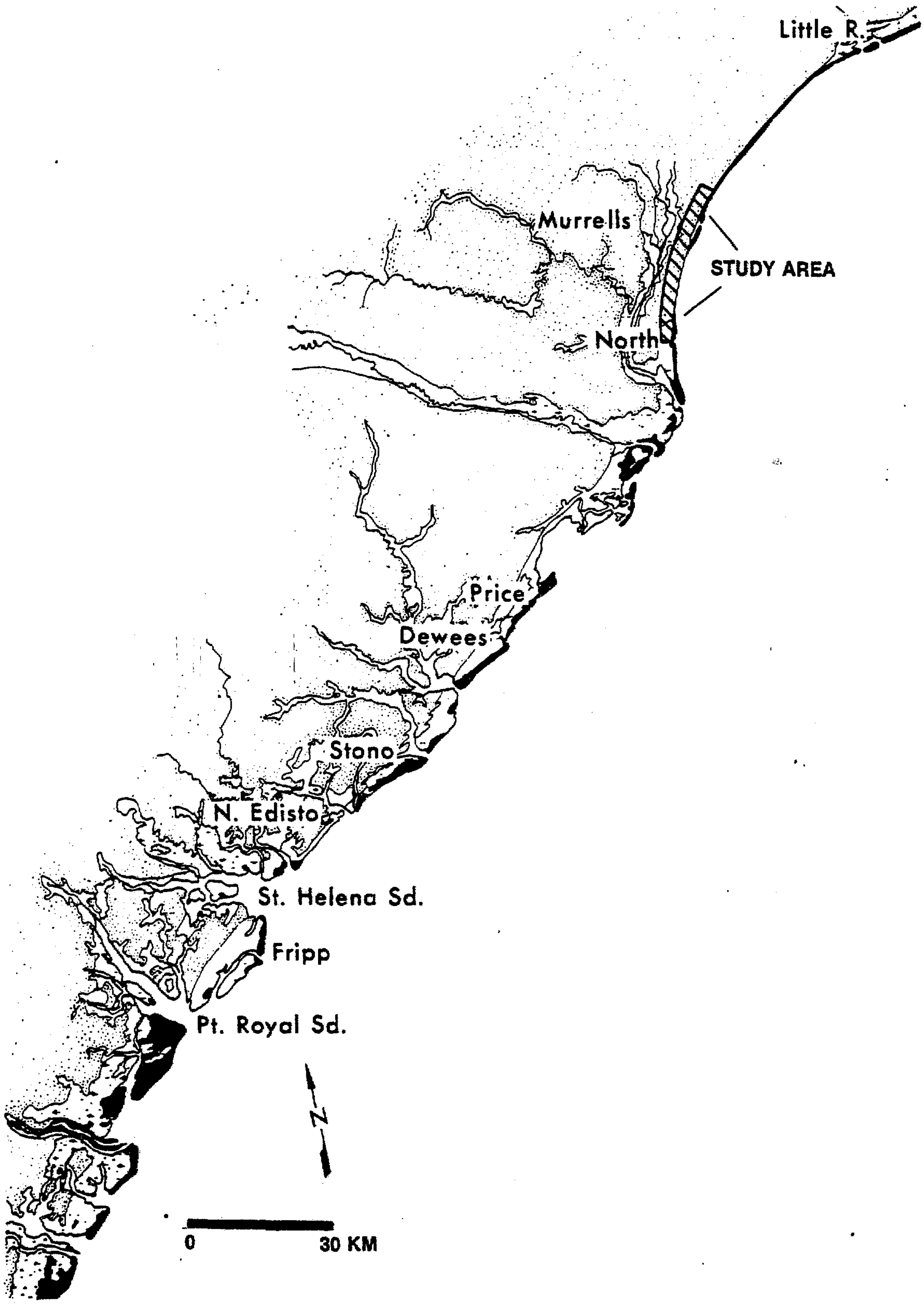


FIGURE 1.2-1
STUDY AREA LOCATION MAP

migrating as the result of long- and short-term local variations in sand supply, shoreline orientation and the proximity to inlets and shoreline structures. The effects of sea-level rise on shoreline recession is relatively uniform along the coastline and is a cause of irreversable net offshore sediment transport. Long-term shoreline recession trends indicate the shoreline within the study area has experienced a net average landward movement.

Clearly, the greatest man-induced causes of shoreline instability are the results of shoreline hardening and inlet improvement and stabilization projects. Problems associated with the dynamic state of natural inlet channels are commonly magnified by dredge spoil disposal practices and the construction of inlet jetties. The Murrells Inlet stabilization project, completed in 1980, has substantially altered sediment transport in the nearshore area along adjacent beaches. The Georgetown County areas of Litchfield Beach and Huntington Beach State Park, extending 6.8 miles south of the Murrells Inlet jetties, have experienced significant shoreline accretion and erosion at various locations following the jetties' construction.

Beach and offshore erosion is a condition that occurs along the majority of Georgetown County's coastal areas. Erosional impacts on shoreline development are most directly related to the demand for shoreline armoring. In general, this area has had moderate increases in both soft and hard shoreline protection measures such as seawalls, groins, rip-rap, sand bags, beach scraping, dune restoration and revegetation, sand fences and limited beach renourishment.

Groins, piers and jetties are manmade structural barriers, each of which interrupts the natural sand transport across the nearshore littoral zone. Net sediment transport along the county's coastline is generally southward, with periods of large reversals toward the north caused by variations in wave climate. The magnitude and direction of the longshore currents, created by waves breaking at an angle to the coast, determine sand transport along the coastline.

1.3 PREVIOUS STUDIES

Recent investigations of the Georgetown County shoreline have focused on the Pawley's Island and Debidue Beach shorefront developments. Erosional impacts on the county's coastal population is of considerable concern when developing and implementing viable shorefront management policies. Accordingly, shoreline data representing all coastal areas were collected, compiled, and reviewed with regard to quality and quantity to identify the needs for additional data. Previous data collection efforts and a review of Georgetown County's earlier shoreline studies are summarized below.

An early field investigation that included the Garden City shoreline area was conducted in 1955 by the Corps of Engineers (Charleston District) to document post-hurricane beach profile response. Beach profiles were established and surveyed to approximately 2.0 feet below MSL (1929 NGVD). The COE estimated erosion rates following the occurrence of Hurricane Hazel as great as 52 cubic meters per meter at Myrtle Beach (COE Reconnaissance Report, 1983). In a 1983-84 field reconnaissance effort for a report of recommended beach erosion control and hurricane protection measures (March 1984), the COE resurveyed the shoreline areas from North Myrtle Beach to Garden City and established additional transects along this shoreline.

In another beach erosion study (Hubbard et al, 1977), both navigation charts and aerial shoreline photography were analyzed to estimate linear short- and long-term erosion rates. Based on 25 to 100 years of successive shoreline data, they concluded that long-term erosion rates are in the range of 1-3 feet/year with the exception of areas adjacent to tidal inlets and shoreline stabilization structures. They qualitatively described short-term stability as directly dependent on the number and intensity of extratropical and tropical storms occurring for a particular number of years.

After construction of two jetties at Murrells Inlet in 1977, the Corps of Engineer's Coastal Engineering Research Center (CERC) began a formal study to monitor the effect of the Murrells Inlet navigation project on both the inlet and the adjacent beaches. The Phase I monitoring program provided for quarterly surveys along 43 transect lines between 1979 and 1982. The scope was then reduced to Phase II field surveys to monitor 18 transects semi-annually through October 1987.

The Murrells Inlet Monitoring Study provides valuable data to assess the effects of inlet stabilization on long- and short-term shoreline fluctuations for the Garden City and Huntington Beach/Litchfield Beach areas. This investigation is the most comprehensive study conducted within the study area, which includes a 10-year program for the continuous collection of coastal data. CERC's digitized survey data was acquired for comparative shoreline analysis in the Georgetown County study area.

The COE published an interim report (March 1985) to highlight and summarize their findings, particularly detailing those areas that are presently experiencing the greatest change. The following shoreline changes were noted:

1. Significant growth of the ebb tidal shoal extending seaward of the approximately 3400 foot long jetties.

2. Extreme erosion rates in a region between 2.5 and 3.5 miles south from the jetties.

3. The accretion of large volumes of sand on the south shoreline adjacent to the south jetty.

Preliminary results from the analysis of wave and directional current data suggest the directions of longshore sediment transport are variable in the vicinity of the jetties, while the sheltering effects of the jetties allow minimal southerly transport within an area 2.0 miles south from the jetties.

Cubit Engineering (1981) conducted a study of limited scope for Pawley's Island which addressed general coastal processes, shoreline variability specific to Pawley's Island and recommendations for potential alternatives to shoreline maintenance. In this study, 12 beach profiles were surveyed over some three miles of island shoreline. Field notes providing station documentation and actual profile data were obtained from Cubit for replication in this study. Conclusions presented by the Cubit study acknowledged Pawley's Island has experienced a high degree of shoreline variability adjacent to both inlets. A chronological analysis of inlet migration indicates that Midway Inlet migrated south between 1872 and 1934, after which this trend reversed to the position of the entrance channel at its present position. A terminal groin (685 ft) was constructed on the south bank along the inlet in the 1950s and has been effective in preventing further migration of the inlet entrance channel. Deposition of southerly littoral drift appears to have resulted in the cyclic migration of both the

Pawley's and Midway Inlet channels to the south, with subsequent recutting to the north or breaching during storms. Analysis of shoreline movement at Pawley's Inlet for the period from 1872 to the mid-1960's indicate that this inlet had migrated south a nominal 6500 feet. Barrier crest elevations are generally low (8-15 feet) with significant probability for flooding during low-frequency storms.

In a 1976 investigation, the Clemson University Department of Forestry measured shoreline fluctuations using aerial photographs for approximately 10-year intervals between 1939 and 1975. Six stations were established along the southern end of Debidue Island adjacent to North Inlet to measure historical shoreline movements. Based on these maps, they summarized that the southern spit migrated south, accreting 1800 meters between 1872 and 1939 and is presently eroding. These erosion rates vary between 6 and 11 feet/year over the period from 1963 to 1975.

A 1975-76 investigation of North Inlet was conducted by the COE-CERC to evaluate the hydraulics and dynamics of a natural tidal inlet. Over a two-year period from July 1974 to June 1976, intensive field studies were undertaken to collect a wide range of physical data.

Channel hydrography data, longshore current velocities, wind data, visual wave data and bathymetric and beach profile data were collected to evaluate inlet dynamics. In addition, three tide gages were installed to provide continuous water surface records in the vicinity of the inlet. The study focused on the analysis of 1) inlet hydraulics, 2) longshore currents adjacent to the inlet, and 3) seasonal morphology of North Inlet's tidal shoals and adjacent beaches.

The authors concluded North Inlet is hydraulically ebb-tidal dominant, longshore currents are primarily controlled by wind-stress, and the exchange of sediments between the inlet channels and adjacent beaches suggests a distinct seasonal pattern in response to both high-energy conditions and seasonal changes in MSL.

In 1985, Research Planning Institute (RPI) conducted a preliminary assessment of three development tracts along Debidue Island. The scope of this study included an analysis of historical shoreline movement, estimates of long-term shoreline trends based on historical shoreline maps, identification of environmentally sensitive areas, and a review of state and federal development restrictions with recommendations for areas of preservation and development. Conclusions of the RPI study acknowledged the extreme shoreline variability along the southern reaches of Debidue and the relative shoreline stability of the beach segment north of the Debidue Colony Seawall.

Maps of historical shoreline changes in the Georgetown County area are based on shoreline field surveys and vertically controlled photography compiled in a cooperative shoreline movement study by the National Ocean Service (NOS) and the Corps of Engineers Coastal Engineering Research Center (CERC). Shoreline positions were mapped beginning in 1872 and are compared with subsequent survey data of 1926, 1934, 1962-63 and 1983.

1.4 PRESENT STUDY

The objective of the present study is to formulate a comprehensive shorefront management plan based on an understanding of existing shoreline conditions specific to each coastal area. To provide background information, data collection efforts include the following control data:

1. Land use data,
2. Tide data,
3. Wind data,
4. Storm data,
5. Wave data,
6. Aerial photographs,
7. Historical shoreline movement data,
8. Inventory of major coastal structures and beach nourishments,
9. Sediment data,
10. Beach profile data,
11. Floodplane maps, and
12. Existing coastal management practices in the study area.

Shoreline data were evaluated in depth and the need for further data acquisition were identified. The present project initiated a comprehensive shorefront monitoring program to address the need for additional data. The monitoring efforts included:

1. Establishing fifty-six survey stations along the Georgetown County shoreline; each station control point consisted of a permanent benchmark and a survey monument. Vertical elevations of these benchmarks were surveyed by professional surveyors, and carefully documented so that the data from future surveys can be replicated with confidence using the new control reference points.

2. Beach profiles were measured at each monitoring station in April 1986. The profile transects commenced landward of the primary dune and offshore

to the -3 ft (mean sea level datum) wherever possible.

3. Sediment data were collected at 21 monitoring stations.

4. An extensive field investigation was conducted to document the existing shorefront condition and coastal structures including seawalls, bulkheads, rip-rap, groins, jetties, and stormwater discharge structures.

Using the historical information and the recently collected site specific data, the following analysis was conducted:

1. Development patterns were evaluated.

2. Sediment grain size analysis was conducted to provide sediment statistical parameters to provide essential information for estimating littoral processes and future beach nourishment design.

3. Volumetric changes of beach sand were computed using comparative beach profile data.

4. Short-term erosion rates were computed based on the mean high water contour movement derived from comparative beach surveys.

5. Long-term erosion rates were estimated using the historical shoreline maps. This shoreline recession rates, were subsequently used to predict 25 and 50 year future shoreline.

6. Ideal present profiles were established.

7. The storm impact zones were calculated by computer model simulation.

8. The inlet dynamics were assessed for Murrells Inlet, Midway Inlet, Pawley's Inlet, and North Inlet.

Upon examining the pertinent information and the results of the analyses, a comprehensive shorefront management plan was recommended. A similar study was conducted for Horry County shoreline concurrently with the present study for Georgetown County.

2.0 LAND USE

2.1 EXISTING LAND USE

The study area covers most of the coastal region of Georgetown County except North, South and Cedar Islands. It lies within the Waccamaw Neck, a region delineated as one of the six major planning areas in Georgetown County. The Waccamaw Neck is bordered on the north by Horry County, on the west by the Waccamaw River/Intracoastal Waterway, on the south by Winyah Bay and on the east by the Atlantic Ocean. The following presentation of the land use data is extracted from the land use plan prepared for the Waccamaw Neck by the Georgetown County Planning Commission (1985). It closely represents the development in the study area as most of the development in the Waccamaw Neck is concentrated within the immediate coastal area.

The first attempted Spanish settlement on this continent was made on Waccamaw Neck in 1526 near the Bellefield House within the Hobcaw Barony. In the nineteenth century, rice plantations dominated the land use in the Waccamaw Neck. In the 1840's almost half of the rice produced in the United States was grown on the plantations in Georgetown County. By the turn of the twentieth century, however, commercial production of the rice in the county had nearly ceased due to the loss of slave labor and the competition from mechanized farms in the southwest. Rice production was replaced by the timber industry which has dominated land use in Waccamaw Neck for several decades.

Presently, Waccamaw Neck plantations are being transformed into residential communities for permanent and seasonal residents. Because of the abundant natural amenities, tourism has assumed a major role in the economy of the area. The tourist attractions include Brookgreen Gardens, Pawley's Island, Huntington Beach State Park, and numerous resort developments in the area. Murrells Inlet has become one of the favorite places to enjoy seafood along the Carolina coast.

Population

While most of Georgetown County has experienced a modest increase in population, that of the Waccamaw County Census Division (CCD) has grown at a much faster rate -- at least three times faster than the other CCD's. Table 2.1-1 presents the population and socio-economic data for the Waccamaw Neck. A unique characteristic of the Waccamaw Neck population, as illustrated by Table 2.1-1, is its variability. Because the area is a popular summer resort, the peak population during summer season can be 4 to 5 times larger than the permanent population. These seasonal influxes causes severe strains on service delivery systems such as potable water, sewer and electricity.

The 1980 Waccamaw Neck population was 6,513 people. Of this total, 70% were white and 53% were male. The mean family size was 3.6 persons/family. The average household size was 2.7 persons. Median household income was $14,938 and per capita income was $7,343. The retail trade, professional services and entertainment provide the bulk of the employment opportunities in the Waccamaw Neck.

Land Use

The Waccamaw Neck consists of approximately 51,504 acres and only 7% of it was developed as of 1985. Considering the existing development, land held in public trusteeship (Brookgreen Garden, Huntington Beach State Park, etc.), and wetlands unsuitable for development, only 17,467 acres are available for future development. For the purposes of land use survey, the Waccamaw Neck can be divided into four areas: Murrells Inlet/Garden City Point, Litchfield, Pawley's Island, and Arcadia/Hobcaw. Table 2.1-2 summarizes

Table 2.1-1. Waccamaw Neck Socio-Economic Data, 1980-2005.

	1980	1985	1990	1995	2000	2005
Permanent Population	6,523	9,138	11,913	14,024	16,295	18,910
Employment	2,838	3,976	5,184	6,103	7,091	8,229
Dwelling Units	4,792	6,713	8,752	10,303	11,971	13,892
School Enrollment	1,625	2,276	2,967	3,493	4,058	4,709
Auto Registration	3,480	4,875	6,356	7,482	8,693	10,088
Peak Population*	30,156	38,985	51,725	64,902	78,969	93,385

*Includes permanent population, seasonal overnight tourists and day visitors.

Source: Waccamaw Regional Planning and Development Council, <u>Horry and Georgetown Counties Socio-Economic Data by Study Periods Each Five Years, 1980-2005</u>

Table 2.1-2. Existing Land Use for Waccamaw Neck.

Land Use Category	Murrells Inlet Garden City Point	Litchfield	Pawley's Island	Arcadia Hobcaw	Total
Single-Family Residential	623	379	679	89	1,770
Multi-Family Residential	40	91	19	20	170
Residential Subtotal	663	970	698	109	1,940
Commercial	88	62	81	0	231
Public/Semi-Public	34	46	76	2	158
Golf Courses	139	349	326	101	915
Other Public Uses	7,664	276	0	15,671	23,611
Streets	325	249	300	54	928
Wetlands	2,960	1,589	1,593	13,155	19,297
Vacant or Undeveloped Land	3,342	3,072	4,314	6,739	17,467
TOTAL ACERAGE	13,575	6,105	7,387	24,437	51,504

Source: Waccamaw Regional Planning and Development Council, Field Survey, June, 1985.

the existing land use in each area under nine categories: single family residential, multi-family residential, commercial, public/semi-public, golf courses, other public uses, street, wetlands, and undeveloped land.

Murrells Inlet/Garden City Point

Garden City Point is a long and narrow peninsula, about 3.7 miles in length surrounded by the ocean and tidal marshes. It has been developed to the point that, as of 1985, less than 9% of the developable land was vacant in Garden City Point. Major problems currently associated with development in Garden City Point are access and sewer capacity. Waccamaw Drive is the only access road running the entire length of the Point, and the closest access from U.S. 17 is via Atlantic Avenue, about 3 miles north of the southern tip of the peninsula. The nearest fire station in Murrells Inlet is about 6 miles from the peninsula tip.

Litchfield

Huntington Beach State Park occupies the northern portion of the area between Murrells Inlet and Midway Inlet. The rest of the coastal area consists of three major developments: North Litchfield; Litchfield By The Sea; and South Litchfield. The principal land uses in this area are single-family residential and low-density multi-family resort development. Similar to Garden City Point, the access to the coastal area is also limited.

Pawley's Island

Pawley's Island has only 5 acres of vacant land available for future development which is about 3% of the total developable land. The primary problem associated with development in this area is the lack of a central sewage collection system.

Arcadia/Hobcaw

The Belle W. Baruch Nature Preserve, donated to the State of South Carolina for wildlife and marine research, is located at the southern end of Debidue Island. Immediately north of the Belle W. Baruch Nature Preserve is a low-density residential development, the DeBordieu Colony. The northern portion of Debidue Beach is occupied by the Arcadia Plantation and is presently undeveloped.

2.2 FUTURE LAND USE

As the population of the Waccamaw Neck increases, additional land will be needed for residential, commercial, public/semi-public and other various uses. According to the development growth trend, a future land use was projected by the Waccamaw Regional Planning and Development Council in accordance with zoning ordinances and development standards established by Georgetown County. The future land use projection is shown in Table 2.2-1.

Table 2.2-1. Future Land Use - Waccamaw Neck Totals.

Land Use Category	Acerage Needed 1990	1995	2000	2005	TOTAL
Residential					
Single-Family	618	451	451	590	2,110
Multi-Family	86	88	131	160	465
TOTAL	704	539	582	750	2,575
Commercial	70	53	57	66	246
Public/Semi-Public	48	37	39	45	169
Streets*	123	94	102	129	448
TOTAL ACERAGE	945	723	780	990	3,438

*Assumed average for streets was 15% of projected developed acerage

Source: Waccamaw Regional Planning and Development Council, 1985.

3.0 BACKGROUND INFORMATION AND DATA COLLECTION

3.1 TIDES

Tidal data have been collected by the National Ocean Survey (NOS) at four open-coast gages in the vicinity of the study area over the last 30 years. North to south, these locations include Hog Inlet Pier, Myrtle Beach Pier, Springmaid Pier and Pawley's Island Pier. The gage at Myrtle Beach Pier was operational between 1957 and 1978, with subsequent installation at Springmaid Pier for the period 1978 through 1982. The longest continuous tidal records are for the primary gage at Charleston and cover the period from 1920 to the present. Using spectral and harmonic analyses, these tidal data obtained at the Charleston and local gage locations require correlation for the computation of statistical parameters such as local daily MHW, MLW, tidal variation along the coastline (phase lag) and the rise in mean sea level.

Analyses of tidal data is completed on a periodic 19-year cycle, termed a Tidal Epoch. The tide gage installed at the Myrtle Beach Pier measured a rise in mean sea level equal to 0.34 feet between 1929 (NGVD-MSL) and the 1941-59 Tidal Epoch. Mean sea level increased an additional 0.13 feet between the 1941-59 and the 1960-78 Tidal Epoch along the gage stations adjacent to both Georgetown and Horry Counties. This translates into a 5.6-inch rise in sea level for the last 49 years in this coastal location.

A recent study conducted by the U.S. Environmental Protection Agency (EPA,1983) predicts a possible sea-level rise of 1 foot over the next 30 to 40 years and 3 to 5 feet over the next 100 years (Figure 3.1-1). This rise in sea-level will subject areas currently flooded in a 100-year storm event to extreme flooding during higher frequency events, particularly in coastal areas characterized by low barrier-crest elevations.

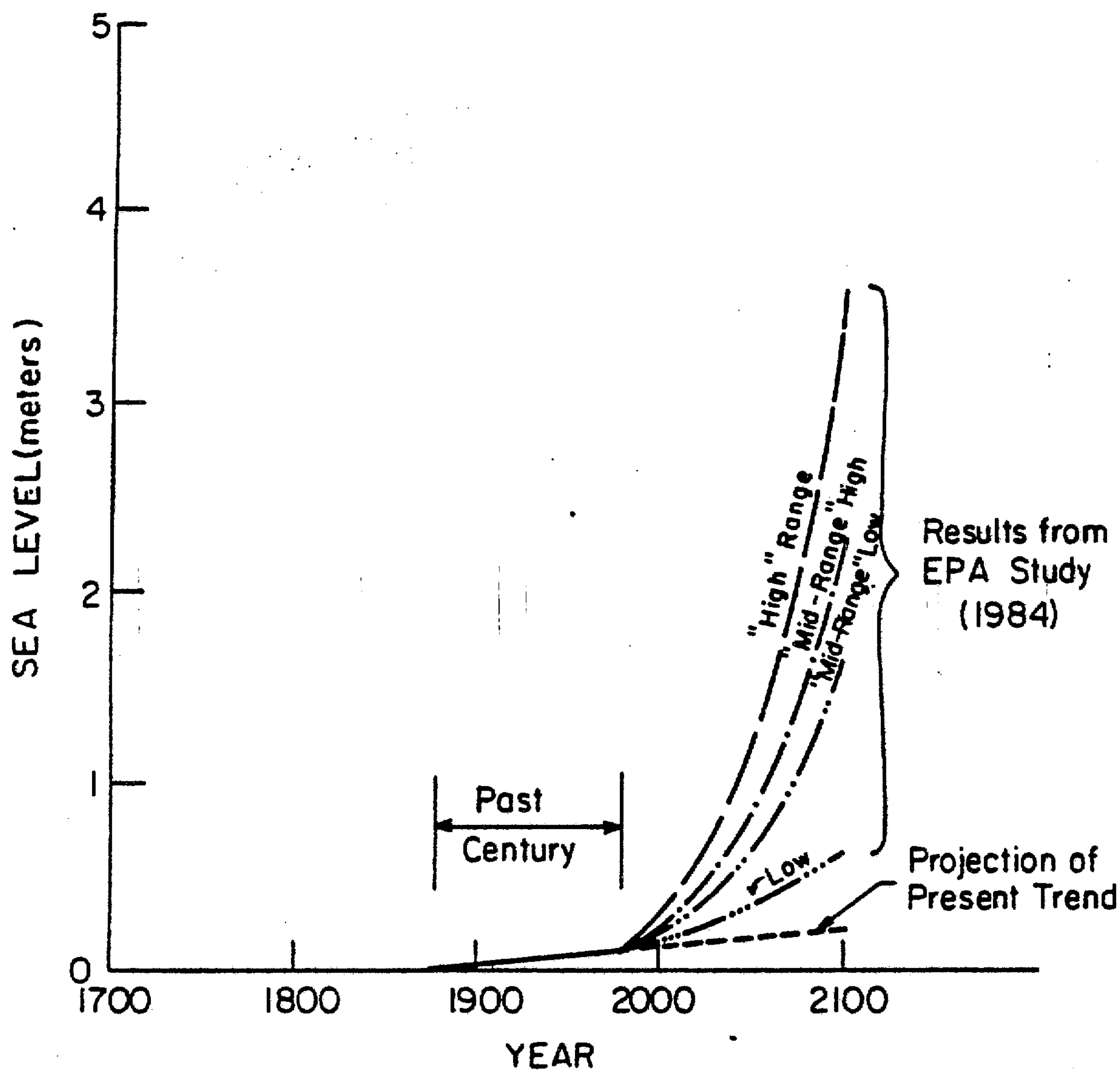


FIGURE 3.1-1
SEA-LEVEL RISE OVER THE LAST CENTURY AND PROJECTIONS BASED ON A RECENT EPA STUDY (EPA, 1983)

Records of water-level variation obtained from tide gages often include water elevations associated with storm tides, which are valuable for predicting flood elevations. Extreme storm-generated fluctuations in water-surface elevations over the last Tidal Epoch (1951-1978), including astronomical tides, are shown in Table 3.1-1. These are derived using data obtained at the Charleston gage and corrected for estimates of water-surface levels at the local gages within the study area.

3.2 WIND

A wind-rose diagram, indicating average annual occurrence of both wind speed and direction, is shown in Figure 3.2-1. This diagram was derived from wind information for the period 1942-1972 as observed at the U. S. Air Force Base at Myrtle Beach (U.S. Air Force, 1975) and may be considered representative of conditions throughout the study area. In-depth analysis of similar data presented for each month over the period 1942-1972 indicates the predominance of NNE winds during the fall months (October-December). This corresponds to the more frequent occurrence of northeasters and associated higher levels of wave energy resulting in net southerly sediment transport, as well as more noticeable beach erosion observed during this period.

Similar analysis indicates the predominance of southerly winds during the summer months (April-August) corresponding to net northerly sediment transport and a gradual rebuilding of the beach by the longer, lower frequency summer waves. The months of October and November have the lowest average wind speeds (5.2 ft/sec) and the greatest occurrence (over 20%) of calm periods (winds less than one knot). Table 3.2-1 lists average wind speeds and directions on a seasonal basis as measured at the Myrtle Beach Air Force Base. The shoreline orientation of the study area varies

TABLE 3.1-1. Tidal Elevation Along Horry And Georgetown County Coast

	TIDAL ELEVATION (FEET)				
Location	MHW	MLW	MSL	HHW*	LLW**
Hog Inlet Pier	5.00	0.00	2.50	10.00 MLW	-3.5 MLW
Myrtle Beach	5.10	0.00	2.55	14.00 MLW	-2.5 MLW
Springmaid Pier	5.25	0.20	2.72	8.50 MLLW	-3.0 MLLW
Pawley's Island Pier	4.91	0.00	2.45	10.00 MLW	-3.5 MLW

*Estimated highest high water observed based on extreme water levels at Charleston, SC..
**Estimated lowest low water observed.

Source: NOAA-NOS, 1986

AVERAGE WIND ROSE FOR 1942-1947 &1949-1972 AT MYRTLE BEACH, SOUTH CAROLINA

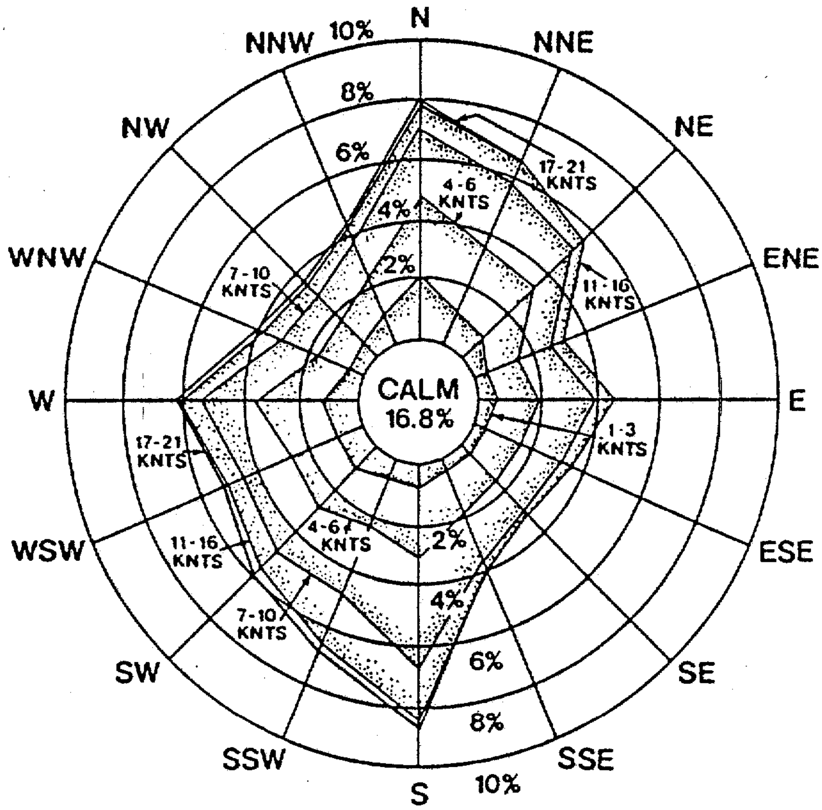


FIGURE 3.2-1
WIND ROSE AT MYRTLE BEACH, SOUTH CAROLINA

Table 3.2-1. Seasonal Mean Local Wind Speed Versus Wind Direction Given in Miles Per Hour (Measured at the Myrtle Beach Air Force Base).

	Wind Direction						
Season	ENE	E	ESE	SE	SSE	S	SSW
Jan-Mar	8.77	8.60	8.06	7.23	7.76	9.04	10.26
Apr-Jun	8.79	9.12	8.63	8.09	8.52	9.77	10.37
Jul-Aug	7.82	8.08	8.09	7.35	7.99	9.23	9.67
Sep-Dec	7.73	7.68	7.25	6.53	6.96	7.83	8.87

approximately 45° from an ENE-WSW orientation at the north end to a NNE-SSW orientation at the south end. As a result, wind from a particular direction will have a different bearing relative to the shoreline at different locations over the study area.

3.3 STORM DATA

The most severe hurricanes-of-record to affect Georgetown County struck the coast in 1822, 1854, and 1954. Hurricane Hazel (1954), characterized as a low-frequency storm produced peak storm tides of 6.0 to 10.0 feet along portions of the Georgetown County shoreline. Horry County was severely impacted by Hazel's 15.5 ft storm tides along Myrtle Beach and it was classified as a low-frequency 100-year return-interval storm event (COE, 1983).

Horry and Georgetown County have been adversely affected by significantly less severe hurricanes, the most recent being Hurricane David in 1979. The most recent significant hurricanes which made landfall along the South Carolina Coast are presented in Figure 3.3-1. High-frequency storms, referred to as northeasters, also produce a storm tide or super-elevation of the ocean that allows the propagation of greater wave heights onto the beach-dune face, often resulting in significant beach-dune erosion, vegetation loss and structural damage.

Often these more-frequent storms, which can severely impact the beach-dune system, are not well documented. During hurricanes, tropical storms and northeasters, the characteristic physical processes (current magnitude and direction, wave conditions, and sediment transport) in the nearshore zone may be drastically altered, resulting in the transport of large quantities of sand both offshore and along the coast. In addition, unstabilized inlets can be expected to undergo accelerated migration.

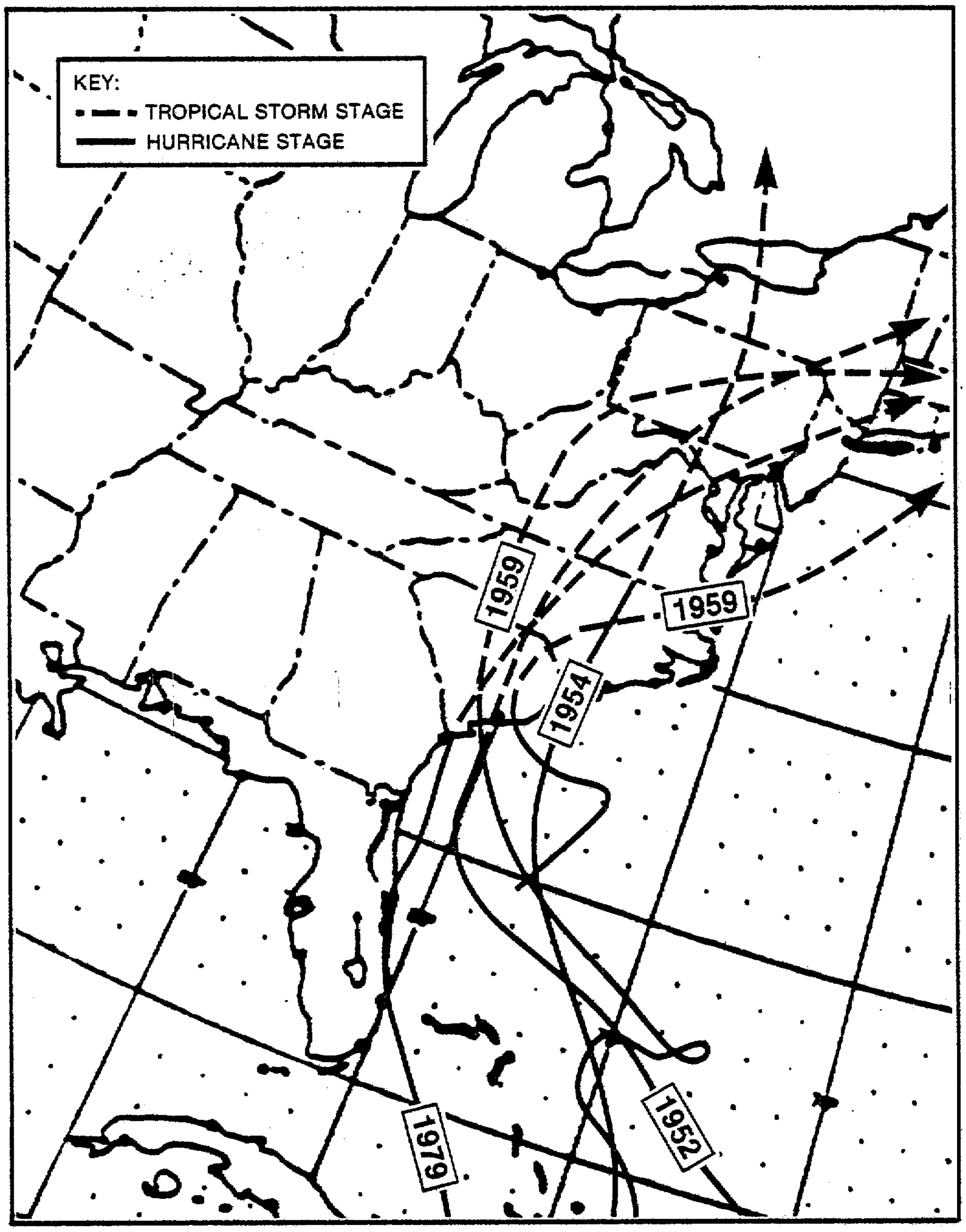


FIGURE 3.3-1
HURRICANE TRACKS FOR STORMS
IMPACTING THE SOUTH CAROLINA COAST
FROM 1952 TO 1979

Historically significant hurricanes that have tracked in relatively close proximity to the northern portion of the South Carolina coast have been analyzed by FEMA to determine site-specific hurricane characteristics. These historical storm parameters were applied for the estimation of future probabilities of the recurrence of flood conditions for the purpose of issuing flood insurance.

A statistical analysis of historical hurricane records along the Horry and Georgetown County and adjacent coastline areas was interpreted in a 1983 FEMA study to forecast the probable future incidence of a hurricane event. Relative to the Horry and Georgetown County shoreline orientation, 33° east of north, hurricanes were classified by their landfalling characteristics. Based on this analysis of documented tropical storms and hurricanes, the FEMA study (1983) estimates that 136 landfalling, exiting and alongshore storms can be expected to track within 150 nm of a point along the Georgetown County coast every 100 years. Figures 3.3-2 and 3.3-3 present storm tracks for hurricanes impacting the South Carolina coastline between 1883 and 1920.

A circle of radius equal to approximately 150 nm., whose locus is the center of Georgetown and Horry counties coastal segment defines the area where hurricane crossings could impact the Georgetown County coastal areas (Figure 3.3-4). Hurricanes tracking within 150 nm. of the coastline are designated as alongshore. Table 3.3-1 is a summary of the probability of occurrence of storm orientation reported in the 1983 FEMA study, using historical hurricane tracks for a 150-nm radius of the study area.

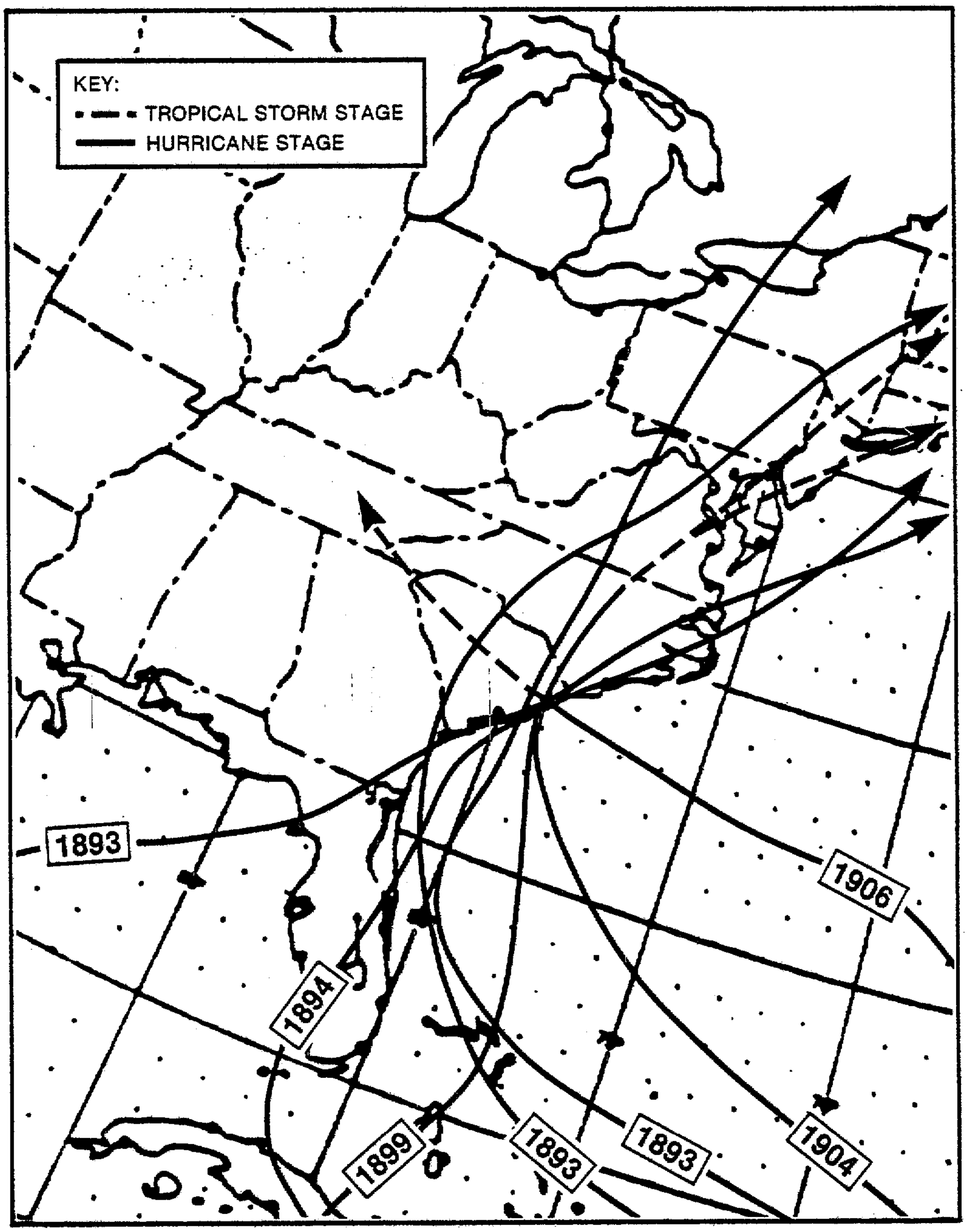


FIGURE 3.3-2
HURRICANE TRACKS FOR STORMS
IMPACTING THE SOUTH CAROLINA COAST
FROM 1883 TO 1906

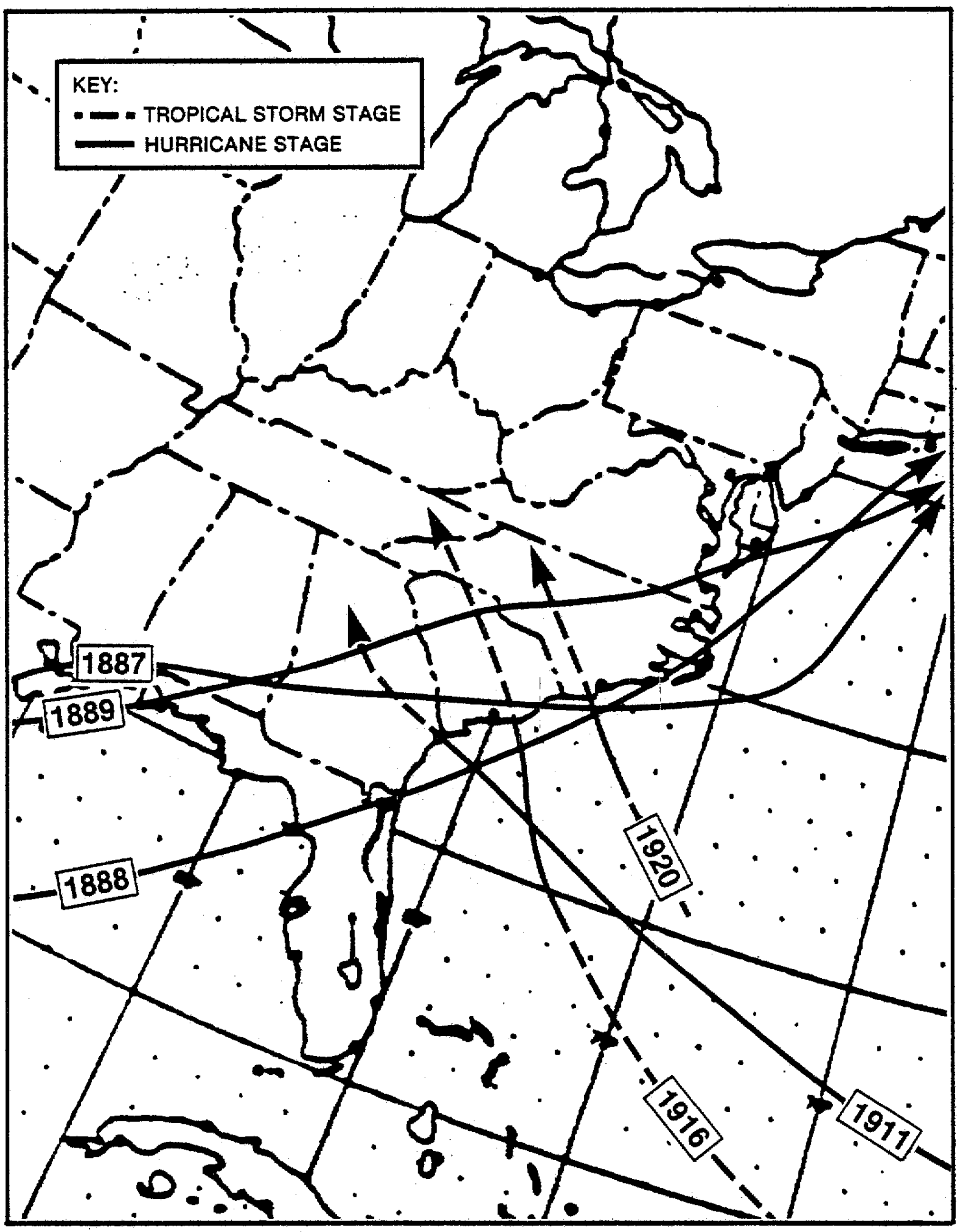


FIGURE 3.3-3
HURRICANE TRACKS OF STORMS IMPACTING THE SOUTH CAROLINA COAST FROM 1887 TO 1920

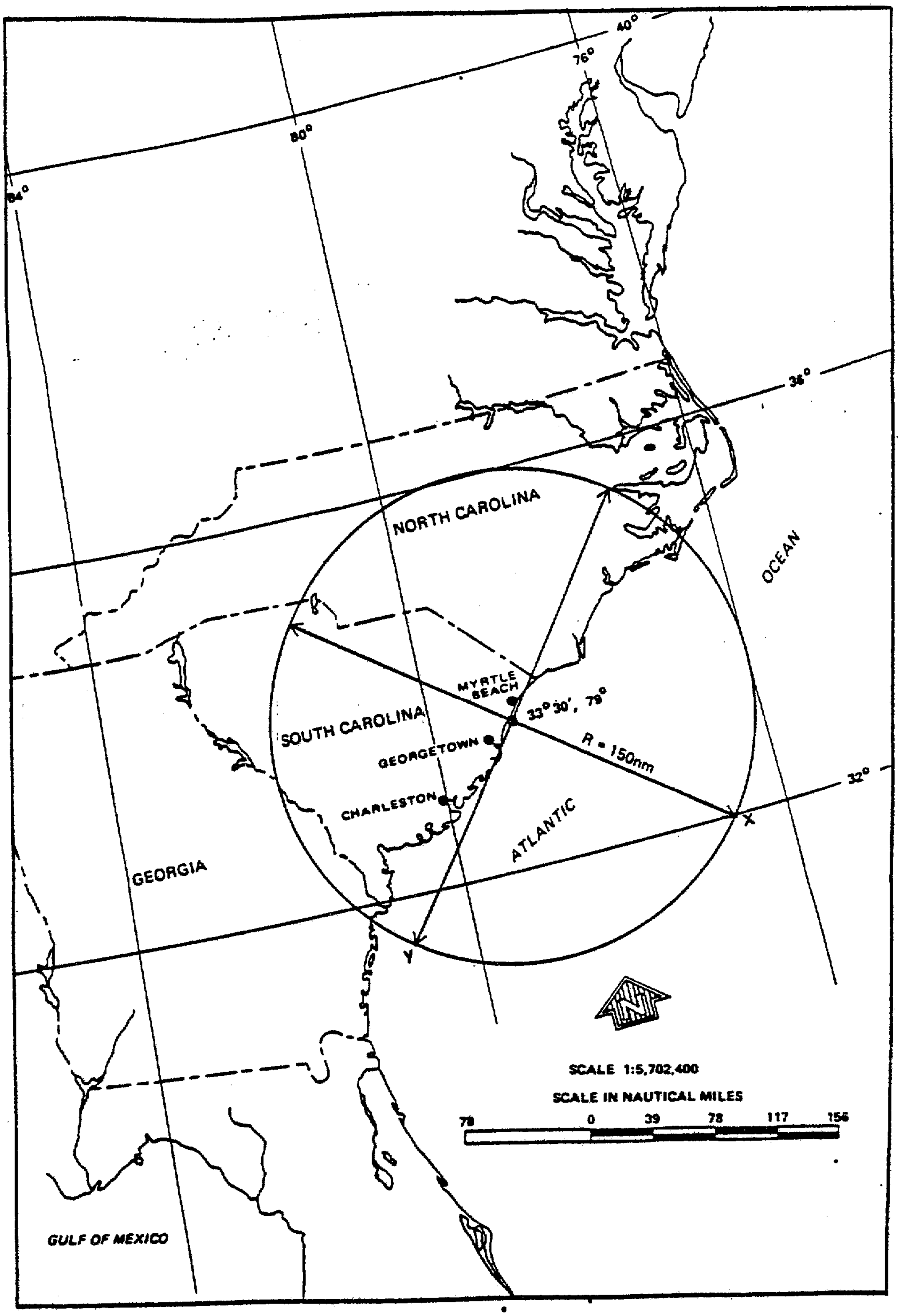


FIGURE 3.3-4
CROSSING AXIS AND CIRCLE FOR STORM STATISTICAL ANALYSIS - HORRY AND GEORGETOWN COUNTIES (FEMA, 1983)

TABLE 3.3-1

Landfalling storms	18.4%
Exiting storms	37.5%
Alongshore storms	44.1%

Predicted peak combined total storm tides for varying return intervals are presented in Figure 3.3-5 whereas Figure 3.3-6 presents the same for specific locations along the open coast.

An earlier study, done to determine maximum tide elevations for the entire coast of South Carolina, was conducted for the Federal Insurance Administration. Using the National Weather Service (NWS) SPLASH hydrodynamic model to calculate peak storm tides, Meyers (Meyers, 1975) predicted Hurricane Hazel's storm tide variation along the coast from Georgia to the South Carolina/North Carolina border (Figure 3.3-7). This particular hurricane struck the Myrtle Beach area at a time that coincided with that of the astronomical high tide. High water marks (which include wave effects) were documented as 15.5 feet at Myrtle Beach.

During a hurricane event, onshore winds displace the ocean water onto the local coastline. In the vicinity of an inlet along the adjacent low-lying shorelines, storm surge flooding with wave effects superimposed will erode the foreshore and, in some places, overtop the primary dunes. As an example, Hurricane Hazel caused seaside overtopping and breach of the spit extending south from Pawley's Island.

Hurricanes Grace (1959) and David (1979) are the most recent (since 1954) hurricanes to have directly impacted the Horry and Georgetown County shoreline. These storms were relatively moderate storms, characterized as high frequency 10-year return period events.

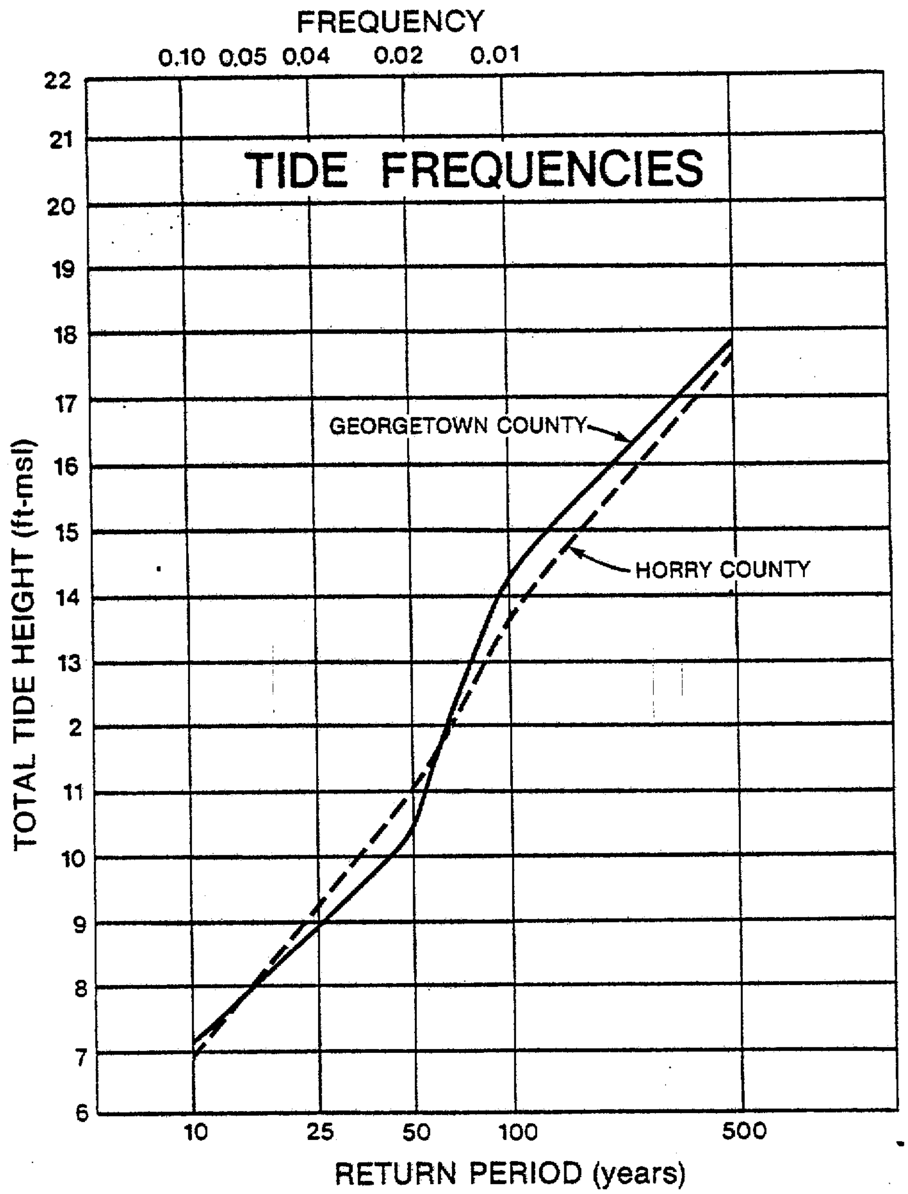


FIGURE 3.3-5
PREDICTED PEAK TOTAL COMBINED STORM TIDES FOR VARYING RETURN INTERVALS

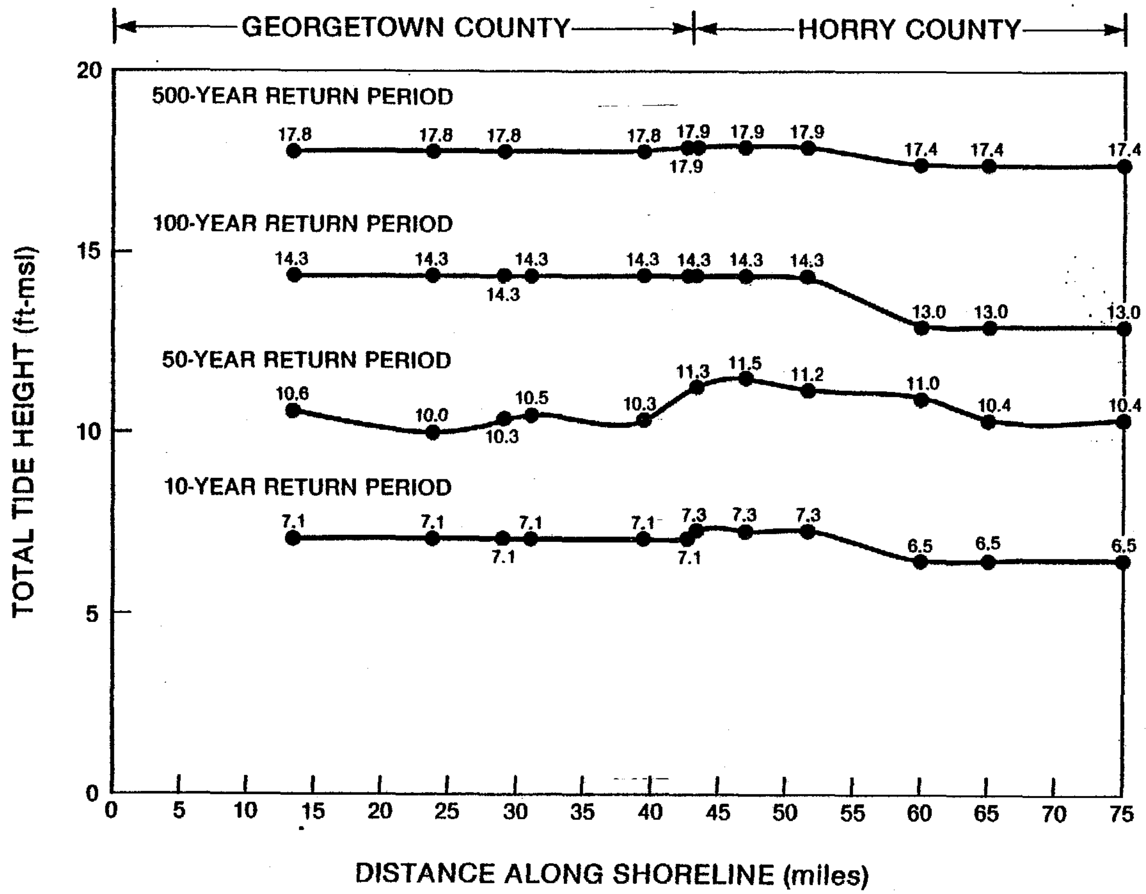


FIGURE 3.3-6
PREDICTED PEAK COMBINED TOTAL STORM TIDES ALONG THE HORRY AND GEORGETOWN COUNTY SHORELINE (FEMA, 1983)

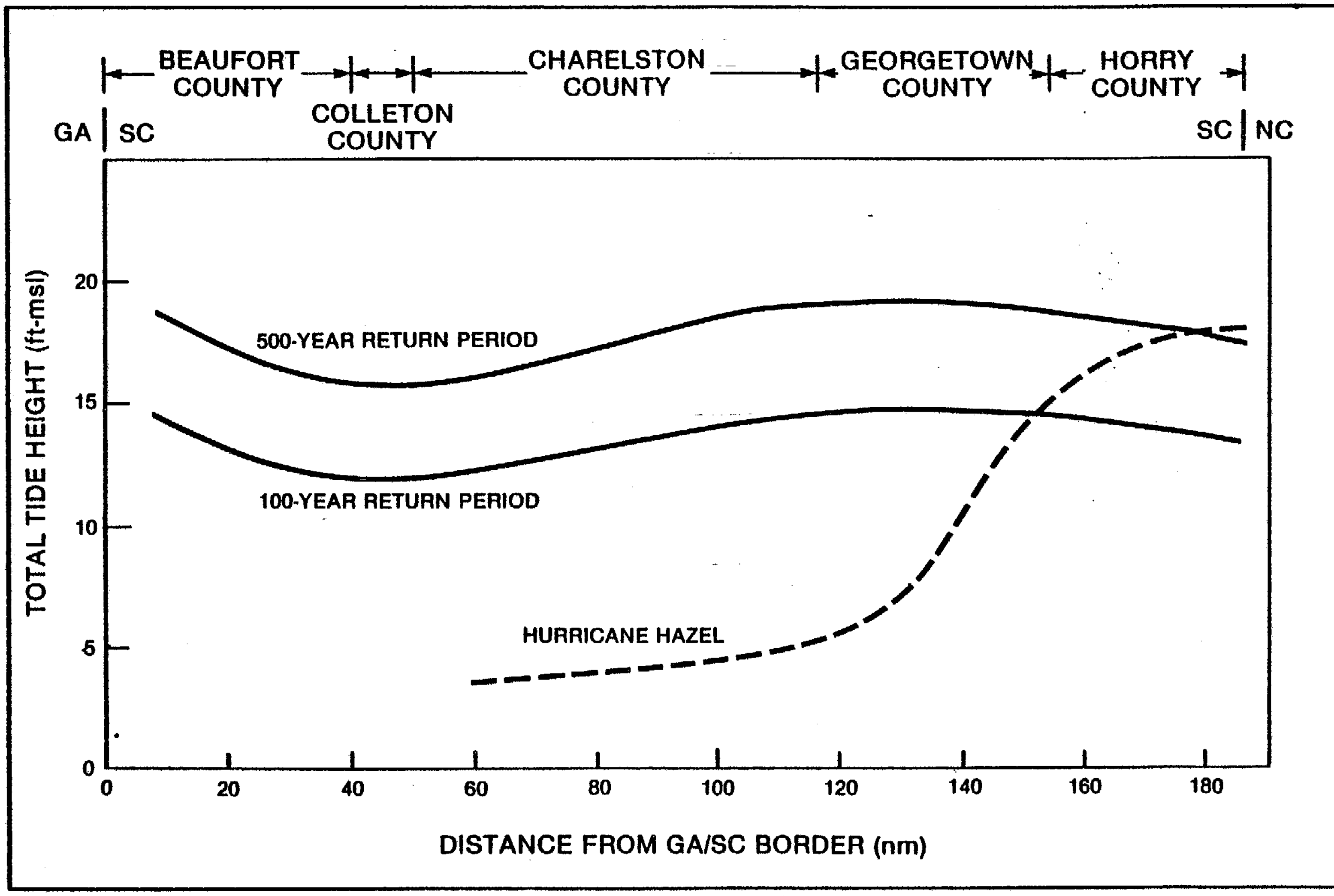


FIGURE 3.3-7
SPLASH SIMULATION OF HURRICANE HAZEL'S TOTAL COMBINED STORM TIDES ALONG THE SOUTH CAROLINA COAST (MEYERS, 1975)

3.4 WAVES

The Waterways Experiment Station (WES) of the U.S. Army Corps of engineers (USCOE) has compiled detailed hindcast wave statistics from a Wave Information Study (WIS) for the Atlantic Coast (USCOE, 1984). The data consists of wave height, period and direction computed for three-hour intervals, excluding tropical storms, over a 20-year period (1956-1975) at various stations located offshore along the coast. The data are presented in three phases:

> Phase I consists of large-scale numerical hindcast of deep water wave data from historical surface pressure and wind data.
>
> Phase II consists of numerical hindcasts at a finer scale to better resolve the sheltering effects of the continental geometry. Phase I data serve as the boundary conditions at the seaward edge of the Phase II grid.
>
> Phase III consists of transformation of Phase II wave data into shallow water and includes long waves.

Phase III wave data are not yet available for the stations appropriate to the study area; however, shallow water wave calculations have been made for Myrtle Beach by means of a wave-refraction computer model (Siah et al. 1984) utilizing the Phase II data. The results of these calculations are included as a general representation of shallow-water wave conditions typical of the study area.

WIS station 47, located at latitude 33.64° north and longitude 78.13° west, or approximately 40 miles due east of Myrtle Beach, is the closest station with available wave data for the study area. Accordingly, Phase II data from this station were summarized and input into the aformentioned wave refraction model to obtain shallow water wave data. Figure 3.4-1 presents a seasonal summary of this

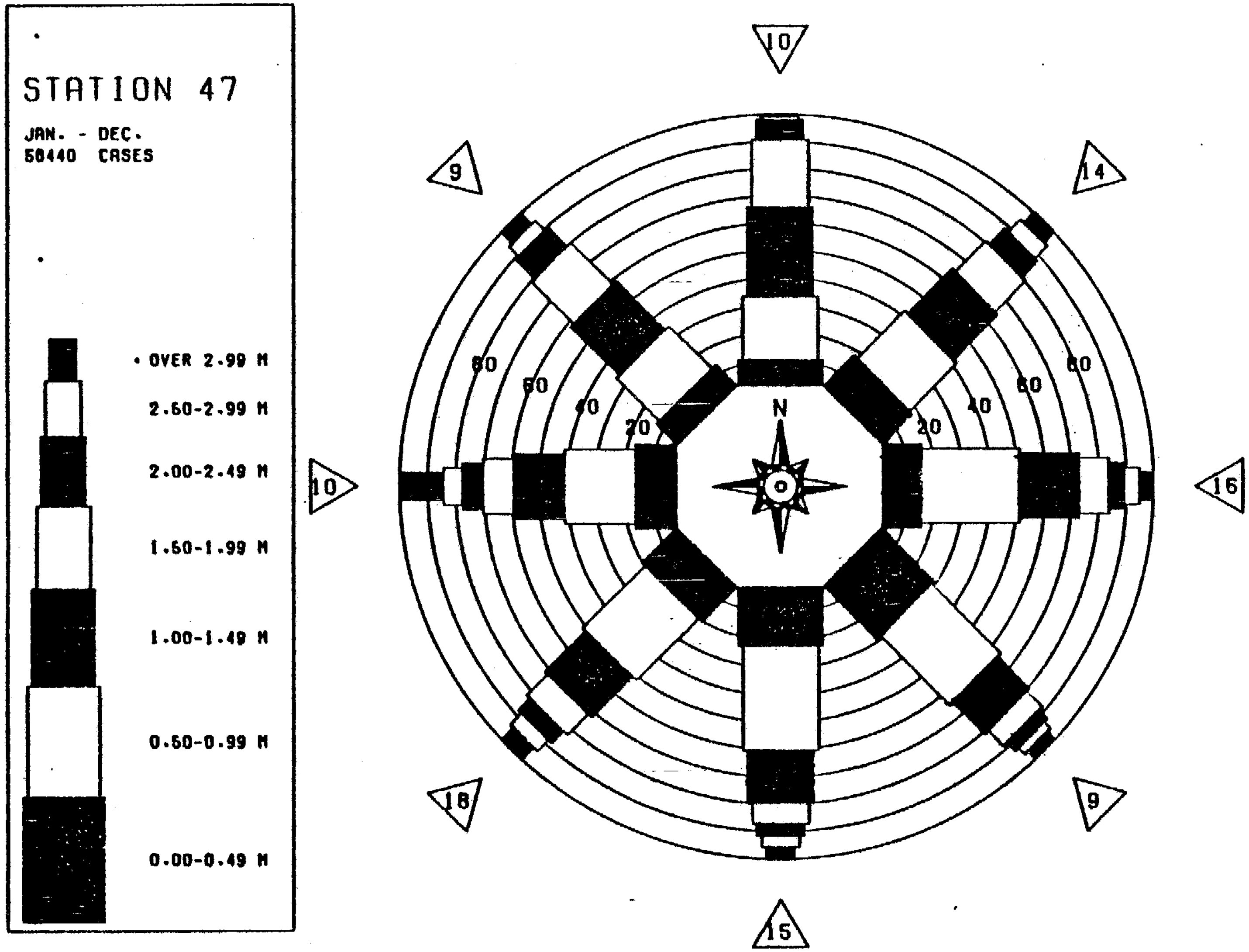


FIGURE 3.4-1
WAVE ROSE OFFSHORE OF MYRTLE BEACH

Phase II data in the form of a wave rose for waves refracted landward from deep water. Table 3.4-1 presents a seasonal summary of onshore wave conditions calculated by refracting the Phase II data over the nearshore bathymetry in the Myrtle Beach area. It should be noted that the onshore wave conditions depicted in Table 3.4-1 occurred only when weather conditions were conducive to their formation and therefore do not represent an annual average. Rather, they represent average conditions when waves actually occur from this direction window, during 49% of the year. The remaining 51% of the year may be considered as either calm or lacking any significant onshore wave energy component. Inclusion of these periods in the calculation of average wave conditions will result in lower average wave heights than presented in Table 3.4-1. It should also be noted that the approximately 45° shoreline variation over the study area, as well as localized refraction and shoaling in the vicinity of inlets will result in significant variations in wave orientation relative to the shoreline over the entire study area.

3.5 LITTORAL DRIFT ESTIMATES

Alongshore sediment transport, or littoral drift, is driven by the shore-parallel component of current velocities in the surf zone. In concurrence with onshore/offshore sediment transport, littoral drift is the primary factor that determines long-term changes in beach morphology. Unnoticeable on a day to day basis except during storms, this form of sediment transport becomes significant when interrupted by a shore normal structure such as a groin or jetty. The currents driving this littoral drift result primarily from the transfer of momentum by wave forces and secondarily from wind, tidal and Coriolis forces. Frictional forces near the bottom and turbulence resulting from velocity gradients across the surf zone act to reduce the current velocity.

Table 3.4-1. Average Occurring Wave Heights (ft) by Direction and Season for the Myrtle Beach Area (Siah et al,1984).

	Wave Direction						
Season	ENE	E	ESE	SE	SSE	S	SSW
Jan-Mar	4.4	4.8	4.4	4.5	4.3	4.2	4.4
Apr-Jun	3.1	3.2	3.1	3.2	3.1	3.0	2.9
Jul-Sep	2.9	3.3	2.8	2.2	2.4	2.1	2.4
Oct-Dec	4.1	4.3	4.0	3.8	4.1	3.9	3.8

The direction of littoral drift varies with the direction of longshore currents. Seasonal trends within the study area indicate southerly transport in the fall, winter, and early spring months and northerly transport in the summer. These trends, however, vary annually as well. As a result, annual gross transport volumes often far exceed annual net transport volumes. The direction and quantity of net transport depends primarily on the wave climate over the time period and the shoreline location. It should be noted that the largest percentage of the gross and net annual littoral transport occurs during storm events.

Many methodologies and associated formulas have been presented to quantitatively predict magnitudes of alongshore sediment transport. Generally, these formulas become quite complicated while the accuracy of their predictions often remains questionable. Rather than derive a new methodology or assess the validity of existing ones, Table 3.5-1 presents predictions of sediment transport rates made in previous studies of the northern reach of the South Carolina coast. From this table, a qualitative assessment of littoral drift rates may be made. It is important to note that the presence of groin fields, natural inlets as well as stabilized inlets, and the approximately 45° difference in shoreline orientation will result in significant localized variation in sediment transport rates over the study area.

3.6 HISTORICAL AERIAL PHOTOGRAPHS

The most comprehensive aerial photographic records of the South Carolina coastline, of reasonable resolution (1:20000), are available from the Agricultural Stabilization and Conservation Service (ASCS) and NOS. A detailed listing of aerial photographic records is available through the South Carolina Cartographic Information Center, Columbia, South Carolina.

Table 3.5-1 Previous Estimates of Net Littoral Drift Rates in the Myrtle Beach Vicinity

Source	Region	Net Drift Rate - Direction
CSE/OA (1985)	Myrtle Beach	3.4×10^5 yd^3/yr. - Southerly
Finely (1976) & Nummendahl & Humphries (1977)	Debidue, North Islands	$0.72 - 3.21 \times 10^5$ yd^3/yr* - Southerly
Kana (1976)	Capers Island	$0.82 - 2.72 \times 10^5$ yd^3/yr* - Southerly
Kana (1976)	Bull Island	1.67×10^5 yd^3/yr - Southerly
Knoth & Nummendahl (1977)	Bear Island	$0.74 - 1.89 \times 10^5$ yd^3/yr* - Northerly
USACE, Charleston (1975)	Murrell's Inlet	1.32×10^5 yd^3/yr - Southerly
Hubbard, et al. (1977)	Murrell's Inlet	2.28×10^5 yd^3/yr - Southerly

*Converted from tons/yr assuming a specific weight of 90 lbs/ft^3.

Aerial photographs are useful in assessing historical shoreline changes in order to distinguish between long-term trends and short-term trends. After corrections for true scale and camera tilt are included, limitations and errors in calculating shoreline movement are primarily due to water level corrections and locating the still water line excluding the effects of wave motion.

Aerial photos of Murrells Inlet and the adjacent shorelines were taken by the COE between 1977 and 1981 on a monthly basis. Extending over 14 miles of shoreline from the Surfside Holiday Inn area south to Midway Inlet, flights were continued through October 1982 on a quarterly basis.

Qualitative analysis along the entire Georgetown County shoreline using photographs from 1872 to 1973 (Hubbard, 1977) provides data to assess long-term shoreline variability. The summations of individual measurements were used to calculate the 25-, 50- and 100-year net accretion and erosion trends.

Using NOS-COE shoreline movement maps for Georgetown County from 1873, 1925-26, 1934, 1962-63, 1969-70, and 1983, shoreline changes were depicted for each of the inlet areas and described in more detail in Section 7.0.

In addition, assessment of both shoreline movement changes and shorefront development patterns relied upon historical aerial photographs provided by ASCS, NOS and SCCC. These data cover an extensive period of records beginning in 1939 with more frequent flights in later years.

3.7 SHORELINE DATA

Historical shoreline changes are one of the best indications of erosion trends and littoral processes. Qualitative depiction of the shoreline changes can be obtained from the comparison of aerial photographs. Section 3.6 lists the available aerial photographs within the study area. These photographs were usually taken at different tidal phases, therefore, they may not be adequate to represent short-term changes because of the resolution and accuracy. However, they can represent the long-term shoreline changes reasonably well.

To qualitatively depict shoreline changes, the National Ocean Service (NOS) and Coastal Engineering Research Center have compiled aerial photographs, historical shoreline surveys, and U.S. Geological Survey base maps to construct a series of shoreline movement maps from Cape Henlopen, Delaware to Tybee Island, Georgia. These maps were horizontally controlled according to the 1927 North American datum. These shorelines indicate the location of local mean high water line relative to 1929 NGVD. Shoreline movement maps covering the study area were complied from the January 1983 NOS aerial photography and field surveys performed in 1969-70, 1962-63, 1934, 1925-26, and 1872. Since these maps were both horizontally and vertically controlled, they were used as the primary data source to estimate the long-term erosion rate in the study area.

3.8 BEACH PROFILE DATA

Comparative beach-dune profiles derived from periodic field surveys relative to permanent vertically controlled stations provide a high quality future data base. Initially these data collected for specific time intervals (5 to 10 year period) allow valuable estimates of short-term shoreline fluctuations. In future years (20 to 30 years), these data will be useful to predict local long-term erosion rates. In addition, the shoreline recession associated with sea-level rise and storm effects can be more accurately quantified with a consistent, reliable data base.

During a 1955-1958 COE post-hurricane reconnaissance study for Horry and Georgetown Counties (COE,1983), surveys were conducted within Georgetown County along the Garden City shoreline areas. In April 1958, 12 profile stations were established and surveyed, five of which were located and replicated in the present study for comparative analysis. The seaward limit of these profiles was approximately -2.0 feet MSL (1929 NGVD). Subsequently, between November 1983 and March 1984 the COE resurveyed the stations established during the previous 1955-58 erosion study.

Comprehensive monitoring to evaluate both the effects of the Murrells Inlet jetties on the adjacent shorelines and the hydraulic performance of the jetties on sediment transport processes began in September of 1979. The COE has established brass-capped concrete monuments and documented bench marks extending north 7 miles to the northern limit of Surfside Beach (station #5135) and south 7 miles to Midway Inlet. Monitoring stations, extending both north and south, were located at greater spacing intervals with increasing distance from the inlet.

Along the Huntington State Park shoreline adjacent to the Murrells's Inlet jetties, these profiles were spaced at 500 ft intervals. Between 0.75 and 2 miles, spacing was increased to 1000 ft. In the remaining area to Midway Inlet, these profiles were located at 5000-ft intervals. Profile locations and transect lines were perpendicular to the 1977 shoreline as shown in Figure 3.8-1.

A total of 43 offshore profiles were surveyed quarterly by the Charleston District COE over a 5-year period ending in 1982. Subsequently, 18 profiles are to be surveyed on a semi-annual basis through 1987. Profiles were surveyed from the sand dunes offshore to the -18.0 contour for all

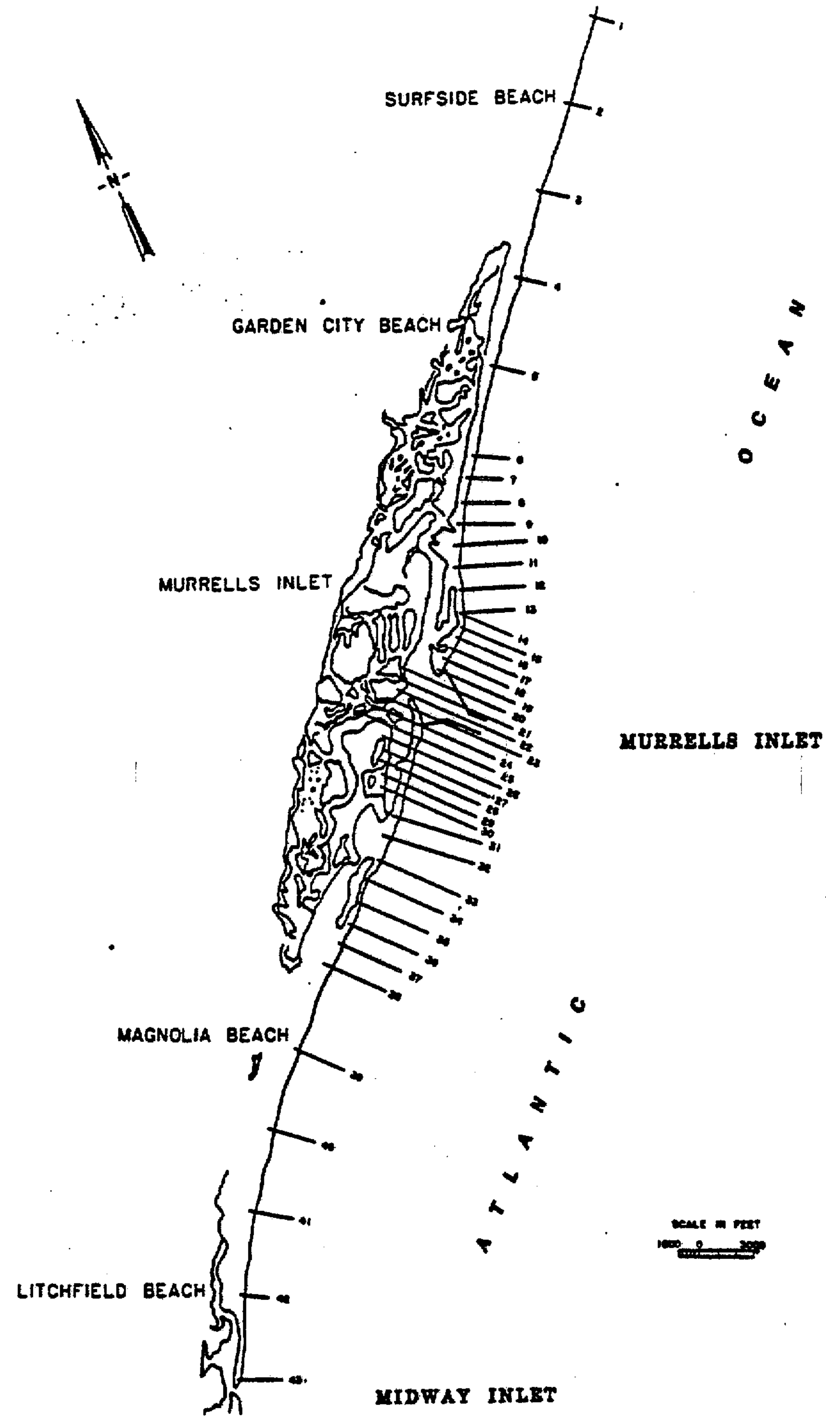


FIGURE 3.8-1
SURVEY PROFILE LOCATION MAP FOR
MURRELLS INLET MONITORING PROGRAM

profiles, using a fathometer at high tide to overlap points surveyed on land using rod and level.

A 1981 shoreline management study (Cubit, 1981) established 12 stations along the approximately 3.6 miles fronting Pawley's Island. These stations were non-uniformly spaced with 7 stations located on the north half of the island and the remaining 5 stations south to Pawley's Inlet. Original reference control points established during this study were not located although the central points for comparative analysis purposes were replicated based on documentation from the previous baseline. Insufficient documentation and significant profile disparities between the 1981 and 1986 surveys deemed these comparisons questionable and therefore invalid.

A beach profile survey program was conducted by the project team in April 1986. After reviewing the historical beach profile data collected by the U.S. COE and other investigators between 1958 and 1984, 56 survey stations were established in the Georgetown County study area. The spacing between the stations was generally 1/3 mile. Of these stations, 29 coincided with historical survey stations which were either recovered or replicated according to available historical survey field notes. The remaining 27 stations were "new" stations established during the present study. There were 12 stations established in Garden City, 18 in the Litchfield area, 12 in Pawley's Island, and 14 in Debidue Beach. Figure 3.8-2 shows the location of each survey station.

Each survey station consisted of a survey monument and corresponding benchmark (BM). The survey monument provides permanent demarcation of the station location as well as a reference point from which to conduct beach profiles. The location of the monuments were carefully documented with

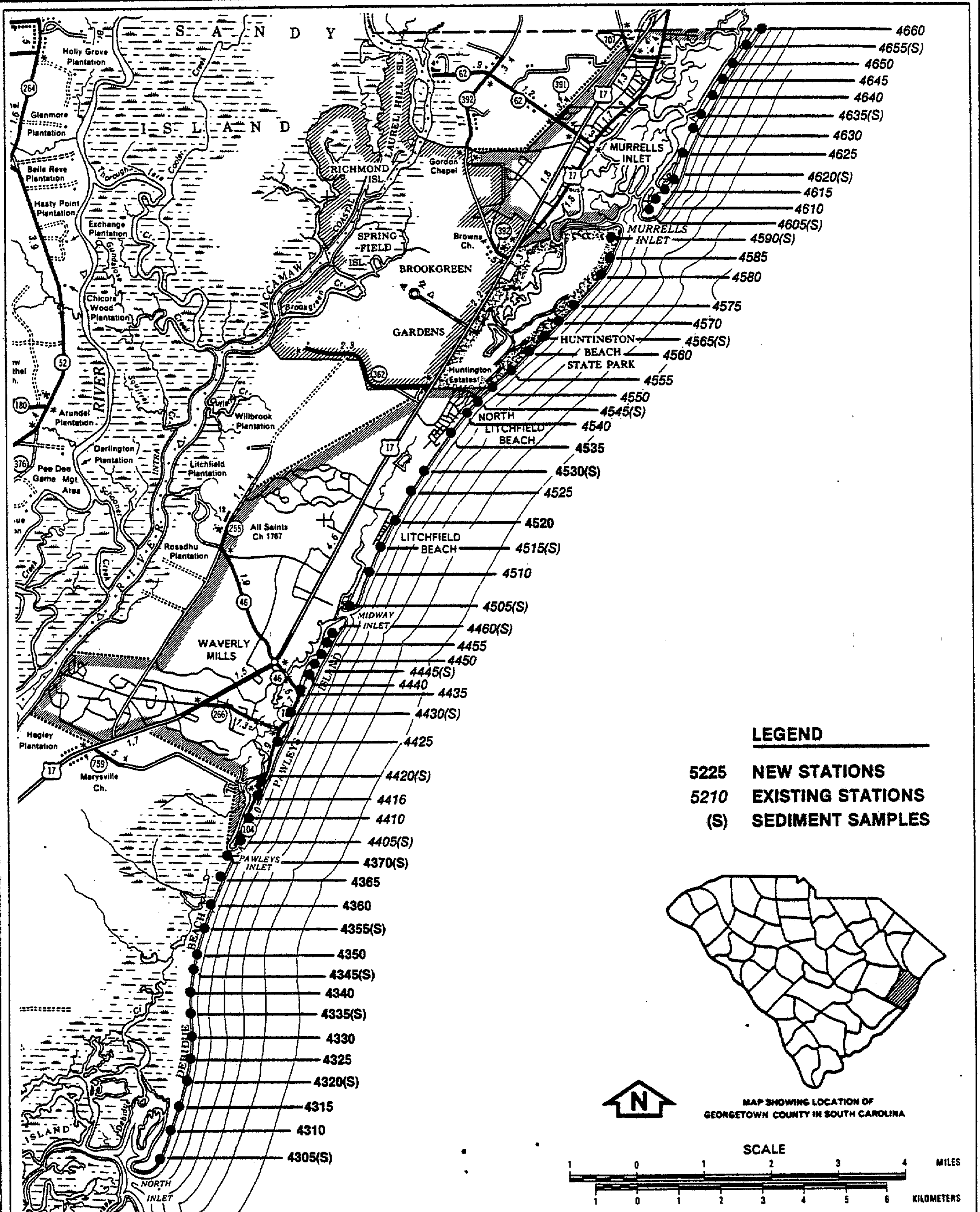


FIGURE 3.8-2
BEACH PROFILE SURVEY AND SEDIMENT SAMPLE STATION LOCATION MAP

survey notes which include general location descriptions, monument descriptions and tie-in distances to nearby landmarks, profile azimuths and relative offsets. This documentation should allow survey replication on a later date even though the monument may be destroyed. Newly established or replicated survey monuments consisted of a P,K. nail and brass cap on which a 4-digit SCCC station number was inscribed, attached to either a permanent structure of an eight foot section of 4 in. by 4 in. wood post embedded near the sand dune in more remote areas. The associated BM, a vertically controlled reference point with elevation surveyed in relation to MSL, usually took the form of a railroad spike in a 4 in. by 4 in. post or a power pole, a P.K. Table 3.8-1 shows a list of the SCCC station numbers, the transect bearings, and the associated COE station number.

Profile azimuths were generally perpendicular to the shoreline orientation. Wherever possible, surveys commenced well landward of the actual beach foreshore in order to include all relevant portions of the active dune system or characteristic upland at each station. The profile surveys extended seaward to MLW at the majority of the stations. Sediment samples were taken from three locations at each of 21 survey stations for grain size analysis. The three sample locations corresponded to the toe of dune or existing seawall, MHW and MLW. Sediment sample stations are presented in Figure 3.8-2 and Table 3.8-1

Nine out of 12 Cubit Engineering (1981) monuments were replicated. The remaining three stations could not be located because of insufficient documentation.

It is important to note that beach profile data were effected by beach fills near Murrells Inlet. Between December 1978 and June 1980, 633,497 cubic yards of dredged

Table 3.8-1. Survey Stations Cross-Reference Table.

Area	SCCC #	CERC # (1979-82)	COE # (1983-84)	Bearing	Sediment Sample
Garden City	4660	--	206+28	S56E	
	4655	144+25			x
	4650	--	239+00	S54E	
	4645	120+80	--	S60E	
	4640	--	270+00	S54E	
	4635	81+50	--	S60E	
	4630	--	300+00	S58E	x
	4625	51+50	--	S72E	
	4620	31+61	--	S72E	x
	4615	21+61	--	S72E	
	4610	11+46	--	S45E	
	4605	1+31	--	S45E	x
Litchfield	4590	59+62	--	S45E	x
	4585	72+31	--	S45E	
	4580	92+00	--	S52E	
	4575	122+00	--	S46E	
	4570	142+00	--	S46E	
	4565	162+00	--	S46E	x
	4560	182+00	--	S42E	
	4555	202+00	--	S48E	
	4550	222+00	--	S44E	
	4545	242+00	--	S43E	x
	4540	252+00	--	S52E	
	4535	--	--	S44E	
	4530	--	--	S46E	x
	4525	302+00	--	S59E	
	4520	--	--	S48E	
	4515	352+00	--	S61E	x
	4510	374+45	--	S54E	
	4505	402+00	--	S50E	x
Pawley's Island	4460	--	--	S50E	x
	4455	--	--	S58E	
	4450	--	--	S66E	
	4445	--	--	S66E	x
	4440	--	--	S62E	
	4435	--	--	S62E	
	4430	--	--	S64E	x
	4425	--	--	S60E	
	4420	--	--	S60E	x
	4416	--	--	S60E	
	4410	--	--	S60E	
	4405	--	--	S60E	x

Table 3.8-1. (Continue)

Area	SCCC #	CERC # (1979-82)	COE # (1983-84)	Bearing	Sediment Sample
Debidue	4370	--	--	S84E	x
	4365	--	--	S64E	
	4360	--	--	S66E	
	4355	--	--	S64E	x
	4350	--	--	S66E	
	4345	--	--	S80E	x
	4340	--	--	S82E	
	4335	--	--	S78E	x
	4330	--	--	S80E	
	4325	--	--	S78E	
	4320	--	--	S78E	x
	4315	--	--	S78E	
	4310	--	--	S78E	
	4305	--	--	S76E	x

spoil material from the Murrells Inlet entrance channel was placed north of the inlet (stations 4615 to 4625) and 542,944 cubic yards of dredged material was placed south of Murrells Inlet (stations 4575 and 4580).

3.9 SEDIMENT DATA

Previous studies to evaluate the native beach sand on Georgetown County's shoreline for grain size characteristics and statistics do not exist in a documented form. References to beach and dune sediments were described qualitatively in the geomorphology sections of recent shoreline studies (Cubit, 1981 and RPI, 1985).

To provide basic sediment grain size statistical parameters such as mean phi, median phi and the relative grain size distributions (phi_{84} and phi_{86}), a summary of data collected in a 1955 COE study along the Myrtle Beach shoreline is presented. Surface sand samples were taken at Myrtle Beach during September and October field reconnaissance surveys and analyzed for grain size distributions. Samples were taken at 16 locations along the foreshore area at mid-tide. Table 3.9-1 presents a summary of these data averaged for all locations.

In 1972, sand samples were taken by the COE at three locations along Garden City and analyzed for grain size distribution. The average mean grain diameter of these samples was 0.33 mm for a composite representing sediments sampled at the toe of the dune, mid berm and "at the water's edge".

Beach sediment samples along North Myrtle Beach were collected in a 1985 study to determine the distribution of sediment characteristics along the beach foreshore area. Mean grain size, standard deviation, skewness and size fractions were computed at 3 locations along eight stations.

Table 3.9-1. Summary of Sediment Characteristics

NATIVE BEACH SAND AT THE MID-TIDE LEVEL

AVERAGE	Phi_{84} 1/	Phi_{16} 2/	Phi_{Mean} 3/	$Phi_{sorting}$ 4/	Median Dia (mm) 5/
15 surface samples	2.50 (0.18mm)	1.45 (0.37mm)	1.98 (0.26mm)	0.53	0.23
13 samples from 1 ft below surface	1.55 (0.17mm)	0.65 (0.64mm)	1.10 (0.33mm)	0.43	0.27
28 samples (both types)	2.53 (0.17mm)	1.18 (0.44mm)	1.86 (0.28mm)	0.68	0.24

1/ 84% of the sand has a diameter greater than that shown.
2/ 16% of the sand has a diameter greater than that shown.
3/ Average of Phi_{84} and Phi_{16}.
4/ One-half the difference between Phi_{84} and Phi_{16}.
5/ Half the sand is larger and half smaller than the indicated size.

GARDEN CITY BEACH NATIVE BEACH SAND SAMPLES

PROFILE SECTION	LOCATION ON PROFILE	16 PHI UNITS	84 PHI UNITS	MEAN PHI UNITS	S.D. PHI UNITS	MEDIAN DIAM PHI UNITS	MEDIAN DIAM mm	SHELL CONTENT
70 + 00	Toe of Dune	1.89	2.32	2.11	.22	2.12	.23	1%
	Mid Berm	1.94	3.06	2.50	.56	2.32	.20	1%
196 + 05	Toe of Dune	.32	2.32	1.32	1.00	1.84	.28	21%
	Mid Berm	1.43	2.47	1.95	.52	1.19	.27	1%
	Water's Edge	.80	2.40	1.60	.80	1.74	.30	1%
255 + 00	Toe of Dune	0.0	2.25	1.13	1.13	1.36	.39	32%
	Mid Berm	-.07	2.40	1.17	1.24	1.51	.35	34%
	Water's Edge	-.14	2.40	1.13	1.27	1.79	.29	39%
Composite		0.77	2.45	1.61	0.84			

Source: COE Reconnaissance Report, 1983

The samples were described as well-sorted fine sands (2.0 to 3.0 phi, or 0.25 to 0.125 mm) with average mean grain-size equal to 2.64 phi or 0.16 mm. Variation along the length of shoreline represented by these samples was found to be negligible and uniform across the profile. It should be noted that the sediments were collected at +6.0, +2.5 and -2.5 feet (MSL) elevations along the profile.

From a comparison of sand from Garden City, North Myrtle Beach and Myrtle Beach, sand sizes vary consistently along the length of the shoreline. The average mean grain size for North Myrtle Beach, Myrtle Beach and Garden City were computed to be 0.16, 0.20 and 0.33mm, respectively. As part of the present study, sediment samples were taken from 21 survey stations. At each station, three samples were collected at the toe of the dune, MHW and MLW results of the sediment analysis are presented in Section 5.0. The sampling stations are depicted in Figure 3.8-2 and Table 3.8-1.

3.10 BEACH MORPHOLOGY

Beach morphology varies considerably over the study area and an area-wide classification can only be given in general terms. Factors contributing to this overall variation include the proximity of tidal inlets and swashes, the amount and type of development along a particular reach, shoreline orientation, the existence of shoreline erosion control structures and the quantity of sediment supply available to the reach, in particular, local variations in sand supply.

The intertidal portion of the beaches in the study area may, in general, be classified as mildly sloping beach of low elevation. This combination results in a relatively wide low-tide beach and very little to no high-tide beach at many places. This characteristic is a result of the considerable tide range combined with the relatively small grain size of the natural beach sediments that maintain a mild beach slope. Occasionally along the study area, this flat face is interrupted by an upper beach berm above the mean high water line (MHWL). This berm extends to the dunes or to the immediate upland if the dunes have been removed or destroyed. At several locations along the study area, beach surveys showed evidence of active ridge and runnel, and associated swash-trough systems indicating seasonal onshore transport that would be expected during the month of the survey, i.e. April.

In general, the southernmost ends of the barrier islands within the study area exhibit southerly migration trends in the form of migrating spits. Accordingly, the shorelines adjacent to unstabilized inlets typically exhibit accretional tendencies as a result of sediment storage and sand bypassing at the inlet via inlet shoal migration. Therefore, the shorelines in the immediate vicinity of inlets should be considered quite unstable and subject to severe short-term and large-scale variations in morphology, particularly in response to storm events. This phenomenon has resulted in various forms of inlet stabilization via structures at several of the developed sections of shoreline within the study area. A discussion of typical beach profile characteristics for each of the reaches of the study area is presented in the following sections.

Garden City Beach

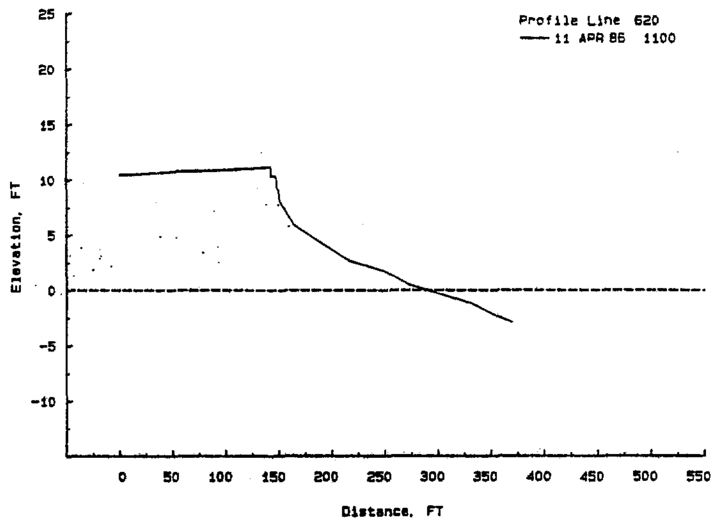
Approximately 3.4 miles of Garden City Beach shoreline lie within Georgetown County. When comparing the shoreline characteristics of developed areas that include bulkheads and groins, to the unaltered, natural shoreline sections, a distinct variation in beach morphology becomes apparent. The back beach system along the armored sections of shoreline, which are located at the immediate north and south ends of the Garden City reach, is characterized by a relatively flat plateau at elevation 10-12 ft. Any dunes that may have once existed appear to have been leveled. Natural vegetation has been severely depleted, particularly along areas where buildings lie within 10-20 ft of the bulkhead. The beach face itself extends from the bulkhead at an average elevation of +8 ft (NGVD) and drops sharply to the apparent limit of wave uprush where it then begins to flatten out. This steep buildup of sand landward of the limit of wave uprush is characteristic of the sand-trapping effects of the existing groin system. Figure 3.10-1a presents a typical beach profile along the armored stretches of Garden City Beach (station 4620).

The apparently unaltered back beach system along the central portion of this shoreline exhibits one or two well-developed and well-vegetated dune ridges with crest elevation of up to 15 ft. Houses in this area are generally located further landward from the beach, thereby better maintaining the overall integrity of the natural dune system and its stabilizing natural vegetation. Seaward of the dunes lies a characteristic berm varying between 15 ft to 30 ft in width and averaging 8 ft-9 ft elevation. The intertidal beach advances seaward at a more gradual slope at this location that along the armored sections of shore both to the north and the south. Figure 3.10-1b is typical of the beach profile along the central section of Garden City Beach as surveyed during April 1986 at station 4635.

Litchfield - Huntington Beach

The 7.1-mile stretch of shoreline between Midway Inlet and Murrells Inlet consists of Litchfield Beach to the south and Huntington Beach State Park to the north. This stretch of shoreline may also be divided into two sections when evaluating beach characteristics. Distinct variations in beach morphology are apparent between the shoreline of

A



B

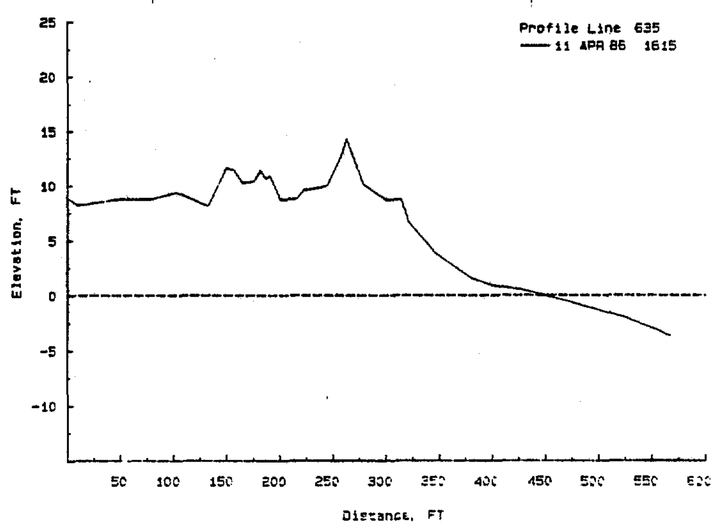


FIGURE 3.10-1
A) TYPICAL BEACH PROFILE AT GARDEN CITY POINT
B) TYPICAL BEACH PROFILE NEAR INLET HARBOR

Litchfield Beach and Huntington Beach State Park.

The southernmost 1,500 ft of South Litchfield Beach north of Midway Inlet exhibits features characteristic of an actively migrating and dynamic recurved sand spit. Land elevations rarely exceed +8 ft and vegetation is sparse. The spit averages 300 ft in width, and increases to 700 ft at its southernmost end. Along the remaining approximately 3.3 miles of South Litchfield Beach, the back beach system becomes increasingly extensive while the beach face system maintains a consistent profile. The relatively stable dune system at this location is both well developed and well vegetated, and often exceeds +20 ft in elevation. The number of distinct dune ridges increases from one to three in a northward direction. A berm, 30 ft to 40 ft in width, extends from the seawardmost toe of the dune system at an average elevation of +7.5 ft. This berm is also well vegetated and undergoes a gradual transition to a mildly sloping dry beach face that extends to the approximate mean high water line where the intertidal beach flattens out considerably. A dry beach of 60 ft to 80 ft in width exists at high tide along this shoreline. These morphological characteristics and the absence of any evidence of scarping are indicative of a stable beach system. Figure 3.10-2a (station 4530) is representative of beach conditions along the majority of the South Litchfield Beach and Litchfield By the Sea shoreline during the period of the survey.

Beach morphology along the northernmost 2,000 ft of Litchfield Beach and the entire 3.5-mile stretch of the Huntington Beach State Park shoreline has been significantly affected by the Murrells Inlet Navigation Project which included the construction of jetties at the inlet for purposes of stabilization. The 4,000 ft of shoreline immediately south of Murrells Inlet has undergone localized accretion resulting from the landward migration of the

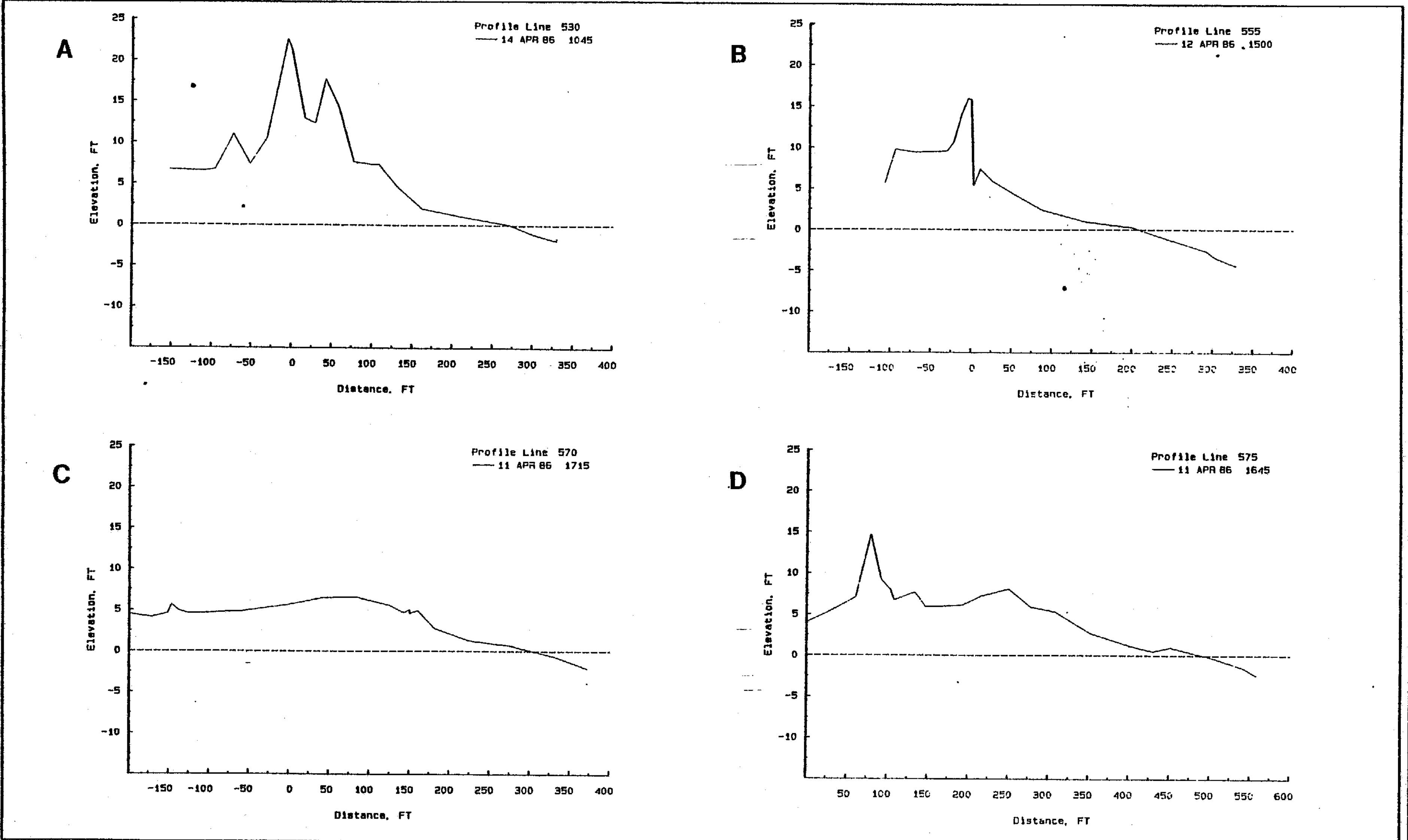


FIGURE 3.10-2

A) TYPICAL BEACH PROFILE NEAR LITCHFIELD BY THE SEA

B) TYPICAL BEACH PROFILE NEAR NORTH LITCHFIELD BEACH

C) TYPICAL BEACH PROFILE AT HUNTINGTON BEACH STATE PARK

D) BEACH PROFILE AT NORTHERN HUNTINGTON BEACH STATE PARK

southern portion of the inlet ebb tidal shoal system subsequent to construction of the jetties. This is a typical phenomenon generally associated with inlet stabilization and is not expected to abate in the near future.

Typically, the back beach dune system along the northernmost 2,000 ft of Litchfield Beach and the southern half of Huntington Beach State Park is narrower than that to the south and consists of a single dune ridge. The elevation of this ridge decreases progressing northward from approximately 18 ft to 8 ft in elevation. Accordingly, the dune to the south presently exhibits severe scarping as indicated in Figure 10-2b which is located in front of the northernmost house at North Litchfield Beach (station 4555), while the beach along the southern half of the State Park exhibits lower overall elevations and a very mild beach face slope as depicted in Figure 3.10-2c (station 4570). Vegetation along the back beach system is fairly abundant. The high tide beach along this entire stretch of shoreline is narrow to nonexistent at some locations.

Along the northern half of Huntington Beach State Park, the shoreline begins to exhibit a wider beach face and the re-emergence of a dune system located some distance from the actual beach face. This is due to the landward migration of the southern portion of the Murrells Inlet ebb tidal shoal and corresponding accretion of new beach immediately south of the navigation project. The present dune system consists primarily of a well-vegetated single dune ridge of elevation 10 ft-12 ft. An upper berm system interspersed with small dune mounds extends seaward of this major dune ridge to the beach face at approximately the 5 ft contour. The width of this upper berm system increases northward from a point 200 ft north of the north park beach access to about 900 ft from Murrells Inlet. The width of high tide beach likewise from increases northward. Figure 3.10-2d (station 4575) presents the present day characteristic features of the northern Huntington Beach State Park shoreline.

<u>Pawley's Island</u>

Beach morphology over the 3.6 mile stretch of Pawley's Island shoreline is significantly affected by shoreline armoring, inlet migration and inlet shoals. In general, the island can be divided into three sections, each with distinct morphological characteristics. These morphologically similar areas include the southern spit section, the central island section and the northern island section.

The southern spit section is designated by a narrow land formation extending northward approximately 0.8 miles from Pawley's Inlet. This spit, formed during the southerly migration of Pawley's Inlet, is approximately 200 ft wide from its bay shoreline to the open coast mean high water line. Most of this shoreline reach has been bulkheaded although in many places the bulkhead is presently buried by wind blown sand. An extensive groin field is also present along this entire shoreline reach and appears to be retaining sand above the mean high water line. A sparsely vegetated, narrow dune system with a maximum elevation of +8 ft to +10 ft exists along the northern two-thirds of this stretch but is absent along the southern third. The beach face starts at approximately the +6 ft to +7 ft contour and maintains a relatively mild slope. Analysis of profiles and field observations indicate very little high tide beach, typically 20 ft-25 ft wide but as narrow as 5 ft-10 ft at some locations. The narrow width and low elevation of this southern spit section make it vulnerable to wave overtopping in the event of a storm. Combined with a large volume of runoff from the mainland that could be routed through Pawley's Creek during the occurrence of a major storm, these

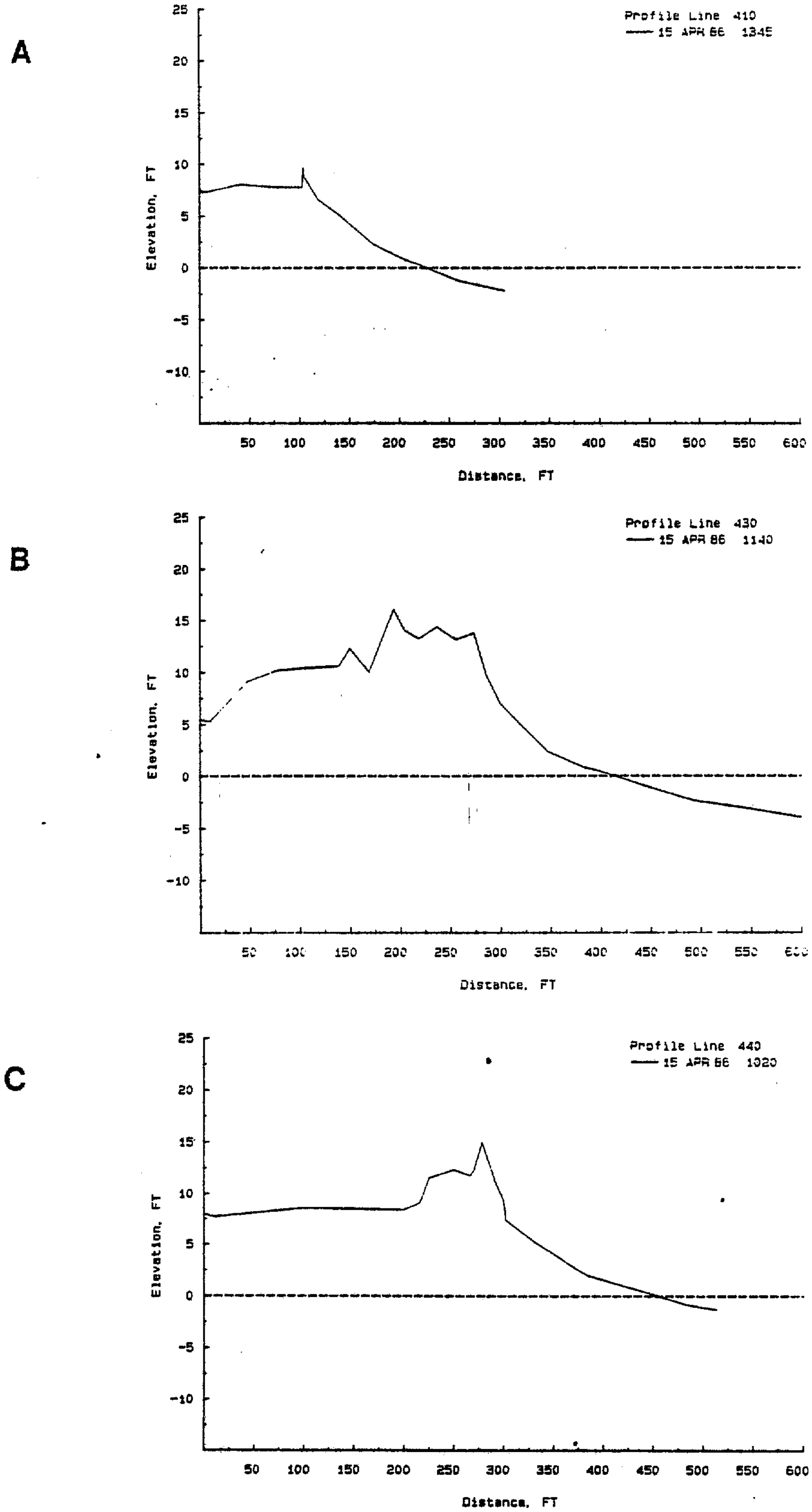


FIGURE 3.10-3
A) BEACH PROFILE AT SOUTHERN PAWLEY'S ISLAND, B) BEACH PROFILE AT CENTRAL PAWLEY'S ISLAND, C) BEACH PROFILE AT NORTHERN PAWLEY'S

conditions could be conducive to a breach of the island in this southern spit section. Figure 3.10-3a is a typical profile of the beach along this southern section.

The central island section extends approximately 1.9 miles from a point along the northern reach of the southern spit section to Pawley's Island Pier. The widest portion of Pawley's Island is located along this section as are the highest dunes, ranging as high as 25 feet in some locations. In general, the dune system is better developed and supports a greater abundance of natural vegetation than the dune system along the southern spit section. The existing groin system along the central section has resulted in sand trapping in the immediate vicinity of these groins. Old timber bulkheads located at the very southern extent of this reach appear to have little effect on the overall beach morphology and are at present buried by sand in many places. The beach face starts at approximately the 7 ft-8 ft contour and extends seaward at a considerably steeper slope than do the beaches to the north or south. The high tide beach remains very narrow, averaging about 30 ft in width. Figure 3.10-3b (station 5430) depicts a representative profile of a beach segment along the central island shoreline.

The northern island section consists of approximately 0.9 miles of shoreline from Pawley's Island Pier to Midway Inlet. The majority of homes along this section are set back from the beach and the shoreline is almost entirely unarmored. The combination of these factors results in a dune system that has retained its natural morphology. This morphology is characterized by a single, well-developed dune ridge ranging from 12 ft to 15 ft in elevation and extending landward to a back beach plateau at the approximate 8 ft elevation. With few exceptions, this entire system beach-dune systems remains well vegetated. The beach system along this section has been significantly affected by its proximity to Midway Inlet. As a result of inlet migration and shoaling processes the beach along this north section is among the widest in the entire study area. Extending from the dune system at approximately the 7 ft-8 ft contour, the beach face slopes seaward at a very gradual rate. At least 80 ft to 100 ft of dry beach presently exists at high tide on the extreme north end of the island. This width decreases southward to the Pawley's Island Pier where it returns to a typical 30-40 ft width. Figure 3.10-3c (station 5440) is a representation of beach profile characteristics along the northern section of Pawley's Island.

Debidue Island

Similar to Pawley's Island, beach morphology over the 4.6 miles of Debidue Island shoreline is affected by seawalls, inlet migration and inlet shoaling. Accordingly, Debidue Island can likewise be divided into three general shoreline areas when discussing beach morphology, each typified by distinct physiographic characteristics. For discussion purposes, these sections will be designated as the undeveloped southern spit section, the wider central island section, and the undeveloped northern section.

The undeveloped southern spit section of the Debidue Island shoreline extends approximately 1.2 miles north from North Inlet. The majority of this spit has formed over the last 100 years. Beach morphology here is typical of a relatively young spit and is significantly affected by the shoaling and migration cycles of North Inlet. This reach is moderately vegetated with sea grasses that lend stability to the back beach dune system. This system consists of two distinct dune ridges along the southern end of the spit forming one dune ridge towards the northern end where the spit narrows. Dune elevations average about +12 to +15 ft. A mildly

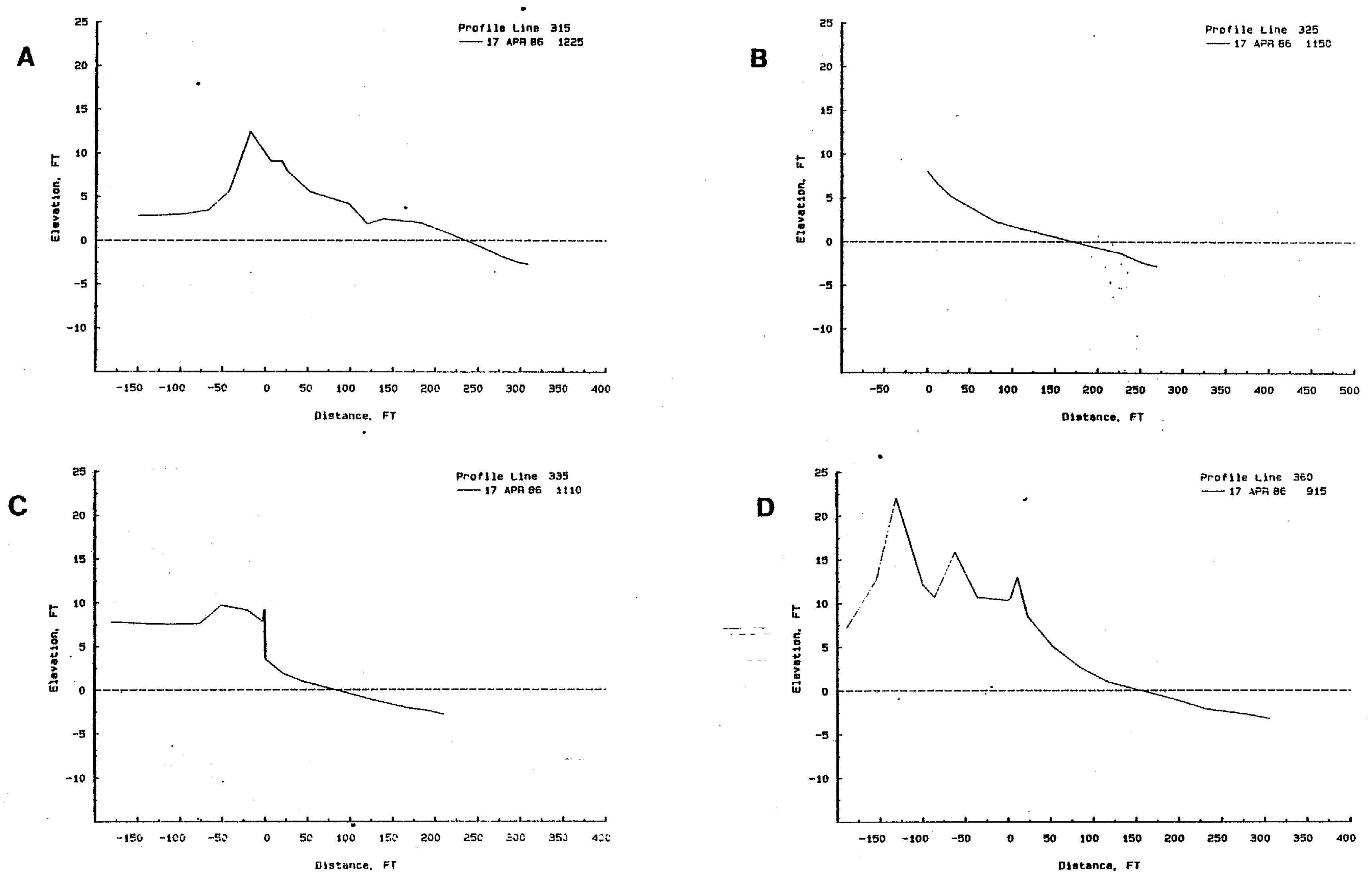


FIGURE 3.10-4

A) BEACH PROFILE AT DEBIDUE BEACH NEAR NORTH ISLAND

B) BEACH PROFILE AT CENTRAL DEBIDUE BEACH

C) BEACH PROFILE AT DEBORDIEU COLONY

D) BEACH PROFILE AT NORTHERN DEBIDUE BEACH

sloping berm, heavily vegetated with wax myrtle, extends 30 ft-40 ft from the toe of the dune at elevation +6 ft to a steeper beach face at the 5 ft contour. During the April 1986 field survey, the beach face characteristically extended to a swash-trough at about elevation +2 ft, then rose to a 30-40-ft wide plateau at approximately +3 ft before gently sloping offshore. Figure 3.10-4a (station 4315) illustrates the characteristics of the southern spit profile.

Although these characteristics are typically associated with an accreting beach, in this case they are primarily attributable to the effects of the North Inlet shoal system. The high tide beach at this location during the April survey was virtually non-existent. Observations of wave run-up into the seawardmost extent of the older wax myrtle vegetation would indicate a trend of chronic shoreward migration of the shoreline. Such apparent contrasts serve as evidence of the highly unstable shoreline conditions along this southern section of Debidue Island.

The central island section consists of 1.7 miles of shoreline beginning at the north extent of the Debidue Island spit and continuing to the northern extent of the Debordieu Tract development. The southern half of this shoreline reach remains in its natural state although it has undergone accelerated erosion in the recent past. The landward location of the back beach relative to the seawall constructed along the northern half of the reach is significant. The natural dune system here consists of a well-defined ridge rarely exceeding 10 ft in elevation. Vegetation in the form of beach grasses is sparse due to shoreline recession, whereas wax myrtle and shrubs are abundant. The latter, however, do little to maintain the integrity of the dune system. The transition from dune to beach face takes place at approximately the 6 ft contour and the beach maintains a gradual, mild slope towards the ocean. The observed high tide beach is approximately 30-40 ft in width. Figure 3.10-4b (station 4325) is a representative profile of the unarmored reach of the central island shoreline.

The northern half of the central island section has been armored by a wooden seawall landward of which an artificial dune line has been constructed to elevations of 20 ft and vegetated with native seagrasses. During the period of survey, the beach elevation immediately seaward of the seawall averaged +3 ft on the south end, rising to approximately +6 ft at the north end. Accordingly, the seawall at the south end is exposed to wave uprush on a daily basis. Figure 3.10-4c presents a typical profile along the seawalled portion of the central Debidue Island shoreline.

The undeveloped northern section of the Debidue Island shoreline extends north from the northern limit of development along DeBordieu Tract approximately 1.9 miles to Pawley's Inlet. The back beach system along this section of shoreline is typified by a well-developed and well-vegetated dune system consisting of 2 or 3 distinct dune ridges at elevations often greater than 20 ft. The beach face meets the seawardmost dune at an average elevation of 7.5 ft and maintains a relatively mild slope towards the ocean. The high tide beach is approximately 40 ft to 50 ft wide. The northernmost end of the island exhibits an even wider beach face due to the influence of the Pawley's Inlet shoal system. Figure 3.10-4d (station 4360) is a typical profile of the undeveloped northern section of Debidue Island

3.11 COASTAL STRUCTURE INVENTORY

A wide variety of coastal structures exist throughout the study area. These structures vary greatly as to their type, function, condition, composition, and frequency of occurrence along the specific reaches of shoreline that comprise the study area. Types of structures include seawalls, bulkheads, sandbagging, revetments, groins, jetties and artificial dunes that are often referred to as a soft structure. These structures are designed for reclamation and retention of uplands, shoreline stabilization, inlet stabilization, dune and upland armoring, and beach enhancement. The condition of structures is widely varied and can generally be considered to be a function of age and original design. The U.S. Army Corps of Engineers, in a 1983 report assessing shoreline structural conditions north of Murrells Inlet asserted that the majority would not be able to withstand a major hurricane. Structural composition varies between concrete, timber, rock, gravel, filter cloth and beach sand. Frequency of occurrence ranges from the heavily armored shoreline reaches of Pawley's Island to the virtually structure-free beach along the Litchfield-Huntington shoreline.

The inventory maps included as Appendix D provide a detailed depiction of the type, composition and frequency of structures presently existing along the entire study area. The following paragraphs include additional discussion on the background, condition, function and apparent present day effectiveness of these structures over the specific shoreline reaches comprising the study area. Revegetation, sand fences, dune walkovers, and other "minor" structures are not included in this shoreline inventory.

<u>Debidue Island</u>

Approximately 82% of the Debidue Island shoreline remains devoid of any shoreline structures. The primary exception to this is the approximately 4,100 ft wooden seawall along the central developed portion of the island known as the

Debordieu Tract. This seawall was constructed of pressure-treated timber with an approximate top elevation of +8.5 ft MSL. It currently serves the dual purpose of protecting the upland residential development from the storm surges and waves associated with moderate storms, as well as daily wave run-up while retaining backfill that was artificially placed on its landward side during the development of the Debordieu Tract.

In response to accelerated erosion south of the developed portion of the DeBordieu Tract, an artificial dune extending 1500 ft south of the seawall was constructed in early 1986. Averaging 13-15 ft in elevation, the dune is set well landward of the natural dune ridge and has also been vegetated. The dune should provide a valuable upland buffer in the event of a severe storm as well as an additional reservoir of sand to supplement natural beach-building processes.

The remnants of two derelict timber groins are located on the beach face approximately 0.7 miles south of the southern end of the DeBordieu Tract seawall. The groins were built in 1971 by the Belle W. Baruch Plantation Institute in an attempt to stabilize the receding beach at that location. The groins were unsuccessful and only remnant piles and a few sheet sections presently remain. A timber groin also exists at the northern end of Debidue Island approximately 0.4 miles south of Pawley's Inlet. The groin was built around 1970 by the Arcadian Plantation. The groin remains in a good state of repair above the mean high water line but has lost its panels seaward of this line. As a result, although there is an observable buildup of sand along its updrift side, the groin poses no significant littoral barrier.

Pawley's Island

The most predominant structures along the Pawley's Island shoreline are a system of groins of various lengths and spacings, extending from the southern tip of the island north to the Pawley's Island fishing pier. Originally, groins were constructed of palmetto logs in the late 1940's by the South Carolina State Highway Department (SCSHD). These groins have since been replaced and additional ones built by the SCSHD so that, at present, a system of 23 groins of creosote timber construction exists along the shoreline. Many of these groins have been extended and/or armored with stone at their seaward ends. In many cases the rock has settled substantially thereby decreasing its effectiveness. The existing groins are in various states of repair and, as a result, exhibit varied degrees of effectiveness. Generally, the groins seem to be effective in trapping wind-blown sand above the mean high water line, however, their relatively short length precludes potential for trapping significant quantities of alongshore littoral drift. It should be noted that the groin field could potentially be useful in retaining future beach fill constructed at this location, although their relationship to beach restoration should be evaluated.

A large terminal training groin, approximately 685 feet in length, was constructed at the north end of the island by the SCSHD in the late 1950's. This groin, constructed of creosote timber and armored with stone, was intended to prevent further southerly migration of the Midway Inlet channel and corresponding erosion of Pawley's Island. In this sense the groin has been effective in stabilizing the inlet.

Both the northern and southern ends of Pawley's Island have been armored with rock revetments that appear to have been successful in retarding upland erosion associated with inlet migration. Wooden bulkheads at the landward extent of many of the groins were observed at intermittent locations along the central and southern reaches of the island shoreline. At several of the locations, the bulkheads had become buried by sand, thereby precluding an accurate assessment of both their condition and linear extent. The length of the bulkhead was estimated to be at least 2,500 ft and general observations indicate fairly good overall conditions.

Pawley's Island Pier was originally built by a Mr. Arthur Erick in the late 1940's. The pier was destroyed in 1954 by Hurricane Hazel and rebuilt to its current 680 ft length in the spring of 1955. Around 1970 the pier was sold to Pawley's Island developers and in 1971, ownership was passed onto the Pawley's Island Pier Village Association, who remain its current owners. (Personal communication - Doc Lanchicotte).

Litchfield-Huntington Beach

With the exception of approximately 920 ft of concrete block bulkhead fronting the Litchfield Inn, this entire stretch of shoreline is structure-free. The bulkhead at the Litchfield Inn was constructed to retain backfill for the swimming pool, patio and other upland amenities. The bulkhead appears to be performing well as no indication of lost backfill, fissures in the wall, nor flanking was observed upon visual inspection. The north tip of this shoreline reach is bounded by the south jetty at Murrells Inlet.

Murrells Inlet Navigation Project

In 1971, Congress authorized a navigation improvement project for Murrells Inlet under the provisions of Section 201 of the Flood Control Act of 1965. Construction of the project began in 1977 and was completed in 1980. Primary design features of the project included jetties north and south of the inlet, a weir section, the creation of a navigation channel and the option for construction of a deflector dike in the event that the navigation channel migrated into the deposition basin (see Figure 3.11-1). The south jetty is 3,319 ft long, of typical rubble-mound construction and capped with an asphalt walkway at an elevation of +9 ft MLW. The north jetty is 3,445 ft long and is also built of rubble-mound construction to an elevation of +9 ft MLW. A 1,315 ft weir section of the north jetty was built to an elevation of +2.2 MLW to allow sand to pass over it into the deposition basin during periods of southerly sediment transport. As the basin becomes filled with sand, a dredge can remove the sand and deposit it on nearby beaches. The deposition basin was originally dredged to a depth of -20 ft MLW and the navigation channel to a depth of -10 ftMLW, resulting in more than a million cubic yards of sand being pumped to beaches of Garden City to the north and Huntington Beach State Park to the south. The deflector dike has not been constructed because to date, the navigation channel has not shown a tendency to migrate into the deposition basin (Douglass, USACE - 1985).

Garden City Beach

North of Murrells Inlet, the shoreline along Garden City Beach is armored by a system of groins and seawalls at both its north and south ends. Commencing 2,250 ft north of the north jetty, a 2,670 ft timber seawall varying in elevation from +9 ft to +11 ft serves to retain backfill and protect the upland residential properties from wave run-up as well as storm surges and waves associated with moderate storms. Two groins were constructed along the southern half of this seawall in 1968 and two others were constructed along the northern half in 1970. All four groins are 270 ft in length and were constructed of creosote timber and stone by the South Carolina State Highway Department.

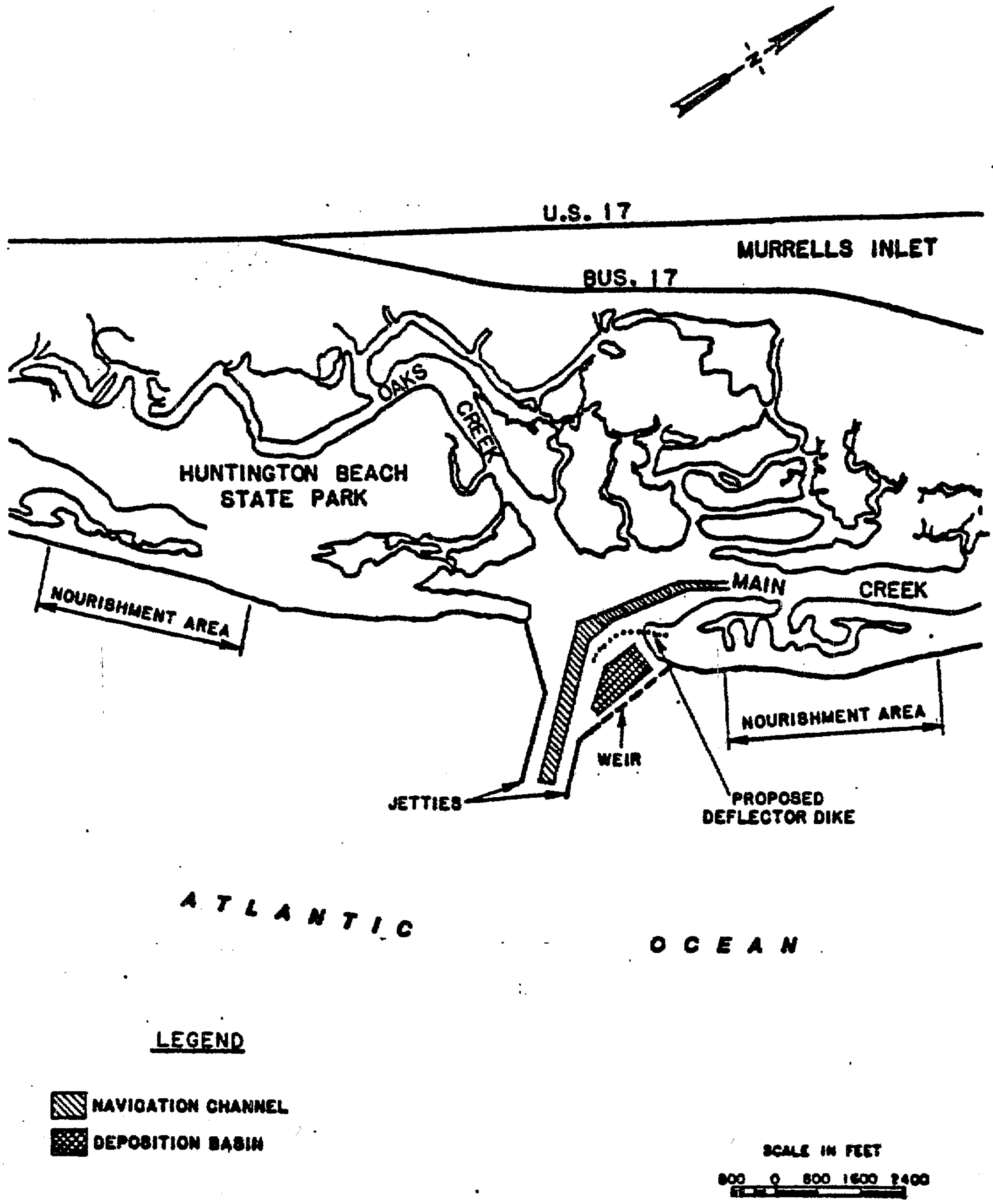


FIGURE 3.11-1
MURRELLS INLET NAVIGATION
IMPROVEMENT PROJECT

Another timber seawall is located approximately 3,900 ft south of the Georgetown-Horry County Line; it varies in elevation from +9 to +11 ft. The seawall serves to retain backfill and protect upland residential property from wave impacts. Three groins were constructed along the northern half of this seawall in 1970 and three others were constructed along the southern half in 1974. All six groins are 200 ft in length and were constructed of stone by the South Carolina State Highway Department.

4.0 SHOREFRONT DEVELOPMENT PATTERNS

Shorefront development along the section of Georgetown County shoreline encompassed in this study may be generally classified as residential in nature. Over virtually the entire study area, buildings along the coast are either single family residences, relatively low-density multi-family comdominiums, or resort complexes. This is in contrast to the Horry County shoreline where the majority of the coastal development is higher-density commercial structures consisting of high-rise hotels, older low-rise motels, campgrounds and mobile home parks. Also in contrast to Horry County is the fact that approximately 48% of the Georgetown County study area is still undeveloped, while barely 20% of the Horry County study area has escaped development. The following paragraphs present a more-detailed breakdown of shoreline development patterns along the Georgetown County study area.

Debidue Island

Development along the Debidue Island shoreline has been limited to the construction of primarily single-family and a few multi-family residences along the DeBordieu Tract. this development has been taking place over the past 15-20 years and has included canalization of tidal creeks and construction of dykes, causeways, impoundments and other alteration of wetlands immediately upland of the DeBordieu Tract (Kana et al, 1985).

South of the Debidue Tract lies the Belle W. Baruch Plantation, consisting of more than 16,000 acres that were set aside in 1964 by the late Belle w. Baruch to be held in trust for marine science and related research. It is not likely that this stretch of shoreline will ever be developed. North of the Debidue Tract are two plots of land referred to as Arcadia I and II. Both plots are privately owned and, more than likely, will be subject to development plans in the near future. No public access to the b3beaches of Debidue Island is provided through the island uplands. In all, approximately 20% of Debidue Island has been developed as either single-or multi-family construction , while 80% remains undeveloped. It should be noted that several sections of Debidue island have been designated by the Coastal Barriers Resources ACT (CBRA) as being "undeveloped coastal barriers" and therefore ineligible for federal subsidiary for flood insurance as well as certain infrastructure.

Pawley's Island

Pawley's Island was first settled in the late 1700's as a summer retreat from the hot, malaria-infested lowland plantations located. More recently, the island has been extensively developed as a summer resort community. All beachfront property is privately owned and, with the exception of several condominiums in the vicinity of Pawley's Island Pier, the island consists entirely of single family residence. Public access to the beach is made available from a small public parking lot at the southern tip of the island and at various street ends along the island (Cubit-1981). Very few undeveloped shorefront tracts remain on Pawley's Island.

Litchfield - Huntington

The southernmost 5000' of Litchfield Beach is presently undeveloped. Commencing north from this point, however, development in the form of multi-family condominiums and single family residences line the shore. In general, the multi-family developments have gone up in the last 10-15 years, whereas most of the single-family residences are somewhat older. Approximately 1.3 miles of shoreline immediately south of Myrtle Beach State park, denoted primarily as North Litchfield Beach, consists entirely of single-family residences. The Myrtle Beach State

Park,shoreline, extending from this point north to Murrell's Inlet is entirely undeveloped. Public access to the beach is available via the State Park and at a few locations south to Midway Inlet. In all, approximately 63% of the Litchfield-Huntington shoreline may be classified as undeveloped, 10% as multi-family/commercial and 27% as single-family residences.

Garden City Beach

Approximately 80% of that portion of Garden City Beach shoreline that lies within Georgetown County is developed with single family residences. The remaining shoreline may be classified as 11% multi-family residence and 9% undeveloped. Public beach access is very limited as virtually the entire beachfront is privately owned and fronted by private homes or condominiums. Exhibits presented as Appendix E provide a graphic chronological history of development trends along the entire Garden City shoreline. A discussion of these trends follows.

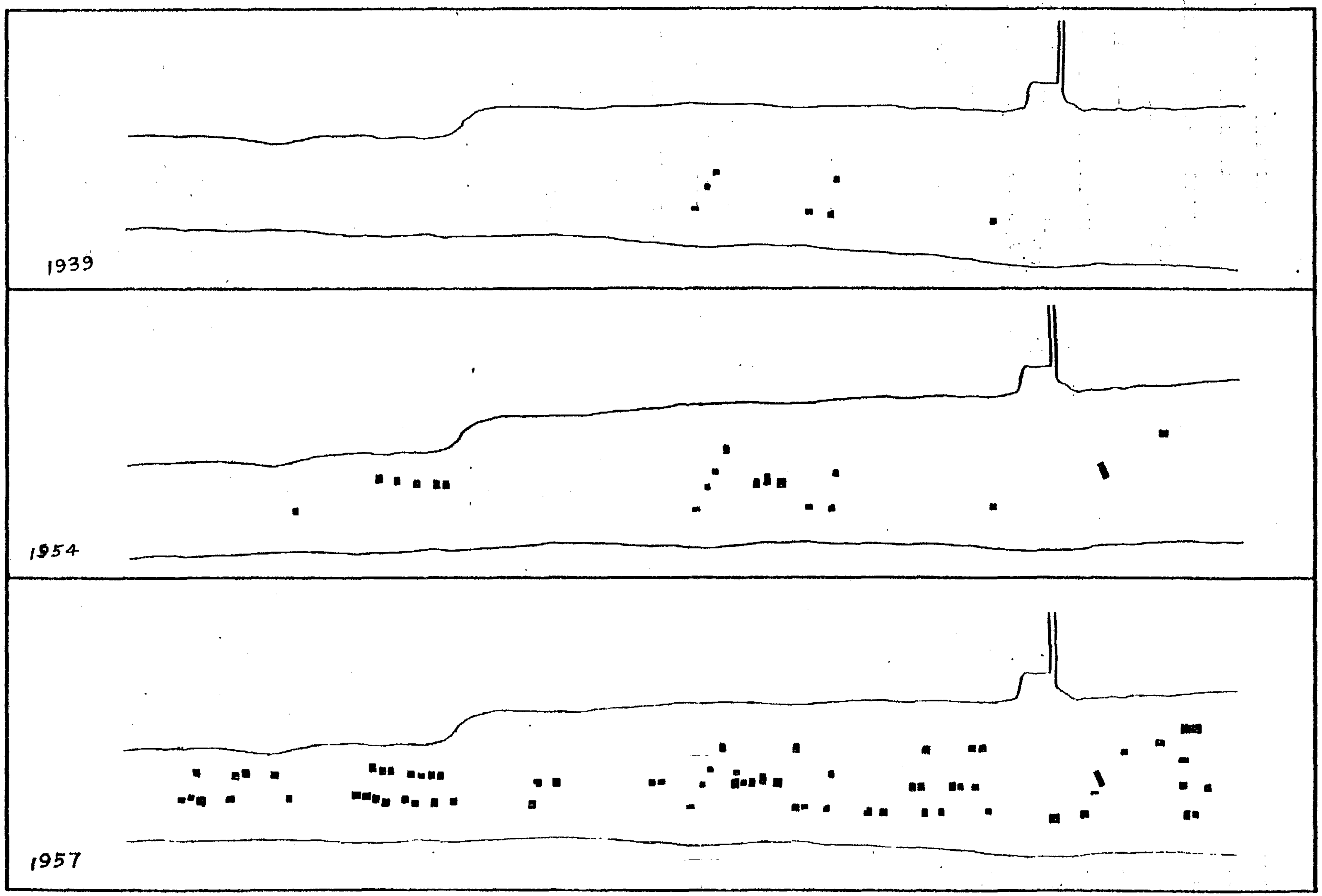
Garden City Beach Development History

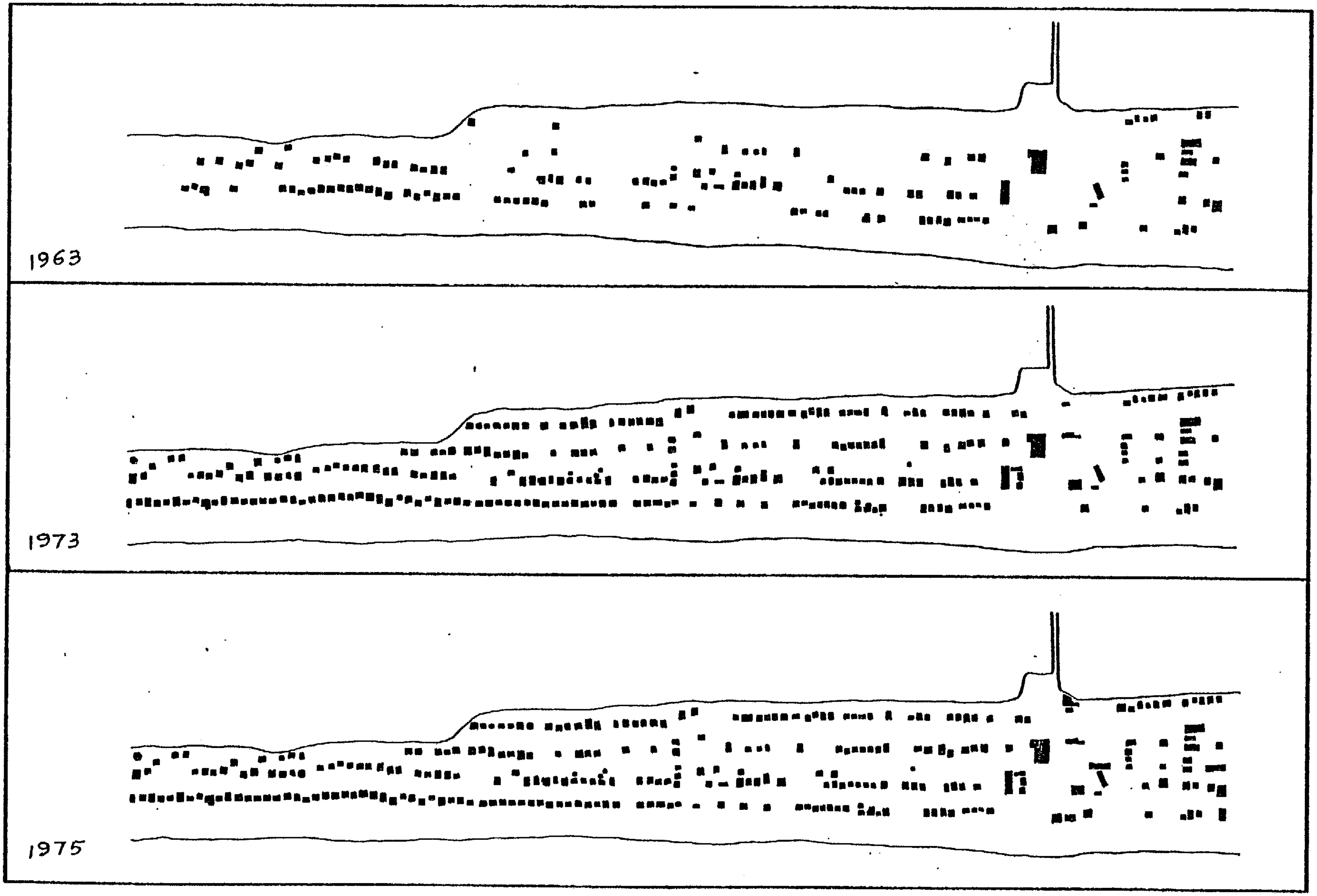
Of specific interest to the South Carolina Coastal Council, as outlined in the contract to perform this study, was the development trend of the entire Garden City shoreline. Accordingly, in-depth research was performed that resulted in a chronology of development patterns within the immediate vicinity of the shoreline of both the Georgetown (3.4 mile) and Horry County (1.8) mile segments of Garden City.

This research consisted of acquiring historical aerial photography of the Garden City area for as many different years as possible and then analyzing the photography to determine periods of construction for all discernible buildings. Aerial photography was obtained from more than a half-dozen sources and was usually taken from high altitudes, thereby requiring a magnifying glass, or in some cases photo enlargements, in order to accurately identify individual structures. The final product, included as Appendix E, consists of a series of exhibits reduced from 1" = 200' aerial photo-maps (flown in 1982) coded to depict the oldest known date that each structure has been in existence. These maps do not necessarily depict buildings that were razed to make room for newer structures, however, the majority of those buildings erected along the coastline after 1982 have been included. Figure 4.0-1 and 4.0-2 show the example of the development pattern between 1939 and 1975.

Examination of the various sources of photography indicates that in 1939, only seven houses had been built in the Garden City area. These houses were located in the immediate vicinity of the present day Georgetown-Horry County line, presumably convenient to the nearest form of transportation to the mainland. development obviously continued from this point forward, but the occurrence of Hurricane Hazel in 1954 destroyed or severely damaged much of the construction to that time. For example, post-storm photography indicates that approximately 75 homes within a one-mile radius of the county line successfully survived the hurricane. this included a building that is now the Kingfisher Inn. analysis of the same photography, however, indicates that approximately 100 homes were blown or floated off their foundations, some all the way into the westward-lying marsh.

By 1957, the Garden City area appears to have recovered from the damage caused by Hurricane Hazel and development began to resurge. Approximately 200 homes existed at that time in the area and construction was beginning to spread both farther north and south of the county line. Development accelerated to the point that by 1963, several hundred homes extended as far as 1.75 miles south of the county line and all the way to the north end of the present-day Garden City


1939
1954
1957


1963
1973
1975

limit. In addition, several large commercial buildings in the vicinity of the Kingfisher Inn had also been constructed. The period 1963 to 1973 was one of continual rapid growth and development throughout Garden City. Of particular note was the large number of single-family residences constructed to the south, extending to what is now the Garden City Point area adjacent to Murrell's Inlet.

By the mid-1970's Garden City consisted of well over 1,500 homes, condominiums and commercial buildings. Further development took place primarily along the northern and southern extremities of the city and on the remaining vacant parcels within the already developed area. From the late 1970's to 1984, residential development of Garden City Point and multi-family/commercial development towards the north end of Garden city continued. In addition, a relatively new form of construction, best described as multi-family low rise condominiums, came into the area. In some instances, older private homes were demolished to provide available land for this type of construction. since 1984, development trends have consisted typically of single-family residence in the Garden City Point region and multi-family condominiums and high-rises in northern Garden City.

5.0 SEDIMENT ANALYSIS

Beach sediment data were collected at 21 stations within the Georgetown County study area. Surface sediment samples were collected at the following three locations along the profile; 1) toe of the primary dune or seawall, 2)locations of MHW or approximately +2.5 ft MSL, and 3) location of MLW or approximately -2.5 ft MSL. Sediment samples were selected at approximately every third station and at stations adjacent to inlets to provide information on sediment statistics and grain size distribution. Selection of sample stations was in consideration of the proximity to inlets, piers and shorefront structures to accurately represent the sand characteristics along specific shoreline reaches. Representative samples containing at least 200 grams were collected, labeled and analyzed for size frequency distributions.

Sediment sizes are generally expressed by the grain diameter (mm) or using phi (ϕ) units which are related to grain diameter by the expression: $\phi = -\log_2$ (mm). Figure 5-1 presents grain size scales with conversions tables and Wentworth size class descriptions. For all samples, grain sizes were expected to range between coarse sand (0.75 phi or 0.60 mm) and very fine sand (4.00 phi and 0.06 mm) which for unconsolidated sand required sieve analysis methods. As an extremely small fraction (<1%) of the sample is in the silt range, requiring pipette or hydrometer analytical methods, analysis for this fraction of sediment grain sizes was not justified. Particle sizes equal to or greater than 0.75 phi were dried and weighed and a brief description of the visual characteristics of the remaining pan fraction noted. Although the majority of the samples were comprised of grains smaller than 0.75 phi, a few samples contained an unusually large fraction of very coarse sand sizes with shell fragments.

Millimeters	Microns	Phi (ϕ)	Wentworth Size Class	
(1 Kilometer)		-20		
4096		-12		
1024		-10	Boulder (-8 to -12ϕ)	
256		-8		
64		-6	Cobble (-6 to -8ϕ)	GRAVEL
16		-4	Pebble (-2 to -6ϕ)	
4		-2		
3.36		-1.75		
2.83		-1.5	Granule	
2.38		-1.25		
2.00		-1.0		
1.68		-0.75		
1.41		-0.5	Very coarse sand	
1.19		-0.25		
1.00		0.0		
0.84		0.25		
0.71		0.5	Coarse sand	
0.59		0.75		
0.50	500	1.0		
0.42	420	1.25		
0.35	350	1.5	Medium sand	SAND
0.30	300	1.75		
0.25	250	2.0		
0.210	210	2.25		
0.177	177	2.5	Fine sand	
0.149	149	2.75		
0.125	125	3.0		
0.105	105	3.25		
0.088	88	3.5	Very fine sand	
0.074	74	3.75		
0.0625	62.5	4.0		
0.053	53	4.25		
0.044	44	4.5	Coarse silt	
0.037	37	4.75		
0.031	31	5.0		
0.0156	15.6	6.0	Medium silt	MUD
0.0078	7.8	7.0	Fine silt	
0.0039	3.9	8.0	Very fine silt	
0.0020	2.0	9.0		
0.00098	0.98	10.0	Clay	
0.00049	0.49	11.0	(Some use 2ϕ or	
0.00024	0.24	12.0	9ϕ as the clay	
0.00012	0.12	13.0	boundry)	
0.00006	0.06	14.0		

FIGURE 5-1
GRAIN SIZE SCALES AND WENTWORTH SIZE CLASS DESCRIPTIONS (Folk and Ward 1957)

Grain size data were entered into a computer data base and statistically analyzed according to the graphic methods described by Folk and Ward (1957). Statistical methodology developed by Folk and Ward includes a greater portion of the grain size distribution (90%) for determining sediment characteristics as opposed to alternative methods (Inman, 1952) which include only the distribution of sizes within the first standard deviation (68%). The methods of Folk and Ward (1957) adequately analyze data which are skewed or demonstrate a bi-modal distribution.

Mean grain size, median grain size, standard deviation of the grain size frequency distribution, skewness and kurtosis are the statistical parameters computed for evaluation of the sample data. Cumulative frequency plots of grain size distributions and a table summarizing phi, weight retained, cumulative weight, weight percent and cumulative percent are presented for each sample in Appendix B. Most commonly, to characterize a sample, the average grain size (mean) and the standard deviation or degree of sorting are discussed. The greater the standard deviation, the less the degree of sorting and greater the variability of sediment sizes.

For more specific analysis, skewness (α) is computed as a measure of the degree of departure from a normal distribution of grain sizes. A positive value is skewed to the right (contains a greater range of sediment sizes) and a negative value (excess coarse grains) is skewed to the left. Kurtosis (β) is a measure of the peakedness of the distribution of sediment sizes, where β=1.0 is associated with a normal distribution.

Table 5.1 presents a summary of sediment statistical parameters for sample data collected along Garden City Beaches, Litchfield/Huntington Beaches, Pawley's Island and Debidue Beach shorelines. These samples, listed from north

Table 5.0-1. Summary of Sediment Statistical Parameters Along Georgetown County

	TOD				MHW				MLW			
Station	φ_{50}	mm	σ	α	φ_{50}	mm	σ	α	φ_{50}	mm	σ	α
4655	1.2*	.44			1.4*	.38			1.9	.27	0.9	-0.3
4635	1.9	.27	0.6	-0.1	1.9	.27	0.8	-0.4	2.0	.25	0.9	-0.4
4620	2.1	.23	0.5	-0.2	2.2	.22	0.5	-0.2	1.7*	.31		
4605	2.1	.23	0.7	-0.5	1.7	.31	0.8	-0.2	**		**	**
Murrells Inlet												
	Avg = 1.8	.29			Avg = 1.8	.29			Avg = 1.9	.27		
4590	2.5	.18	0.5	-0.4	2.5	.18	0.4	-0.2	2.0	.25	0.7	-0.3
4565	1.8	.29	0.5	0.0	2.2	.22	0.5	-0.2	2.3	.20	0.5	-0.3
4545	2.5	.18	0.4	-0.4	2.5	.18	0.4	-0.3	2.3	.20	0.6	-0.3
4530	2.3	.20	0.4	-0.3	2.3	.20	0.8	-0.4	1.6	.33	0.8	0.2
4515	2.2	.22	0.4	-0.2	2.4	.19	0.6	-0.4	2.0	.25	0.7	-0.3
4505	2.3	.20	0.5	-0.2	2.0	.25	0.7	-0.4	1.9	.27	0.8	-0.4
Midway Inlet												
	Avg = 2.3	.20			Avg = 2.3	.20			Avg = 2.0	.25		

*Large portion of coarse sand fraction
**Sample with grain size analysis insufficient

φ = grain size in phi units
σ = standard deviation in phi units
α = skewness

Table 5.0-1 (Continued)

Station	TOD φ50	TOD mm	TOD σ	TOD α	MHW φ50	MHW mm	MHW σ	MHW α	MLW φ50	MLW mm	MLW σ	MLW α
4460	1.9	.27	0.5	-0.1	1.7	.31	0.6	0.0	1.6	.33	0.7	0.1
4445	1.9	.27	0.7	-0.4	2.4	.19	0.4	-0.4	2.1	.23	0.7	-0.4
4430	1.9	.27	0.5	0.0	2.0	.25	0.6	-0.2	1.3*	.41		
4420	2.1	.23	0.5	-0.3	2.2	.22	0.5	-0.2	2.4	.19	0.6	-0.4
4405	2.3	.20	0.4	-0.2	2.6	.16	0.3	-0.1	1.8	.29	0.8	-0.1
Pawley's Inlet Avg =	2.0	.25		Avg =	2.2	.22		Avg =	1.8	.29		
4370	2.0	.25	0.5	-0.2	1.5*	.35			2.2	.22	0.5	-0.3
4355	1.8	.29	0.6	-0.1	2.2	.22	-0.9	-0.5	2.2	.22	0.9	-0.5
4345	1.8	.29	0.6	-0.2	2.6	.16	0.4	-0.1	2.0	.25	0.9	-0.5
4335	1.8	.29	0.6	-0.1	2.4	.19	0.4	-0.3	2.3	.20	0.8	-0.4
4320	2.4	.19	0.4	-0.2	1.9	.27	0.7	-0.2	1.8	.29	0.8	-0.3
4305	2.1	.23	0.4	-0.2	2.0	.25	0.6	-0.2	2.3	.20	0.6	-0.5
North Inlet Avg =	2.0	.25		Avg =	2.1	.23		Avg =	2.1	.23		

*Large portion of coarse sand fraction
**Sample with grain size analysis insufficient

Source: Applied Technology and Management, Inc. and Olsen Associates, Inc., 1986 to south, indicate a high-degree of variability for the entire shoreline fronting Garden City. This data set was biased by the recent placement of artificial fill along the Myrtle Beach shoreline immediately north of Garden City combined with the beach nourishment project which placed 633,497 cubic yards of Murrells Inlet dredge material along the Garden City shoreline in Georgetown County during the period 1978 to 1980. Of the 12 samples collected along this shoreline 4 contain a large fraction of coarse sand grains as presented in Figure 5-1. Recognizing this possible bias, grain sizes along Garden City Beaches ranged between 1.2 and 2.1 phi, or 0.44 and 0.23 mm. The average standard deviation of the distribution of grain sizes, i.e. a measure of sorting, was found to be moderate ($\sigma(\phi) = 0.7$). Specific conclusions drawn from these sediment statistics are only applicable in a temporal sense and will be expected to vary as the natural shoreline processes (waves conditions, shoreline orientation, nearshore slope and normal sediment population) sort and redistribute the non-native beach nourishment material.

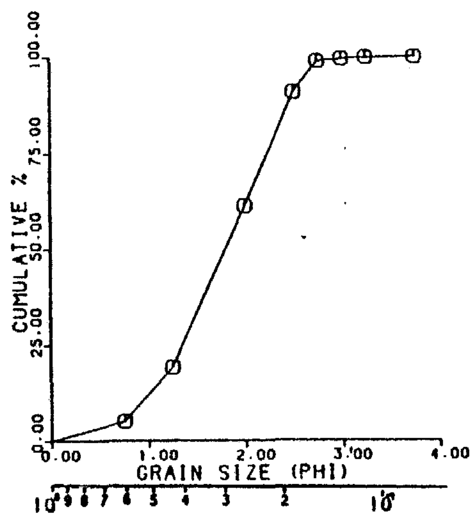
Mean grain sizes for sediment samples collected at six stations along the Huntington Beach State Park and Litchfield Beach shorelines were relatively uniform, averaging 2.3 phi, and represented a higher degree of sorting then the Garden City Beaches. The average standard deviation, including samples across the profile and along the shoreline, is equal to 0.5 phi. Characteristically, samples were found to have higher variability (less sorted) across the profile than along the length of local shoreline and generally coarser towards the location of mean low water.

Sediment samples were collected at 5 stations along Pawley's Island. Mean grain sizes ranged from 1.6 to 2.6 phi, or 0.33 to 0.16 mm, and exhibited a moderately sorted distribution with an average standard deviation of 0.6 phi. The grain size distributions varied along the entire shoreline and across the individual profile stations. An average grain size for this area was calculated as 2.1 phi neglecting the extreme value of 1.3 phi found for sample 4430 MLW.

Debidue Beach sand characteristics were found to be slightly coarser with all samples negatively skewed and containing a greater fraction of coarse grains. Mean grain sizes ranged between 1.5 and 2.6 phi with an overall average mean grain size equal to 2.1 phi. Again, these sand samples varied as to the degree of sorting. Standard deviations ranged from 0.4 to 0.9 phi and averaged 0.6 phi. Figure 5-2 presents typical sediment statistical parameters for a station located along the seawall adjacent to DeBordieu Colony (#4335).

North to south, the average grain size increase slightly between Huntington Beach and North Inlet.

CUMULATIVE FREQUENCY CURVE OF SAMPLE: 4335 TOD



SAMPLE: 4335TOD DATE: 19860514 STATION: 4335
PROJECT: SCCC SAMPLE WEIGHT: 179.80 GRAMS

PHI	WEIGHT RET. (G)	CUMULATIVE WEIGHT (G)	WEIGHT PERCENT	CUMULATIVE PERCENT
0.75	9.00	9.00	5.0	5.01
1.25	25.60	34.60	14.2	19.24
2.00	75.40	110.00	41.9	61.18
2.50	53.00	163.00	29.5	90.66
2.75	14.50	177.50	8.1	98.72
3.00	1.20	178.70	0.7	99.39
3.25	0.70	179.40	0.4	99.78
3.75	0.30	179.70	0.2	99.94

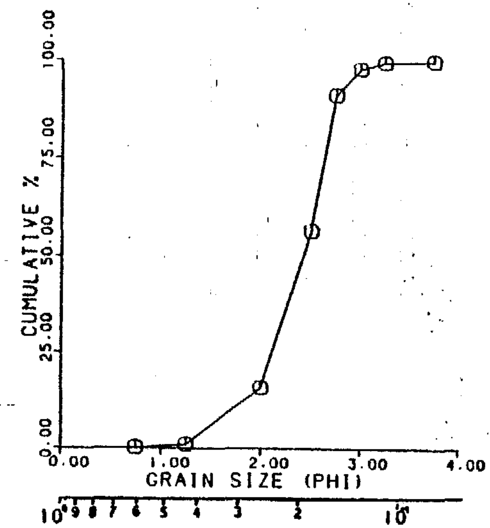
PAN 0.00 GRAMS

STATISTICAL PARAMETERS

MEDIAN=	1.8
GRAPHIC MEAN=	1.8
INCLUSIVE GRAPHIC STANDARD DEVIATION=	0.6
INCLUSIVE GRAPHIC SKEWNESS=	-0.1
GRAPHIC KURTOSIS=	0.9

NOT ENOUGH DATA POINTS ENTERED, MIN=4

CUMULATIVE FREQUENCY CURVE OF SAMPLE: 4335 MHW



SAMPLE: 4335MHW DATE: 19860604 STATION: 4335
PROJECT: SCCC SAMPLE WEIGHT: 232.70 GRAMS

PHI	WEIGHT RET. (G)	CUMULATIVE WEIGHT (G)	WEIGHT PERCENT	CUMULATIVE PERCENT
0.75	0.40	0.40	0.2	0.17
1.25	1.90	2.30	0.8	0.99
2.00	34.60	36.90	14.9	15.86
2.50	94.70	131.60	40.7	56.55
2.75	80.00	211.60	34.4	90.93
3.00	16.10	227.70	6.9	97.85
3.25	4.10	231.80	1.8	99.61
3.75	0.80	232.60	0.3	99.96

PAN 0.00 GRAMS

STATISTICAL PARAMETERS

MEDIAN=	2.4
GRAPHIC MEAN=	2.4
INCLUSIVE GRAPHIC STANDARD DEVIATION=	0.4
INCLUSIVE GRAPHIC SKEWNESS=	-0.3
GRAPHIC KURTOSIS=	1.1

FIGURE 5-2
SEDIMENT STATISTICAL ANALYSIS AT DEBORDIEU COLONY

6.0 BEACH PROFILE AND EROSION ANALYSIS

6.1 COMPARATIVE BEACH PROFILES

Previously surveyed beach-dune profiles, replicated by this study, were assembled for comparative analysis. Data were analyzed using 3 profile surveys conducted in 1958, 14 new profiles established in 1979 by the USCOE, Coastal Engineering Research Center, and 12 stations established in 1981 along Pawley's Island. Shoreline response associated with the construction of the Murrells Inlet jetties necessitated monitoring of adjacent beaches that provided yearly data from 1979 to 1982.

All available data, including field-survey notes, were collected and digitized. Profiles were entered into a common data base along specific shoreline segments and adjusted horizontally and vertically using both field survey notes and reference control point information. Comparative beach-profile survey data recovery is summarized in Table 6.1-1. Where vertical or horizontal control of comparative surveys could not be established, the data were flagged accordingly or deleted.

Qualitatively, successive surveys were reviewed for both consistency and quality. Comparative survey records covering the period 1958 to 1986 were considered for long-term erosion analysis. Profile data along Garden City and Huntington-Litchfield Beaches, collected between 1979 and 1986, were surveyed to monitor the effects of the Murrells Inlet jetties and represented short-term profile data. Comparisons of Pawley's Island survey data between February-March 1981 and April 1986 represent short-term shoreline variation.

Analysis of volumetric changes and shoreline movement using these comparative profile data were encumbered by the limited data base. Accordingly, long-term erosion and

Table 6.1-1. Inventory of Comparative survey data

AREA	PROFILE #	YEAR OF COMPARATIVE SURVEY DATA	COMPARATIVE DATA TOTAL NO. SURVEYS
GARDEN CITY	4605	1979, 1980, 1981, 1982, 1986	5
	4610	1980, 1981, 1982, 1986	4
	4615	1979, 1980, 1981, 1982, 1986	5
	4620	1979, 1980, 1981, 1982, 1986	5
	4625	1979, 1980, 1981, 1982, 1986	5
	4630	1958, 1984, 1986	6
	4635	1979, 1980, 1981, 1982, 1986	5
	4640	1958, 1984, 1986	6
	4645	1958*,1983*, 1986	6
	4650	1958, 1984	5
	4660	1958, 1984, 1986	5
LITCHFIELD HUNTINGTON	4505	1979*, 1981*, 1982*, 1986, 1980*	4
	4510	1986	1
	4515	1979, 1981, 1982, 1986, 1980	4
	4520	1986	1
	4525	1979, 1981, 1982, 1986, 1980	4
	4530	1986	1
	4535	1986	1
	4540	1979, 1981, 1982, 1986, 1980	4
	4545	1986	1
	4550	1986	1
	4555	1979, 1981, 1982, 1986, 1980	4
	4560	1986	1
	4565	1986	1
	4570	1979, 1981, 1982, 1986, 1980	4
	4575	1979, 1981, 1982, 1986, 1980	4
	4580	1979, 1981, 1982, 1986, 1980	4
	4585	1986	1
	4590	1979, 1981, 1982, 1986, 1980	4
PAWLEY'S ISLAND	4405	1981, 1986	2
	4410	1981, 1986	2
	4416	1981, 1986	2
	4420	1981, 1986	2
	4425	1981, 1986	2
	4430	1981, 1986	2
	4435	1981, 1986	2
	4440	1981*, 1986*	2
	4445	1981, 1986	2
	4450	1981, 1986	2
	4455	1981*, 1986	2
	4460	1981*, 1986	2

*Profiles excluded where survey comparisons were not valid

Table 6.1-1. (continued)

AREA	PROFILE #	YEAR OF COMPARATIVE SURVEY DATA	COMPARATIVE DATA TOTAL NO. SURVEYS
DEBORDIEU	4305	1986	1
	4310	1986	1
	4316	1986	1
	4320	1986	1
	4325	1986	1
	4330	1986	1
	4335	1986	1
	4340	1986	1
	4345	1986	1
	4350	1986	1
	4355	1986	1
	4360	1986	1
	4365	1986	1
	4370	1986	1

accretion rates were limited to 3 stations within the entire Georgetown County study area. To supplement this limited data set, 23 new profiles were established at approximately 2,000-ft intervals along the Huntington-Litchfield Beach shoreline and Debidue Beach. The survey profile locations are shown in Figure 3.8-2

6.2 VOLUMETRIC ANALYSIS

Comparative beach-dune profiles were analyzed along Georgetown County's shoreline to determine the rates of long-term and short-term volume changes. Individual comparative profiles were examined to compute changes in profile volume where volume is defined as cross-sectional area multiplied by a unit width. As discussed in Section 6.1, data records representing 25 or more years (i.e. 1958 surveys) allowed an estimate of long-term profile volume changes, whereas the remaining data base (1979 to present) would allow only for estimating short-term volume variability.

Short-term profile changes are caused by severe storms or structural shoreline modifications, such as jetties, shorefront structures and dredging. Seasonal storms, i.e. northeasters and hurricanes or tropical storms, cause the beach to erode and the shoreline to fluctuate. Over a relatively short period of time, several days to many years, sand will be transported shoreward and the beach recovers by accretion or onshore sediment transport. In contrast, profile changes which maintain a consistent trend over a long period of time (generally greater than 25 years) are catagorized as long-term changes or trends. In response to the pervasive rise in mean sea level, the beach profile shifts landward to maintain a natural equilibrium state.

Two methods were used to compute volume changes, the first method follows a prescribed control-volume approach and the second method computes volume changes across the profile for the limits of the region in common comparison. Figures 6.2-1 and 6.2-2 define the width of the profile over which volume changes are computed using the 1)control volume and 2) comparative profile segment approach, respectively.

In the control-volume method, volume changes were computed between the +10.0' and -3.0' contour wherever possible. When low dune-crest elevations and seawalls precluded using the +10.0' contour, an alternative maximum contour elevation was chosen. Unit control volumes, average annual volume changes and net volume changes are presented in Tables 6.2-1, 6.2-2, and 6.2-3 for all comparative profiles. Negative volume changes represent erosion. The control volume, representing the portion of the profile used to determine volume changes, is limited by the initial position (x_{min} and x_{max} in Figure 6.2-1) of the earliest survey date. The control volume method analyzes only part of the dynamic portion of the beach profile, which includes the entire primary dune seaward to the point of limiting depth, or depth of closure, which is defined as the shoreward depth which experiences seasonal profile variations. Volume changes calculated using the landward and seaward limits established by the initial control volume may not and often do not represent the actual magnitude of the volumetric change over the active profile. To demonstrate this analysis flaw, Figure 6.2-2 shows serious erosion at Station 4555 between 1979 and 1968, however, the control volume method, shown in Figure 6.2-1, indicates only small changes. The control volume method is used in this report because it is required to establish the ideal present profile.

The purpose of the profile data collected along the shoreline by the USCOE, both north and south of Murrells

CONTROL VOLUME METHOD

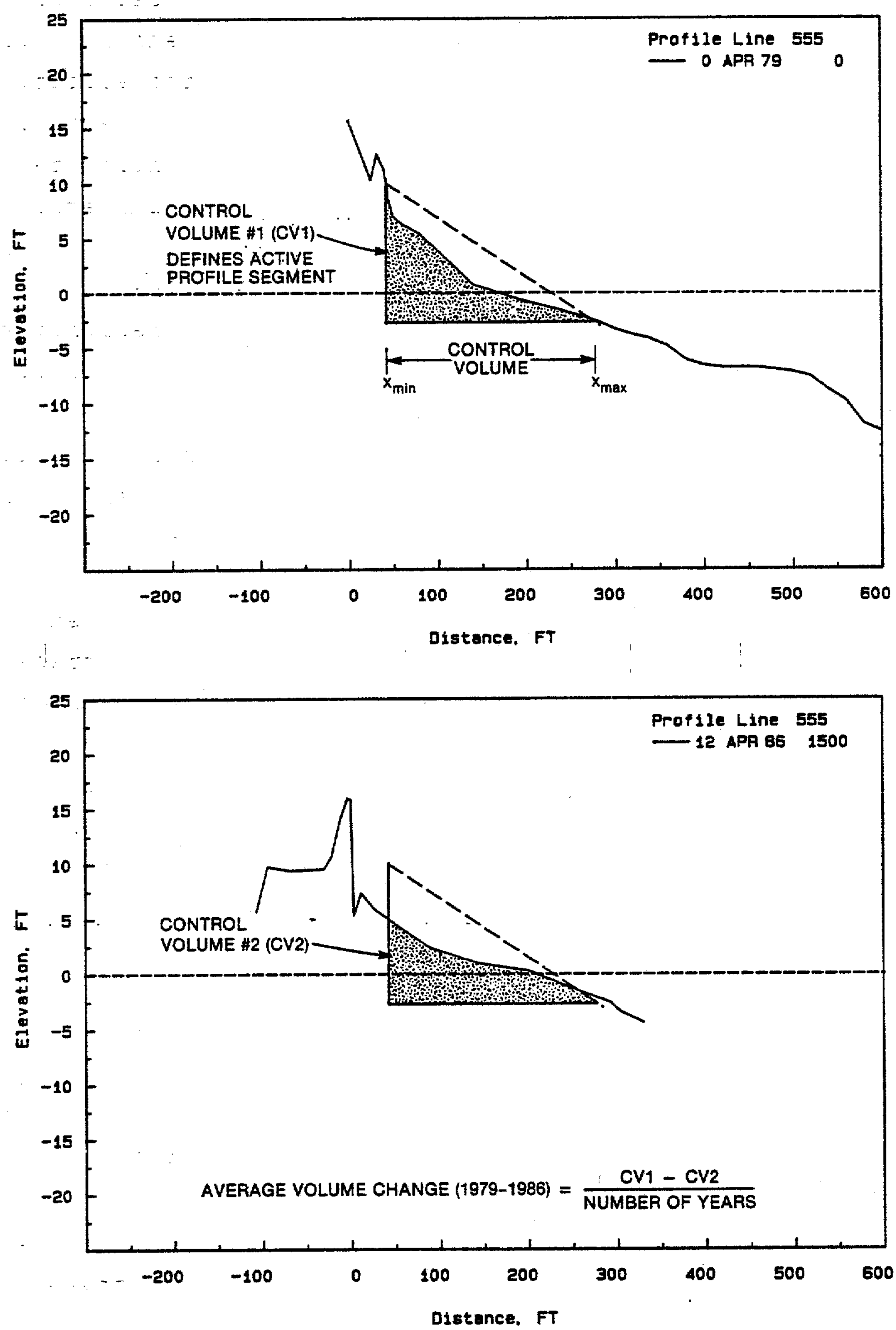


FIGURE 6.2-1
DEFINITION SKETCH FOR COMPUTING AVERAGE VOLUME CHANGES USING THE CONTROL VOLUME METHOD AT PROFILE #4555

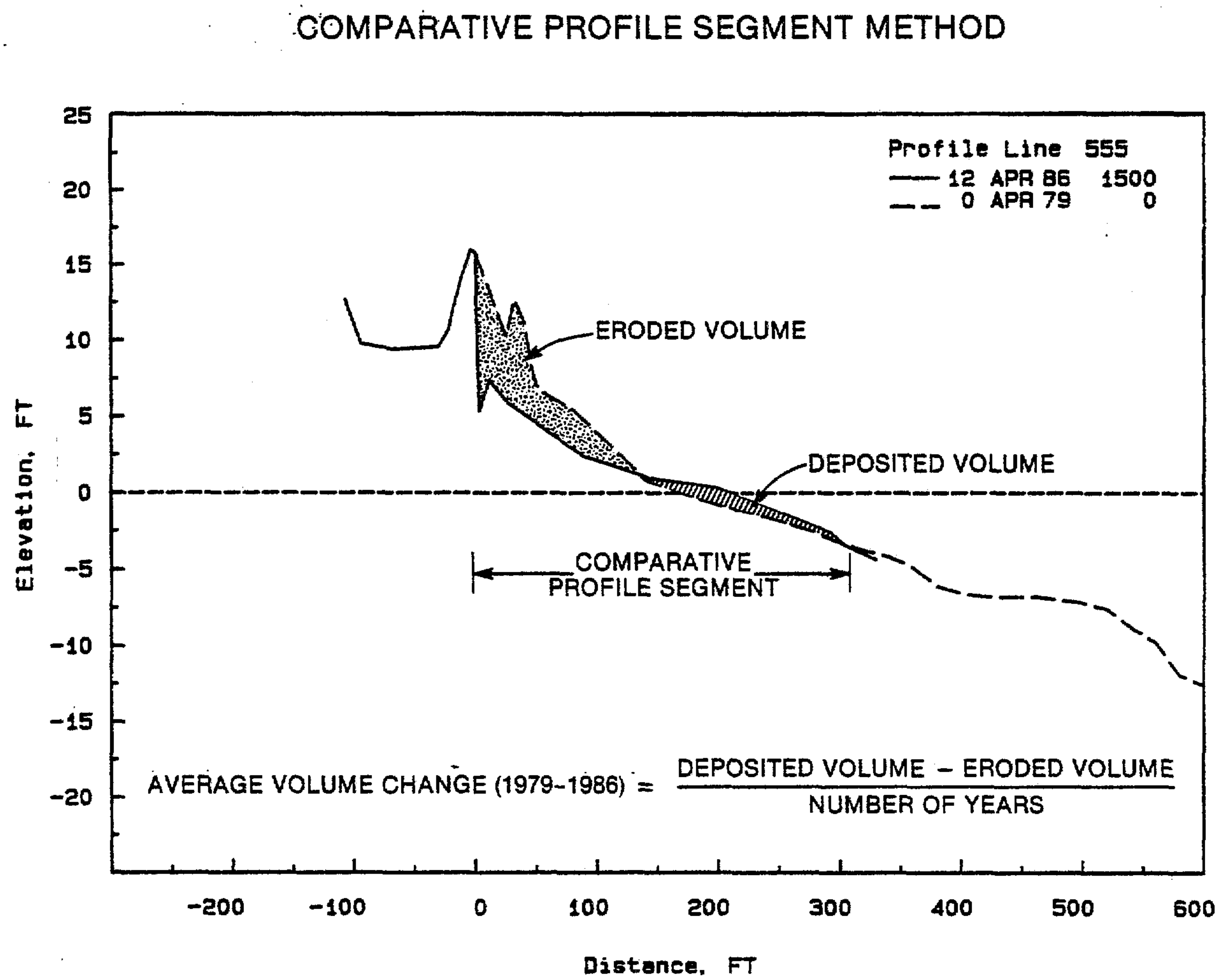


FIGURE 6.2-2
DEFINITION SKETCH FOR COMPUTING AVERAGE VOLUME CHANGES USING THE COMPARATIVE PROFILE SEGMENT METHOD AT PROFILE #4555

Table 6.2-1. Average, Net and Unit-width Volume Changes between 10.0 ft and -3.0 ft MSL (Garden City)

Station	1958-84 (26 yrs)	1979-80 (1 yr)	1980-81 (1 yr)	1981-82 (1 yr)	1982-86 (4 yrs)	1984-86 (2 yrs)	1979-86 (7 yrs)	1958-86 (28 yrs)
	Average Volumetric Change (yd^3/ft/yr)						Net Volumetric Changes (cy^3/ft)	
Garden City								
4605		8.2	7.0	4.2	0.1		20.0	
4610			18.1	-0.8	-5.3		-3.8	
4615		32.2	-13.9	-7.3	-3.3		-2.2	
4620		13.0	14.2	-10.9	-0.2		16.1	
4625		2.3	27.0	-17.2	0.2		12.7	
4630	2.8					3.9		81.4
4635		3.6	-1.9	2.0	1.8		10.9	
4640	1.0					2.9		21.5
4660	0.6					-1.0		13.2

Unit-Width Volume (yd^3/ft)

Station	January 1958	Sept 1979	Sept 1980	Sept 1981	Sept 1982	March 1984	April 1986
Garden City							
4605		60.2	68.4	75.4	79.6		80.2
4610			47.8	65.9	65.1		44.0
4615		46.4	78.6	64.8	57.5		44.2
4620		20.2	33.5	47.5	36.7		35.9
4625		42.1	44.4	71.4	54.2		54.8
4630	54.7					128.3	144.2
4635		30.8	34.4	32.5	34.4	41.7	41.7
4640	39.6					66.9	61.1
4645	33.5					23.6	96.8
4660	30.9					46.0	44.1

Table 6.2-2. Average, Net and Unit-Width Volume Changes Between 10.0 ft and -3.0 ft (Huntington/Litchfield)

	Average Volumetric Change ($yd^3/ft/yr$)				Net Volumetric Changes (yd^3/ft)
Station	1979-80 (1 yr)	1980-81 (1 yr)	1981-82 (1 yr)	1982-86 (4 yrs)	1979-86 (7 yrs)
Huntington and Litchfield Beach					
4515	1.5	-5.9	1.9	0.7	0.3
4525	3.1	-5.4	-3.7	0.7	-3.1
4540	-20.6	-1.9	2.3	-0.3	-21.6
4555	-6.3	0.5	-4.0	1.6	0.5
4570	-12.4	9.7	12.6	0.6	12.4
4575	-2.6	30.1	2.4	1.1	34.4
4580	7.9	17.4	2.1	3.5	40.3
4590	9.0	-1.8	MD	10.6	60.4

	Unit-Width Volume (yd^3/ft)				
Station	Sept 1979	Sept 1980	Sept 1981	Sept 1982	April 1986
Huntington and Litchfield Beach					
4515	46.9	48.3	42.5	44.4	47.2
4525	40.9	44.0	38.6	35.0	37.9
4540	56.3	35.7	33.8	36.1	34.7
4555	55.1	31.5	32.0	28.1	34.6
4570	42.6	30.3	40.0	52.5	55.1
4575	44.4	41.7	71.9	74.2	78.8
4580	139.0	146.0	163.4	165.5	179.3
4590	101.8	110.8	109.0		162.2

Table 6.2-3. Average, Net and Unit-Width Volume Changes Between 10.0 ft and -3.0 ft (Pawley's Island)

Station	Average Volumetric Change ($yd^3/ft/yr$) 1981-86 (5 yrs)	Net Volumetric Changes (yd^3/ft) 1981-86 (5 yrs)	Unit-Width Volume (yd^3/ft) Feb-Mar (1981)	Unit-Width Volume (yd^3/ft) April (1986)
<u>Pawley's Island</u>				
4405	1.2	5.8	40.5	46.3
4410	0.0	0.0	44.8	44.8
4416	-0.2	-1.2	35.2	34.0
4420	-3.0	-14.9	41.4	26.5
4425	-0.1	-0.6	33.7	33.1
4430	1.0	5.2	32.7	37.9
4435	-1.1	-5.7	43.5	37.8
4445	1.6	7.9	33.5	41.4
4450	1.2	6.1	36.2	42.2

Inlet, was to monitor the effects on shoreline planeform changes caused by jetty construction. The Murrells Inlet monitoring study was designed to study this major perturbation. The effects of these jetties and inlet dredging have caused substantial volumetric changes along several profiles.

The nature of seasonal variation in profile cross-section is well-documented and accepted. Winter profiles result from offshore sand transport, with sand stored in a bar. During summer months the beach recovers as moderate wave conditions transport this bar onshore, resulting in a more gentle (summer) profile. Accordingly, the short-term volume changes presented in Tables 6.2-1 and 6.2-2 for the 1980-1981 surveys along the Garden City and Huntington-Litchfield Beach shoreline represent seasonal shoreline variation, and must be regarded as a short-term, seasonal shoreline change. Figure 6.2-3 represents the seasonal profile variations of a hypothetical survey depicting volume changes which result from winter and summer wave conditions.

A second approach, the comparative profile segment method, examines volume changes over a greater portion of the active profile. This method will attempt to qualify and substantiate the control volume methodology which may inaccurately represent the magnitude of erosion or accretion for profiles which experience a high degree of variability. Using the comparative profile segment approach, Table 6.2-4 and 6.2-5 presents the average annual volume changes and the net volume changes including notes to depict locations of man-induced profile modifications. A comparison of profile surveys analyzed using both methods to compute volume changes revealed that the nature of the variability, either erosion or deposition, was generally consistent between the control volume and the comparative profile segment approach for Georgetown County profile data.

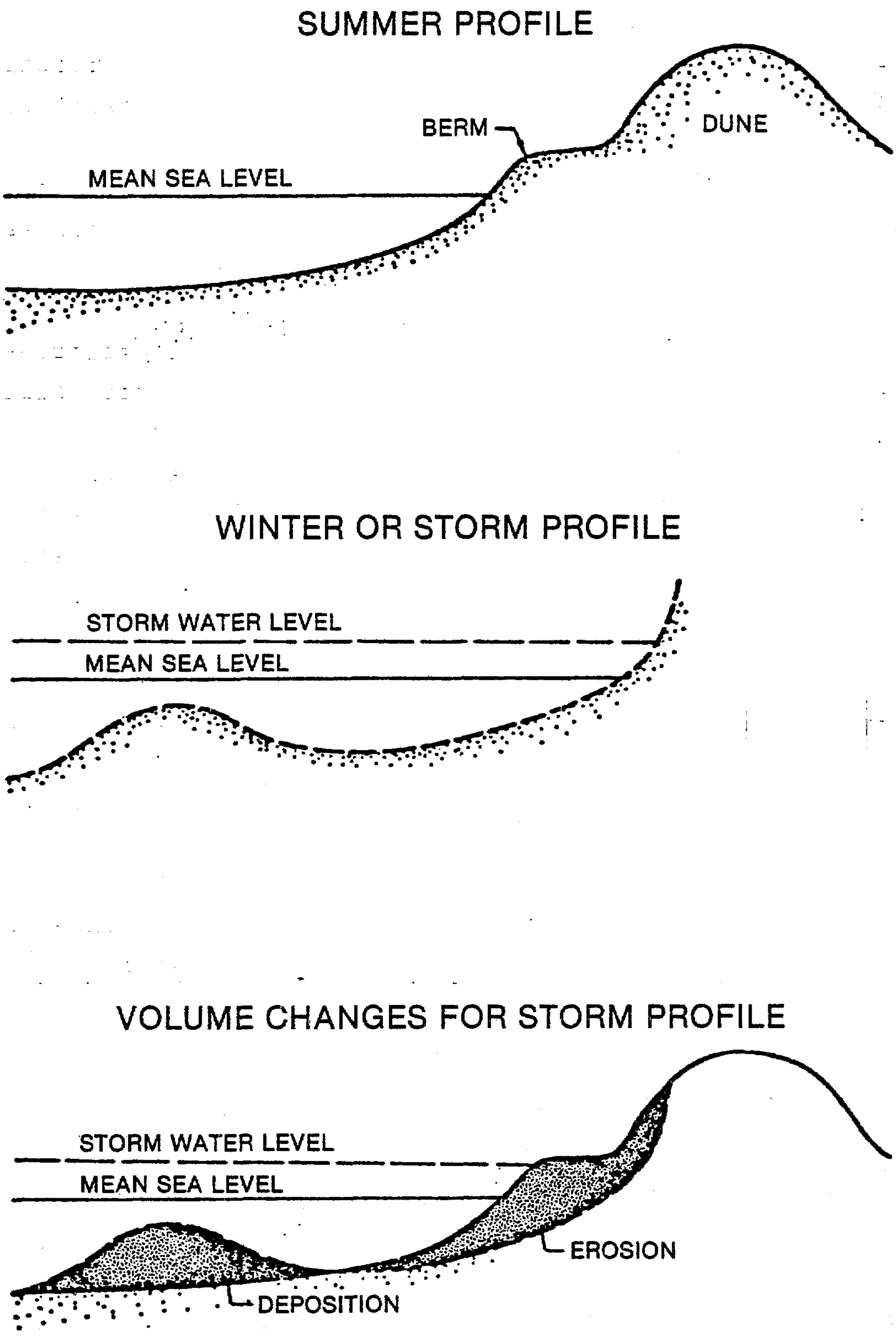


FIGURE 6.2-3
IDEALIZED SEASONAL PROFILE VARIATION AND THE ASSOCIATED VOLUME CHANGES

Table 6.2-4. Average and Net Volume Changes between Comparative Profile Surveys

	Average Volumetric Change ($yd^3/ft/yr$)		Net Volumetric Changes (yd^3/ft)		Notes
Station	1958-86 (28 yrs)	1979-86 (7 yrs)	1979-86 (7 yrs)	1958-86 (28 yrs)	Shoreline Structures, Nourishment, etc
Garden City					
4605		2.9	20.2		
4610		0.0	-0.1		1500' North of Murrells Inlet Jetties
4615		-4.0	-2.5		Beach Nourish-ment
4620		3.0	20.8		12/78-6/80
4625		1.6	11.2		"
4630	2.6		72.2		
4635		5.1	35.7		
4640	0.3			9.1	
4660	0.6			16.9	

	Average Volumetric Change ($yd^3/ft/yr$)	Net Volumetric Changes (yd^3/ft)	Notes
Station	1979-86 (1 yr)	1979-86 (7 yrs)	Shoreline Structures, Nourishment, etc
Huntington and Litchfield Beach			
4515	0.9	6.1	
4525	1.7	8.9	
4540	-3.4	-23.8	
4555	-1.8	-12.2	
4570	4.9	34.0	
4575	13.8	96.3	Beach Nourish-ment 11/80-12/80
4580	6.7	46.9	"
4590	31.5	220.7	500 ft South from Murrells Inlet South Jetty

Table 6.2-5. Average and Net Volume Changes Between Comparative Profile Surveys (Pawley's Island)

	Average Volumetric Change (yd^3/ft/yr)	Net Volumetric Changes (yd^3/ft)	Notes
Station	1981-86 (5 yrs)	1981-86 (5 yrs)	Shoreline Structures, Nourishment,etc
<u>Pawley's Island</u>			
4405	1.2	5.8	
4410	-0.1	-0.5	
4416	-0.9	-4.6	
4420	-3.3	-16.4	
4425	-1.6	-8.2	
4430	1.6	7.9	
4435	-1.6	-7.8	South 300' from Pawley's Island Pier
4445	-2.3	-11.4	
4450	-1.4	-6.7	

Garden City

Profile variability, based on average annual volume changes along the shoreline segment south from Kingfisher Pier to Murrells Inlet, was greatest for stations fronting Inlet Harbor. Net accretion occurred at the five beach profiles extending south from Kingfisher Pier along 2 miles of Garden City shoreline within Georgetown County. Erosional trends were observed at profiles immediately north of the Murrells Inlet north jetty where the beach was nourished between 1978 and 1980.

Long-term volumetric changes were computed at 3 stations along the Garden City shoreline. These trends indicate erosion at stations #4640 and #4660, where long-term erosion rates ranged from -0.3 to -0.6 yd^3/ft for the last 28 years.

Profiles along the shoreline immediately north of Murrells Inlet (2000 ft) eroded from 1981 to 1986. Beach nourishment along this shoreline segment (12/78 to 6/80) has resulted in a beach planeform out of equilibrium with the natural shoreline processes.

Huntington-Litchfield Beach

Analyses of volume changes for Huntington-Litchfield Beach profiles indicate a short-term depositional trend over the northern and southern shorelines. Beach profiles for stations #4540 and #4555 consistently eroded from 1979 to 1986. This shoreline has experienced a sediment deficit which is a direct result of Murrells Inlet jetties. Longshore currents fail to transport sufficient sand to this reach of shoreline so that there is a net deficit in southerly sediment transport to these beaches. The sheltering effects of an extensive ebb tidal shoal and the 0.6 mile long jetties have caused northerly longshore currents to predominate along the northern reaches on Huntington Beach.

Pawley's Island

Pawley's Island has accreted at the southernmost beach profile station (#4405) during the period of February-March 1981 to April 1986, and eroded along the shoreline reach between station #4410 and #4425, a shore distance of approximately 6000 feet. Erosion along the northern shoreline of Pawley's Island is evident on the comparative profiles seen in Figure 6.2-4. Applying a control volume extending across the foreshore area of the dune-beach profile, to compute volume changes at stations #4445 and #4450 resulted in a net depositional trend. A visual comparison of the 1981 survey data with 1986 surveys for profiles at stations #4445 and #4450 depict erosion along the primary dune. The most significant volume changes for this profile occurred along the primary dune portion of the profile and are more accurately represented using the comparative profile segment methodology.

Analysis of volume changes for beach profiles at stations #4555 and #4450 are better represented using a greater region along the profile for computing volume changes. The control volume does not account for erosion landward or seaward of the original control points (X_{min} and X_{max}) established using the foreshore region of the earliest survey. Short-term beach profile variations in the region of the primary dune may be described by the elevation of the dune crest and the width of the dune. These characteristics of the primary dune represent the first line of defense against wave and high-frequency storm tide impacts on the beach-dune system.

Volume changes for shoreline areas that are characterized by large profile fluctuations or for cases where early survey

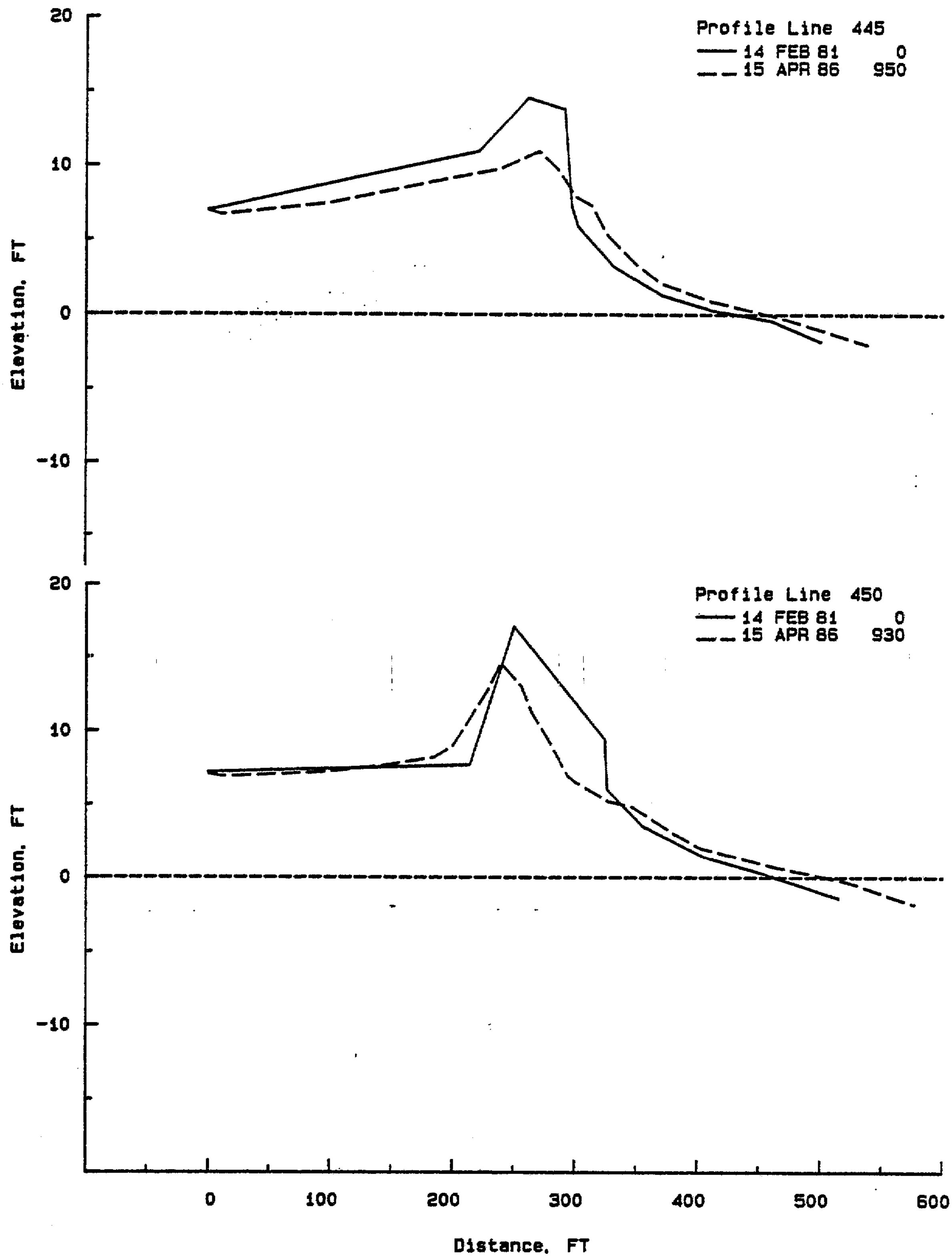


FIGURE 6.2-4
COMPARATIVE BEACH PROFILE SURVEYS FOR STATIONS 4445 AND 4450 BETWEEN 1981 AND 1986 ALONG PAWLEY'S ISLAND

data represent a steeper winter storm profile, the actual volume change may be underestimated or inaccurately assessed. Also, the dynamic portion of the profile extending to the depth of closure, or the limiting depth associated with an active profile, is not considered in these results.

6.3 SHORT-TERM SHORELINE EROSION RATE

Shoreline changes or beach erosion can be characterized using the following categories:

1. Initial volume changes can be caused by a discrete event such as a storm or beach nourishment. These sudden shoreline perturbations can occur within several days or overnight.
2. In response to sudden shoreline perturbations, beach profile will undergo a period of recovery. As an example, immediately following storm erosion, beach fill, or coastal structure construction, the beach profile will re-adjust as it reaches a new state of equilibrium. The rate of changes is greater at the initial stage of recovery, and decreases as it approaches equilibrium. The period of recovery normally is less than 10 years except for unusually large disturbances.
3. Beach profiles will experience periodic changes as it adjusts to differences in seasonal wave climate. The lower frequency summer waves will cause onshore sediment transport, resulting in a mild beach slope and wide beach face. The high energy winter wave climate results in offshore sediment transport and formation of offshore bars which characterize the winter profile. A mature stable shoreline will endure seasonal erosion/accretion and yet maintain long-term stability.
4. Long-term changes are caused by sea level rise, wind and wave climate, shoreline orientation, offshore

bathymetry, inlet dynamics, and other geological features. Long-term variation is typically much smaller than the short-term changes. A stable shoreline with negligible long-term erosion trends may have substantial seasonal variation. Therefore large quantity of time series data will be required to filter out short-term changes and accurately quantify long-term trends.

The first three categories are considered short-term changes and are evaluated according to contour movement based on comparative beach profile data.

In general, comparative beach survey data were available between 1979 and 1986, although few stations also had 1958 data. No greater than 5 sets of survey data were available at individual stations where the time period between consecutive surveys ranged from 1 year to 5 years, excluding the 1958 data. Comparisons between consecutive surveys are presented in Appendix B.

Shoreline changes, or contour movement of the beach topography, can be interpreted using shoreline recession/ accretion rates. However, appropriate contour elevations should be selected to obtain meaningful results. The beach face near MSL usually has a mild slope (approximately 2 to 3% along the study area), consequently, the MSL contour position is very sensitive to profile changes. For example, when the dune erodes, the material may be deposited to the foreshore area. Accordingly, the MSL contour is moved offshore. The MSL contour would appear to be the result of beach accretion, but in reality it may be the result of dune erosion. Therefore, the movement of a contour in a dynamic zone below MSL can yield misleading results. The mean high water line (about 2.98' NGVD) is located along a steeper beach slope (about 5 to 8% within the study area), and as a result was less sensitive to the spacial redistribution of the beach material and more accurately reflects both erosion or accretion.

Table 6.3-1 presents the MHW contour locations and recession rate in the Pawley'S Island area. Tables 6.3-2 and 6.3-3 show MHW contour movement in the Litchfield area. Table 6.3-4 and 6.3-5 present contour movement on Pawley's Island. Comparative profile data is not available for Debidue Beach, therefore the short-term changes can not be computed.

The short-term shoreline recession rate calculated using the available beach-profile database indicates considerable variation for shoreline changes, from 235 ft/yr accretion to 173 ft/yr erosion. The majority of extreme erosion/ accretion rates were derived from comparative data covering a short time period (about 1 year) and reflected the effects of seasonal changes and storm events.

Although the seasonal and yearly shoreline changes were substantial (from 33 ft/yr accretion to 41 ft/yr erosion), the average recession rates over 2 to 7 years were much smaller. Table 6.3-6 summarizes the short-term shoreline recession rates for each area indicate a highdegree of variability within the data as summarized in Table 6.3-6. Since the temporal database is small (5 profiles or less), it is difficult to make conclusive predictions about the short-term erosion rates. As an example, the 1982-86 data showed mostly erosion in the Garden City area, but 1979-86 data showed mostly accretion in the same area.

<u>Pawley's Island</u>
There were only two surveys conducted for Pawley's Island beach profiles (1981 and 1986). Table 6.3-1 presents the changes for the northern portion of the island where erosion occurred between survey dates and the southern reach which

Table 6.3-1 Mean High Water Contour Position (Pawley's Island)

Station	MHW Position (ft) 3/1981	MHW Position (ft) 4/1986	Rate of change* (ft/year)
4405	155	155	0.0
4410	172	166	-1.2
4416	206	199	-1.4
4420	389	354	-6.9
4425	353	345	-1.6
4430	340	341	0.2
4435	718	703	-3.0
4445	336	355	3.7
4450	360	380	3.9
4460	625	653	5.5

* Negative number indicates erosion.

Table 6.3-2. Mean High Water Contour Position (Litchfield Area)

Mean High Water Contour Position (feet from baseline)

Station	4/1979	4/1980	9/1981	4/1982	4/1986
4505	341	191	124	127	114
4515	130	142	142	99	103
4525	165	181	177	136	141
4540	187	138	151	94	94
4555	112	96	74	66	78
4570	143	18	114	173	179
4575	207	149	431	330	347
4580	421	394	502	533	528
4590	826	891	858		809

Table 6.3-3. Mean High Water Contour Movement (Litchfield Area)

Mean High Water Contour Movement Rate (ft/year)
(Negative number indicates erosion)

Station	1979-80	1980-81	1981-82	1982-86	1979-86	1980-86
4505	-150.0	-47.3	5.1	-3.3	-32.4	-12.8
4515	12.0	0.0	-73.7	1.0	-3.9	-6.5
4525	16.0	-2.8	-70.3	1.3	-3.4	-6.7
4540	-49.0	9.2	-97.7	0.0	-13.3	-7.3
4555	-16.0	-15.5	-13.7	3.0	-4.9	-3.0
4570	-125.0	67.7	101.1	1.5	5.1	26.8
4575	-58.0	199.0	-173.2	4.3	20.0	33.0
4580	-27.0	76.2	53.1	-1.3	15.3	22.3
4590	65.0	-23.3			-2.4	-13.7

Table 6.3-4 Mean High Water Contour Position (Garden City)

Mean High Water Contour Position (feet from baseline)

Station	1/1958	4/1979	4/1980	9/1981	4/1982	3/1984	4/1986
4605		410	436	453	466		448
4610			362	396	401		368
4615		315	550	401	328		303
4620		173	154		227		286
4625		237	253	363	300		286
4630	208					373	398
4635		340	353	363	355		359
4640	245					297	267
4650	218					174	
4660	151					203	177

Table 6.3-5 Mean High Water Contour Movement (Garden City)

Mean High Water Contour Movement Rate (ft/year)
(Negative number indicates erosion)

Station	1979-80	1980-81	1981-82	1982-86	1984-86	1979-86	1980-86	1958-84	1984-86
4605	26.0	12.0	22.3	-4.5		5.4	2.0		
4610		24.0	8.6	-8.3			1.0		
4615	235.0	-105.2	-125.2	-6.3		-1.7	-41.2		
4620	-19.0			14.8		16.1	22.0		
4625		11.3	188.6	-15.8		10.5	5.5		
4630								6.3	12.0
4635		9.2	17.1	-2.0		2.5	1.0		
4640								2.0	-14.4
4650								-1.7	
4660								2.0	-12.5

Table 6.3-6 Summary of Short-Term MHW Contour Movement

Average MHW Contour Movement (ft/yr)*

	Garden City	Litchfield Beach	Pawley's Island
4 yr maximum	14.8	4.3	
4 yr minimum	-15.8	-3.3	
4 yr average	-3.7	0.8	
5 yr maximum			5.5
5 yr minimum			-6.9
5 yr average			-0.1
6 yr maximum	22.0	33.0	
6 yr minimum	-41.2	-13.7	
6 yr average	-1.6	3.6	
7 yr maximum	16.1	20.0	
7 yr minimum	-1.7	-32.4	
7 yr average	6.6	-2.2	

*Negative value indicates erosion

has experienced accretion. The rate of accretion increased when approaching Pawley's Inlet.

Litchfield/Huntington Beach

In general, the shoreline between Murrells Inlet and Midway Inlet had the highest degree variability within the study area. Large erosion rates, as high as 150 ft/year, were indicated by the April 1979 and April 1980 data, except near the Murrells Inlet where the south jetty caused substantial accretion. The April 1980 and September 1981 data indicates accretion along this beach segment although this may be the result of a transformation from a winter to summer profile. Similarly, the September 1981 and April 1982 data indicate mostly erosion. The changes in the position of the MHW contour were less significant (from 4.3 ft/year accretion to 3.3 ft/year erosion) between April 1982 and April 1986, which may indicate that the planeform changes are adjusting to the effects of the Murrells Inlet jetties. The greatest temporal variability occurred between station 4540 and 4575. The spatial average of the MHW changes between April 1982 and April 1986 was about 2.2 ft/year erosion.

Garden City

With the exception of recent changes measured between 1982 and 1986, the area near Murrells Inlet north jetty (Station 4605 and 4610) has shown consistant accretion. Station 4615 experienced a high erosion rate as indicated in Table 6.3-5, whereas the shoreline north from station 4615 was predominantly accretional. The spatial average of the MHW changes between April 1979 and April 1986 was about 6.6 ft/year accretion.

6.4 LONG TERM SHORELINE EROSION RATE

NOS shoreline movement maps described in Section 3.7, were used to estimate long term erosion rate. The survey stations were located on the shoreline movement maps, and lateral changes of the shoreline position were measured relative to the 1983 shoreline. With the assistance of magnifying devices, the accuracy of the shoreline position is about 7 feet. Since the time periods between shoreline surveys were 9, 21, 28, and 50 years, the accuracy of the long term shoreline recession rate is about 0.3 ft/year. The time series of the shoreline position at each station is shown in Figures 6.4-1 to 6.4-3 for different section of the study area.

Figure 6.4-1, presents the shoreline changes along Debidue Beach and indicates that there was distinct shoreline movement trends between 1857 and 1925 when the sand spit at the southern end of the island grew rapidly. During this period of time, New Inlet, a previously existing inlet, was closed by the Debidue Spit. In the process of inlet closure, the southern Debidue Beach accreted and the northern Debidue Beach eroded. After the inlet closure, the southern island experienced heavy erosion, while the northern island was accretional. This trend reversal is typical when the shoreline recovers from a major disturbance. Since 1925, North Inlet continuously migrated toward the south with an average rate of about 100 ft per year. The migration and erosion slowed in an exponential fashion which is clearly shown in Figure 6.4-1.

Figure 6.4-2 shows the shoreline changes on Pawley's Island. The variability of shoreline recession was greatest at northern end of the island near Midway Inlet where the southerly migration of the inlet has caused erosion at northern end of Pawley's Island. At present, the southern portion of the island appears to be relatively stable except in the immediate vicinity of Pawley's Inlet.

The shoreline movement along Litchfield/Huntington Beach State Park area (Figure 6.4-3) had greater variability than

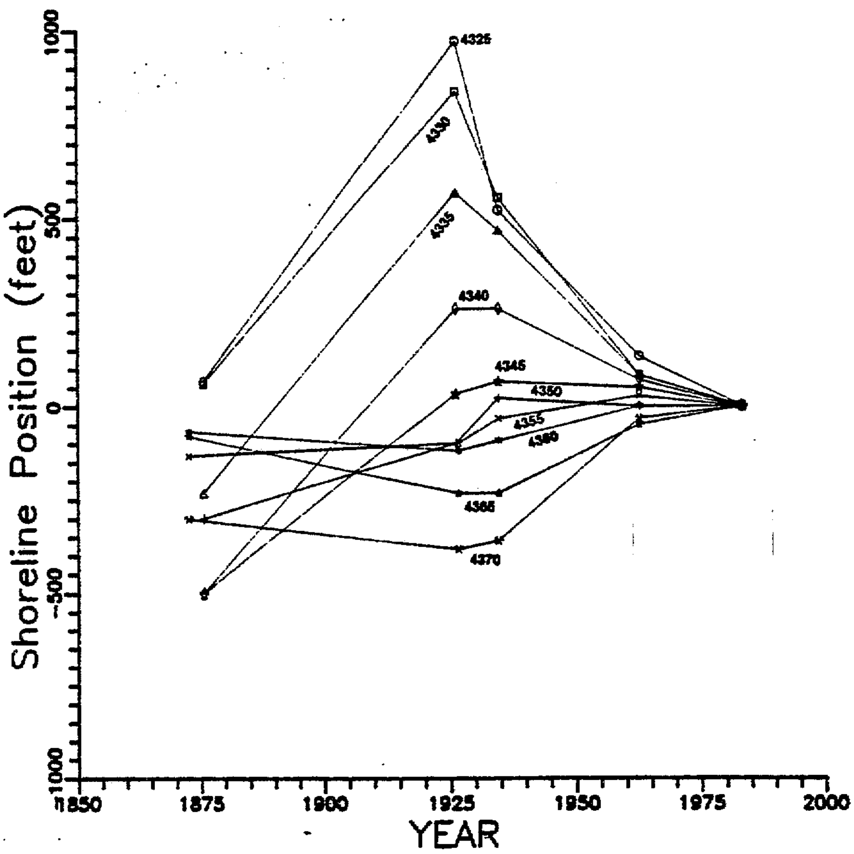


FIGURE 6.4-1
SHORELINE MOVEMENT AT MONITORING STATIONS ALONG DEBIDUE BEACH

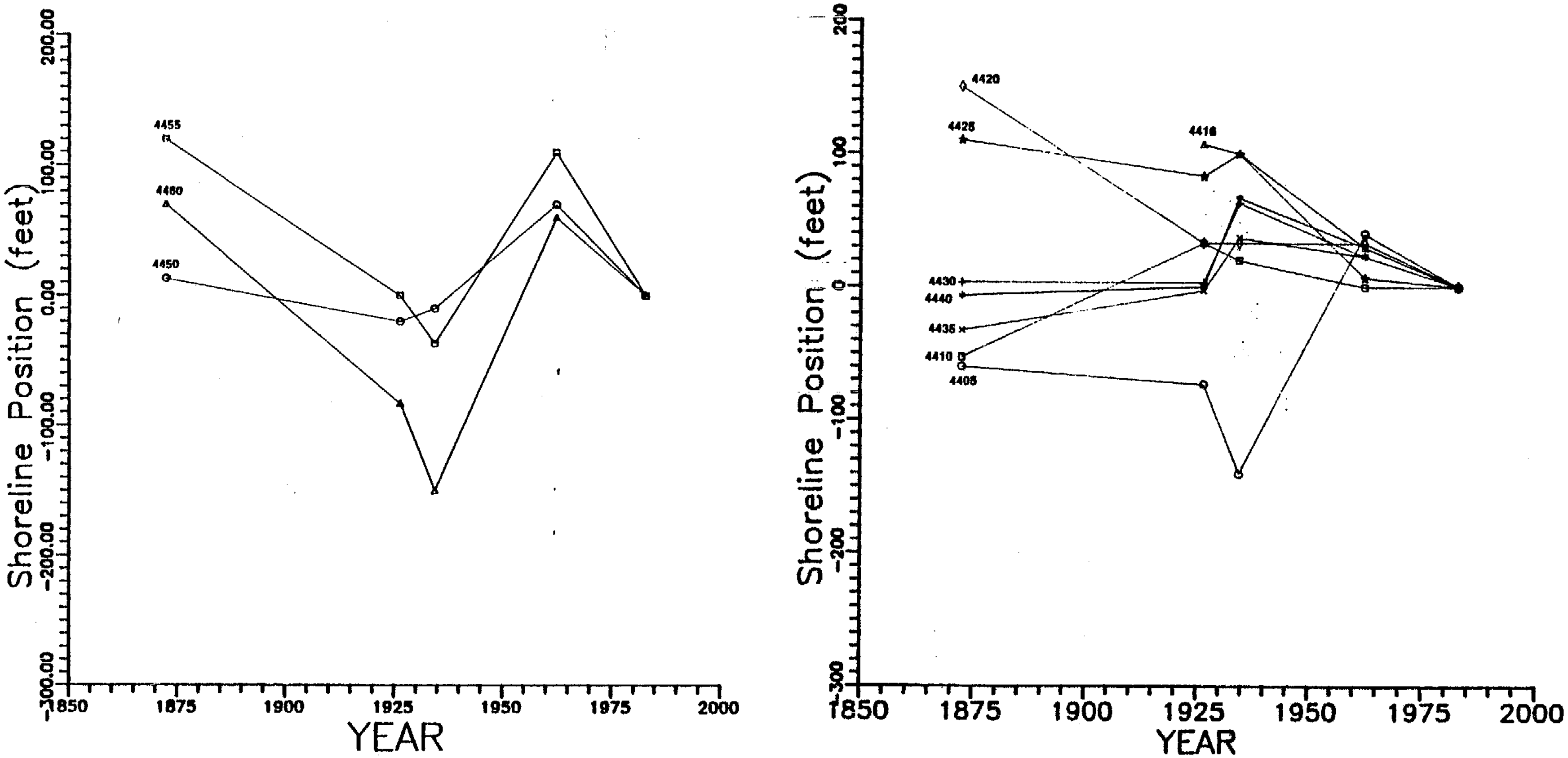


FIGURE 6.4-2
SHORELINE MOVEMENT AT MONITORING
STATIONS ALONG PAWLEY'S ISLAND

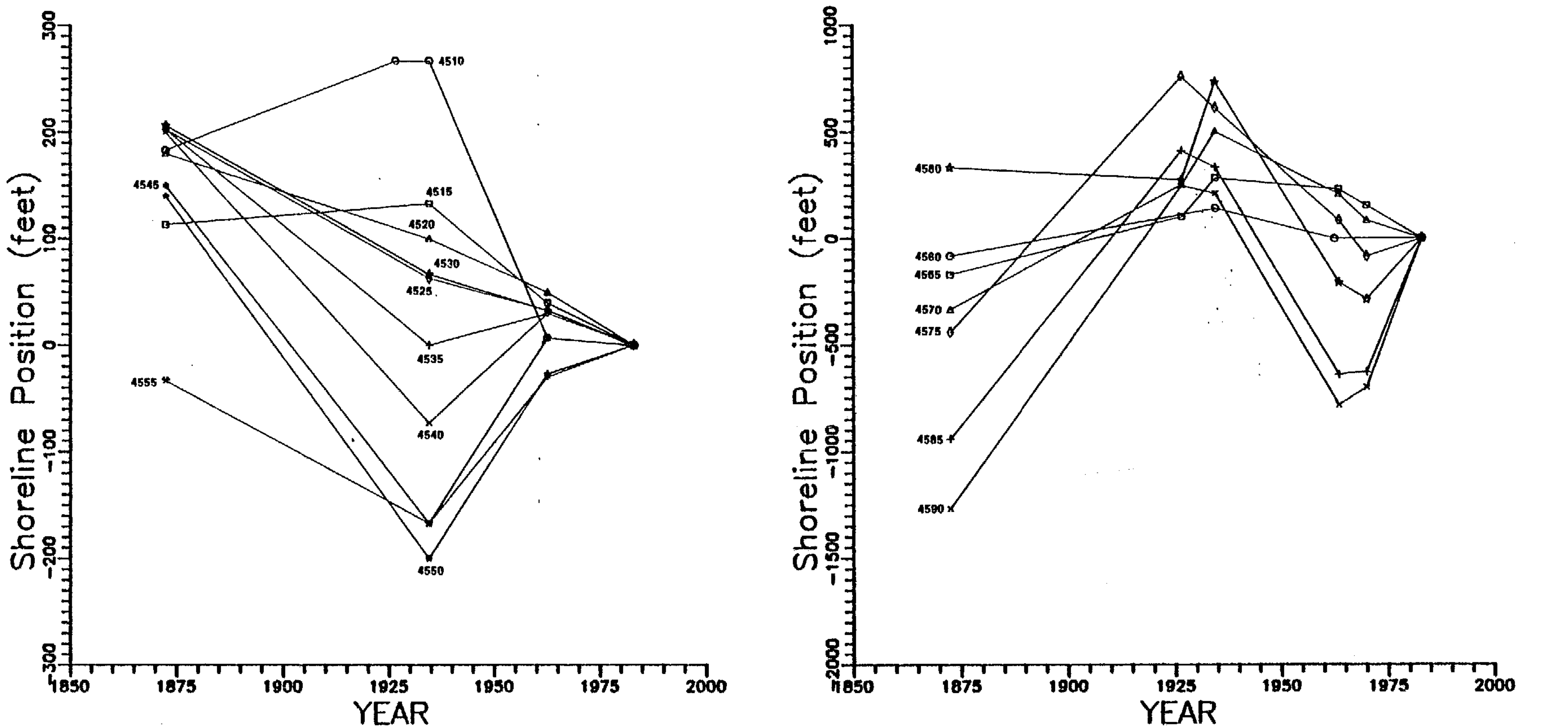


FIGURE 6.4-3
SHORELINE MOVEMENT AT MONITORING STATIONS ALONG LITCHFIELD BEACH AND HUNTINGTON BEACH STATE PARK

Pawley's Island. Similar to Debidue Beach, the pattern of the shoreline movement was reversed around 1926-1934. In the last two decades, the beach in this area has generally experienced erosion except the northern end near Huntington Beach State Park. The recent survey has shown significant accretion on the south side of the Murrells Inlet south jetty.

Shoreline changes along Garden City Point/Garden City, as shown in Figure 6.4-4, were gradual except along the reach between stations 4615 through 4630.

To quantify the long term shoreline recession rate, shoreline data from 1962 to 1983 were used to determine local trends. A linear regression analysis was done for each station using data in the last 21 years. The slopes resulting from the regression analysis was used to assess long term erosion rates. These erosion rates for each area were tabulated in Table 6.4-1 and 6.4-2, and also depicted in Figures 6.4-5 and 6.4-6.

Shoreline recession rates along Debidue Beach followed a distinctive linear trend, ranging from 11.4 ft/year erosion near North Inlet to 2.4 ft/year accretion near Pawleys Inlet. Pawley's Island showed moderate erosion (about 1 to 2 ft/year) except the northern portion near Midway Inlet. The Litchfield area experienced erosion rates of approximately 1.5 to 2.5 feet/year, in contrast, a reach of shoreline in Huntington Beach State Park (Station #4565 to 4570) showed high erosion rate, about 10-12 ft/year. Accretion on the south side of Murrells Inlet resulted in shoreline changes as high as 42 ft/year. Long term erosion rate along Garden City and Garden City Point ranged from 1 to 5 ft/year.

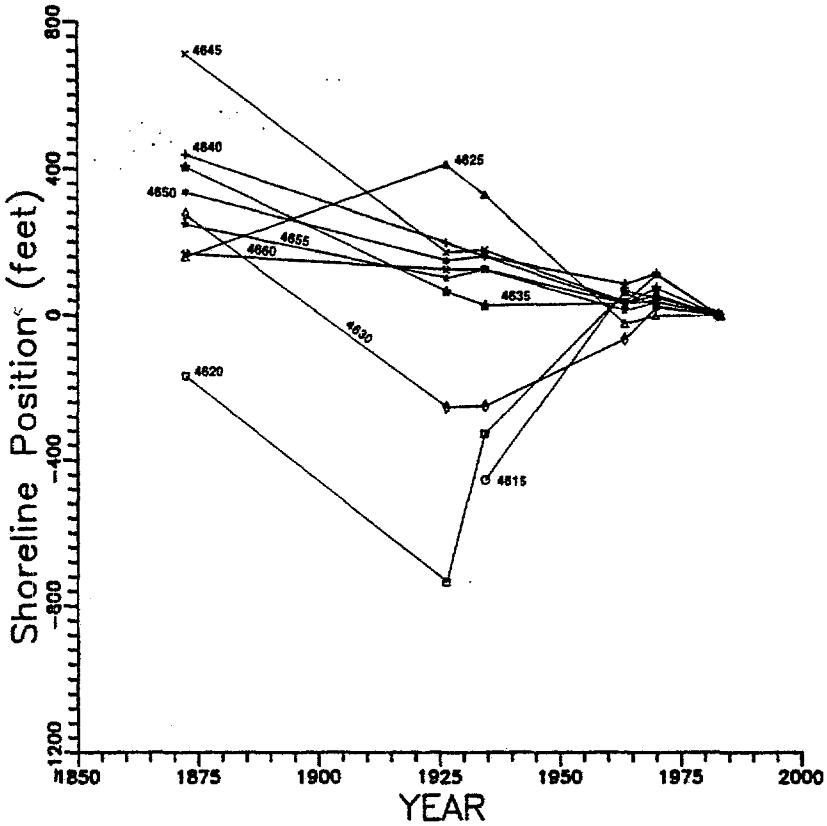


FIGURE 6.4-4
SHORELINE MOVEMENT AT MONITORING
STATIONS ALONG GARDEN CITY

Table 6.4-1. Long-term shoreline accretion/erosion rate

Station	Erosion Rate* (ft/yr)
<u>Debidue Beach</u>	
4305	-11.4
4310	-11.4
4315	-9.8
4320	-11.2
4325	-6.5
4330	-4.0
4335	-4.0
4340	-3.4
4345	-2.4
4350	0
4355	-1.3
4360	0
4365	2.4
4370	1.6
<u>Pawley's Island</u>	
4405	-2.0
4410	-0.6
4416	-2.0
4420	-0.6
4425	-1.8
4430	-1.3
4435	-0.7
4440	-1.4
4445	-0.6
4450	-3.4
4450	-5.4
4460	-2.9

*Negative value indicates erosion

Table 6.4-2. Long-term shoreline accretion/erosion rate

Station	Erosion Rate* (ft/yr)
Garden City	
4605	11.3
4610	-0.8
4615	-3.5
4620	-3.1
4625	1.0
4630	2.7
4635	-2.3
4640	-5.1
4645	-2.9
4650	-2.1
4655	-1.0
4660	-1.9
Magnolia Beach	
4510	-0.3
4515	-2.0
4520	-2.4
4525	-1.6
4530	-1.6
4535	-1.5
4540	-1.5
4545	1.5
4550	1.3
4555	-0.3
4560	0.1
4565	-11.8
4570	-10.0
4575	-2.7
4580	12.3
4585	35.0
4590	42.1

*Negative value indicates erosion

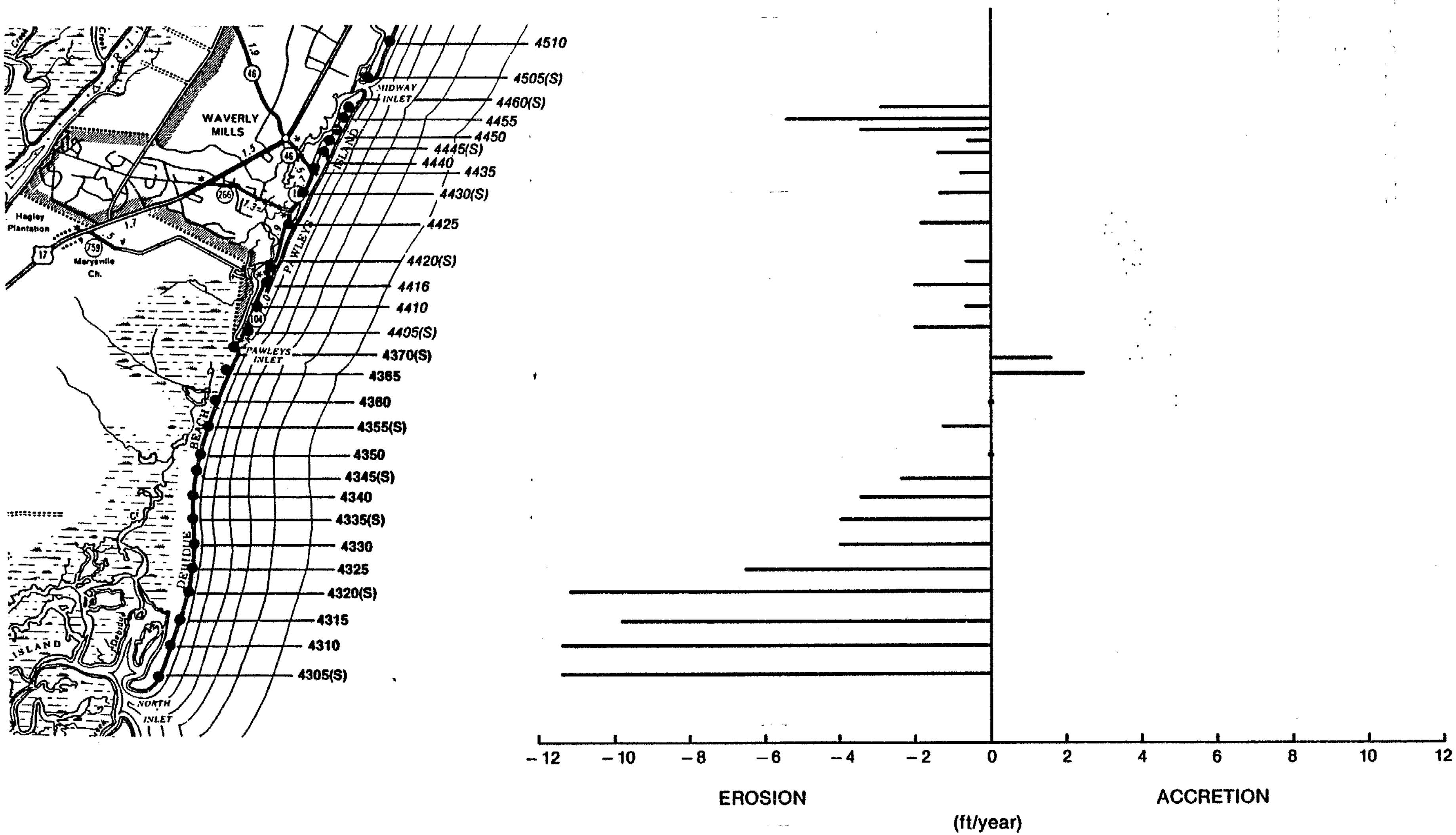


FIGURE 6.4-5
LONG-TERM EROSION RATE ALONG DEBIDUE BEACH AND PAWLEY'S ISLAND

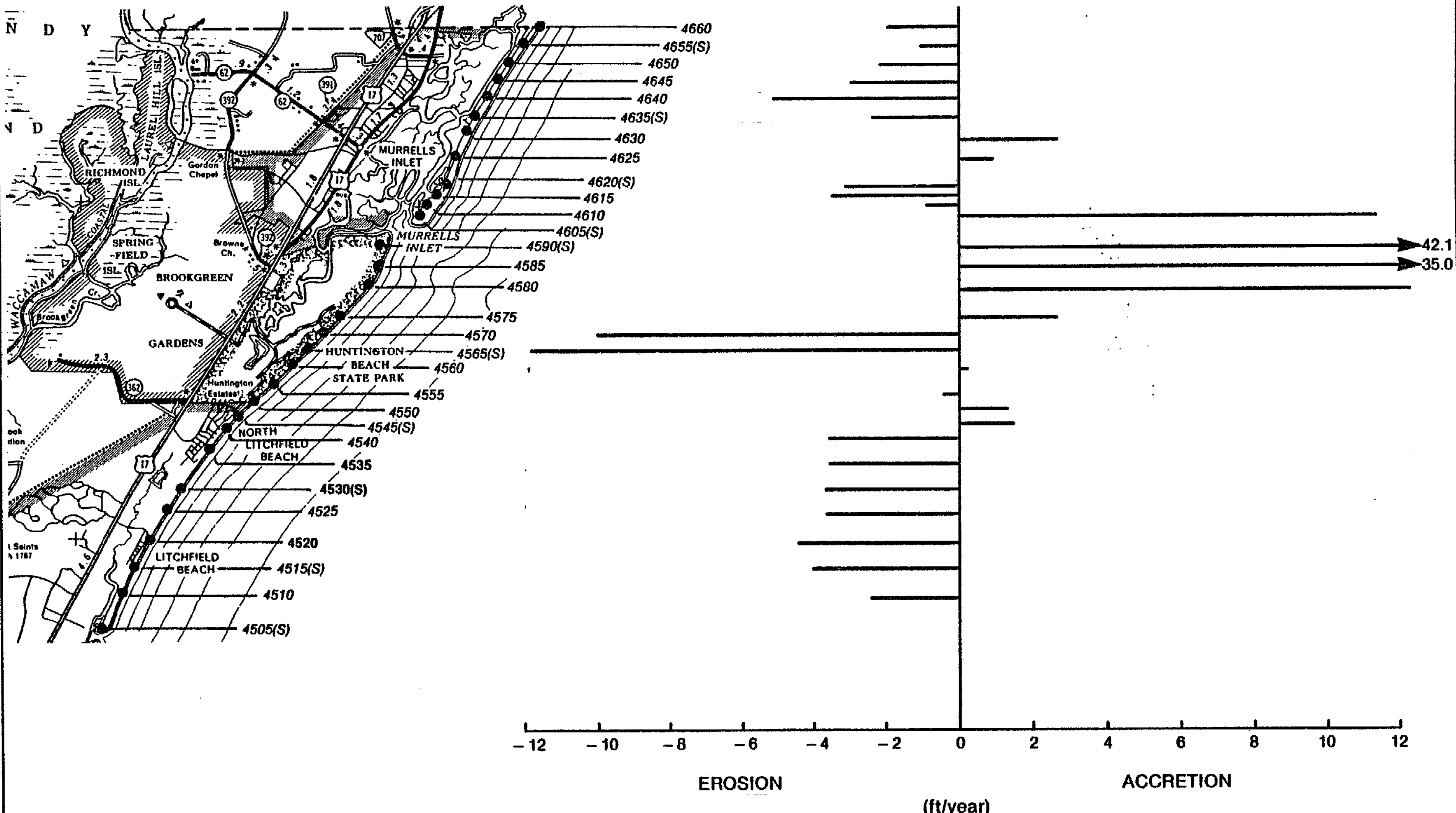


FIGURE 6.4-6
LONG-TERM EROSION RATE ALONG LITCHFIELD BEACH AND HUNTINGTON BEACH STATE PARK

6.5 EFFECTS OF SEA LEVEL RISE

As presented in Section 3.1, one important result of sea level rise is the readjustment of the beach profile to maintain an equilibrium condition, which in turn results in a net offshore sediment transport. To evaluate the shoreline movement in response to sea-level rise using the equilibrium beach-profile concept, one must assume the beach profile is relatively stable for a given mean water level and local wave conditions. The average shoreline recession (horizontal) rate in response to sea-level rise depends on sediment grain size, wave climate and location along the coast. An estimate of horizontal recession using a representative profile can be calculated using the Bruun method from the following empirical formula:

$$R = S \frac{W_*}{(h_* + B)}$$

where: R = horizontal recession

S = vertical water rise in sea-level

W_* = active width of the equilibrium profile

h_* = limiting depth associated with active profile

B = berm or dune height

The limiting depth (h_*) associated with the active profile was determined using a composite of four profiles along the Garden City and Litchfield Beach shorelines. Using offshore beach profile data at Stations 4525 and 4540 and the local rise in sea-level, the horizontal rate of shoreline recession is computed as

$$R = \frac{\frac{0.4667\ \text{ft}}{49\ \text{years}}\ (1118.\text{ft})}{(18.0\ \text{ft} + 17.5\ \text{ft})} = 0.3\ \text{ft/year}$$

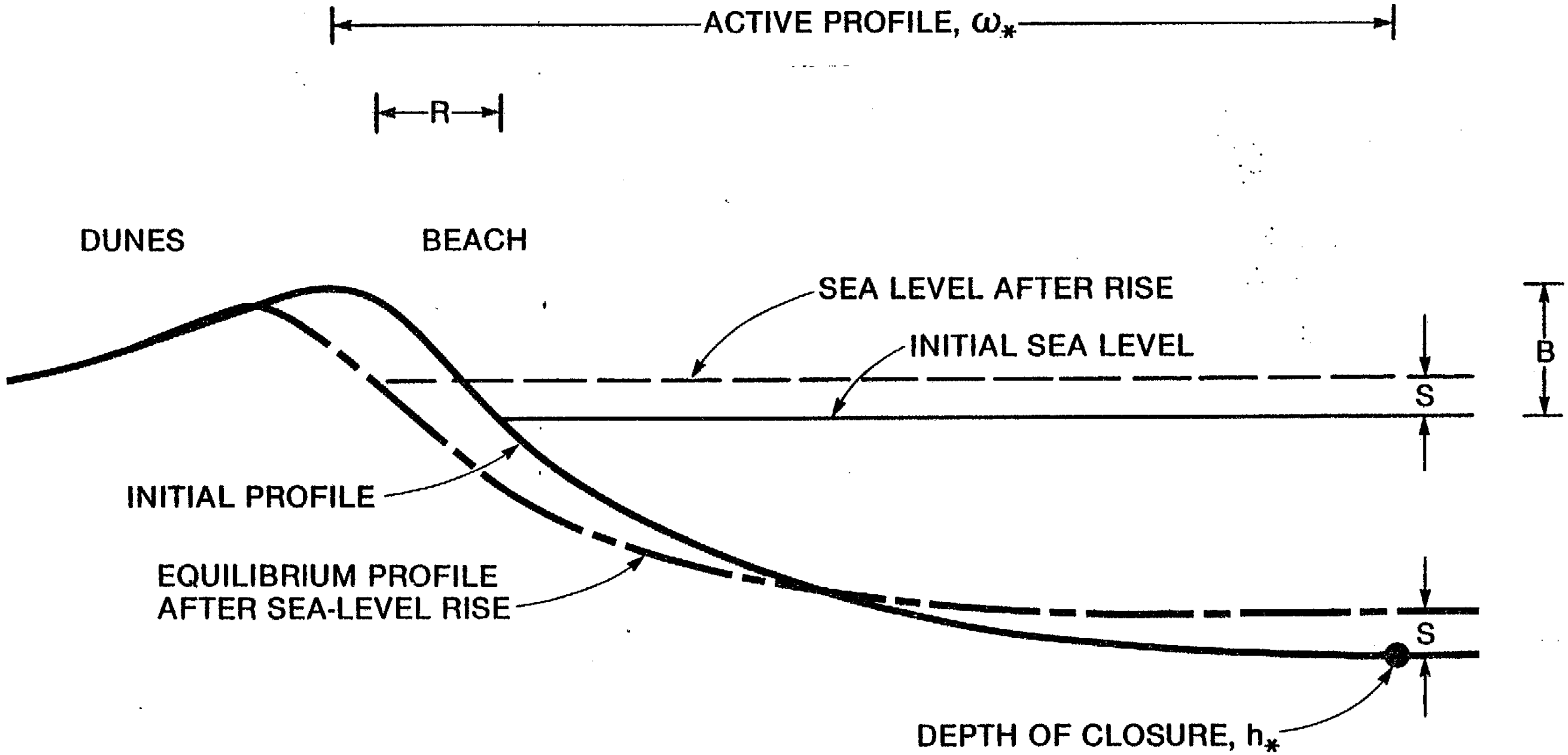


FIGURE 6.5-1
EQUILIBRIUM PROFILE RESPONSE TO SEA-LEVEL RISE (BRUUN METHOD)

The shoreline recession caused by sea level rise is small when compared with short- and long-term erosion caused by the combined result of seasonal variation and storm impacts.

6.6 THE IDEAL PRESENT PROFILE

In accordance with the prescribed methodology outlined in the contract for this study, an Ideal Present Profile analysis was performed for several reaches in the study area. This procedure was developed by Research Planning Institute, Inc. (RPI), as "the most objective way of determining where today's shoreline would 'ideally' be located in the absence of structures" and as "a means of averaging the high and low areas along the beach and evening-out the distribution of sand." The steps in determining the "ideal" present shoreline are presented below (Eiser et al., 1986).

1. Select existing "unaltered" profiles within the study area that have a minimal dune (no structure), intertidal beach, and a typical unit width volume of sand. Profiles around tidal inlets, piers, or other littoral obstructions are not included.
2. Develop a statistical composite profile (ideal present profile) from the selected profiles.
3. Compute the reference unit width volume of sand between the +10' and -5' MSL contour.
4. Superimpose the ideal present profile (IPP) on each surveyed profile so that the beach volume under each is the same (apply minor corrections around piers or near inlets).
5. Determine the ideal shoreline position as the point at which the ideal dune crest falls on each surveyed profile.

This methodology has been applied in the shorefront management plans for Myrtle Beach, prepared by RPI (Kana et al., 1984) and for North Myrtle Beach (Eiser et al., 1986) prepared by Coastal Science and Engineering, Inc. (CSE). In both of these applications, the study area consisted of one continuous shoreline of approximately 9 miles in length, uninterrupted by major inlets and, with the exception of piers, devoid of any shore-perpendicular structures which might be littoral barriers. In contrast, the present study area consists of 31 miles of disjunct shoreline interrupted by several major inlets, municipal boundaries and man-made littoral barriers along certain sections of beachfront. As a result, the IPP methodology was applied separately to several reaches of the study area shoreline. The methodology as employed in this study is presented in the following paragraphs that essentially paraphrase the methodology presented in the North Myrtle Beach Shorefront Management Plan performed by CSE (Eiser et al., 1986).

IPP Generation

Prior to the establishment of an IPP for the shoreline reaches along the Georgetown County study area, steps were taken to insure that the IPP methodology and procedure was properly understood and executed. This was done by first applying the IPP methodology to a section of shoreline in Horry County that extends from Singleton Swash to Withers Swash. As mentioned above, previous investigators had performed IPP analyses over 9 miles of shoreline both to the north and to the south of this section. The results from these studies were used as a comparison and verification of the results obtained in this application. As these shoreline reaches are adjacent to each other, it was expected that the IPP's should be similar, as should be the computed reference unit width volumes of sand. The steps taken to verify the IPP methodology are discussed in the following paragraphs.

Eleven stations along the shoreline reach between Singleton Swash and Withers Swash were examined for suitability in the determination of the IPP. Profiles affected by inlets, shore-protection structures, littoral barriers or any form of beach maintenance were rejected as not meeting the criteria of an "unaltered" profile. Remaining profiles were then examined to insure that the criteria of a well-developed upper beach face and dune, as well as a typical unit-width volume of sand were met. Six profiles met all these criteria and were therefore determined suitable for the generation of the IPP over this shoreline reach. These profiles were taken at survey stations 5425, 5435, 5440, 5445, 5450, and 5455 in Horry County.

In accordance with the prescribed procedure, the first step in determining the IPP is to align all the profiles about a common reference point, thereby resulting in a composite or representative profile. Selection of this reference point is determined as that point which results in the least variation about the mean profile. In their Myrtle Beach study (Kana et al., 1984), RPI determined that the procedure resulting in the least variation about the mean was to overlay all profiles such that the location of the +10' contour became a point in common for each profile. The +10' contour was likewise used as the common reference point for IPP generation in the subsequent North Myrtle Beach study. Observations made when shifting profiles for this and other shoreline reaches in the present study indicate that the +10' contour does not always represent the point resulting in the least variation about the mean. For this particular shoreline reach, this point was determined to be the +2.5' contour, corresponding closely to the approximate mean high water line. Figure 6.6-1 shows the superposition of the six profiles shifted about a common reference point of +2.5'.

Having established this composite profile, the elevation of

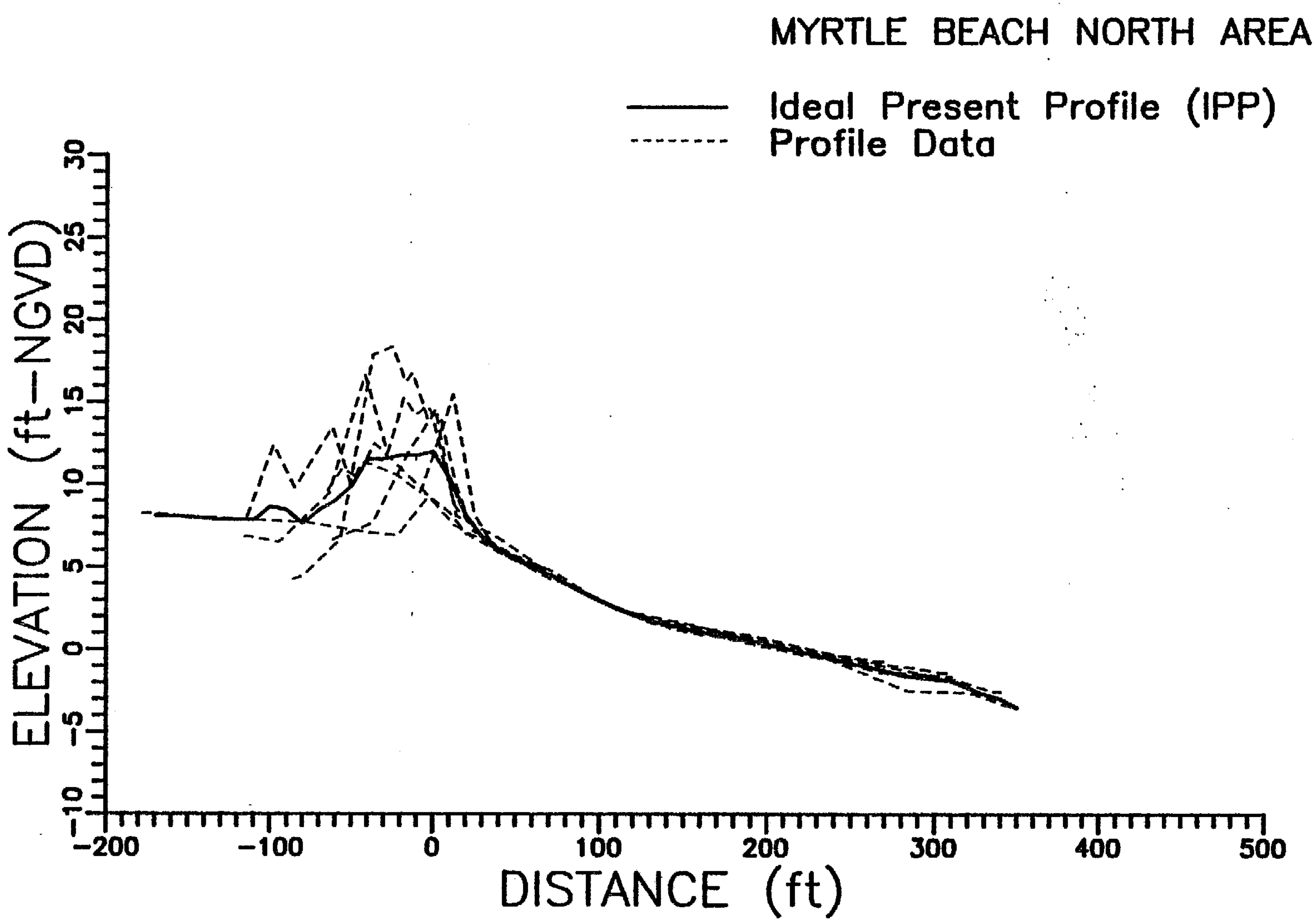


FIGURE 6.6-1
IDEAL PRESENT PROFILE FOR MYRTLE BEACH NORTH AREA

each individual shifted profile was determined at 10 foot increments by means of linear interpolation between actual profile data points. The IPP was then calculated by averaging the elevation of the six profiles at each 10 foot distance increment. The resulting IPP is presented in Figure 6.6-1 by a solid heavy line.

The reference unit volume of sand was computed as the volume between the +10' and -2.5' contours. The -2.5' contour, rather than the -5' contour as used in prior studies, was the approximate seaward limit of beach-profile surveys in this study and therefore the limit of available data. A volume of 47.1 yd^3/ft was calculated between the +10' and -2.5' contours for the IPP along this reach of shoreline. The IPP has a dune crest elevation of +12', a dune width of 40' and a beach width of 312' between the +10' and -2.5' contours (NGVD datum).

Figure 6.6-2 presents a comparison between the IPP derived in this study for the section of Horry County Shoreline extending from Singleton Swash to White Point Swash and the IPP derived by CSE and RPI for the shoreline reaches to the north and south. Table 6.6-1 presents the reference unit volumes and other pertinent dimensions for each calculated IPP. Comparisons of the data presented in this table, as well as the profiles presented in Figure 6.6-2 indicate that profile characteristics, unit volumes, and other pertinent dimensions of the IPP generated in this study are quite comparable to those of the IPP presented in the previous CSE and RPI studies. The fact that the plotted IPP profile falls between adjacent IPP profiles, as do most dimensions magnitudes and volumetric quantities, corresponds appropriately to the fact that the shoreline reach in this study falls between the reaches associated with the two previous studies. The results of this comparison provide an adequate level of confidence as to the proper understanding

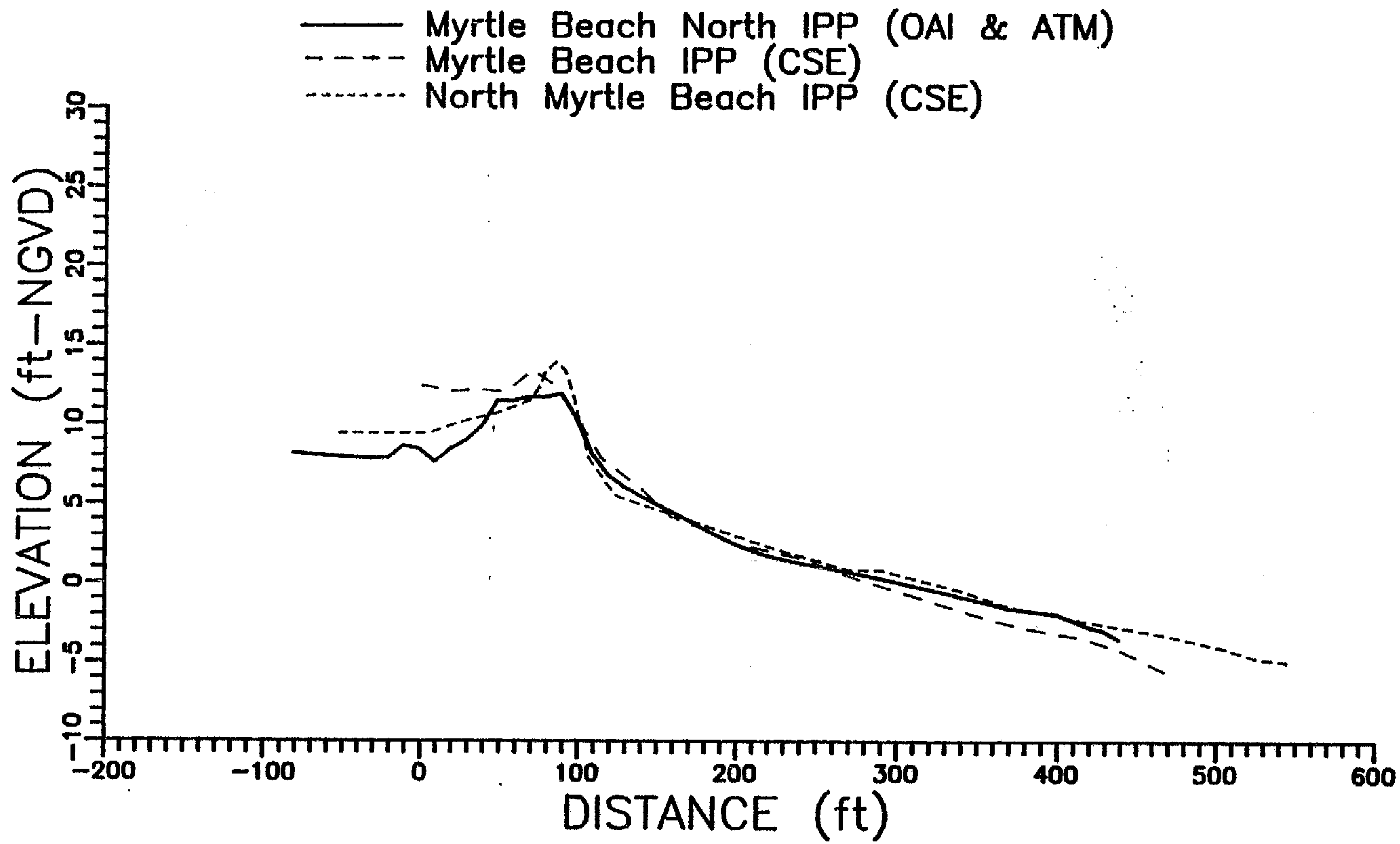


FIGURE 6.6-2
COMPARISON OF THE IDEAL PRESENT PROFILE COMPUTED FOR MYRTLE BEACH NORTH, MYRTLE BEACH AND NORTH MYRTLE BEACH SHORELINE AREAS

Table 6.6-1. Comparison of Profile Characteristics for the IPP Generated in This Study and Those Generated in Previous Studies

Study Area	Unit Volume*	Dune Crest Elevation	Dune Width	Beach Width**
North Myrtle Beach (CSE)	51.7 cy/ft	13.5 ft.	22 ft.	333 ft.
Singleton-White Point Swash	47.1 cy/ft	12.0 ft.	40 ft.	312 ft.
Myrtle Beach (CSE)	44.4 cy/ft	13.0 ft.	50 ft.	263 ft.

*Volume calculated between +10' and -2.5' contours

**Distance between +10' and -2.5' contours and execution of the IPP methodology. Accordingly, the IPP methodology was applied to the shoreline reaches along the Georgetown County study area. A summary of procedures and results for each reach is presented below.

Springmaid Beach to Garden City

The approximately 11.1-mile stretch of beach beginning at Springmaid Beach and extending south to Murrells Inlet is one continuous shoreline, uninterrupted by inlets, featuring a more than sufficient number of adequate profiles along its entirety for the generation of an IPP. Accordingly, an IPP was developed for this entire reach of shoreline to be used in the analysis and depiction of an IPP for each of the municipalities along this reach.

A total of 36 profiles were originally examined for suitability in the determination of an IPP. Of the 36, 10 were determined to meet all relevant criteria for selection. These 10 profiles were taken at stations 5235, 5240, 5245, 5250 and 5255 in South Myrtle Beach, stations 5115 and 5140 at Surfside Beach, and stations 4630, 4635 and 4640 at Garden City Beach. The +5 ft MSL contour was determined as the common reference point resulting in the least variation about the mean when superimposing all 10 survey profiles. Figure 6.6-3 depicts depicts the superposition of the 10 profiles shifted about a common reference point of +5 ft MSL. The solid line in Figure 6.6-3 presents the IPP generated by averaging the elevations of each of these profiles at 10 ft increments. A reference unit volume of 35.7 yd^3/ft was calculated between the +10 ft MSL and -2.5 ft MSL contours for the IPP along this shoreline reach. The IPP has a dune crest elevation of +11.5 ft, a dune width of 44 ft and a beach width of 242 ft between the +10 ft and -2.5 ft MSL contours.

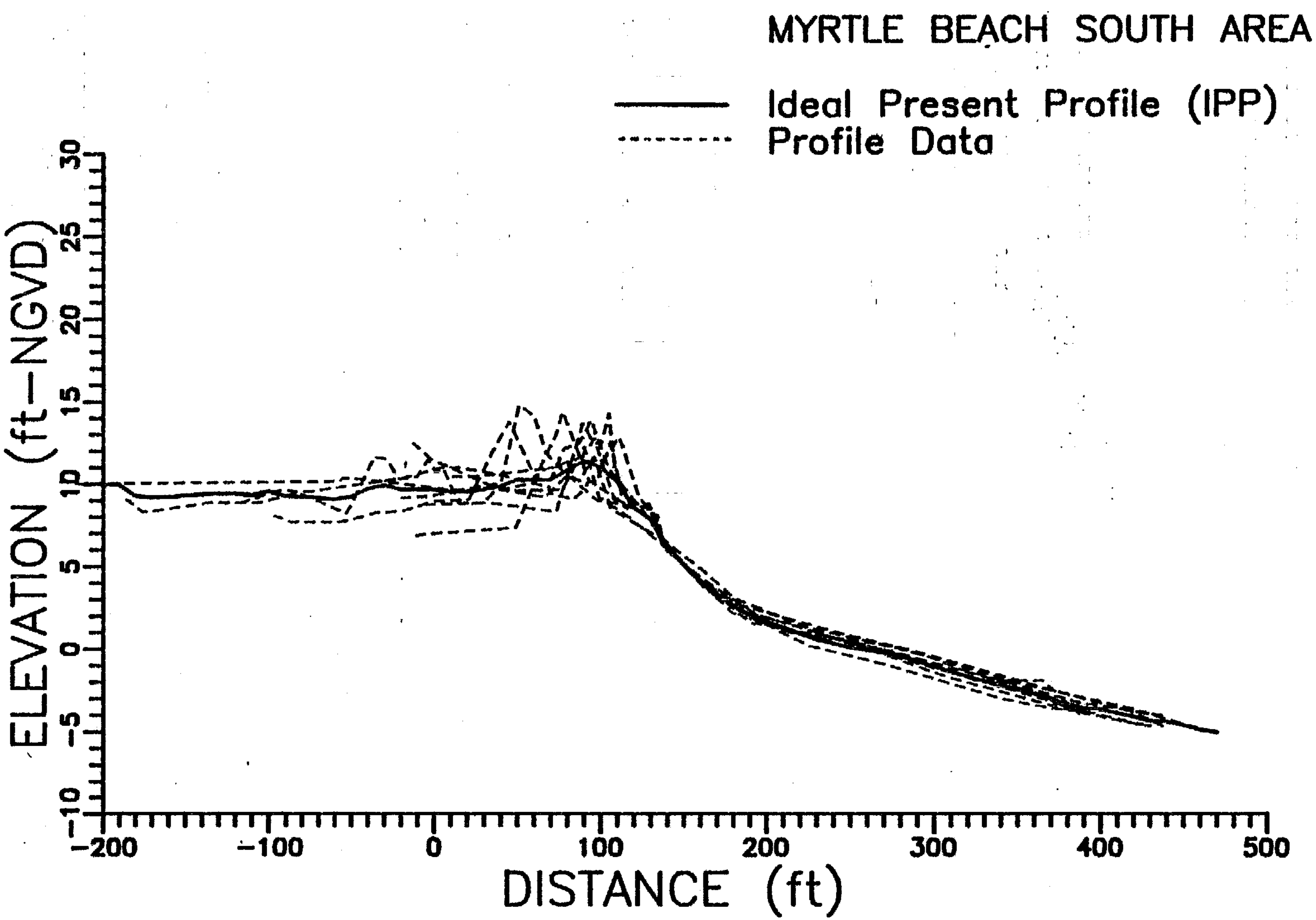


FIGURE 6.6-3
IPP FOR MYRTLE BEACH NORTH AREA

Litchfield-Huntington Beach

A total of 18 profiles taken at stations along this 7.1 mile reach of shoreline between Murrells Inlet and Midway Inlet were examined for suitability in the generation of an IPP. Of the 18 profiles, 7 were determined as meeting all relevant criteria for selection. These 7 profiles were taken at stations 4510, 4515, 4525, 4530, 4535, 4540 and 4545. The +5 ft contour was determine as the common reference point resulting in the least variation about the mean when superimposing all 7 profiles. Figure 6.6-4 shows the superposition of the 7 profiles shifted about the common +5 ft reference point as well as the IPP (heavy solid line) generated by averaging the elevations of each of these profiels at 10 ft distance increments. A reference unit volume of 44.7 yd^3/ft was calculated between the +10 ft and -2.5 ft contours for the IPP along this shoreline reach. The IPP has a dune crest elevation of +16 ft, a dune width of 63 ft and a beach widts of 289 ft between the +10 ft and -2.5 ft contours.

Pawley's Island

Beach profile stations along the Pawley's Island shoreline were determined to be unsuitable for the generation of an IPP. The extensive groin field and intermittent seawalls extending from the south end of the island to the Pawley's Island fishing pier preclude any stations from consideration. Stations to the north of the pier are subject to sporadic shoreline fluctuations resulting primarily from sand storage and bypassing processes at Midway Inlet as well as the effects of the terminal "training" groin there. Most recently, these fluctuations have taken the form of shoreline accretion at these stations. As a result, the IPP methodology was deemed inapplicable for the Pawley's Island shoreline. Alternate procedures were formulated to provide for the assessment of present and future shoreline conditions and these are

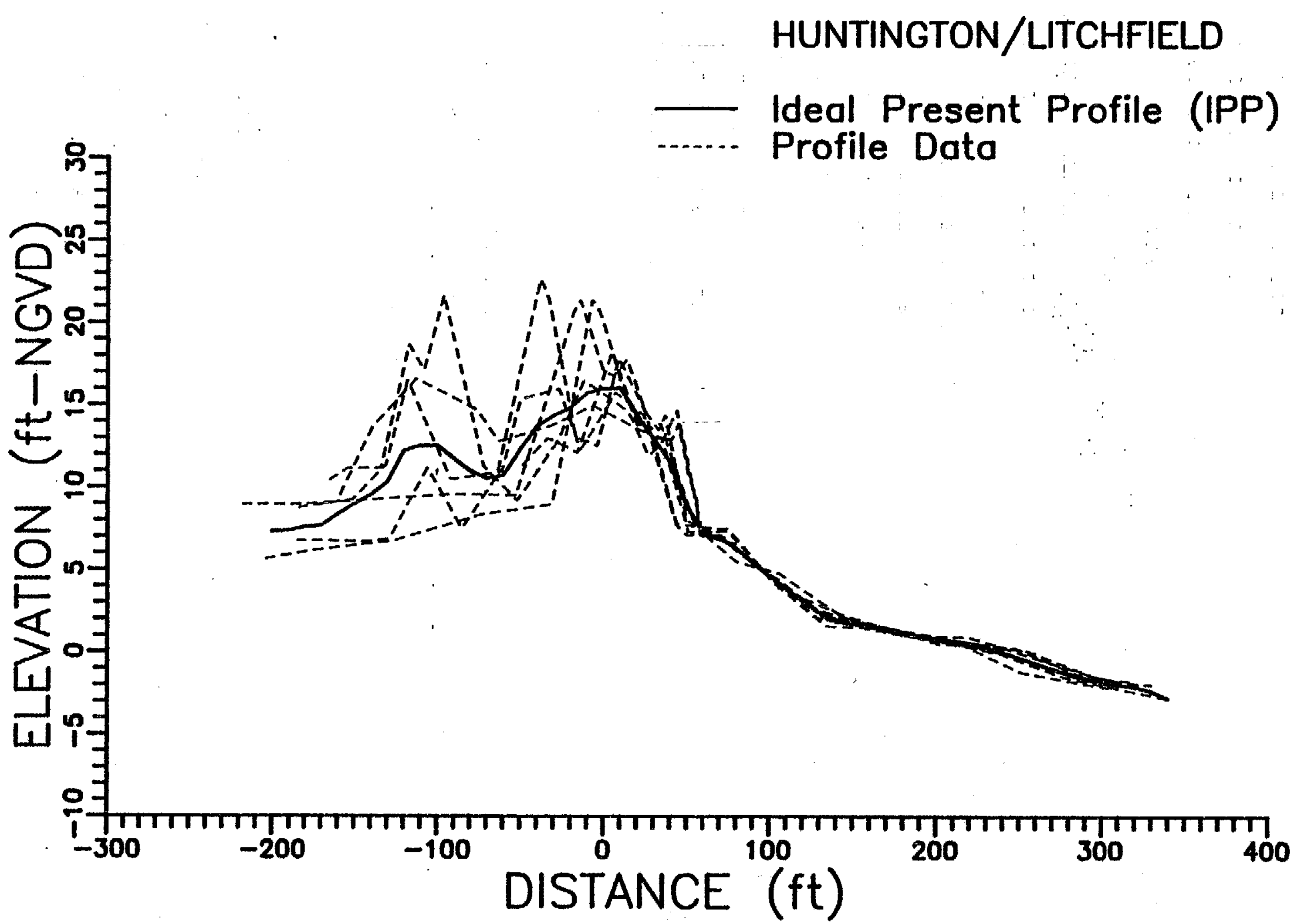


FIGURE 6.6-4
IPP FOR HUNTINGTON/LITCHFIELD AREA

presented in Section 8.1.

Debidue Island

The IPP methodology was also deemed inapplicable for the Debidue Island shoreline, again due to a lack of profile stations suitable for the generation of an IPP. Of the 14 survey stations established along this shoreline, 6 were excluded from consideration due to their proximity to inlets and 3 were deleted since they were located along the seawalled shoreline near the center of the island. The remaining 5 profiles exhibited highly variable shape and slope characteristics, making it impossible to achieve a composite profile with any acceptable degree of deviation about the mean so that it could be considered as representative of the natural, unarmored Debidue Island shoreline. In addition, the rapid and highly variable shoreline translations indicated by historical shoreline change maps support the conclusion that the IPP methodology was not appropriate. Alternate procedures were formulated to provide for the assessment of present and future shoreline conditions and these are presented in Section 8.1.

6.7 IPP COMPARISON WITH EACH STATION

In accordance with the prescribed procedure, the IPP compiled for each shoreline reach was superimposed on the April 1986 profile at each station along that reach. The IPP was then shifted horizontally so that the volumes under both profiles were equal. The volume of sand under each profile was determined by means of an Interactive Survey Reduction Program (ISRP), a computer software developed by the USACE Coastal Engineering Research Center. Wherever, possible, volumes were calculated between the +10' and -2.5' contours, however, in a few instances the existence of seawalls, lack of sufficient dune heights, extensive survey data or other profile anomalies necessitated the selection of alternative contours for volumetric computations.

Accordingly, the IPP was superimposed over the actual profile and horizontally shifted to equate the volumes between these contours. Table 6.7-1 presents the unit volumes under present profiles (April 1986), the variation between this volume and the IPP unit volume and the position of the IPP dune crest relative to the actual dune crest. Once superimposed correctly, the actual and shifted IPP profiles were plotted together. Figure 6.7-1 shows two example plots showing the superposition of the IPP on the profiles at Stations 4555 and 4625, respectively.

Station 4555, located at the northernmost residence in North Litchfield Beach, is an extreme example of IPP superposition on a severely eroded shoreline. In this case the beach-dune system has undergone severe erosion subsequent to the construction of the jetties at Murrell's Inlet. The elevation of the beach foreshore has been lowered and the dune severely scarped. Accordingly, the beach system in front of the scarped dune has a lower unit volume than the IPP. As a result, when superimposing the IPP on this profile, it must be shifted well landward in order to equate the beach volumes under both profiles. This results in the IPP dune crest being located well landward of the existing dune crest. This condition is characteristic of the shoreline extending approximately 2,000' north and south from this station, as well as other excessively eroded sections of the Georgetown County shoreline.

Station 4625 is located along a residential section of Garden City Beach. In this case, the unit volume of sand for the actual profile is greater than that of the IPP. In order to equate the volumes under the profiles, the IPP must therefore be shifted seaward. This results in the IPP dune crest being located seaward of the existing dune crest. In presenting the IPP methodology, its originators infer that "in cases where localized erosion of a natural dune has

Table 6.7-1. Unit Sand Volumes, Variation with IPP Unit Volume and Position of IPP Dune Crest Relative to Actual Dune Crest When Equating Volumes Under the Profiles Along the Georgetown County Shoreline.

Station	Unit Volume (cy/ft)	Variation with IPP Volume (cy/yr)	IPP Dune Crest Position Relative to Actual Dune Crest
Garden City			
4660	36.40	0.70	Landward
4655	34.43	-1.27	Landward
4645	30.49	-5.21	Landward
4640	34.86	-0.84	Landward
4635	43.67	7.97	Seaward
4630	46.37	10.67	Seaward
4625	48.57	12.87	Seaward
4620	33.63	-2.07	Landward
4615	45.87	10.17	Seaward
4610	48.53	12.83	Seaward
4605	45.27	9.57	Seaward
Huntington/Litchfield			
4590	N/A	--	--
4585	N/A	--	--
4580	N/A	--	--
4575	N/A	--	--
4570*	49.57	4.87	Landward
4565	43.33	-1.37	Landward
4560	50.15	5.45	Landward
4555	42.96	-1.74	Landward
4550	45.93	1.23	Landward
4545	42.90	-1.80	Landward
4540	41.77	-2.93	Landward
4535	47.84	3.14	Landward
4530	45.70	1.00	Landward
4525	43.24	-1.46	Seaward
4520	42.85	-1.85	Seaward
4515	38.31	-6.39	Landward
4510	44.73	-0.37	Seaward
4505	N/A	--	--

*Limit of applicability on Litchfield Beach

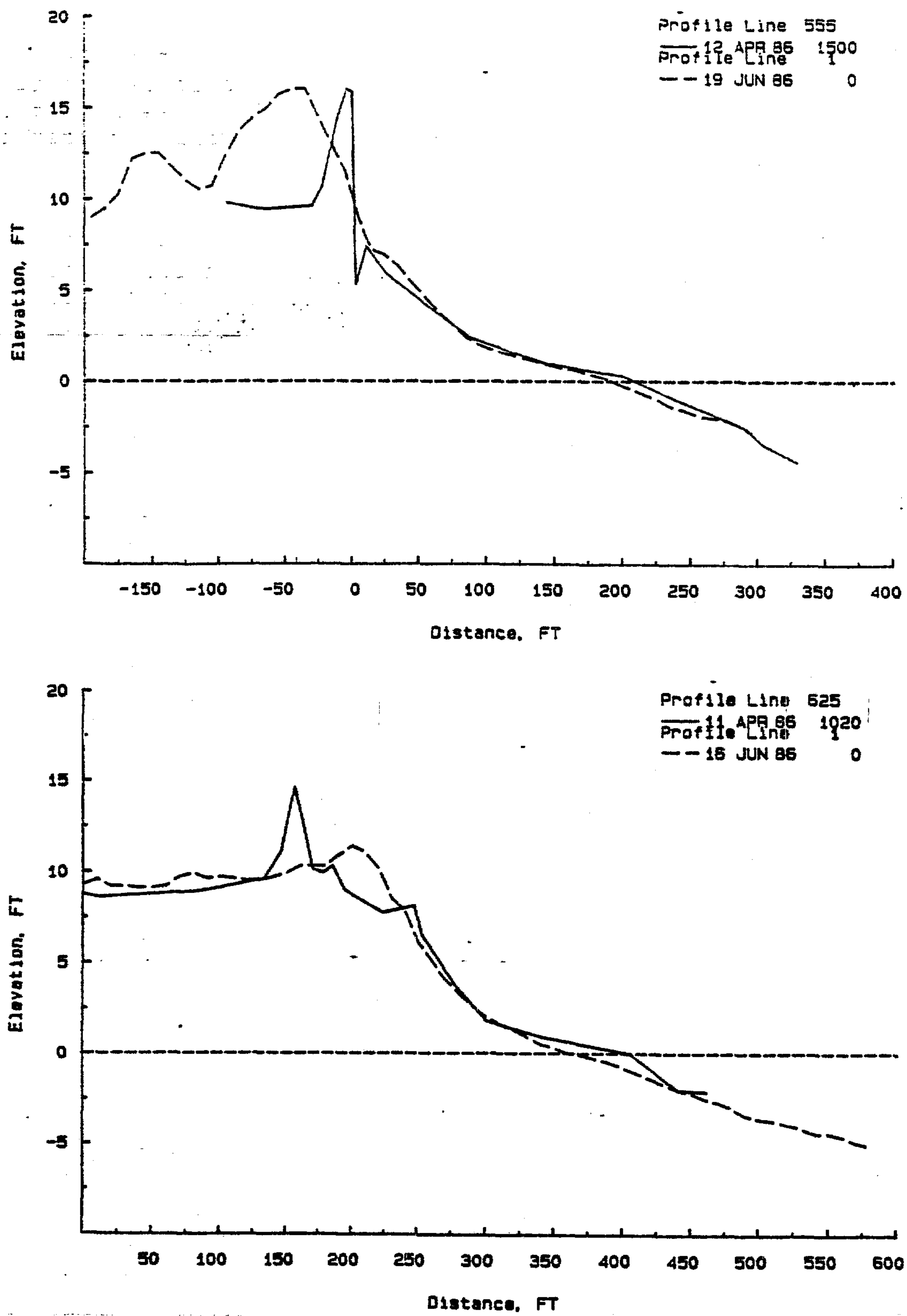


FIGURE 6.7-1
COMPARISON BETWEEN IPP AND
A) PROFILE 4555 AND
B) PROFILE 4625

accelerated...this methodology makes allowance for artificial loss and places the ideal dune crest somewhat seaward of its present position" (CSE, 1986). While it is not readily apparent how this allowance is made based upon equating volumes (particularly in view of the preceding example), it is obvious that localized erosion is not a factor in this case. The location of the IPP dune crest seaward of the actual dune crest is a result of excess sand volume rather than a sand deficit. It is doubtful, in this case, that the IPP dune crest represents the location of the actual dune crest in the absence of structures along the shoreline. In the application of the IPP in this study, all instances where the IPP dune crest fell seaward of the actual dune crest were attributable to excess unit volumes rather than sand deficits.

The IPP should not be considered to be applicable along the area north of profile station 4570 and south of Murrells Inlet. The latter is in a dynamic zone of littoral processes due to the stabilization of the inlet. As with other similar areas adjacent to tidal inlets, it has been classified as an "Inlet Impact".

7.0 INLET ANALYSIS

Tidal inlets assume a major role in both the long and the short-term fluctuations of shorelines within the study area. For example, longshore sediment transport, also referred to as littoral drift, is continually directed toward an inlet channel or gorge. Tidal shoals are formed as the result of the interruption of this longshore transport by strong tidal currents near the inlets. Flood tidal currents transport and deposit these sediments within the lagoon or embayment, whereas ebb tidal currents transport the sediments to the ocean shoals. A stable inlet has balanced the deposition of littoral drift with the scouring effects of tidal currents. Typically the ebb tidal shoal, seaward of the inlet, builds and migrates in the predominating downdrift direction. This is the basic mechanism by which the inlet naturally migrates in the direction of the predominating longshore currents. Correspondingly, the inlet may likewise migrate, in some cases breakthrough at a new location on either the updrift or downdrift shoreline as a result of low frequency storm events.

Inlets, swashes, channels, etc. are examples of natural non-structural barriers to littoral processes, whereas groins and jetties are man-made structural barriers. Significant erosion problems can result when a barrier effectively blocks a large portion of the longshore sediment transport thereby resulting in sand starvation at some locations. Significant sediment trapping potential exists at the entrance of Murrells Inlet and North Inlet and, to a lesser degree, Midway Inlet and Pawley's Inlet. Inlets are continuously affected by reversals in longshore transport and wave refraction around the ebb tidal shoals located seaward of the entrance channel. It is those shorelines in the immediate vacinity of inlets that typically experience the greatest variation in erosion rates and fluctuations of the beach and dune system. The area of influence along a coast affected by a tidal inlet is directly related to the inlet geometry and tidal prism which is an expression of the quantity of water which moves through the inlet and which in turn is responsible for sediment transport.

The stabilization of any natural inlet by dredging or jetty construction would dramatically modify the hydraulic regime, and therefore upsets the long-term dynamic equilibrium previously in existence. The consequence is the initiation of a new balance between hydraulic and sedimentary forces which causes a reconfiguration of tidal shoal formations and adjacent shorelines.

The shorelines adjacent to most natural inlets, formed of unconsolidated sand, are dynamic landforms easily subjected to the effects of storm surge flooding. During a hurricane, the surge and wave set-up along the open coastline are the primary driving mechanism of flow patterns into the bay areas. Extraordinarily high tidal current, through inlets during hurricane storm tides characteristically both erode and flood adjacent channel banks as the increased flow converges in the vicinity of the inlet.

These highly dynamic inlet areas require adequate coastal planning and building criteria for protection of property adjacent to inlets from the hazards of hurricane induced flooding. Channel migration, often associated with unstabilized inlets, may have severe effects on the stability of adjacent inlet channel banks during these severe storm events.

Murrells Inlet

An analysis of historical shoreline movements for Murrells Inlet was based on aerial photographs and NOS-COE shoreline movement maps (see Figure 7-1). For the period between 1872 and 1934 the long-term shoreline trends indicate that north

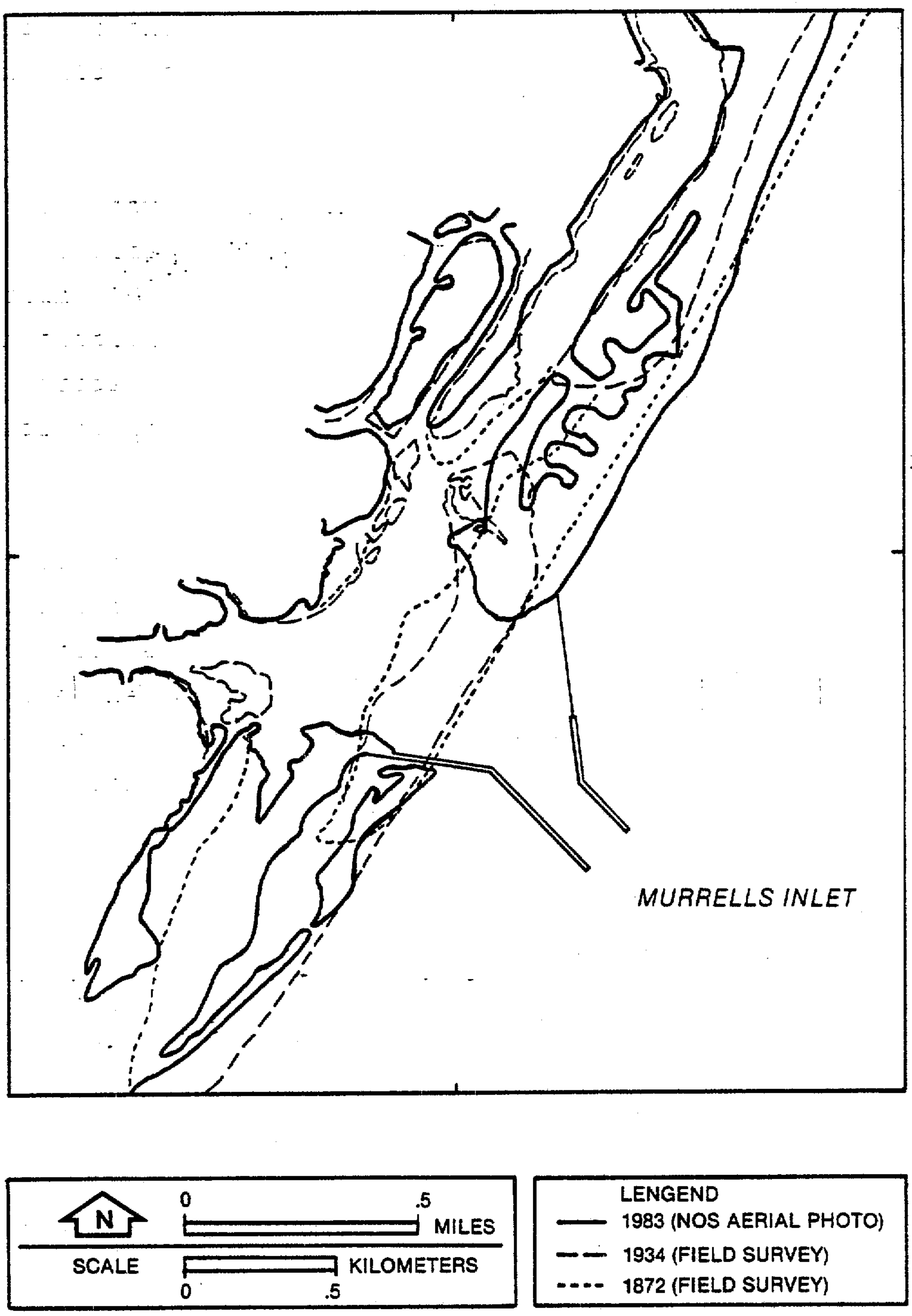


FIGURE 7-1
HISTORICAL SHORELINE POSITIONS NEAR MURRELLS INLET (1872, 1934, 1983)

spit migrated northwards approximately 6500 feet. Subsequent long-term changes show this shoreline to have consistently migrated south from 1934 to 1983. The same shoreline moved south 2000 ft from 1934 to 1963 and 600 ft from 1963 to 1970. During this same period the narrow spit at the north end of Huntington Beach gradually receded until 1970 (Figure 7-2). A Federal navigation project to improve Murrells Inlet for navigation purposes was commissioned and constructed between 1977 to 1979. Stabilization features included two jetties, a navigation channel, a weir section in the north jetty, a deposition basin and designated beach nourishment areas on the adjacent shores. Because the predominant direction of littoral drift was estimated to be southerly, the COE designed the north jetty with a 1315 foot section at a lower relative elevation (+2.2 ft MLW) to allow southerly sediment transport into the deposition basin (Figure 3.11-1).

Since 1979 sediment has accreted to the beginning of the weir section and the remainder of the near shore area has been relatively stable. Sand moving across the weir section is depositing along the edge of the deposition basin and onto a sand spit which has migrated into the navigation channel. An extensive ebb tidal shoal is forming at the end of the north jetty which appears to result from sediment moving north around the south jetty, sand transported from the depositional spit and sand transported by strong offshore currents on the north side of the the north jetty. Characteristically, the location, shape and size of an ebb tidal shoal undergoes slow but substantial changes; the modifications of waves by the ebb tidal shoal can cause substantial localized effects on the adjacent shorelines resulting in long-term erosion and accretion changes.

The south bank of Murrells Inlet, characterized by substantial depositional dunes with healthy vegetation

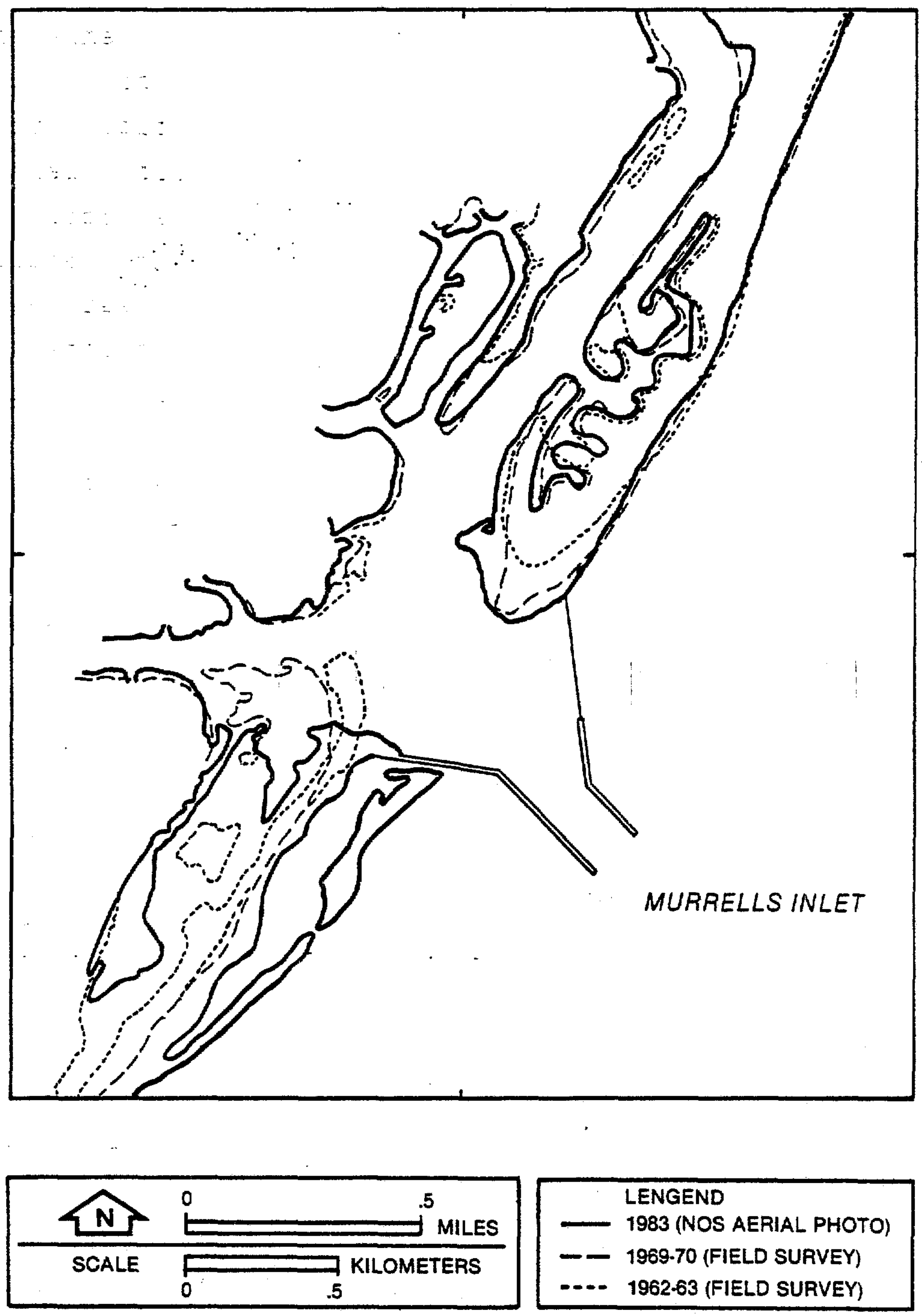


FIGURE 7-2
HISTORICAL SHORELINE POSITIONS NEAR MURRELLS INLET (1962, 1969, 1983)

inland from the north jetty, should be relatively stable with regard to future shoreline positions. Evidence of a washover across the dunes immediately north of the weir jetty was observed during a recent field investigation. Significant winter storm tides often result in flooding of shorelines adjacent to inlets. The shoreline areas in relatively close proximity to this inlet should be regarded as dynamic land forms and protected by judicious coastal planning and management.

Beach profiles located 2.5 to 3.5 miles south from the Murrells Inlet jetties have shown substantial erosion whereas significant accretion has occurred for the length of shoreline 1.5 miles south and adjacent to the south jetty. In addition, an erosional "hot spot" can be detected approximately 3 miles north of Murrells Inlet which could be related to shoreline adjustment caused by inlet stabilization. The relationship between the jetties construction and the erosion of the adjacent shorelines at Murrells Inlet is a typical example of the inlet jetty effects, and have been experienced at numerous similar locations such as the entrance to Charleston Harbor, SC and St. Marys entrance, Florida.

As expected, the stabilization of Murrells Inlet is resulting in the inlet being transformed into a littoral trap. The predicted net result is the eventual collapse of the pre-project ebb tidal shoal and the eventual creation of a new shoal seaward of the approximately 3400 ft long jetties. The modification of the bathymetry north and south of the inlet will be expected to correlate to eventual shoreline translations. The predicted short-term effects will continue, especially near north and south of the inlet, as detected by this study and the ongoing COE monitoring program. Correspondingly, any long term net losses of sediment to the reconfigured Murrells Inlet shoal system will result in additional erosional pressures along the adjacent barrier islands to the south. The effects of inlet jetties will propagate to a greater distance than those presently determined by surveys.

<u>Midway Inlet</u>

Long-term trends indicate Midway Inlet has migrated southward for the last 57 years (Figure 7-3). From an analysis of inlet movement, the north bank moved northward 600 feet between 1872 and 1926 (Figure 7-4). Subsequently the north bank accreted from 1926 to the present, indicating that the predominant direction of littoral drift is southerly. Historical long-term shoreline changes for the southern spit of Litchfield Beach and the northern end of Pawley's Island are summarized in Table 7-1.

Deposition of southerly littoral drift has resulted in the formation of a substantial shoal migrating from the north bank of Litchfield Beach. There is therefore a reasonable expectation for further lengthening, as noted by the previous shoreline growth (1963-1983), and correspondingly substantial accretion along the northern channel bank. Littoral drift material is being deposited at the mouth of the channel during ebb tide, and the deposition is carried into the inlet and re-deposited onto the flood tidal shoal during flood tide. This accretional flood tidal shoal, exposed at low tide, constricts the flow as the main channel separates and branches along the northern and southern inlet banks.

Midway Inlet channel has migrated south and is presently located along the south bank adjacent to Pawley's Island. The ebb tidal shoal extending southward from Litchfield Beach has kept the main channel against the south bank of the inlet causing moderate erosion. To stabilize this shoreline, the southern bank was armored with a timber

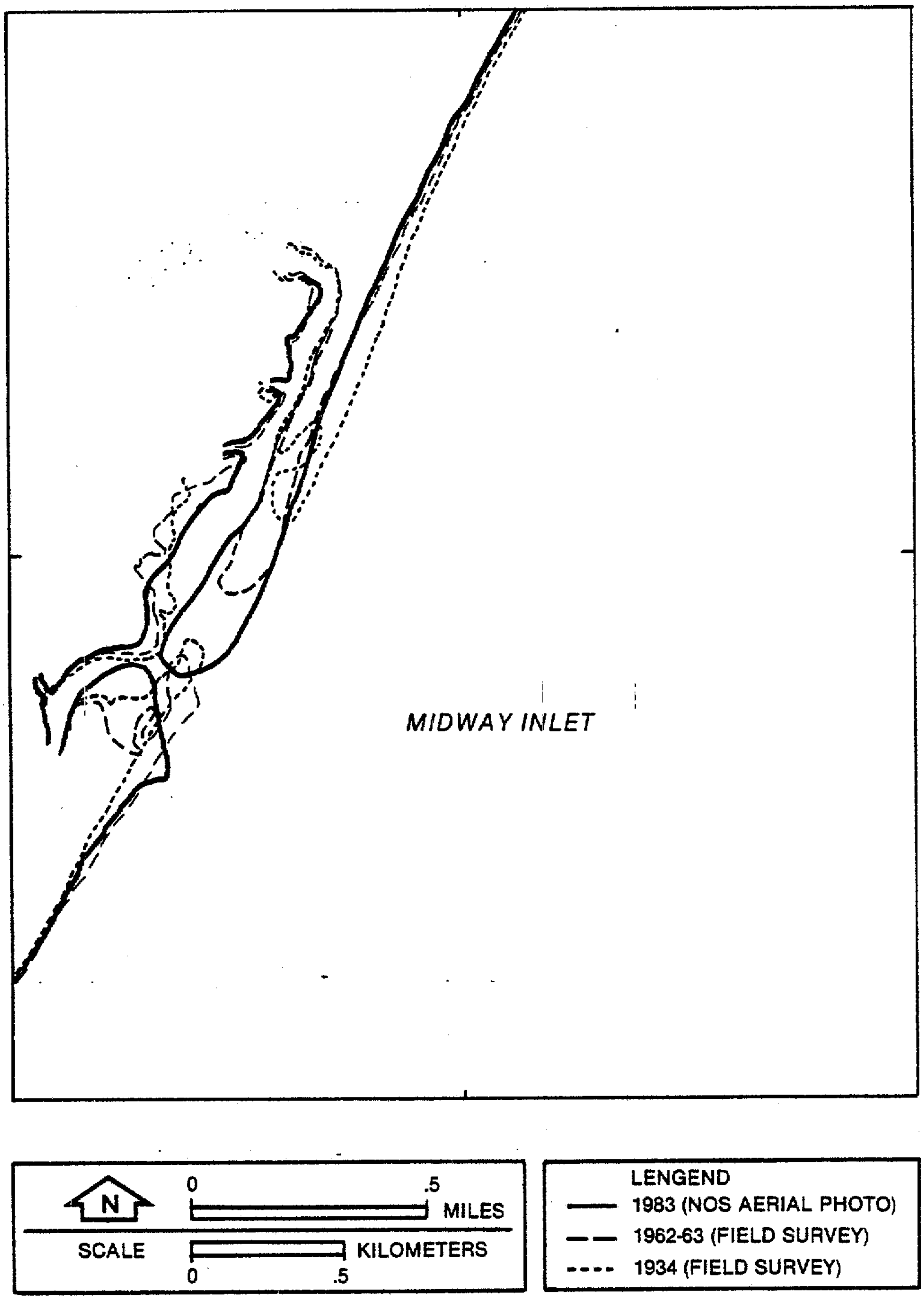


FIGURE 7-3
HISTORICAL SHORELINE POSITIONS NEAR MIDWAY INLET (1934, 1962, 1983)

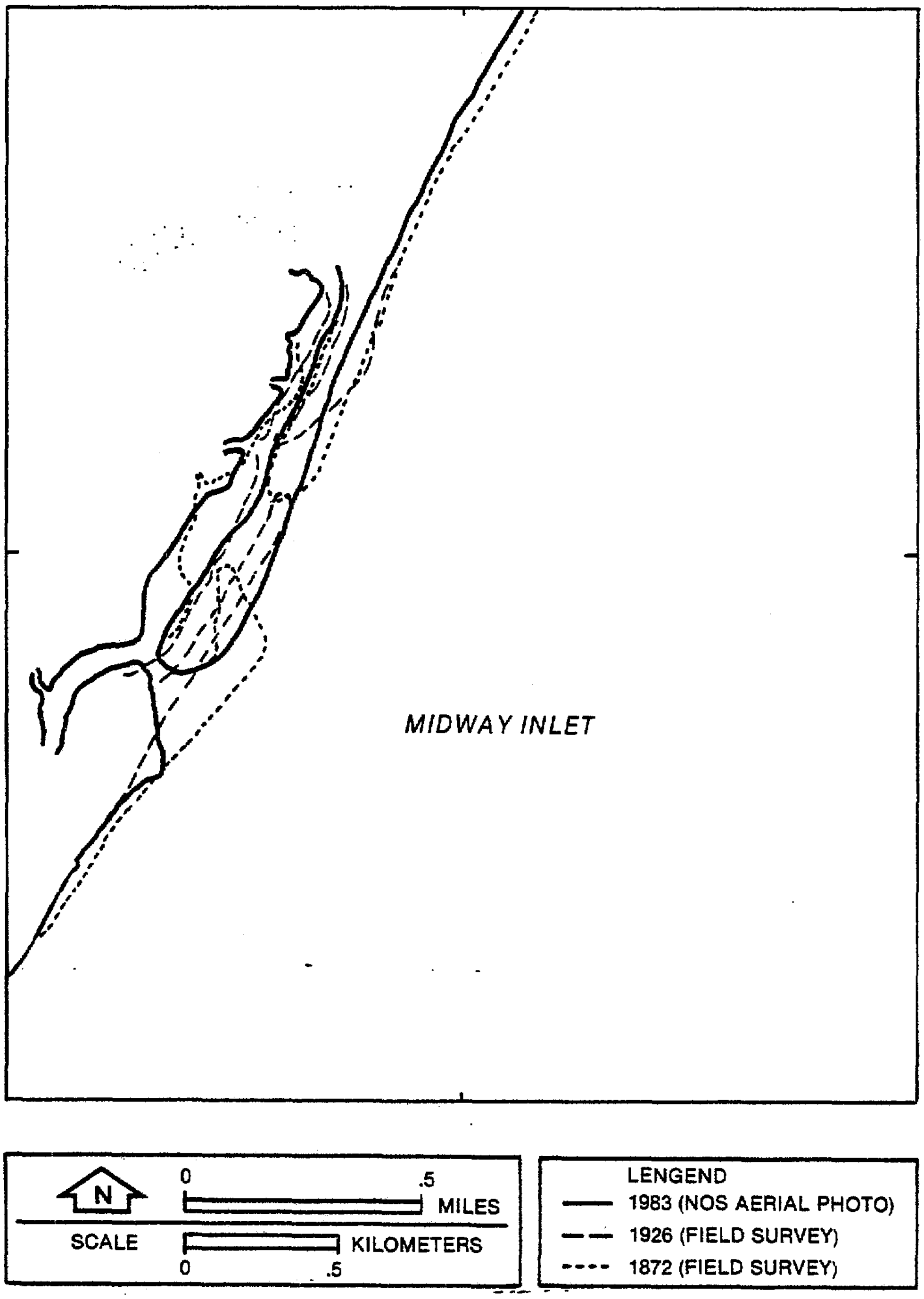


FIGURE 7-4
HISTORICAL SHORELINE POSITIONS NEAR MIDWAY INLET (1872, 1926, 1983)

Table 7.1 Historical Inlet Movement

Dates	South Bank	North Bank
Midway Inlet		
1872-1926	1100' N	600' N
1926-1934	2000' S	800' S
1934-1963	200' S	1000' S
1963-1983	400' S	1100' S
Pawley's Inlet		
1872-1926	3100' N	1450' N
1926-1934	~800' S	2800' S
1934-1963	2100' S	1100' S
1963-1983	1900' N	1900' N
North Inlet		
1872-1926	5400' S	2100' S
1926-1934	340' N	1800' S
1934-1962	650' S	6700' S
1962-1983	1100' N	130' S

"training groin" extending seaward 685 feet, as well as a combination of rubble and concrete sections extending inland along the shoreline.

Although Midway Inlet has been stabilized along the southern bank, continual deposition of sediment creates a navigational hazard and unstable shorelines in the vicinity of this inlet. Periodic dredging, with spoil placed along the northern tip of Pawley's Island would alleviate some of the shoaling problems and stabilize the north channel bank.

Pawley's Inlet

Pawley's Inlet is located between the southern tip of Pawley's Island and the north end of Debidue Beach. This historically dynamic inlet migrated north prior to 1926, south between 1926 and 1963 and is presently migrating to the north (Figure 7-5 and 7-6). Characterized by a long narrow spit (150-200 ft wide), the south end of Pawley's Island is developed by single-family residences fronting the open coast. This segment of beach is structurally armored by a groin field. Comparative profile surveys along this shoreline indicate accretion in the immediate vicinity of the inlet which may have temporarily stabilized the shoreline in the short-term.

From an analysis of long-term shoreline positions, the north end of Debidue Island has accreted along a shoreline segment extending approximately 3500 feet to the south. Longshore sediment transport appears to be relatively balanced along the beaches adjacent to Pawley's Inlet.

In recent years, an effort was made to stabilize the north bank of the inlet using approximately 250 feet of rip-rap placed along the southern tip of Pawley's Island. Additionally, adjacent property owners on Pawley's Spit have built two segments of seawall in an attempt to stabilize and

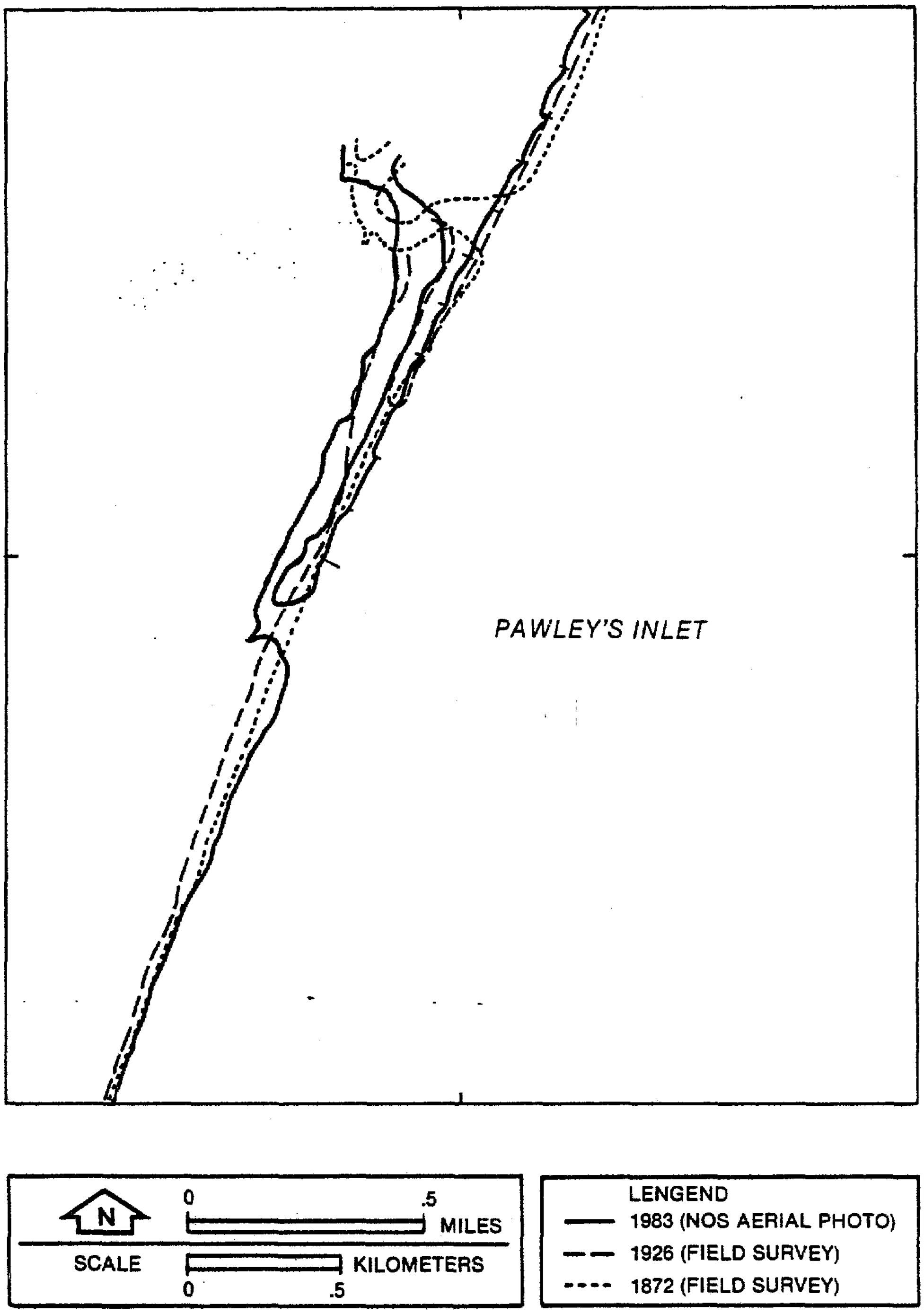


FIGURE 7-5
HISTORICAL SHORELINE POSITIONS NEAR PAWLEY'S INLET (1872, 1926, 1983)

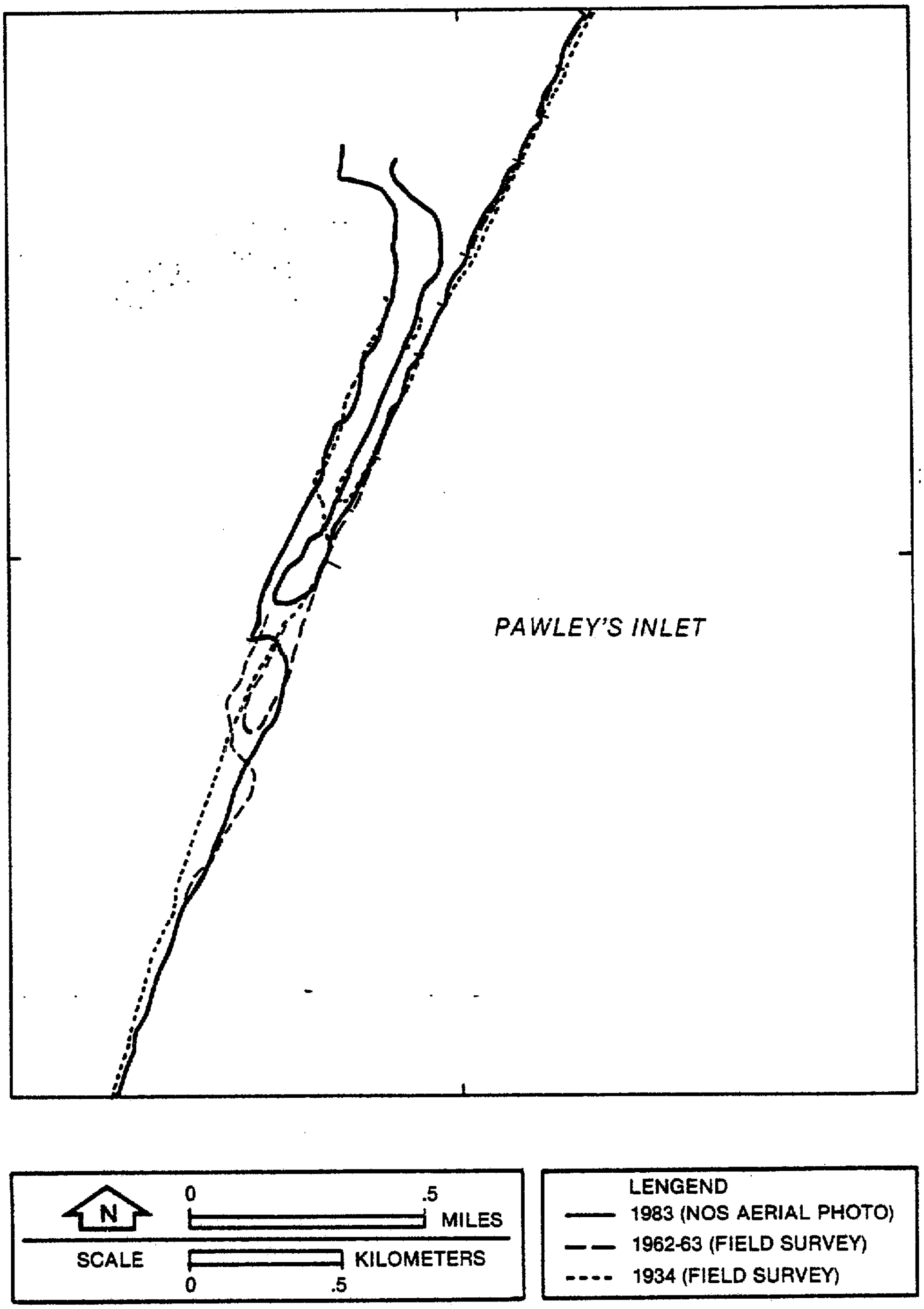


FIGURE 7-6
HISTORICAL SHORELINE POSITIONS NEAR PAWLEY'S INLET (1934, 1962, 1983)

protect individual homes. During seasonal storm tides this irregularity in seawall construction would be expected to potentially destabilize the adjacent non-armored properties along the terminal points of the seawall.

The future stabilization of Pawley's Inlet and protection of buildings along the spit during moderate (50-year) or extreme storm events (100-year) is doubtful. Inlet stabilization for the developments along the adjacent low-lying shorelines is not warranted at this time. Education of homeowners to the hazards of inhabiting this area during severe storms is well-advised. Continued periodic surveys to document shoreline fluctuations at Midway Inlet and the adjacent shoreline should provide the necessary short-term data to assess local perturbations associated with the inlet and temporal variations in the directions of littoral drift.

<u>North Inlet</u>

Documented shoreline movement at North Inlet was based on field surveys and aerial photography from 1872 to 1983 (obtained from the NOS-CERC Shoreline Movement Maps). North Inlet experienced a relatively high degree of variability between 1872 and 1926 (Figure 7-7). Extreme shoreline fluctuations associated with unstabilized inlets, such as North Inlet, can occur through slow trends or rapidly during a storm event. During the period of 1872 to 1926, a large number of hurricanes crossed the South Carolina shoreline in close proximity to North Inlet (Figure 3.3-2 and Figure 3.3-3). Accordingly, the nearly 5400 ft southerly migration of this inlet's south bank may have resulted from a break through due to high storm surge, wave action and local topography.

Long-term shoreline trends indicate the north bank of North Inlet has consistently migrated southwards 6500 ft since 1872 (Figure 7-8). In contrast, the south bank receded

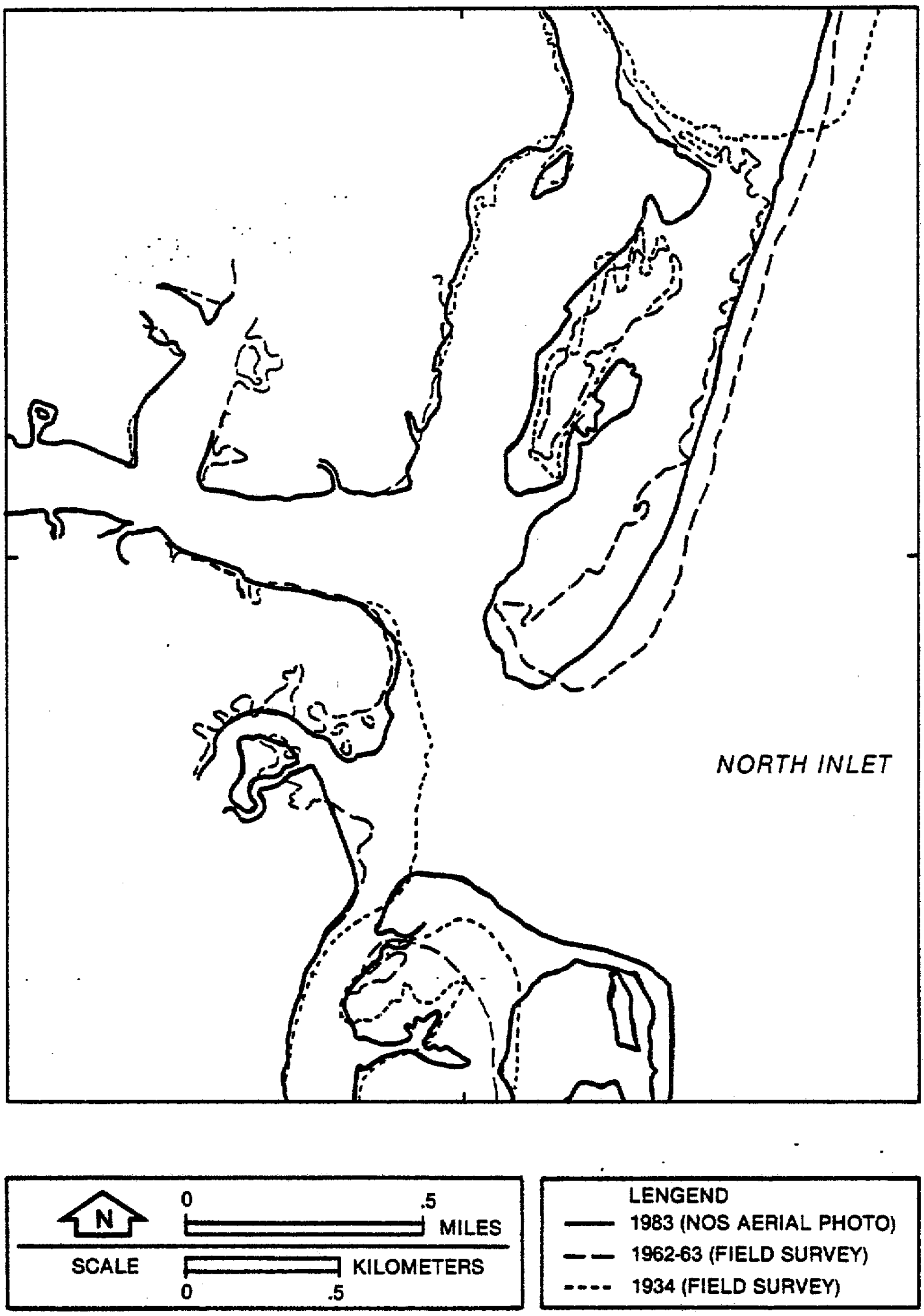


FIGURE 7-7
HISTORICAL SHORELINE POSITIONS NEAR NORTH INLET (1934, 1962, 1983)

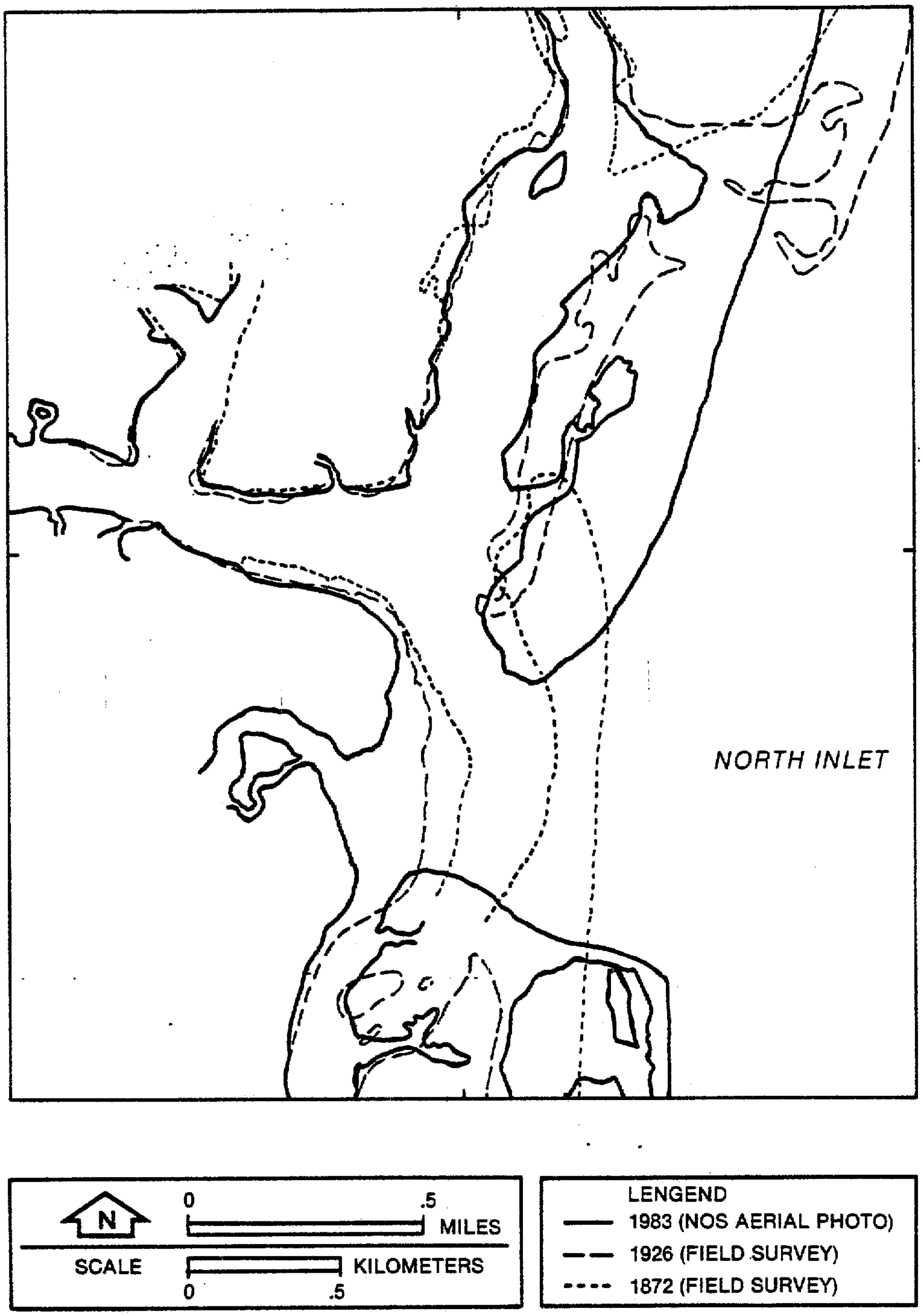


FIGURE 7-8
HISTORICAL SHORELINE POSITIONS NEAR NORTH INLET (1872, 1926, 1983)

approximately 5400 ft between 1872 and 1926, migrated north from 1926 to 1934, receded between 1934 and 1962 and has recently moved to the north about 1100 ft (1962 to 1983). Since 1934, deposition of the southern littoral drift has resulted in the formation of an extensive recurved sand spit characterized by a series of beach ridges.

Tidal inlets along the South Carolina coastline can be classified according to the magnitude of the tidal range and inlet dynamic features as 1) microtidal and 2) mesotidal. A spring tidal range from 0 to 2 meters defines a microtidal coast where an increased tidal range (2 to 4 meters) is characterized as mesotidal (Davies, 1964). The influence of both spring tidal range (1.8 meters) and a relatively low annual wave-energy environment at North Inlet has led to a mesotidal classification (Nummedal and Humphries, 197). In a 1975-76 USCOE-CERC study, North Inlet was selected to evaluate the hydraulics and dynamics of a natural tidal inlet. Over a two-year period, intensive field investigations were undertaken to collect numerous physical and morphological data, including continuous water surface elevations, tidal channel hydrography, littoral processes, and bathymetric profiles.

Based on vertical aerial photos, historical shoreline data and field survey data, an intensive map of the intertidal environment at North Inlet was developed. Analysis of bathymetric changes since 1964 suggest the following: 1) the main ebb channel has deepened and is oriented straight toward the southeast; 2) three small shoals have developed adjacent to the main ebb channel, one terminal shoal and one on either side of the main ebb channel. The northern and southern channel shoals are being controlled by the tidal currents and wave swash. The overall planeform of the ebb tidal delta may indicate a net southerly littoral drift.

Beach profile data were surveyed for 6 transects along Debidue Island and 5 transects along North Island on a quarterly basis from July 1974 to May 1976 (Figure 7-9). Based on these profile data, the average trends in beach erosion and deposition at Debidue Beach and North Island were plotted for the period of July 1975 to May 1976 (Figure 7-10). These data indicate an annual change in beach-face morphology along Debidue Spit, controlled by a seasonal change in mean sea level (MSL) as opposed to the expected dependence on storm cycles.

A longshore wave energy flux factor was computed based on wave height and direction, and gross longshore sediment transport was estimated at 800,000 cubic meters during both years of observation. The net sediment transport for 1974 to 1975 and 1975 to 1976 was 87,000 and 390,000 cubic meters, respectively. Finally, results of beach profile data and intertidal shoal mapping data strongly suggests an "out-of-phase" relationship between beach erosion and channel scour (Figure 7-10) during mid-fall and the spring of 1976. It is evident that there is a sediment exchange and a direct relationship between variations of inlet channel cross-section and the profile volume changes of the adjacent beaches exists.

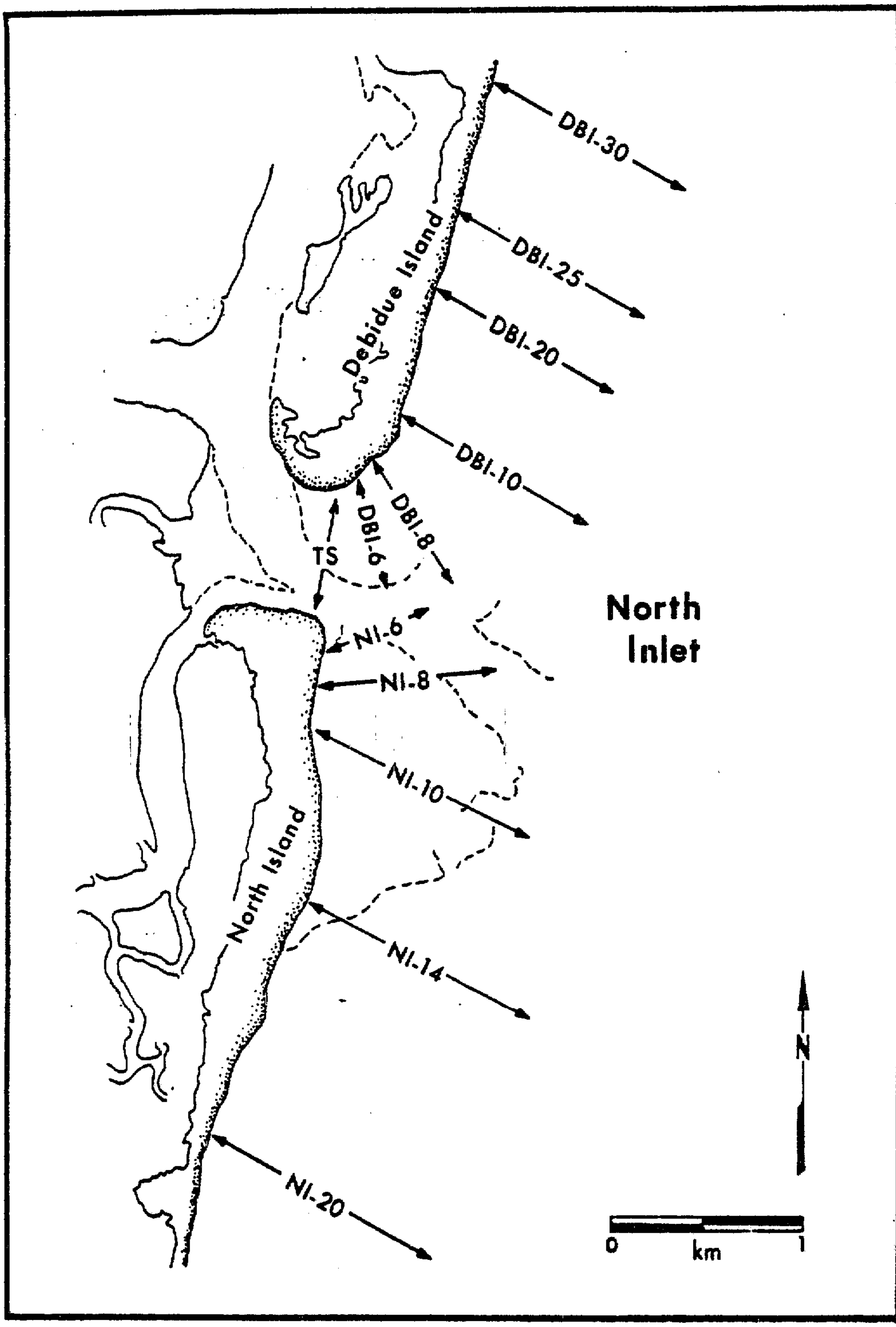


FIGURE 7-9
BEACH AND OFFSHORE PROFILE LOCATIONS
(COE, 1978)

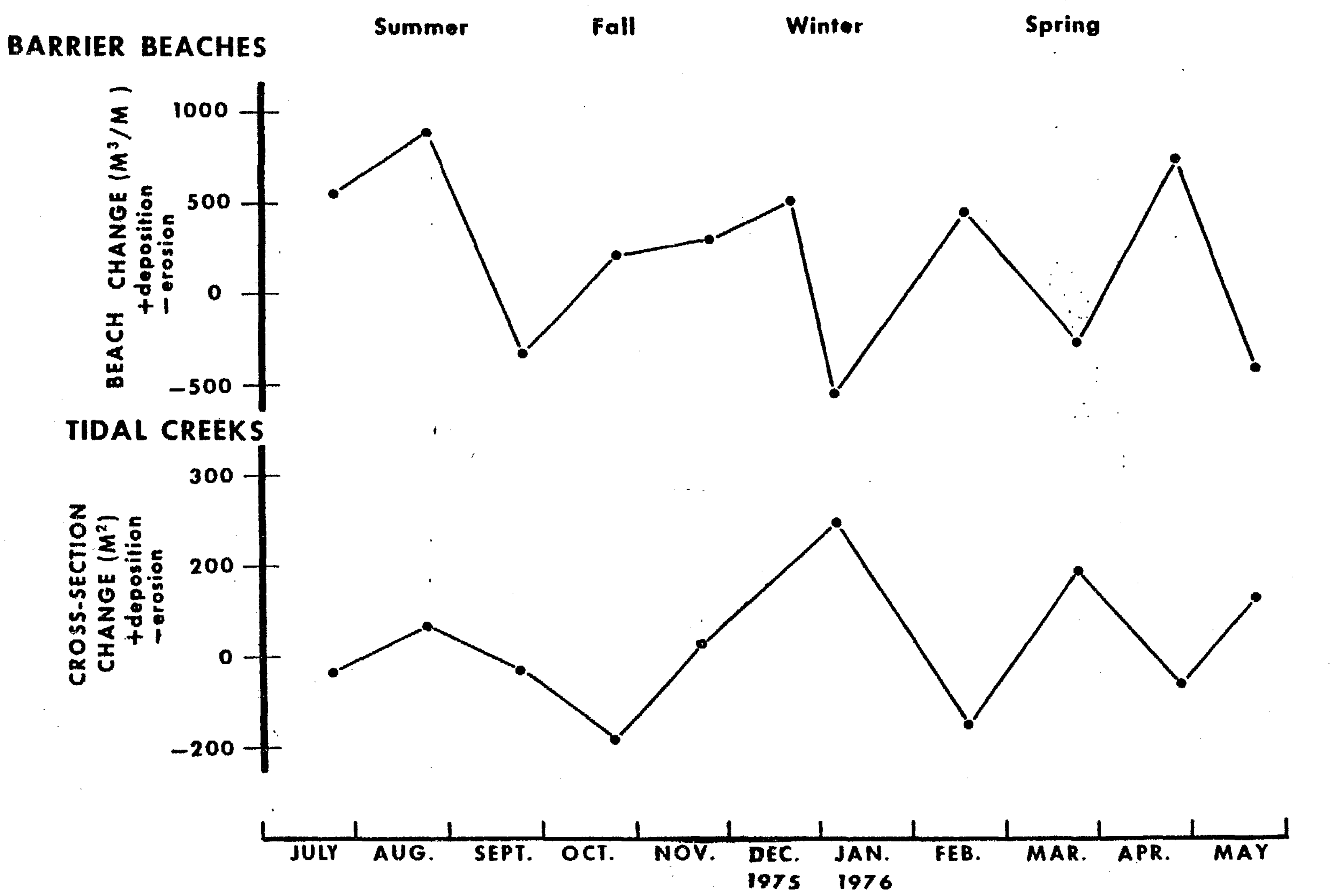


FIGURE 7-10
COMPARISON OF AVERAGE TRENDS IN BEACH EROSION AND DEPOSITION AT DEBIDUE BEACH AND NORTH ISLAND AND CHANNEL CROSS-SECTIONS (COE, 1978)

8.0 FUTURE SHORELINE PREDICTION

8.1 IDEAL PRESENT SHORELINE

The ideal present profiles (IPP) of Garden City and Huntington/ Litchfield Beach were developed in Section 6.6 Once the IPP for each shoreline reach was overlaid on each of the April 1986 profiles such that the volumes under the two were equal, the location of the ideal present dune crest relative to each station was calculated. In accordance with the prescribed methodology the ideal present dune crest was determined as either the peak of the IPP dune or the midpoint of the IPP dune crest, whichever was applicable along each reach. The location of the ideal present dune crest relative to each station was then plotted on the base maps presented as Appendix D. The points representing these locations were connected by a line on the base maps that, in accordance with the prescribed methodology represents the ideal present shoreline (IPS).

The ideal present shoreline is subject to some degree of interpretation, primarily in areas where the ideal present dune crest falls seaward of the existing dune crest. As discussed in the application of the IPP methodology, this situation occurred due to an excess of sand in the profile unit volume rather than as an allowance for artificial loss due to localized erosion. Accordingly, shifting the ideal present dune crest seaward of the existing seawardmost dune line in order to account for excess sand volume was considered to be a miscomputation inherent in the IPP methodology. In such instances, the point representing the IPS defaulted landward to the existing dune crest. Similarly, in other cases the line representing the IPS tended to bulge seaward at stations in the immediate vicinity of piers, reflecting their effect as partial sediment traps. In accordance with the prescribed methodology, the IPS was maintained as a straight line in the vicinity of piers or similar structures.

Contrary to prior applications of the IPS, no concessions were made in this study in the event that the IPS fell "sharply" landward or on top of existing structures due to sand deficits in the profile unit volumes. Prior investigators have incorporated hypothetical assumptions that such sand deficits may be made up by artificial means, primarily beach nourishment, thereby justifying a seaward shift of the IPS. While beach nourishment projects are considered as the preferred means of providing a recreational beach and protecting existing upland development, they are <u>not</u> designed to encourage or accommodate seaward encroachment of building construction. Therefore, incorporation of such assumptions in the establishment of any line that may be used to determine building setbacks of other coastal development restrictions is unjustified, potentially harmful to the beach-dune system as well as coastal development permitted under this premise and inconsistent with accepted coastal management practice. Accordingly artificial shoreline modifications such as beach nourishment will not be considered as justification for less-stringent building codes and/or setbacks within this study.

As discussed in Section 6.6, the IPP methodology can not be successfully applied for Pawley's Island and Debidue Beach because of the predominate groin and seawall structures and the inlet effects. Within these areas, the existing dune crest is used as the reference point to derived future shoreline positions. Where seawall or rip-rap exists at the oceanfront, these shorefront structures are used as the reference baseline.

Table 8.1-1 presents the location of IPS in relation to the survey monuments at each monitoring station along Huntington/Litchfield Beach and Garden City. Table 8.1-2

Table 8.1-1. Ideal Present Dune Crest Locationalong Huntington/Litchfield Beach and Garden City

Station	IPS Location (ft)*
<u>Huntington/Litchfield</u>	
4505	-102
4510	-3
4515	-8
4520	-17
4525	4
4530	42
4535	7
4540	14
4545	9
4550	-29
4555	-4
4560	-24
4565	0
4570	**
4575	**
4580	**
4585	**
4590	**
<u>Garden City</u>	
4605	300
4610	242
4615	195
4620	143
4625	156
4630	277
4635	263
4640	191
4645	138
4655	124
4660	97

*Negative value indicates landward of the monument.
**Station is within inlet impact zone.

Table 8.1-2. Present Dune Line Location along Pawley's Island and Debidue Beach

Station	Dune Line Location (ft)*
Debidue Beach	
4305	**
4310	**
4315	**
4320	26
4325	0
4330	0
4335	0
4340	0
4345	0
4350	17
4355	28
4360	11
4365	0
4370	0
Pawley's Island	
4405	104
4410	104
4416	136
4420	291
4425	194
4430	274
4435	650
4440	278
4445	270
4450	236
4455	247
4460	455

*Dune line location is measured seaward from the survey monument.

**Station is within inlet impact zone.

shows the location of the present dune crest or seawall structures. These ideal present dune lines are shown in Appendix D.

8.2 PREDICTED 25 AND 50 YEAR SHORELINES

It has been established in this study and several previous investigations that, with isolated exceptions, the shoreline along the study area is undergoing a long-term erosional trend which spatially varies in magnitude. This erosion is attributable to several factors including sea-level rise, localized littoral deficits, storms and, to a minor extent, armoring of the shoreline. Whether expressed in volumetric or linear terms, the net result of this long-term erosion is a recession of the shoreline, a reduction of the dry beach as both a recreational amenity and a valuable storm buffer, and an ever increasing encroachment on upland development. Predictions of long-term shoreline recession rates are essential in the determination of setback lines, building codes and erosion control permitting procedures; all of which are elements of a prudent shorefront management plan.

Estimations of long-term shoreline recession rates are projected based on extrapolation of observed historical rates into the future. Accordingly, the accuracy of and confidence level associated with these predictions is directly related to the quality and quantity of information comprising the historical database. The practice of conducting beach profile surveys for the specific purpose of quantifying shoreline change rates is relatively new along the South Carolina coast. As a result, the existing database is somewhat limited for the study area under consideration. Shoreline change maps have been compiled from other sources of shoreline information such as boat sheets, navigation charts, aerial photographs and boundary surveys. These maps while difficult to apply on a site-specific basis, provide a large scale indication of the rates of shoreline change over a longer period of time than any existing profile data for the study area. Application of rates obtained from these maps preclude the large degree of uncertainty that is often associated with the variation in short-term erosion in rates observed at individual profiles. As a result, the maps are quite appropriate in determining an average long-term erosion rate over a particular shoreline reach.

Once average long-term erosion rates were determined for each individual shoreline reach along the study area, they were then applied in the determination of future predicted shorelines. Specifically, the rates were applied to either the IPS or the existing dune line, whichever applicable, over a period of 25 and 50 years thereby resulting in the predicted 25 and 50-year shorelines. The setback distance associated with these lines was consistent over each shoreline reach with the exception of areas in the vicinity of inlets. As previously discussed, shorelines in the immediate vicinity of inlets are subject to significant translation in the event of storms, as well as, long-term natural inlet migration. Accordingly these areas are designated as Inlet Impact zones and are assigned an extra buffer during the prediction of future shoreline locations.

Predictions of potential short-term shoreline recession along the open coast resulting from hurricanes and long-term recession resulting from sea-level rise have also been presented in this study. The former are intended to indicate the immediate area of influence associated with erosion resulting from severe storm events while the latter is extracted as one component of the predicted overall long-term recession rates. In determining predicted future erosion rates for a specific shoreline reach, all available data for that reach were compiled and subjectively evaluated for accuracy and applicability. In order to maintain continuity over each shoreline reach, an average rate was obtained from individual profiles and applied to that reach. Correspondingly, in the prediction of storm-related erosion, the relevant distances were derived from average or representative profiles and were directly applied to each reach. A discussion of the available database and methodology utilized in predicting future erosion rates and distances over each shoreline reach is presented in the following paragraphs.

Garden City

Shoreline movement data for this reach of shoreline consisted of: 1) beach profiles taken at various locations in 1958, 1979, 1980, 1981, 1982, 1984 and 1986, and 2) long-term linear MHWL changes obtained from the NOS-CERC Shoreline Movement Maps for the period 1934-1983. In addition, the IPP profile generated for this reach was used in the calculation of erosion associated with the occurrence of the 25 and 50 year storm.

Previous studies by Kana et. al. have applied linear erosion rates, derived from long-term volumetric erosion rates calculated at individual beach profiles. As discussed previously the IPP methodology has been deemed inapplicable along several sections of the study area. Furthermore, the limited number of 1958 beach profiles and the extreme bias in beach volumes at profiles influenced by inlet and swash migration, as well as beach nourishment, make the applicability of this profile data questionable in the determination of long-term annual volumetric change rates.

Based on these two factors it was decided that a more representative prediction of future shoreline positions would result from the application of average linear erosion rates, determined from the shoreline movement maps, to the individual profiles along the shoreline reach. Accordingly, erosion rates were determined at each station along the reach and averaged to obtain a uniform average rate. Stations that were armored or considered subject to inlet or swash migration were not included in calculating the average rate. The resulting average long-term erosion rate was 1.5 ft/year which corresponds to a distance of 37.5 and 75 feet respectively over 25 and 50 years. These distances were then applied to the existing dune or structure line, whichever was most seaward, along each profile in order to represent the predicted 25 and 50 year shorelines.

Litchfield-Huntington Beach

Shoreline movement data for this reach of shoreline extending from Murrells Inlet to Midway Inlet consisted of: 1) beach profiles taken at various locations in 1979, 1980, 1982 and 1986, and 2) long-term linear MHWL changes obtained from the NOS-CERC Shoreline Movement Maps for the period 1962-1983. In addition, the IPP profile generated for this reach was used in the calculation of erosion associated with the occurrence of the 25 and 50 year storm.

The lack of beach profile data prior to 1979 precluded the determination of an average linear erosion rate based on long-term volumetric changes at individual profiles. Accordingly, this precluded the application of a linear erosion rate, derived from volumetric changes, to the IPS for the prediction of future shoreline positions as prescribed in the IPP methodology. In addition, the majority of the beach profile data in this area since 1979 were collected for the purpose of monitoring shoreline changes caused by the Murrells Inlet Navigation Project in effect "disqualifies" much of it from being representative of natural shoreline migration trends. As previously discussed, the shoreline extending approximately 2.5 miles south of Murrells Inlet has undergone accelerated rates of erosion and accretion due to shoreline reorientation subsequent to stabilization of the inlet. These planeform changes, which may be expected to continue, result in an unstable shoreline and introduces a significant bias if included in the calculations of shoreline change rates.

As a result, the short-term shoreline movement data obtained from beach profiles was not utilized in the determination of an average long-term recession rate. Rather, the NOS-CERC shoreline movement maps were utilized for this purpose. Accordingly, erosion rates were determined at each station along the reach and averaged to obtain a uniform average rate. Stations that were armored or considered subject to inlet effects were not included in calculating the average rate. The resulting average long-term erosion rate was 1.3 ft/yr which corresponds to a distance of 32.5 and 65 feet respectively over 25 and 50 years. These distances were then applied to the existing dune line, defined as the crest of the seawardmost dune, along each profile in order to represent the predicted 25 and 50 year shoreline.

Pawley's Island

Shoreline movement data for Pawley's Island consisted of: 1) beach profiles taken at 12 stations in 1981 and 1986, and 2) long-term linear MHWL changes obtained from the NOS-CERC Shoreline Movement Maps for the period 1934-1983 and 1962-1983. In addition, characteristic profiles obtained from the 1986 beach surveys were utilized in the calculation of erosion associated with the occurrence of the 25 and 50 year storm.

As discussed earlier, apparent discrepancies in datum control and limited documentation were evident in the establishment of the survey stations from which the 1981 beach profiles were conducted. This created an element of uncertainty as to the accuracy level for several comparative beach surveys in representing conditions at Pawley's Island.

Profile comparisons at three stations had to be discarded due to obvious discrepancies in horizontal and vertical control. Profile comparison at other stations failed to reveal a discernible trend in shoreline movement patterns from which an overall average rate could be assigned. Whether this was due to inconsistencies in survey control or merely short-term (5 years) shoreline fluctuations, comparisons of the 1981 and 1986 profiles were considered inadequate for the determination of a shoreline recession rate from which long-term future setback lines could be established.

As a result, the NOS-CERC Shoreline Movement Maps were referred to in the determination of future shorelines at Pawley's Island. Erosion rates were calculated at each station and were averaged to obtain a uniform rate. Stations considered to be subject to inlet effects were not included in calculating this rate, however, since the entire remaining portion of the island is bulkheaded or influenced by groins, armoring was not, in this case, a criteria for eliminating a station from being included in the calculations. The resulting average long-term erosion rate was 1.3 ft/yr which corresponds to a distance of 32.5 and 65 feet respectively over 25 and 50 years. These distances were then applied to the existing dune or structure line, whichever was most seaward, along each profile in order to represent the predicted 25 and 50 year shorelines. It is of interest to note that the calculation of an average erosion rate over both the periods 1934-1983 and 1962-1983 resulted in a rate of 1.3 ft/yr thereby indicating a very consistent trend in shoreline recession.

Debidue Island

Controlled beach profile survey stations had not been established along Debidue Island prior to those set in April 1986 as part of this study. As a result, comparative beach profile data were not available for the assessment of shoreline changes. However, long-term changes (1934-1983 and 1962-1983) are depicted on the NOS-CERC Shoreline Movement Maps. As previously mentioned, the Debidue Island shoreline exhibits the greatest magnitudes of, and variations in, shoreline migration rates along the area. This is reflected on the shoreline movement maps which indicate high rates of erosion at the south end decreasing northward and reversing to mild accretion at the extreme north end. The maps also indicate a high degree of shoreline instability at both ends of Debidue Island.

As a result of this variation in shoreline migration rates, no uniform rate was determined as applicable across the entire island. Accordingly, engineering judgement and subjectivity were utilized in assessing variable rates along the island, particularly at the north and south ends. The south end of the island has undergone extreme shoreline translation, resulting in erosion rates in excess of 10 ft/yr, directly related to the North Inlet shoal system. Along the center of the island recession rates were fairly consistent at 3.4 ft/yr. The north end of the island exhibits a relatively stable to mildly accretional shoreline.

Based on these rates the 25 and 50 year shorelines, when interpreted literally, respectively fall in excess of 250 and 500 feet landward of the existing shoreline along the southern peninsula of Debidue Island. These distances decrease to approximately 150 and 300 feet, respectively at the northern extent of this peninsula and to 85 and 170 feet further north at a point 1700 feet south of the southern end of the Debidue Tract seawall. These projected 25 and 50 year shoreline locations remain constant progressing northward to a point approximately 4000 feet south of Pawley's Inlet. At this point, despite an apparent mild accretional trend, the effects of inlet shoaling and bypassing processes in concurrence with low-lying uplands and historical inlet migration necessitate a more conservative projection of future shoreline location. Accordingly, this location progresses landward towards Pawley's Inlet to a point corresponding to a 25 and 50 year position of 225 and 450 feet, respectively from the existing dune line.

8.3 STORM IMPACTS

As with any shoreline along the southeastern Atlantic coast, the beaches included within the study area are subject to substantial temporal erosion due to the effects of northeasters, tropical storms and hurricanes. These events are associated with short-term superelevations of the water level (storm surge) and increases of onshore wave energy. The setup of the water level allows wave-breaking and wave-runup processes to occur at an increased elevation on the beach foreshore, thereby subjecting the existing dune system and/or upland development to direct wave attack and consequential displacement and damage. The predictable result is large-scale dune erosion or loss, dramatic rates of shoreline recession and destruction of upland structures.

In most instances, however, eroded material is not totally lost from the littoral system, but rather deposited in nearshore bar formations. On a relatively stable shoreline, seasonal variations in local wave climate will return much of the eroded sediment to the beach foreshore and dunes over a period of years, barring the occurrence of similar storms during the rebuilding period. As a result, the extent of erosion that takes place during such events is not always accurately represented or accounted for when assessing long-term erosion rates. When establishing a shorefront management plan, short-term erosion events should be considered to avoid potentially disastrous impacts associated with major storm events.

The predicted storm-surge elevations for the study area are discussed in Section 6.4 of this report. Although substantial damage along the study area shoreline has been documented as a result of land-falling hurricanes, erosion more frequently occurs from northeasters. It is interesting to note that the beach erosion caused by a long duration northeaster and the associated high-water levels can often exceed that of a hurricane passing offshore. More moderate hurricane-induced erosional impacts are due to the relatively shorter storm duration and the proximity of the relatively fast-moving tropical storm to the local shoreline. Nevertheless, erosion associated with the occurrence of the predicted 25- or 50-year hurricane has been considered as the worst-case condition when evaluating setback criteria in this study.

A numerical model has been employed in this study in order to predict the extent of potential future erosion that may be expected along the various study area shoreline reaches as a result of the occurrence of the predicted 25- and 50-year hurricanes. The theoretical basis for the computer model was developed by Dr. Robert G. Dean of the University of Florida and is currently applied by the State of Florida Department of Natural Resources - Division of Beaches and Shores (DNR-DBS) Coastal Construction Control Line Program. In essence, the model calculates the erosion of a characteristic beach profile at each time interval associated with a synthesized storm-surge hydrograph. The model predicts linear erosion of the beach-dune system but does not account for dune overtopping or breaching. The hydrograph represents the rise and fall of the water level over time that occurs during a tropical storm. The IPP or other representative profiles along each reach were simplified and input into the model as the pre-storm profile. Water levels associated with the 25- and 50-year hurricane along each reach were input as the peak of the storm surge hydrograph for each stimulation. The hurricane hydrograph was simulated using the characteristics of an actual storm surge hydrograph. The components of the hypothetical hydrograph correspond with the peak water elevations of the 25- and 50-year hurricane for a 36-hour total storm duration. The hydrograph was skewed with a long rising limb (i.e., time to peak) and a slow falling limb. The rising portion was approximately 20 hours; maximum or peak levels occurred for approximately 10 hours. The falling or receding position was approximately 6 hours. Specific input parameters and the results of these stimulations are presented in the following paragraphs.

Garden City Beach

The previously determined IPP for this reach of shoreline was utilized to represent the pre-storm profile condition. Input requirements of the model necessitate simplifying the profile as a series of straight-line slopes above the pre-storm water level and an exponential equilibrium profile below that water level. The maximum IPP dune height of +11.5 ft was input into the model, as were the 25-and 50-year maximum storm surge elevations of +9.5 ft and +11.5 ft (NGVD), respectively. Landward dune erosion of 116 ft and 152 ft resulted from the model simulation of the 25- and 50-year storm surge, respectively. Figure 8.3-1 presents the IPP, the simplified IPP input as the pre-storm profile and the eroded profiles resulting from the simulation of the 25- and 50-year storm surges. Of particular note is the fact that the primary IPP dune is breached during this simulation. While the simulation of the IPP erosion represents an average condition over the shoreline reach, it is in this case a condition that would result in considerable landward propagation of the flooding and wave action associated with these storm events.

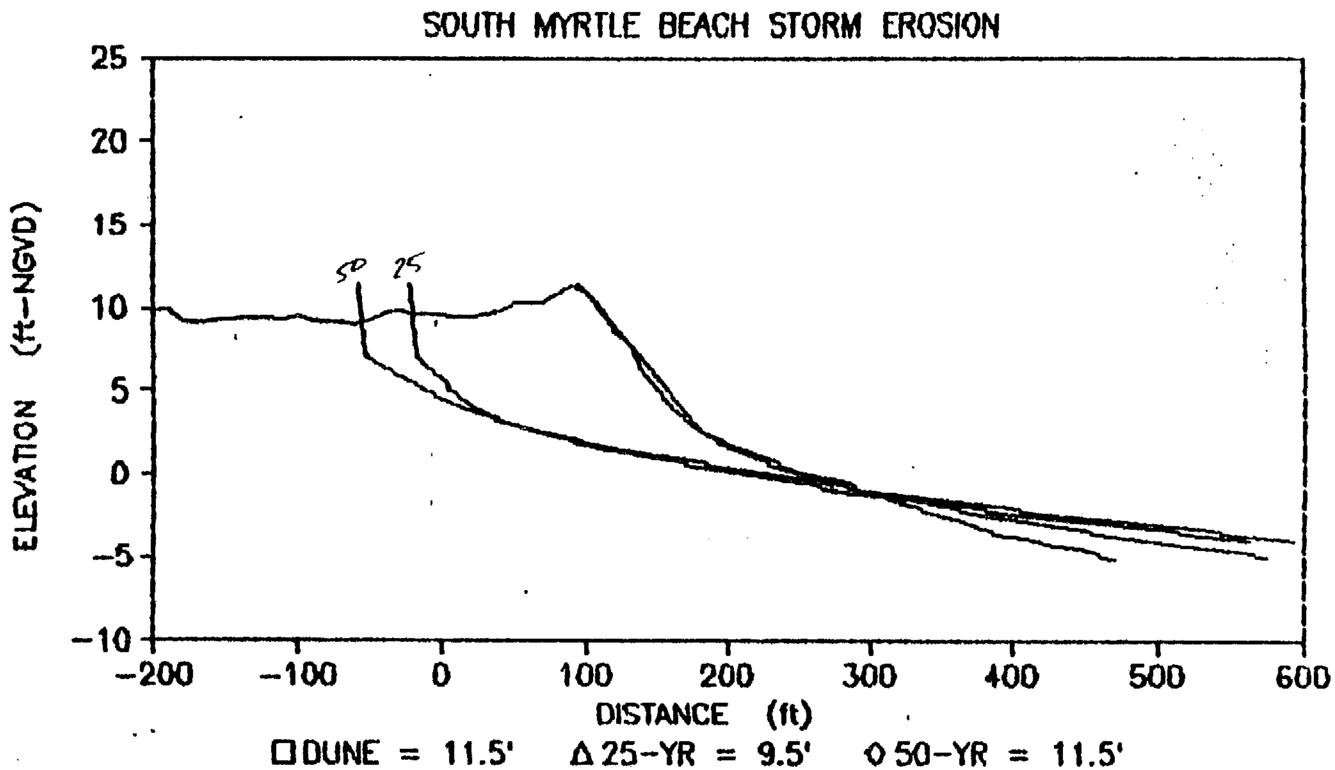


FIGURE 8.3-1
PREDICTED 25- AND 50-YEAR STORM EROSION
(GARDEN CITY)

Litchfield - Huntington Beach

The previously determined IPP for this reach of shoreline was utilized to represent the pre-storm profile condition in this simulation as well. Likewise, the profile was simplified to meet input requirements of the model. The maximum IPP dune height of 16 ft and maximum storm-surge elevations of 10 ft and 12 ft were input into the model for simulation of the 25- and 50-year storm events, respectively. Landward dune erosion of 59 ft and 101 ft resulted from model simulation of the 25- and 50-year storm surge. Figure 8.3-2 presents the IPP, the simplified IPP input as the pre-storm profile and the eroded profiles resulting from the simulation of the 25- and 50-year storm surges. Again, it should be noted that the primary IPP dune is breached in both of these simulations. Likewise, while erosion of the IPP represents an average condition along the shoreline reach, it is in this case a condition that would result in considerable landward propagation of both the flood elevations and wave action associated with these storm events.

Pawley's Island

As we discussed in section 6.2, the IPP methodology is not applicable for the Pawley's Island shoreline due to the effects of both armoring and inlet proximity on beach morphology there. This precluded the application of the storm erosion model to a single profile representative of average conditions along the entire island. As an alternative approach, actual profiles determined to be representative of individual reaches of the shoreline were chosen for application in storm erosion modeling for that reach. As discussed in section 3.10, Pawley's Island can be divided into three distinct sections when addressing characteristic beach morphology. Accordingly, representative profiles were selected from the southern,

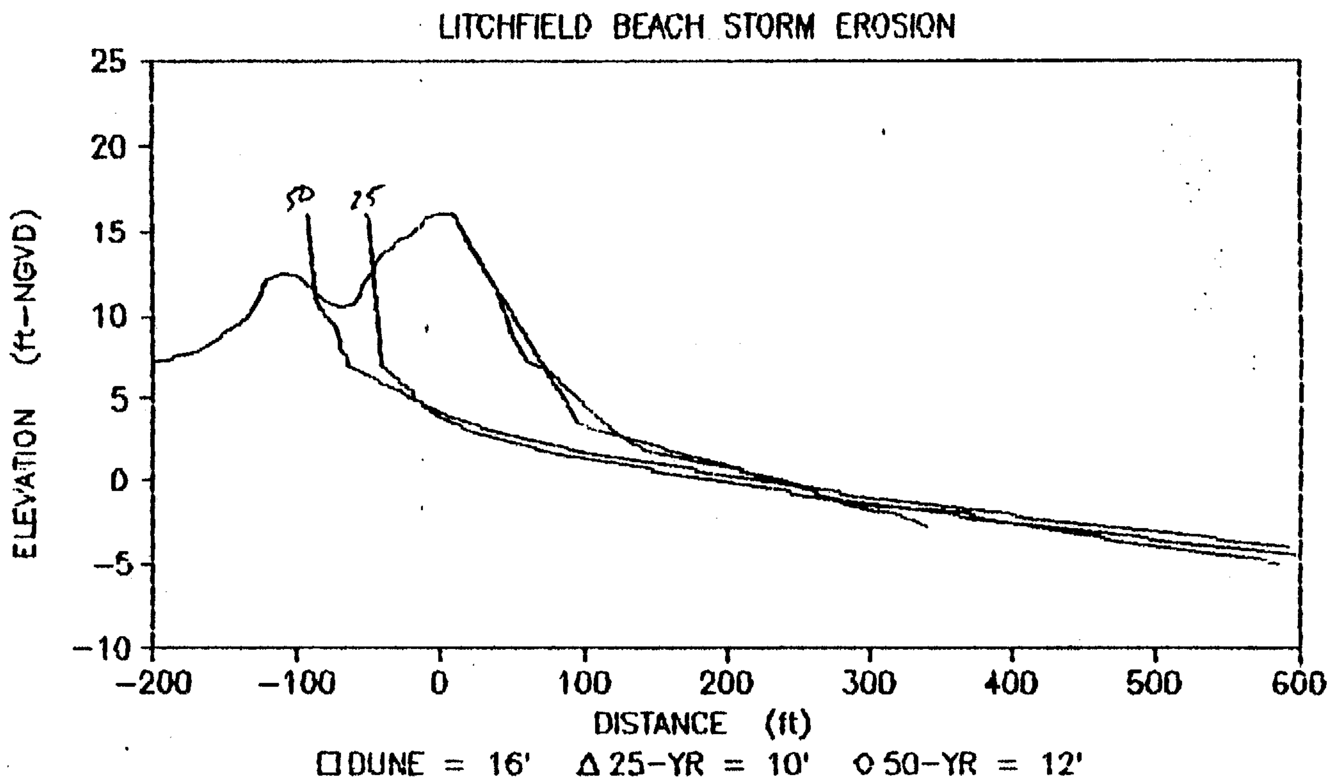


FIGURE 8.3-2
PREDICTED 25- AND 50-YEAR STORM EROSION
(LITCHFIELD/HUNTINGTON BEACH)

central and northern sections of the island for application of the storm erosion model.

The southern spit section of Pawley's Island, while exhibiting a distinctly characteristic profile, rarely reaches elevations greater than the 25-year (+9.5) or 50-year (+12 ft) storm surge. As a result, the majority of this area would be overtopped during either of these low-frequency storm events. As the simulation of erosion associated with overtopping is currently beyond state-of-the-art capabilities, such an erosion prediction for the southern spit of Pawley's Island was deemed unfeasible. Nevertheless, it can be safety assumed that the entire southern spit area would be subject to extreme sediment displacement, structural damage and potential breaching in the event of storm surges of these magnitudes.

Dune elevations along the central and northern sections of Pawley's Island are significantly greater than the surges associated with the 25- and 50-year storms; accordingly, profiles 4420 and 4450 were chosen to represent these sections respectively. Table 8.3-1 presents the pertinent input and output for the simulation of the 25-year and 50-year storm erosion for these profiles.

Table 8.3-1. Input Data and Results for Modeling Erosion Associated With the 25- and 50-Year Storm Surge Along Northern and Central Pawley's Island.

STORM	SURGE LEVEL	ISLAND REACH	STATION	DUNE EROSION
25 year	9.5'	Center	4420	100'
25 year	9.5'	North	4450	48'
50 year	12.0'	Center	4420	135'
50 year	12.0'	North	4450	90'

Figures 8.3-3 and 8.3-4 present the actual profile, the

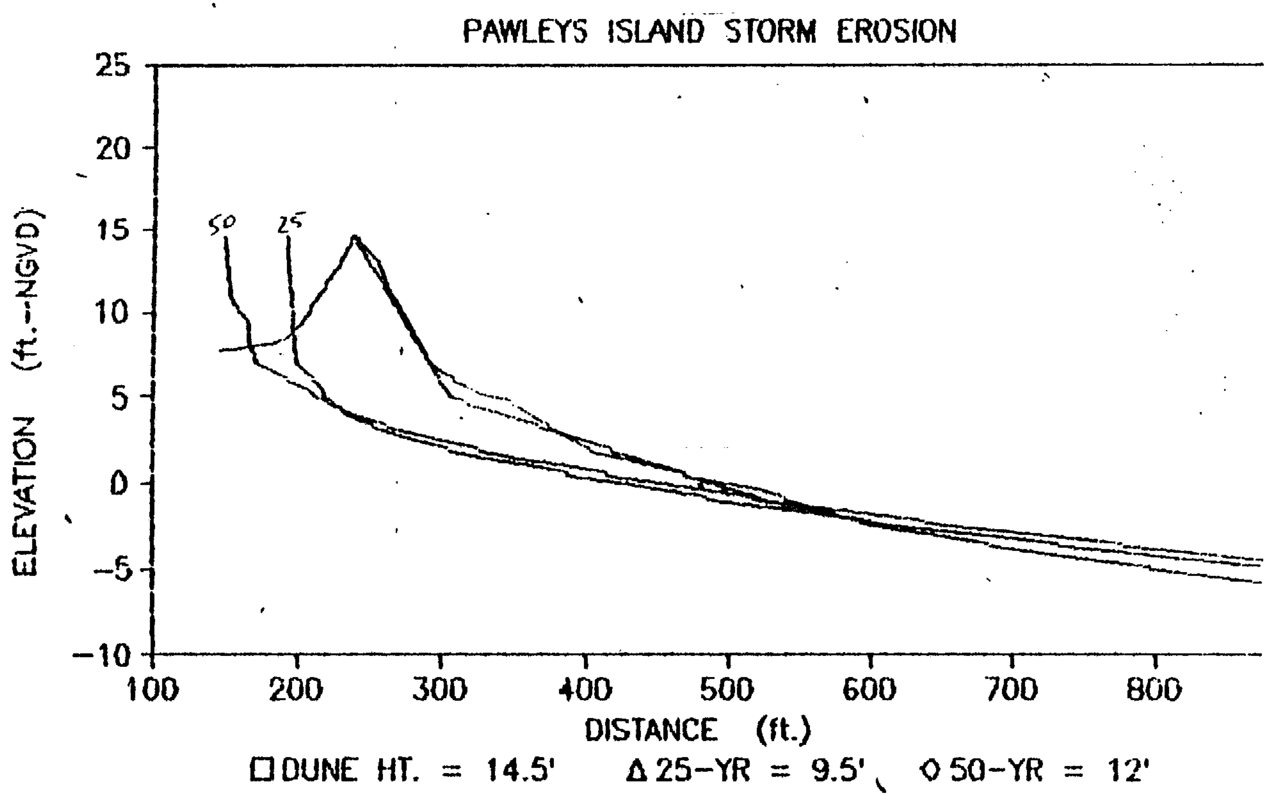


FIGURE 8.3-3
PREDICTED 25- AND 50-YEAR STORM EROSION
(NORTHERN PAWLEY'S ISLAND)

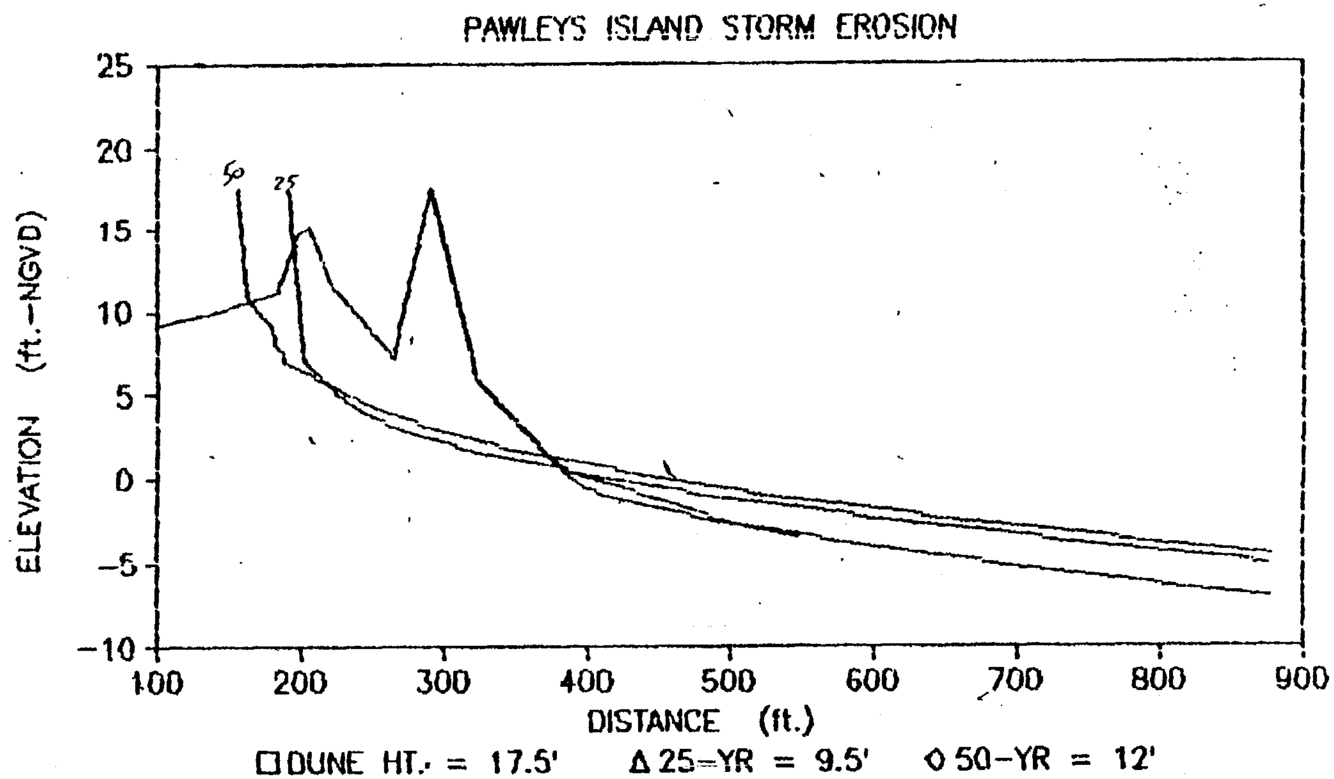


FIGURE 8.3-4
PREDICTED 25- AND 50-YEAR STORM EROSION
(CENTRAL PAWLEY'S ISLAND)

simplified profile input as the pre-storm profile and the eroded profiles resulting from the simulation of the 25- and 50-year storm surges for both the northern and central reaches of Pawley's Island. Analysis of these figures and Table 8.3-1 indicate in the event of such storms the central island shoreline may undergo a considerably greater amount of dune recession than the northern section. This is due primarily to the greater volume of sand per ft. of dune and the milder slopes characteristic of the northern shoreline beach profile. It should be noted that the primary dune would be breached at both profiles for both storm events. Since these profiles were chosen as representatives of their respective shoreline reaches, the degree of erosion associated with each profile as a result of the 25- and 50-year storm surge should be likewise considered representative of each reach.

Debidue Island

The IPP methodology was also deemed inapplicable for the Debidue Island shoreline, and as a result, actual profiles determined to be representative of individual shoreline reaches were likewise chosen for application in storm erosion modeling at that location. Similar to Pawley's Island, Debidue Island can be divided into three distinct sections when addressing characteristic beach morphology. The southern spit on Debidue Island rarely reaches elevations greater than the 25-year (9.5 ft) and 50-year (12 ft) storm surge. Accordingly, the majority of this area would be subject to overtopping, thereby precluding accurate modeling of erosion resulting from either of these low-frequency storm events. It can be concluded, however, that this southern spit section would be subject to considerable sediment displacement and potential breaching in the event of storm surges of these magnitudes.

Dune elevations along the central and northern sections of

Debidue Island are significantly greater than the surges associated with the 25- and 50-year storms; accordingly, profiles 4340 and 4360 were chosen to represent these sections respectively. Table 8.3-2 presents the pertinent input and output for the simulation of the 25- and 50-year storm erosion for these profiles.

Table 8.3-2. Input Data and Results of Modeling Erosion Associated with the 25- and 50-Year Storm Surge Along Northern and Central Debidue Island.

STORM	SURGE LEVEL	ISLAND REACH	STATION	DUNE EROSION
25 year	9.5'	Center	4340	129'
25 year	9.5'	North	4360	110'
50 year	12.0'	Center	4340	169'
50 year	12.0'	North	4360	152'

Figures 8.3-5 and 8.3-6 present the actual profile, the simplified profile input as the pre-storm profile and the eroded profiles resulting from the simulation of the 25- and 50-year storm surges for both the northern and central reaches of Debidue Island. It should be noted that along the central reach, the extent of erosion is such that houses located there may well be threatened by the occurrence of these low-frequency storm events. Erosion along the northern shoreline reach is substantial and, while this area is currently undeveloped, the storm impacts should be taken into account in the formulation of any future development plans.

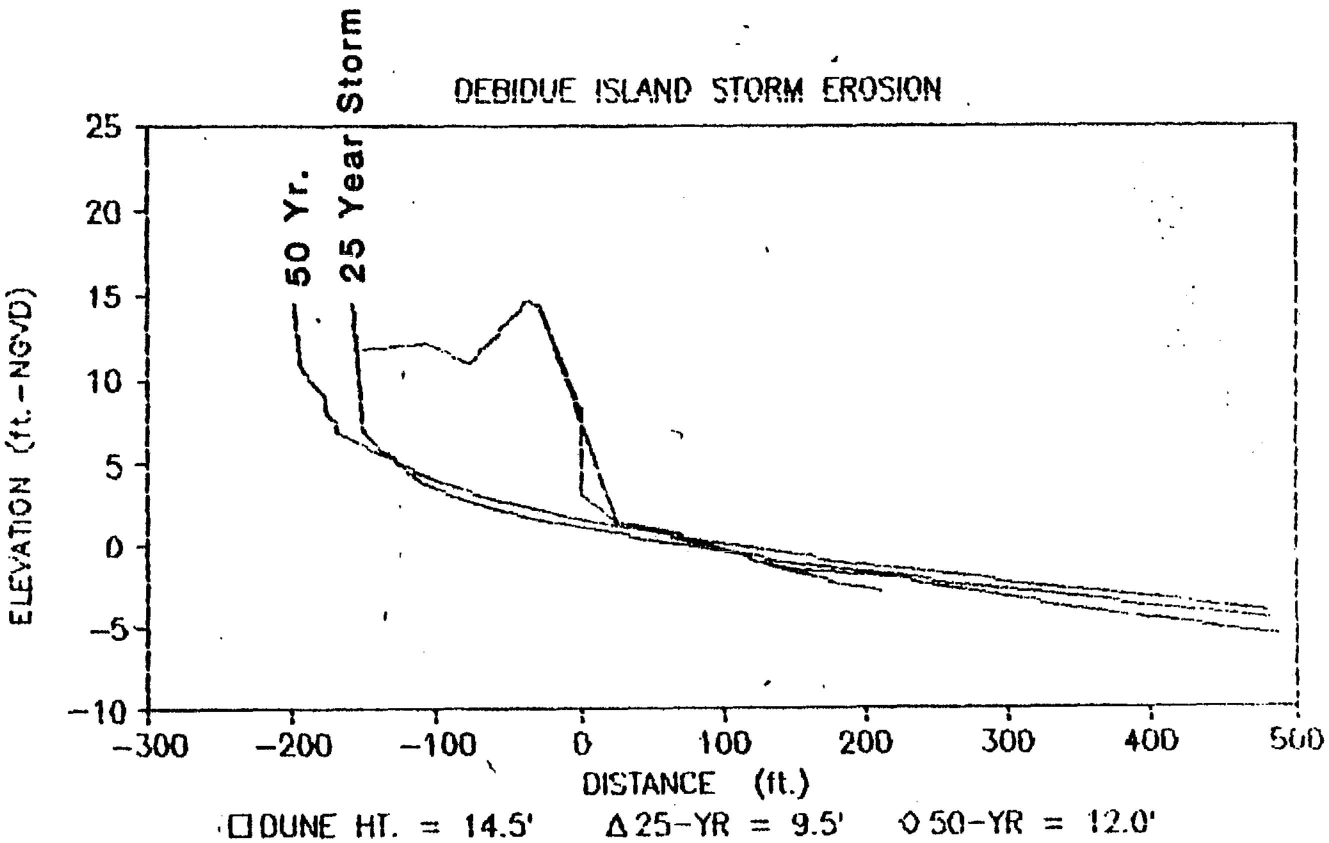


FIGURE 8.3-5
PREDICTED 25- AND 50-YEAR STORM EROSION
(NORTHERN DEBIDUE BEACH)

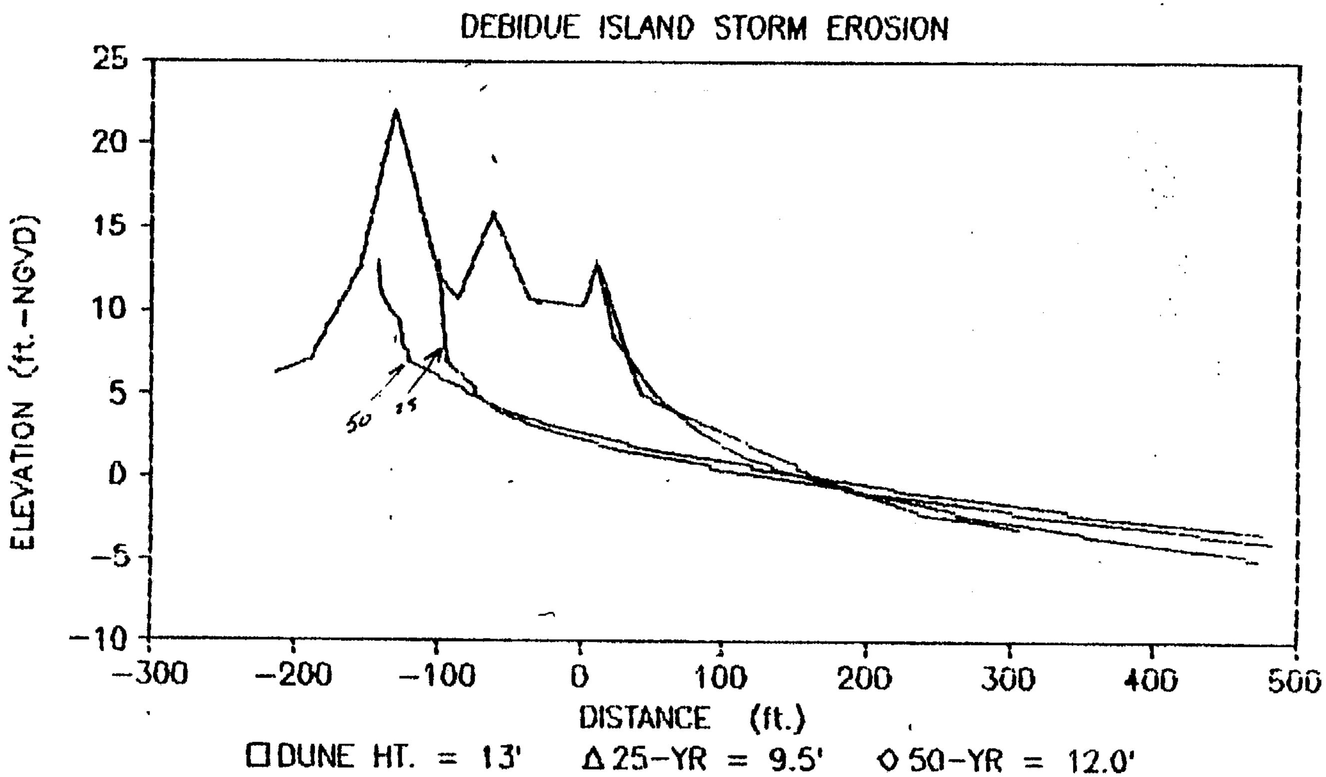


FIGURE 8.3-6
PREDICTED 25- AND 50-YEAR STORM EROSION
(CENTRAL DEBIDUE BEACH)

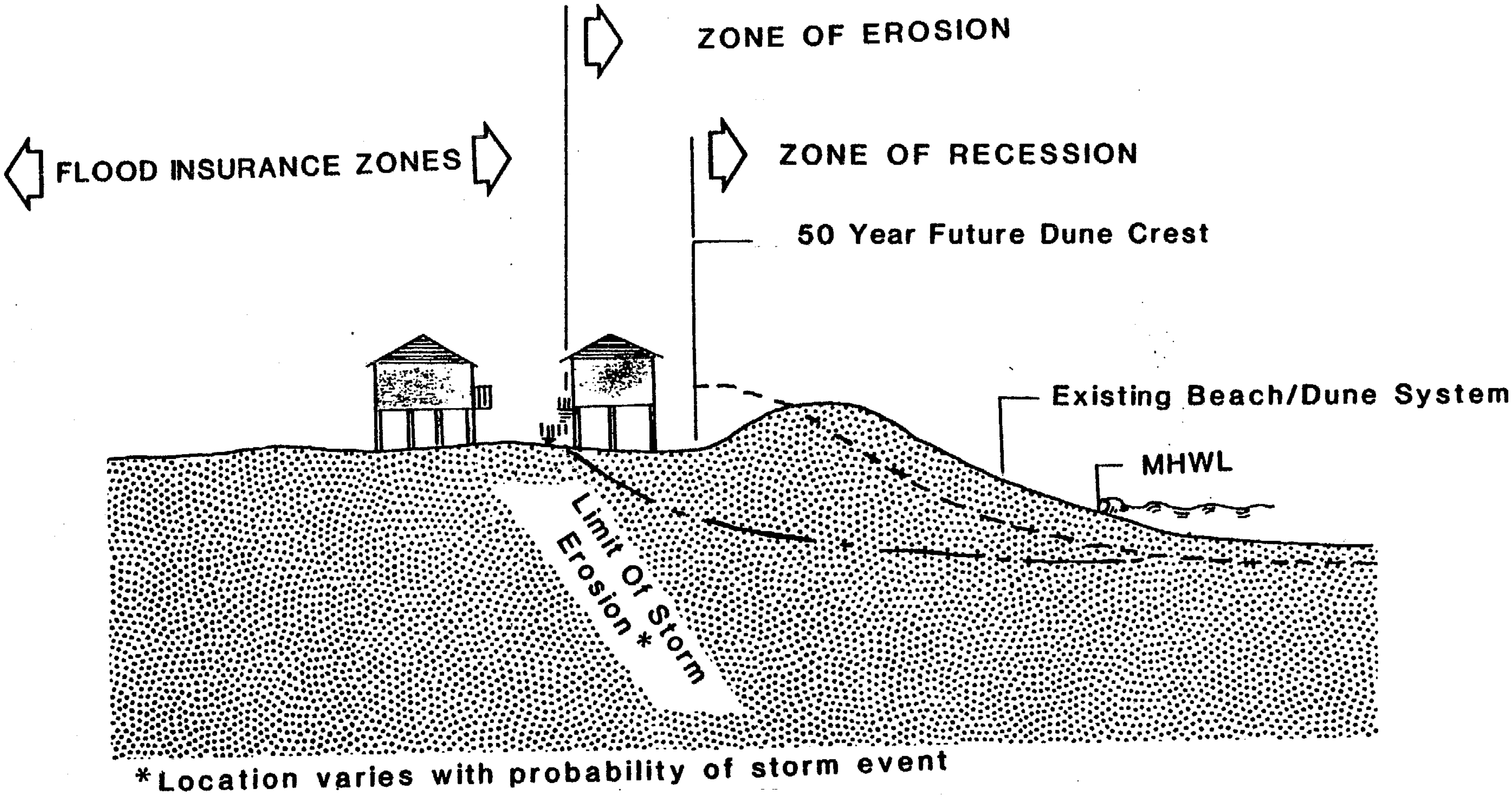
9.0 SHOREFRONT MANAGEMENT RECOMMENDATIONS

9.1 HAZARD ZONES

In contrast to similar efforts by previous investigators, the Shorefront Management Study under consideration has identified multiple coastal hazard zones which are, at present, not currently or effectively regulated by federal, state and local governments along the shoreline of interest. These hazard zones are associated with the:

- Future location of the beach/dune system as a result of erosion and shoreline recession,
- Limit of upland erosion resulting from low frequency storm events, and
- Existing Flood Insurance Zones which in numerous locations under-predict the level of impact for a 1-in-100 year storm.

A conceptual depiction of these coastal hazard zones relative to an existing beach/dune system is included as Figure 9.1-1. It is important to note that the indicated seawardmost two (2) zones are related to the expected long and short-term dynamic fluctuation of both the beach and dune, where existent. The flood insurance zones are the result of the federal government's (i.e. FEMA) efforts to map the impact zones of a 100-year storm for the purpose of making available federally subsidized flood insurance. It should be understood that the flood insurance zones, depicted by FEMA for "A" and "V" zones respectively, are indicative of the flooding limits without, and with waves greater than three ft in height, resulting from a probabilistically determined 100-year storm event. The FEMA methodology does not however, include the prediction of shoreline fluctuations and erosion during the 100-year storm. For that reason, the predicted landward limits of V-



COASTAL HAZARD ZONES

SHOREFRONT MANAGEMENT PLAN

FIGURE 9.1-1
SCHEMATIC DIAGRAM OF THE COASTAL HAZARD ZONES

zones in coastal areas with dunes can be extremely unreliable and inaccurate when the elevation of the existing dune crest exceeds the computed theoretical elevation of the 100-year storm surge. To a large degree, this condition predominates throughout the study area. Hence it is necessary for this shorefront management study to address existing flood insurance zones and the propriety of considering additional building construction guidelines within these extremely high-hazard areas.

9.2 EXISTING SHOREFRONT REGULATORY PROGRAMS

At present, the following three (3) types of developmental regulation are in effect along the Georgetown County shoreline of interest above the approximate MHWL:

- State of South Carolina Coastal Council permitting requirements along the beach and within the adjacent primary oceanfront sand dune "critical area" (via Act 123 of 1977),

- Federal Flood Insurance requirements for construction within "A" or "V" Zones (44 CFR, Parts 59 and 60), and

- Where existent, any locally adopted zoning ordinances and/or setbacks; developer's covenants and restrictions; etc.

Coastal Council regulatory authority allows for the protection of existing fragile beach/dune resources by calling for their classification as "critical areas". The limit of Coastal Council jurisdiction in most instances is a function of the location of the primary ocean front dunes which by definition are "those dunes which constitute the front row of dunes adjacent to the Atlantic Ocean". Accordingly, the "critical area boundary" is further defined in the governing Rules and Regulations for Permitting as follows:

> If the crest of a primary front row sand dune is not reached within 200 feet landward from mean high water, that sand dune is not considered adjacent to the Atlantic Ocean. Council permitting authority shall extend: (1) to the landward trough of the primary front row sand dune if the crest of this dune is reached within 200 feet landward from mean high water; (2) to the seaward side of any maritime forest or upland vegetation if reached before the primary front row sand dune; and (3) to the seaward side of any permanent man-made structure which was functional in its present form on September 28, 1977.

At present, the Coastal Council's regulatory authority is limited strictly to existing conditions. No allowances are made for where the dune crest and/or beach face will be in the future as a result of shoreline recession in areas with historically known rates of erosion. Furthermore, the Council cannot consider the adverse effects of low frequency storm events which can both literally destroy the primary dune in a matter of hours and correspondingly adversely impact life, limb and property.

In accordance with the published regulations for the National Flood Insurance Program, FEMA defines "coastal high hazard areas" as "areas subject to high velocity waters, including, but not limited to hurricane wave wash". These areas are designated by means of maps as V-zones. Construction of habitable structures within such areas must comply with elevation and limited building standard criteria. Areas of "special flood hazard" (i.e. 100-year storm flooding) are likewise designated by mapping for insurance purposes as A-zones. Both A and V zone phenomena are considered to have a one percent or greater chance of occurrence in any given year (i.e. probability of .01). As previously discussed, the methodology for the prediction of 100-year flooding and simultaneous wave action utilized by FEMA does not account for erosion of the beach/dune system. Accordingly, the landward limits of the V-zone for much of the Georgetown County shoreline is grossly inaccurate and therefore unconservative. The result of this shortcoming in the methodology is that both existing and future new construction and/or substantial reconstruction is occurring in certain high hazard areas without having to consider appropriate design criteria. Without state or local intervention, this shortcoming is not expected to change in the foreseeable future.

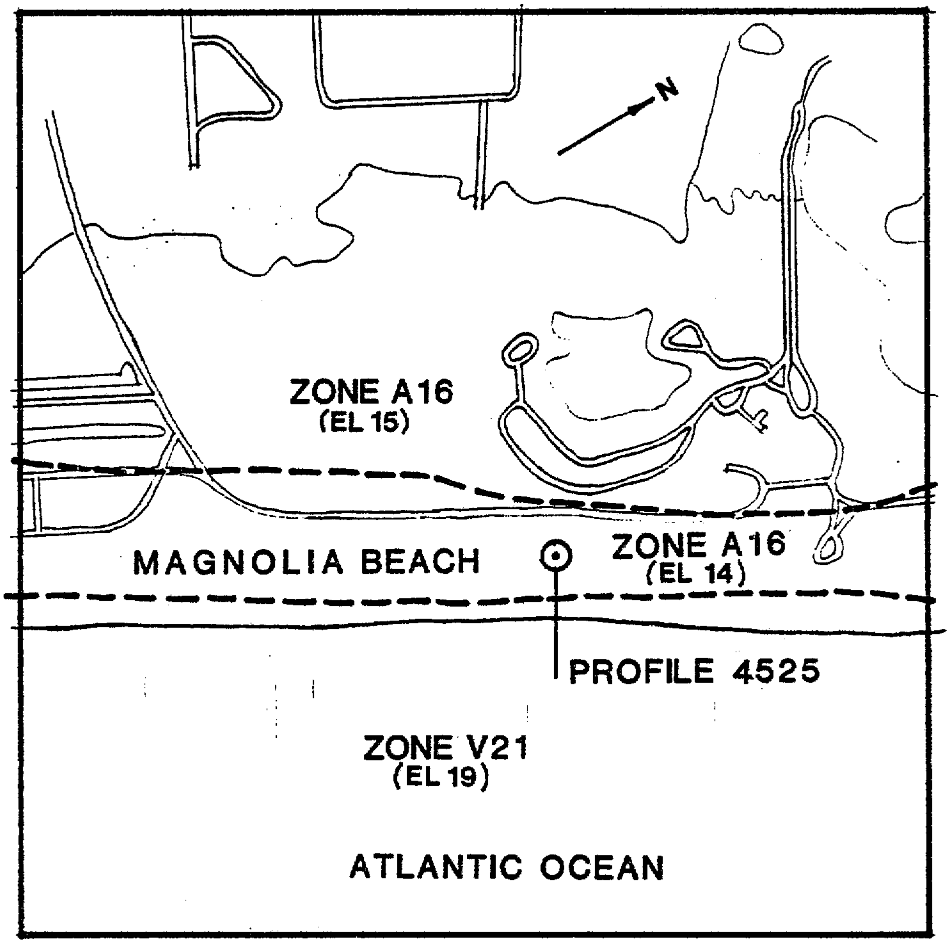
The third general area of potential existing regulation of construction within coastal high hazard areas is "local government", or developer initiated control. For the project area under consideration, no local beach and dune type setback restrictions are in existence. A recent (August 1985) shoreline assessment contracted by the developers of Arcadia I & II and Debidue tracts at Debidue Island, resulted in the recommendation of the adoption of setbacks "ranging from 150 ft. to 250 ft. from the seaward toe of the seawardmost dune or seawall, where existent" (Kana, et al. 1985). The estimated level of storm protection predicted by the consultant for the recommended setbacks varied between the 25 and 50 year storm, dependent on location on the island. To date, the developer for the Debidue properties under discussion is continuing to assess the propriety of the recommended setbacks, (written correspondence).

9.3 EXISTING FLOOD INSURANCE ZONES AND STANDARDS

Both a review of the existing Flood Insurance Rate Maps (FIRMs) for the study area in Georgetown County, as well as the preliminary results of the storm impact analyses, indicate that the V-zone conditions depicted by the FIRMs are extremely unconservative. Along the Georgetown County coast, the V-zones terminate at/or about the seaward face of any dune or similar features which have an elevation exceeding the predicted base flood elevation (BFE) for a 100-year storm. Due to the adoption of nationwide uniform standards for the performance of Flood Insurance Studies by subcontractors, FEMA does not consider erosion of existing beach/dune systems, or other features in the prediction of V-zones.

In Georgetown County, as well as adjacent counties, this shortcoming results in a gross underestimation of the shore normal extent of the impact zone with waves greater than three feet in height expected to occur coincident with a 100-year storm event. Of immediate concern is not only the specified elevation for future construction within V zones, but more importantly the <u>types</u> of construction allowed immediately landward of the beach-dune system. For example, A-zone standards do not require pile foundation, nor the consideration of wave forces. Areas which are mapped as A-zones, but in reality will be subject to severe wave effects during a 100-year storm, therefore are not necessarily subject to prudent building requirements for not only single family residence construction, but also multi-family and commercial buildings. The potential future consequences of this situation are intuitively obvious.

As a specific example, Figure 9.3-1 is an excerpt from FIRM No. 450085 0205 C for an area located within Magnolia Beach, north of Midway Inlet in unincorporated Georgetown County. As noted, the landwardmost V-zone which terminates at the dune line is at elevation +19 ft. Landward of that point is an A-zone at elevation +14 ft. Also noted on Figure 9.3-1 is the location of survey profile No. 5525 which was established as part of this study. The depiction of the



REFERENCE:

COMMUNITY PANEL NO. 450085 0205 C

Mar. 1,1984

GEORGETOWN COUNTY,S.C.

FIGURE 9.3-1
FLOOD INSURANCE MAP NEAR LITCHFIELD BY THE SEA

FEMA flood zones as they relate to the cross section of the beach at profile No. 5525 is shown in Figure 9.3-2.

Previously referenced erosion analyses of the IPP within the Litchfield Beach area for both 25 and 50 year storm events have indicated the dune at this location can reliably be considered to be eroded away as a result of erosion during a 100 year storm. For that reason, the actual physical phenomena expected with such an event will not be as depicted on FIRM No. 450085 0205 C and as interpreted by Figure 9.3-2. Instead, the expected nearshore impact zones will be as shown in Figure 9.3-3 which demonstrates the recalculated elevation and location of the V-zone concurrent with the 100 year storm, including erosion. As shown in this Figure, any structure built immediately landward of the dune should be constructed in accordance with V-zone criteria at elevation +18, and not A-zone criteria at elevation +14. The situation highlighted by this example is typical of existing conditions throughout the majority of the Georgetown County shoreline considered by this study.

Correspondingly, a major recommendation of this study is the implementation of a building construction zone(s) landward of the dune line which will result in the consideration of design criteria sufficient to accommodate the expected impacts of a 100-year storm.

9.4 RECOMMENDED SETBACKS

It is intuitively obvious that in order to adequately protect existing and future beach/dune resources, both the predicted short-term and long-term shoreline impact zones must be accounted for in an enforceable shorefront management plan. For example, the premise of a minimum setback from the 50-year future shoreline is simplistically an effort to prevent construction landward of the location where the active beach is expected to be 50 years hence,

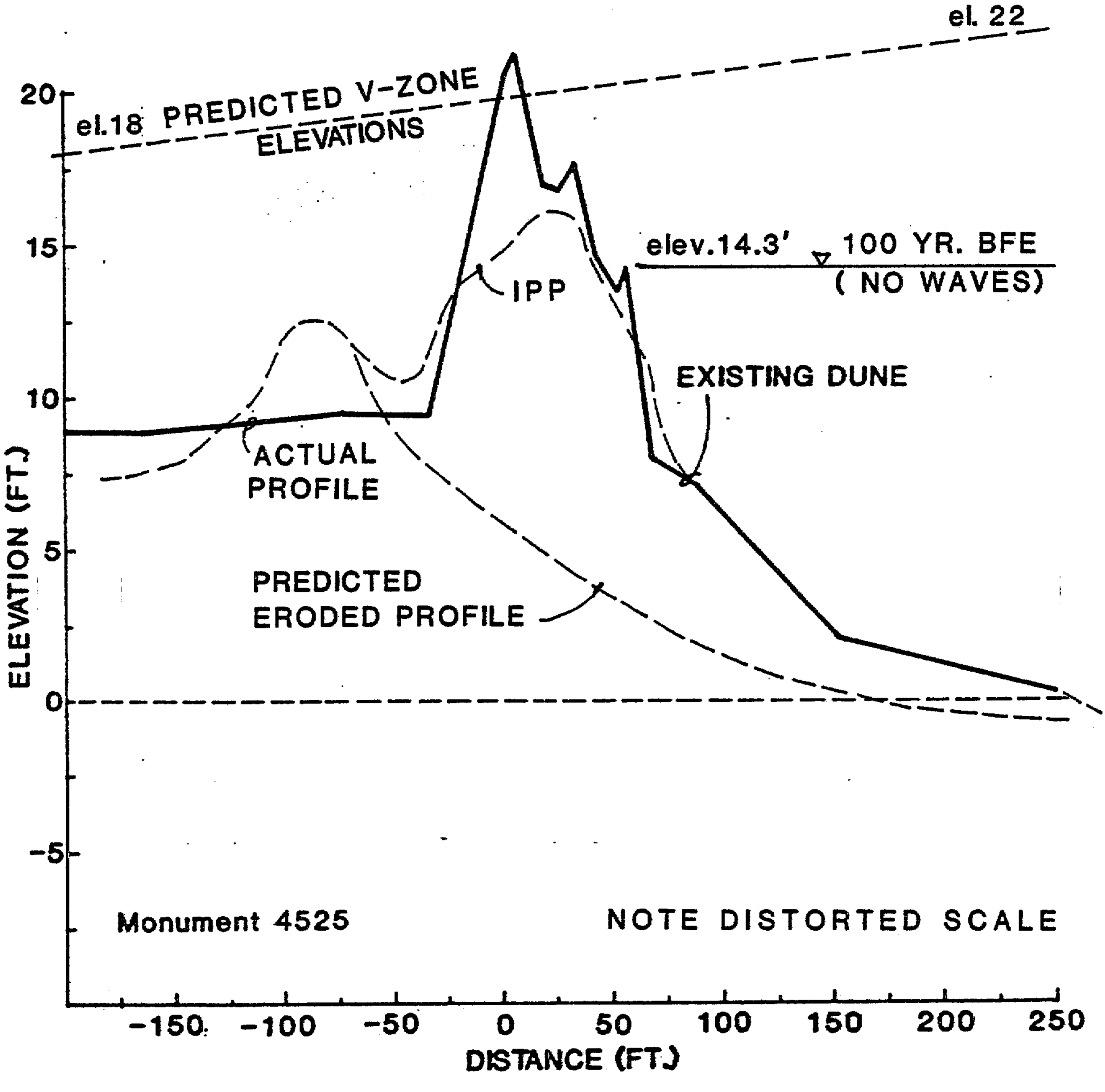


FIGURE 9.3-2
DEFINITION OF V-ZONE WITHOUT
CONSIDERATION OF STORM IMPACTS

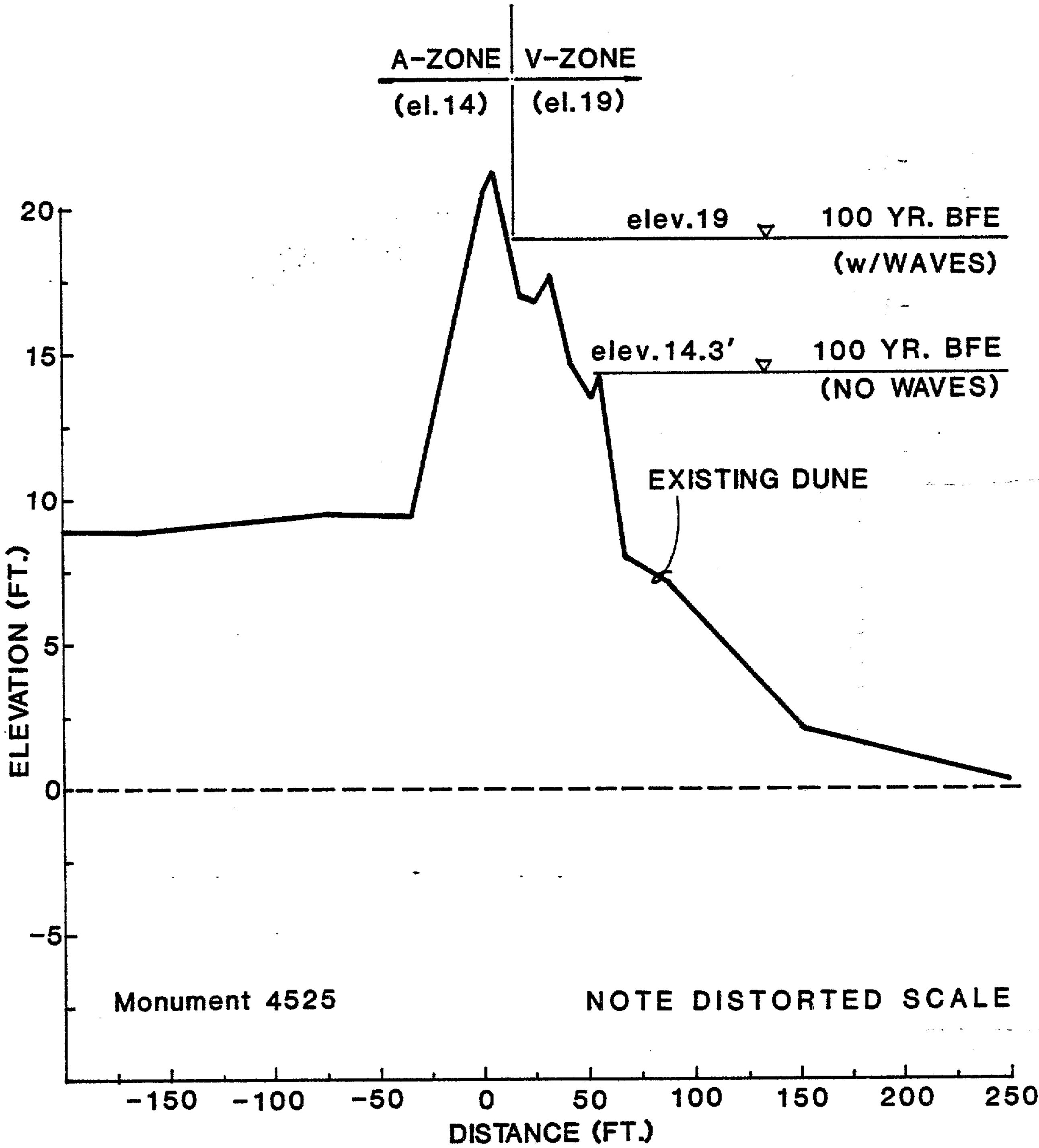


FIGURE 9.3-3
PREDICTED V-ZONE CONSIDERING THE STORM IMPACTS NEAR LITCHFIELD BY THE SEA

conservatively assuming relatively modest but continuous annual rates of beach erosion.

On the other hand, additional magnitudes of setback associated with storm impacts serve two functions:

1. To protect upland development from being constructed in an area subject to significant fluctuation due to storm induced erosion, and

2. To allow for sufficient rebuilding of a comparable dune system by natural processes subsequent to severe storms. Without such, the expected result will be a proliferation of shoreline stabilization necessitated by buildings in eminent danger of structural damage and/or loss. The latter would literally preclude natural dune reconstruction and would result in the expected ultimate loss of the dry recreational beach and the requirement for large scale beach renourishment at significant expense.

The following paragraphs present the recommended setbacks for the individual shoreline reaches along the Georgetown County study area. These setbacks are represented as lines on the maps presented in Appendix D. It should be noted that in establishing these lines, anomalous conditions associated with groins, inlets, etc. which theoretically result in the prediction of a future seaward progradation of the shoreline due to small-scale temporal sand storage, have been "average out" in this analysis. The purpose of this action is to preclude physical discontinuities which be detrimental to area wide recommendations for future shoreline management practices. Furthermore, additional setbacks were employed in the immediate vicinity of inlets in an attempt to provide a buffer zone which would account for the severe sudden shoreline translations and erosional losses that are likely to occur in the event of storms or over the normal course of expected inlet migration.

<u>Garden City</u>

Analysis of shoreline processes along the approximately 3.3 mile stretch of Garden City Beach shoreline indicates a prognosis of long-term erosion and associated recession. At present, existing shorefront development within the Georgetown County portions of Garden City Beach is predominantly single family residence. In contrast, along the Horry County portion of Garden City Beach where new and reconstructed development is occurring, the trend is predominately high density multi-family usage. With the evolving reorientation of the general shoreline from Garden City southward attributable to the stabilization of Murrells Inlet, this segment of Garden City Beach can be expected to potentially undergo highly variable rates of shoreline migration including accelerated rates of erosion and recession. In areas where the shoreline location has been fixed by means of seawalls, groins, etc., landward recession may be terminated but vertical erosion of the wet or dry beachface is expected to continue to occur.

On the average, the 50-year future shoreline recession for Garden City Beach, resulting from analysis of shoreline movement rates, is expected to be approximately 75 feet landward of the existing dune line. As previously discussed, this landward recession is hypothesized solely on historical long-term shoreline recession rates and does not account for short-term effects. Figure 8.3-1 is a depiction of the results of computer modeling of the IPP for this shoreline reach for both the 25-year and 50-year storm event. As noted, this analysis indicates that the impact zone of the 50-year storm is expected to be twice that of the existing dune line. Similarly, the impact zone of the 25-year storm is computed to be about 116 ft landward of the

IPP or approximately one and one-half times the 50-year long-term linear rate.

In consideration of these findings and their relevant application to the shoreline in its present developed state, the minimum recommended setback from the existing dune line along the Georgetown County portion of Garden City Beach should be that distance dictated by the 50-year future shoreline location as predicted from historical long-term recession rates. This corresponds to a distance of 75 feet landward of the existing dune line which is more specifically defined in this application as the crest of the seawardmost dune. In locations where the shoreline has been seawalled, the setback line would default to a point 75 feet landward of the top of the seawall.

Allowances for construction of major habitable structures seaward of the setback line should only be made if a building cannot be constructed or reconstructed landward of that location, and if the setback would result in denial of "reasonable use" of property. It is recommended that the latter should be considered to be no more than single family residence usage. Non-habitable structures should not be allowed seaward of this point except for dune overwalks, sand fencing, and erosion control measures, where warranted. In no event should these recommendations take precedence over existing or future setbacks or regulatory programs which are considered to be more stringent.

Litchfield-Huntington Beach

Analysis of shoreline processes along this reach extending from Murrells Inlet to Midway Inlet continue to indicate a relatively uniform long-term erosion rate and associated shoreline recession along its majority. An exception to this is the shoreline immediately south of Murrells Inlet where considerable accretion has occurred as a result of the construction of the navigation project there. It should be noted, however, that accelerated erosion has occurred at the south end of Huntington Beach State Park and along the adjacent residential section that is North Litchfield Beach as a result of the Murrells Inlet Navigation Project. The potential acceleration of these rates of erosion and accretion due to reorientation of the shoreline and the effects of the jetties in blocking littoral drift has been presented previously in this report.

The Huntington Beach State Park shoreline is currently undeveloped and is very likely to remain that way. Single family residences line the central portion of the shoreline reach comprising Litchfield and North Litchfield Beach. South of this, several low-density multi-family resort complexes have been constructed. The southernmost tip of this reach is currently undeveloped. With the exception of the concrete block wall fronting the Litchfield Inn, this entire shoreline reach is unarmored. These development trends and the aforementioned shoreline processes are important factors in the determination of a setback line along the Litchfield-Huntington Beach shoreline.

The quantification of shoreline erosion trends for this section of the study area, based upon analysis of historical shoreline movement rates, indicates shoreline recession rates which, when extrapolated into the future, result in a predicted 50-year shoreline location approximately 65 feet landward of the existing dune line. Figure 8.3-2 presents a depiction of the results of computer modeling of the IPP for this shoreline reach for both the 25-year and 50-year storm event. As noted, this analysis indicates that the impact zone of the 50-year storm is expected to be about 100 ft landward of the existing dune line or one and one-half times the predicted 50-year shoreline recession. The impact zone associated with the 25-year storm, at 59 ft from the existing dune line, is actually expected to be less than the predicted 50-year shoreline recession. The relatively narrow storm impact zones, as compared to the 50-year predicted shoreline recession, is attributable primarily to the relationship between the beach profile and the volume of sand associated with the profiles on this shoreline reach. The latter result is less predicted erosion during storm events.

In consideration of these findings and their relevant application to the shoreline in its present developed state, the minimum recommended setback from the existing dune line along the Litchfield-Huntington Beach shoreline should be that distance dictated by the 50-year future shoreline location as predicted from historical long-term landward of the existing dune line which is more specifically defined in this application as the crest of the seawardmost dune.

Again, allowance for construction of major habitable structures seaward of an adopted setback should only be made if a building cannot be constructed or reconstructed landward of that location, and if the setback would result in denial of "reasonable use" of property. The latter should be considered to be no more than single family residences. In no event should these recommendations take precedence over more stringent future or existing setbacks. Non-habitable structures seaward of the proposed setback should be limited to dune overwalks, sand fencing and erosion control measures, where warranted and fully permitted.

Pawley's Island

Along the approximate 3.8 mile stretch of Pawley's Island shoreline, analyses of shoreline processes continue to indicate a prognosis of long-term erosion and associated shoreline recession. The only potential exception to this is at the immediate north end of the island where ebb tidal shoal migration has resulted in accretion there over the past few years. A groin field extends south of the Pawley's Island Fishing Pier over the majority of the island and is believed to have some beneficial effect in reducing the rates of shoreline recession there. Much of the southern half of the shoreline is also bulkheaded which, while "fixing" the shoreline location and attenuating normal upland recession, contributes to vertical erosion of the beachface.

On the average, the 50-year future shoreline recession for Pawley's Island, as determined from historical shoreline migration trends, is expected to be about 65 feet landward of the existing dune line. In locations where the shoreline has been seawalled or bulkheaded, the recession is determined to be 65 feet from the structure. As previously noted, this landward recession is hypothesized solely on historical long-term linear recession rates and does not account for short-term effects. Figures 8.3-3 and 8.3-4 depict the results of computer modeling of representative profiles of the Pawley's Island shoreline for both the 25 and 50-year storm event. As noted, this analysis indicates that the impact zone of the 25 and 50-year storms are 100 feet and 135 feet respectively or about 1.5 and 2 times the long-term recession rate.

Based on these findings, an inconsideration of the type of development as well as the shorefront armoring in existence along Pawley's Island, the minimum recommended setback from the existing dune line or shorefront structure along the island shoreline should be that distance dictated by the future location of the 50-year shoreline. As predicted by analysis of linear shoreline migration trends, this distance correponds to 65 feet landward of the existing dune line as shorefront structure.

As is the case in the establishment of all setback lines, allowance for construction of major habitable structures seaward of an adopted setback should only be made if a building cannot be constructed or reconstructed landward of that location, and if the setback would result in denial of "reasonable use" of property. The latter should be considered to be no more than single family residences. In no event should these recommendations take precedence over more stringent future or existing setbacks. Non-habitable structures seaward of the proposed setback should be limited to dune overwalks, sand fencing and erosion control measures, where warranted and fully permitted.

Debidue Island

The Debidue Island shoreline exhibits both the largest magnitude and variation in shoreline migration rates over the entire study area. The southern end of the island is experiencing extremely high erosion rates while the northern end has of late been undergoing mild accretion. The central portion of the shoreline exhibits a mild erosional trend. The majority of the island is undeveloped with the exception of the Debidue Tract along the center of the island where the shorefront is hardened by a seawall. Predictably, the beach in front of the seawall has undergone vertical erosion such that virtually no dry beach exists at high tide. The south end of the island is part of the Belle W. Baruch nature preserve and is unlikely to be developed in the future while the north end of the island is slated for future development.

The quantification of shoreline erosion trends along the Debidue Island shoreline, as based on linear shoreline migration, resulted in varying locations of the 50-year shoreline. This was a result of the spatial variation in shoreline erosion rates over the length of the island shoreline. The southernmost extent of the island was designated as an Inlet Impact Zone and, accordingly, the entire peninsula making up this section should be subject to the restrictions of the prescribed setback program. As mentioned previously, this area is designated as a nature preserve which should preclude any future development there. North of this point a setback of 315 feet corresponding to the predicted 50-year future shoreline is recommended to a point 1700 feet south of the Debidue Tract seawall, whereupon the setback reduces to 170 feet, reflecting the milder recession rates observed there. These setbacks are relative to the existing dune line or seawall, whichever applicable. The 170 feet setback continues north to a point approximately 4000 feet south of Pawley's Inlet where historical inlet migration trends, low-lying uplands and inlet effects necessitate a setback gradually increasing to 450 feet near the inlet and the designation of this area as an Inlet Impact Zone.

Once again, allowance for construction of major habitable structures seaward of an adopted setback should only be made if a building cannot be constructed or reconstructed landward of that location, and if the setback would result in denial of "reasonable use" of property. The latter should be considered to be no more than single family residences. In no event should these recommendations take precedence over more stringent future or existing setbacks. Non-habitable structures seaward of the proposed setback should be limited to dune overwalks, sand fencing and erosion control measures, where warranted and fully permitted. It is recommended that no future major habitable structure be constructed in designated Inlet Impact Zones.

9.5 COASTAL CONSTRUCTION ZONE

The implementation of minimum coastal construction standards landward of the MHWL are recommended as a result of the analyses performed in conjunction with this study. These standards should be in addition to all existing building codes and should not supercede local, state or federal standards which can be considered to be more stringent.

The most obvious technique for the local implementation of such standards is through the adoption of a zone specifying an area of interest extending landward from the MHWL a specified distance. Within this "coastal construction zone", the following minimum criteria should be addressed:

- Design wind speed should be computed in accordance with the 1986 revisions to the 1985 Standard Building Code.

- Effects of waves where appropriate. All wave, hydrostatic and hydrodynamic loads should be considered during design as acting concurrent with the design wind speed.

- Elevation criteria of the lowest supporting structural member in the shore parallel direction which would include the effects of waves.

- Erosion during a 100 year storm event which would affect foundation design.

- Others.

For ease of implementation at the local level, all new or substantially improved structures built within such a zone should be certified by an appropriate design professional as to compliance with the adopted standards.

9.6 EROSION CONTROL PERMITTING PROCEDURES

The analyses and results contained herein indicate that long term erosion trends are expected to continue unabated throughout the majority of the study area. Short term variations in this prediction include lower rates of erosion and varying accretion in depositional areas adjacent to tidal inlets or within designated spoil areas north and south of Murrells Inlet.

In the long run, however, continuing shoreline recession and the effects of development pressures, both old and new, will result in the requirement for permit requests for erosion control structures. Additionally, it is easily shown that average annual long term recession rates will be exceeded by the impacts of low frequency storms, which statistically can be expected to occur. Due to the demonstrated proximity of existing lines of construction to not only the 50 year future shoreline position, but also the zone of impact of even a 25 year storm, a comprehensive and consistent policy should be developed and enforced regarding future erosion control measures.

Erosion along South Carolina's shoreline has progressed to a degree that a substantial number of habitable structures can be jeopardized by future major storms. It is in the State's general interest to allow protection of upland property, but not in a manner that will damage or degrade the beach-dune system. Beach restoration is unequivocally the protective measure considered as most beneficial to the beach-dune system. However, in some locations, economics may not favor beach restoration; and even if restoration is expected, the time scales for implementation of such projects may be so long that interim protection for upland structures in immediate jeopardy may be justified. Coastal armoring, e.g., sloping stone revetments, is a possible means of providing such interim protection. However, it is known that armoring can potentially adversely impact the adjacent beach-dune system.

In brief, seawalls and shoreline armoring can be expected to adversely affect the beach/dune system in the following ways:

1) They can interfere with alongshore sediment transport processes,

2) They prevent sand from being added to the littoral system during storms, and

3) They can cause additional erosional stress on adjacent non-armored properties during storms.

Regardless, armoring or hardening of natural shorefront areas is detrimental to the beach/dune system and should be avoided if at all possible. Since it is logical, however, to assume that future structures will be required, it is likewise logical to require applicants for permits required to construct such erosion control measures to mitigate their known quantifiable impacts.

Prior to the issuance, or local approval of any shoreline armoring permit, the following minimum type of assessment should be made:

1) <u>Alternative to Armoring</u> - Possible alternatives to armoring include: (a) relocating the endangered structure landward, (b) elevating the structure on

piling, or (c) both.

2) Legality of Structure - If the structure to be protected was constructed legally, this would tend to favor armoring.

3) Degree of Jeopardy of Structure - This factor addresses the possibility that a moderate storm could jeopardize the integrity of the structure. If the foundation type and degree of erosion are such that a storm of moderate intensity (return period of 10 to 20 years) would jeopardize the stability of the structure, this would tend to favor the issuance of a permit to armor.

4) Conforming or Non-Conforming Structure - If a structure has a conforming (i.e. pile-supported) foundation, then the structure is not as vulnerable to erosion damage as if the structure were on shallow footings or a slab foundation. A conforming foundation can lose all fill beneath the structure as a result of a severe storm and retain the structural integrity. Hence the recommendations for coastal construction zones.

5) Presence of Other Armoring in the Area - If there exists armoring along the same alignment as proposed, this would tend to favor armoring. Filling in small gaps along heavily armored shoreline is in some instances desirable.

6) General Potential for Adverse Impact on Beach/Dune System - Consideration should be given to the magnitude of the effect that armoring would have on the supply of sediment to the beaches and the potential for interference with the longshore

sediment transport.

Similarly, a quantitative assessment should be made to establish a required annual volume of mitigative sand placement in order to ensure no adverse impact to the beach-dune system would result from the issuance of the requested permit. This mitigation approach would take the form of quantifying the volume of sediment that would be lost to the beach system due to gradual erosion in addition to possibly adverse alongshore effects.

The result of quantifying "sediment impacts" would be to allow for the addition of appropriate permit stipulations requiring mitigation through sand placement on an average annual basis concurrent with all future permit applications for shoreline armoring or hardening.

9.7 SHORELINE RESTORATION

As previously mentioned, large scale beach restoration or "nourishment" is the preferred erosion control alternative for a section of shoreline for the following major reasons:

- It can result in substantial protection of upland property,

- It results in the creation and/or maintenance of a beach suitable for active and passive recreational activities, and

- It compensates for the long term effects of erosional forces by offsetting deficits in the littoral budget.

Since the success of beach nourishment projects constructed to date has generally been demonstrated to be directly related to the length of shoreline restored, the solution does not necessarily lend itself to small scale applications in either a practical or cost-effective manner. The determination of applicability is best performed on a case-by-case basis. There is no question, however, that the beach nourishment experience has been proven to be a technically viable approach to mitigating beach erosion.

In cases where large scale beach restoration is not feasible, the combination of smaller sand fills in combination with stabilizing structures should be considered. Typically, the latter take the form of terminal groins at the ends of barrier islands and/or groin fields. The utilization of stabilizing structures is generally most viable when the adverse effects of inlets must be accounted for such as in lower Georgetown County. For example, on Pawley's Island, which can be considered to be a high probability "candidate" for future beach restoration, the upgrading of the existing groin field could serve to greatly increase the longevity of a nourishment project constructed at that location.

Short-term, smaller scale erosion control measures which can address either limited or emergency type erosional conditions without resorting to armoring would include:

- Beach scraping from the intertidal beach,
- Jet-pumping of sediment from the outer reaches of the alongshore bar or littoral zone, and
- Trucking of beach quality fill from an acceptable upland source or inlet shoals.

Except for the placement of compatible fill from a remote source, both scraping and jet-pumping should not be carried out on a frequent basis without the requirement for monitoring to determine the response of the local shoreline to the removal of sediment from the intertidal beach, since the latter could potentially adversely affect adjacent properties and the beach/dune system.

9.8 LONGTERM MONITORING OF SHORELINE PROCESSES

The South Carolina Coastal Council has recently embarked on a longterm program to monitor statewide beach conditions by means of beach surveys performed several times per year. The purpose of the effort is to generate a data base of historical shoreline trends and to begin to develop a capability to predict future trends. Portions of the survey baseline used to acquire this data will result from the utilization of the monumented baseline established for this study and by those of similar studies performed along the Grand Strand and other areas of the State.

Recommendations for future expansions of this data acquisition program based upon similar efforts in other coastal states would include the following at a minimum:

a. The acquisition of offshore data for eventual comparative purposes on an annual basis. Ideally, offshore profiles should be taken at no less than one per mile and should extend to the limit of active sediment transport which is typically -15 to -20 ft.

b. Aerial photography of the state's coastline on a yearly basis. Any contract for such work should allow for re-flights of specific areas within seven (7) days of a major storm event affecting the South Carolina coast.

c. The eventual rigorous monumenting of a statewide survey baseline to include both vertical and horizontal control (i.e., South Carolina State Plane Coordinate System) and appropriate legal descriptions of the resultant baseline.

REFERENCES

Baca, B.J., Siah, S.J., and Kana, T.W. 1986. A Wetlands Enhancement Plan for Debordieu Development. Coastal Science and Engineering, Inc., Columbia, South Carolina.

Clemson University, Clemson. Department of Forestry. 1976. Debidue Beach and North Inlet Land Form History Since 1733. Technical Paper No. 4.

County of Georgetown. 1981. Pawley's Island, South Carolina, Beach Erosion Management Strategy. Georgetown, South Carolina. Cubit Engineering, Limited. Clemson, South Carolina.

Douglass, S.L. 1985. Coastal Response to Navigation Structures at Murrells Inlet, South Carolina. U.S. Army Coastal Engineering Research Center Technical Report CERC-85-8. Vicksburg, Mississippi.

Eiser, W.C., Kana, T.W., and Williams, M.L. 1986. Analysis of Historical Erosion Rates and Prediction of Future Shoreline Positions. Summary Report for the City of North Myrtle Beach, South Carolina. Coastal Science and Engineering, Inc., Columbia, South Carolina.

Federal Emergency Management Agency. 1983a. Flood Insurance Study, County of Horry, South Carolina.

Federal Emergency Management Agency. 1983b. Flood Insurance Study, Georgetown County, South Carolina.

Jordan, L.W., Dukes, R., and Rosengarten, T. 1986. A History of Storms on the South Carolina Coast. South Carolina Sea Grant Consortium, Charleston, South Carolina.

Kana, T.W., Siah, S.J., Williams, M.L., and Sexton, W.J. 1984. Analysis of Historical Erosion Rates and Prediction of Future Shoreline Positions. Summary Report for the City of Myrtle Beach, South Carolina. Coastal Science and Engineering, Inc., Columbia, South Carolina.

Myers, V.A. 1975. Storm Tide Frequencies on the South Carolina Coast. NOAA Technical Report NWS-16. Silver Springs, MD.

North Inlet Corporation and Prince George Corporation. 1985. Shoreline and Environmental Assessment of the Debidue, Arcadia I, and Arcadia II Tracts, Debidue Island, South Carolina. Prepared by RPI Coastal Science and Engineering, Inc., Columbia, S.C.

North Inlet Corporation. 1985. Debordieu, South Carolina, A Planned Unit Development: Development Standards. Georgetown, South Carolina.

Nummedal, D. and Humphies, S.M. 1978. Hydraulics and Dynamics of North Inlet, South Carolina, 1975-76. Prepared for U.S. Army Coastal Engineering Research Center, GITI Report 16. Vicksburg, Mississippi.

South Carolina Coastal Council. 1981. A Study of Shore Erosion Management Issues and Options in South Carolina. Columbia, South Carolina. Prepared by the South Carolina Sea Grant Consortium, Charleston, South Carolina.

South Carolina Coastal Council. 1979. Guidelines and Policies of the South Carolina Coastal Management Program. Columbia, South Carolina.

South Carolina Sea Grant Consortium. 1984. Beach Erosion Inventory of Charleston, South Carolina: A Preliminary Report. Charleston, South Carolina. Prepared by the University of South Carolina, Geology Department, Columbia, South Carolina.

South Carolina Sea Grant Consortium. 1977. Beach Erosion Inventory of Horry, Georgetown, and Beaufort Counties, South Carolina. Prepared by University of South Carolina, Coastal Research Division, Geology Department, Columbia, South Carolina.

Town of Surfside Beach. 1985. Land Use Plan for Surfside Beach, South Carolina. Surfside Beach, South Carolina.

U.S. Army Corps of Engineers. Charleston District. 1983. Myrtle Beach, Horry, and Georgetown Counties, South Carolina: Reconnaissance Report on Beach Erosion Control and Hurricane Protection. Charleston, South Carolina.

U.S. Army Corps of Engineers. Charleston District. 1977. Specifications for Construction of Channel and Jetty System: Murrells Inlet Navigation Project. Charleston, South Carolina.

U.S. Army Corps of Engineers. Charleston District. 1976. Revision of Weir System and Jetty and Channel Alignments: Murrells Inlet Navigation Project. Charleston, South Carolina.

U.S. Army Corps of Engineers. 1962. Interim Hurricane Survey of Myrtle Beach, South Carolina. Charleston, South Carolina.

Waccamaw Regional Planning and Development Council. 1983. Horry County Land Use Plan, 1980. Conway, South Carolina.

Wilson, H.S., ed. 1983. South Carolina's Migrating Beaches. Proceedings of a Conference Sponsored by the South Carolina Sea Grant Consortium. The South Carolina Sea Grant Consortium, Charleston, South Carolina.

Zarillo, G.A., Ward, L.G., and Hayes, M.O. 1985. An Illustrated History of Tidal Inlet Changes in South Carolina. South Carolina Sea Grant Consortium, Charleston, South Carolina.