CM317

Shoreface Sediment Distribution Patterns: A Measure of Inlet Influence?

Submitted to
Sebastian Inlet Tax District

Submitted by

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EXECUTIVE SUMMARY

This study was designed to establish the area of inlet influence based upon surficial sediment grain-size distribution patterns. It was hypothesized that ebb tidal currents at Sebastian inlet jet fine-grained littoral drift seaward such that the surficial sediments proximal to the inlet are coarser than updrift (northern) areas or distal downdrift (southern) areas.

Surficial sediment samples were collected on two occasions representing summer and winter climatic conditions. The summer samples were collected over a ten day period in September, 1991. The winter samples were collected over a fifteen day period in late April and early May, 1992.

To establish the area of inlet influence the graphic depictions of alongshore and cross-shore grain-size data (%gravel, %sand, %mud, and 24 phi sand-size classes) were visually inspected. A significant shift in the relative abundance of the grain-size data in the proximity of the inlet was interpreted to be a consequence of the inlet effect. The alongshore distance to this shift was then assumed to be the limits of inlet effect.

The grain-size surficial sediment distribution pattern within the study area suggests the area of inlet influence

within the shoreface is approximately -5,000 ft (updrift) to +6,000 ft (downdrift). Inner shelf sediment patterns suggest the area of influence is also approximately ±5,000 ft.

The area of inlet influence is not masked by winter storm conditions although the elevated wave climate did coarsen the distal updrift shoreface. A fining of the distal downdrift inner shelf was also noted and may be genetically related to the shoreface coarsening.

This study has demonstrated that textural distribution patterns of surficial sediments can be used as a method to delineate the area of inlet influence. Within the Sebastian Inlet area the presence of coquina rock outcrops in downdrift areas proximal to the inlet has resulted in highly variable grain-size distribution patterns which have hampered quantification of the area of inlet effect.

It should also be noted that the estimates of inlet effect presented herein are based upon the surficial sediment grain-size distribution patterns. Therefore, these estimates can only be used to delineate the limits of hydrodynamic influence. The data presented herein can not be used to infer how this hydrodynamic activity has effected the local sediment budget and therefore coastal accretion or recession rates.

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INTRODUCTION

It is widely accepted that most of Florida's improved navigational inlets interrupt longshore sand migration and often promote accelerated erosion of down drift beaches (Dean and Walton, 1973; Jones and Mehta, 1980; Stauble et al., 1987). However, the magnitude and extent of erosion attributable to a specific inlet is generally unknown. In light of the recent Florida circuit court case involving the town of Ocean Ridge and the South Lake Worth Inlet District it appears imperative that the "inlet effect" be quantified.

During the South Lake Worth Inlet hearings an expert witness testified that the first 2,000 ft of beach south of the inlet was in a state of critical erosion. However, the court ordered the Inlet District to initiate a restoration program along 2.5 miles (13,200 ft) of beach south of the inlet and a long term monitoring program to include a 10 mile area centered on the inlet. Because beach restoration projects stress natural and recreational resources and are always costly, the scale of such beach restoration projects should be limited to downdrift beaches documented to have erosion problems attributable to the presence of the inlet.

Attempts have been made to establish the degree to which an inlet contributes to downdrift shoreline erosion. These studies are usually based upon an analysis of a series of aerial photographs or beach profiles (e.g., Foster and Savage, 1989). In many areas however, an appropriate data set is not available (i.e., long term beach profile data) or the margin of error is very large (e.g., aerial photography; Smith and Zarillo, 1990).

This study was designed to establish the area of inlet influence based upon surficial sediment grain-size distributions. Dean and Walton (1973) noted that inlets modify prevailing wave and current patterns and impound material that would otherwise drift along an uninterrupted segment of the coastline. Therefore, a distinct pattern of surficial-sediment texture should be present in the coastal areas proximal to an inlet that is distinguishable from distal areas. Tsein (1986) and Liu and Zarillo (1989) noted an increase in the mean grain size of surficial sediments in the vicinity of Shinnecock and Moriches Inlets (Long Island), although they did not attempt to spatially quantify the inlet effect.

In this study, it is hypothesized that ebb tidal currents at Sebastian Inlet jet fine-grained littoral drift seaward such that the surficial sediments proximal to the inlet are coarser than updrift (northern) areas or distal downdrift (southern) areas. The inlet effect will be quantified using closely spaced (1,000 ft) shore normal sampling transects.

GOAL AND OBJECTIVES

The goal of this study is to delineate the area of inlet influence using shore-normal and shore-parallel distribution patterns of selected grain-size classes within the foreshore, shoreface and inner shelf. To achieve this goal four objectives must be met:

(1) Design a sampling program of sufficient spatial resolution,

(2) Collect and analyze sediment samples,

(3) Construct plots of cross-shore and longshore sediment distributions,

(4) Delineate the area of inlet influence as revealed by sediment distribution plots.

BACKGROUND AND PREVIOUS WORK

A variety of methods have been employed to study the effects of physical processes operating on or within the coastal zone. The most common methods included aerial photography, beach profiling, wave and current measurements and surficial sediment mapping. All of these methods vary with respect to time scale resolution, availability of data, cost and work effort required to collect and analyze the data.

Foster and Savage (1989) utilized aerial photography to document historic shoreline changes and predict future shoreline evolution. Available photographic data sets allow historical trends to be investigated, however the margin of error in estimating shoreline change is often large (Smith and Zarillo, 1990).

Beach profiles have been used by Aubrey (1979), Bowen (1980) and Dean (1983) to examine seasonal shoreline changes, as well as the impact of storm events. While relatively inexpensive to collect, profiles are labor intensive and most regions lack profile data prior to the early 1970's.

Measurements of currents, wind and waves have been used by Niedoroda and Swift (1981), Dally et al. (1985), and Fox and Davis (1976) to model and predict shoreline response to various physical conditions. However, reliable measurements are costly and require considerable effort to obtain. Also, these measurements quantify instantaneous conditions which may not represent the long-term processes driving coastal sediment dynamics.

Surficial sediment distributions have also been used in the study of coastal processes. Pettijohn (1975) demonstrated that sediments contain valuable information regarding the depositional setting. Miller and Zeigler (1964) and Zenkozich (1967) concluded that although sediments are subject to temporal modifications such as seasonal changes, the general distribution patterns will remain unchanged. Thus, these patterns represent the equilibrium, time-averaged response of the sediment to shoreface hydrodynamics. In this study, surficial sediment distributions were chosen for analysis because (1) they represent long-term conditions and (2) the cost and work effort required for data collection are reasonable in light of the amount of information that can be deduced from the samples.

There are three primary factors that influence the characteristics of surficial sediments in the coastal zone (1) sediment source, (2) biologic productivity and (3) hydrodynamic processes (Carter, 1988). The primary source of coastal sediment is terrigenous material which is ultimately derived from the weathering and erosion of continental rocks.

However, biogenic material may also be an important sediment constituent, particularly within the subtropical and tropical climatic regions of high carbonate productivity (Davis, 1978). For example, along the southeastern U.S. Atlantic coast there is a concomitant decrease in quartz sand and increase in biogenic sediment from north to south (Milliman, 1972). This change reflects both increasing distance from the quartz source area and increasing carbonate production associated with the lower latitude climatic conditions (Gorsline, 1963; Giles and Pilkey, 1965). Localized terrigenous source areas (e.g., eroding headlands) and productivity (e.g., patch reefs) can also influence the characteristics of surficial sediments in the coastal zone.

Hydrodynamic processes also influence nearshore surficial sediment patterns (Komar, 1976; Davis and Ethington, 1976; Leatherman, 1979; Greenwood and Davis, 1984). These include shallow water waves, astronomic tides and oceanic circulation patterns.

Surficial marine sediment distribution patterns are generally mapped using the physical attributes of texture and composition. Visher (1969), Folk and Ward (1957) and Friedman (1967) concluded that the texture of natural sediment contains information regarding the source, mode of transportation and energy level of the transporting processes. The most common method to resolve textural patterns utilizes grain-size frequency distributions whereby statistical (granularmetric) parameters such as sample mean, mode, sorting and skewness are used to characterize surficial sediments (Taney, 1961). Visher (1969) attempted to divide grain-size frequency distributions into subpopulations which he suggested were indicative of specific depositional environments (see also Bein and Sass, 1978; Liu and Zarillo, 1989).

Mineral composition can also be used to quantify sediment distribution patterns and source area. In studies by Cherry (1965) and Judge (1970), heavy mineral analysis was used to determine the source of sediment along the California coast. Visual inspection of the surficial sediments within the study area suggest heavy mineral concentrations are less than one percent. Lenard and Cameron (1981) and Hoskin and Nelson (1971) studied the composition of rare carbonate beaches in Maine and Alaska in an effort to determine source and transport pathways.

Regional sediment distribution patterns along the east central Florida coast have been described by the Coastal Oceanographic and Engineering Laboratory (1970, 1987), Field and Duane (1974), Meisburger and Duane (1971), and Ferland and Weishar (1984). The region's inlet systems have been described by the Coastal Engineering Laboratory (1965), Bruun et al.

(1966), Mehta et al. (1976), Davis and Fox (1981), Stauble (1988) and Coastal Technology Corporation (1988). These studies focused primarily on inlet geomorphology and hydrodynamics.

Bruun et al. (1966) constructed the first physical model of Sebastian Inlet in an effort to predict the effects of inlet stabilization on shoreline stability and inlet navigability. Mehta et al. (1976) examined the effect of the inlet on the economics, recreation, water quality and shoreline stability. Stauble et al. (1987, 1988) conducted research on sediment dynamics and the evolution of the flood tidal delta. Walther and Douglas (1991) presented data supporting the hypothesis that tidal inlets selectively remove fine-grained sediment from the littoral system. Studies by Wang et al. (1991, 1992) utilized a physical model designed to examine the effects of different jetty configurations on local hydrodynamics and sediment transport. Prior to the study presented herein however, no detailed investigation of sediment distribution patterns had been undertaken at Sebastian Inlet.

STUDY AREA

A. Location and History

Sebastian Inlet (Figure 1) is one of four inlets that interrupt the continuity of a narrow barrier island complex that separates the Indian River Lagoon from the Atlantic Ocean. It is located along the central part of Florida's east coast, approximately 45 miles south of Port Canaveral and 23 miles north of Fort Pierce Inlet. The barrier island complex is composed of recent sediments which are underlain by the Pleistocene Anastasia Formation. Along portions of the open ocean shoreline, coquina rock outcrops occur just below mean low water. A narrow, sandy beach continuously borders the seaward side of the island and a marshy lowland fringes the lagoon side. The barrier island rarely exceeds 1 mile in width or 20 ft in elevation (Meisburger and Duane, 1971).

Based upon a detailed history of the inlet compiled by Coastal Technology Corporation (1988), the first attempt to construct an inlet in the Sebastian area was made in 1886. Over the next 70 years the inlet closed, re-opened and shifted location numerous times. The present configuration was maintained after a major dredging operation in 1947-48 to establish a new channel. Since 1948, a series of dredging projects and jetty improvements have kept the inlet open in it's existing configuration. In 1970, the north and south jetties were extended to their present length. The south jetty is a sand tight rubble mound structure. The north jetty, on the other hand, is a composite of the original rubble mound section built before 1955 and a pier structure supported by concrete pilings. The net southerly longshore drift entrapped by the north jetty has created an updrift offset. The strong flood tidal currents cause sediment to be transported through the inlet throat and deposited on the flood tidal delta. In 1962, a sand trap was constructed at the western edge of the inlet channel to capture sediment entering the lagoon on a flooding tide. This material is then mechanically transferred to downdrift feeder beaches. This sand trap was dredged in 1972, 1978, 1985 and 1989. Existing maintenance permits provide for sand transfer over the next 25 years.

B. Hydrodynamics

Physical conditions at Sebastian Inlet make it hydrodynamically unique because the sides of the inlet are limited by rock. As a consequence the cross-sectional area is approximately one-half what would be expected if the inlet were free to enlarge, while admitting the existing tidal prism (Jones and Mehta, 1980). Consequently, the current through the inlet is exceptionally strong, causing sediment to be transported a considerable distance into and out of the inlet (Jones and Mehta, 1980).

The tidal range at Sebastian inlet is microtidal (less than 6.0 ft; Hayes, 1975). The spring tidal range is about 5 ft in the offshore region and reduces to less than 1.5 ft in the lagoon (Wang et al., 1991). This reduction in range is due to the friction between the water and the rock lined throat section, as well as the curvature of the channel (Mehta et al., 1976). The phase lag between lagoonal high or low tide and slack water in the main channel is approximately 2 hrs.

Bruun et al. (1966) estimated the tidal prism of the inlet to be equal to 3.5 x 10^8 ft^3 during spring tides. Tidal currents measured in the inlet throat section ranged from 6.6 ft/s on the flood tide to 5.0 ft/s on the ebb tide (Wang et al., 1991). Current velocities such as these keep the throat section free of sand since the currents are too swift to allow deposition (Mehta et al., 1976).

C. Winds

The prevailing winds at Sebastian Inlet are northeasterly during the winter and east to southeasterly during the summer. Localized convective thunderstorms or tropical storms and hurricanes are characteristic of the summer and fall months. Thunderstorms generate winds with variable directions whereas most of the tropical storms and hurricanes follow tracks that are out of the southwest, south, or southeast, in order of decreasing frequency (Mehta et al., 1976). Winter months are characterized by northeasters generated by high pressure systems. These storms are usually more destructive than the tropical storms due to a larger fetch and longer duration (Mehta et al., 1976).

D. Waves

Coastal Technology Corporation (1988) compiled a summary of available wave data which indicates that wave height and approach are dominantly controlled by local weather conditions. In the fall and winter months wave heights average 4.5 ft and approach from the east-northeast. During the spring and summer months wave heights average 3.0 ft and approach from the east-southeast. During the passage of summer hurricanes and winter northeasters, average wave heights range from 6 to 10 ft. Wave heights greater than 10 ft occur only about 5 days a year.

E. Littoral Drift

The net southerly littoral drift into the northern boundary of the study area averages 234,000 $yd^3\ yr^{-1}$, of which 1,300 $yd^3\ yr^{-1}$ is removed from the budget via the accretion of updrift beaches (Wang et al., 1992). Approximately 75,000 $yd^3\ yr^{-1}$ accumulates within the flood shoal complex and 6,800 $yd^3\ yr^{-1}$ is added to the sediment budget from the erosion of downdrift beaches (Wang et al., 1992). Therefore, approximately 164,500 $yd^3\ yr^{-1}$ or nearly 70% of the initial drift exits through the southern boundary of the study area by natural sand bypassing processes.

On average approximately 60,000 yd^3 yr^{-1} of sand is removed from the sand trap and mechanically transferred to a downdrift feeder beach. Thus, on average, there is a net sediment loss of approximately 9,500 yd^3 yr^{-1} (approximately 4% of initial drift) in the vicinity of Sebastian Inlet.

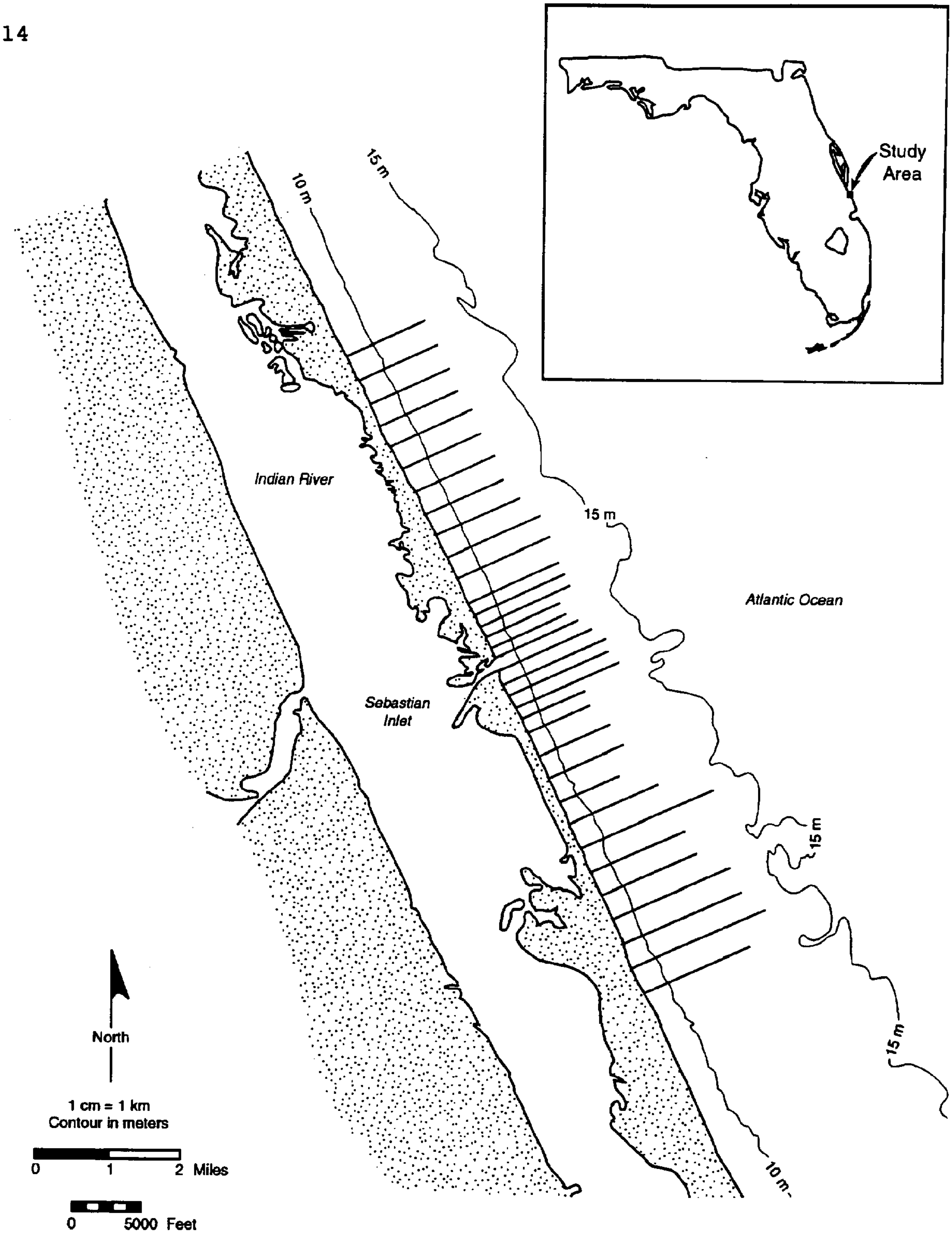


Figure 1. Location map of study area which consists of a ten mile section of coastline centered at Sebastian Inlet, Florida. Ten sediment samples were collected along twenty seven shore-normal transects from mean high water to -42 ft water depth.

Methods

In order to delineate the area of inlet influence using surficial sediment distribution patterns, the methods described below were employed to achieve each of the four specific objectives described above.

A. Design of Sampling Program

Determining the longshore and cross-shore limits of the study area was critical to the success of this project. Mehta et al. (1976) indicated that downdrift erosion occurred at least 2,000 ft south of the inlet. Clark (1989) identified a 2.2 mile stretch of downdrift beach as an area of critical erosion. Work and Dean (in press) present data suggesting accelerated shoreline erosion is occurring along approximately 3 miles of beach south of the inlet.

Therefore, based upon review of available published information and personal communication with a number of experts on coastal processes and engineering, a sampling program consisting of a ten mile section of coast centered on Sebastian Inlet was chosen for this study (Figure 1). This length exceeds the inlet effect limits suggested by the above mentioned studies.

Twenty seven shore-normal transects were established at fixed DNR survey marker locations. Sampling transects were spaced 1,000 ft apart within the first mile proximal to the inlet, thereafter transects were spaced 2,000 ft apart. This longshore sampling density is considerably greater than other surficial sediment distribution studies conducted on the shoreface (c.f., Chauhan et al., 1988; Liu and Zarillo, 1989; Tsien, 1986). Ten sediment sampling stations were established along each transect: mean high water, mean low water, the base of the beach face in the landward trough of the longshore bar and at depths of 6, 12, 18, 24, 30, 36 and 42 ft (Figure 2). This cross-shore sampling interval was designed to extend below the fair weather wave base (W. Dally, personal communication, 1990) and therefore includes the zone of active sediment transport.

B. Data Collection and Analysis

Surficial sediment samples were collected on two occasions representing summer and winter climatic conditions. The summer samples were collected over a ten day period in September, 1991. The winter samples were collected over a fifteen day period in late April and early May, 1992. Along each transect a bathymetric profile was acquired using a Sytex depth recorder and LORAN C navigational system. The offshore samples were collected with a modified Ponar grab sampler from the R/V Phoenix. The penetration depth of the grab sampler is approximately 5 inches. This depth is considered adequate to include the maximum mixing depth of the surficial shoreface sediments which are reworked under fair-weather hydrodynamic conditions (Stubblefield et al., 1977; Davis, 1985). Therefore, the surficial sediment samples collected during this study are assumed to represent a time-averaged seasonal cycle of erosion and deposition. Intertidal and surfzone samples were collected by hand. In the laboratory approximately 150 g of sediment were separated from each bulk sample using a sample splitter. Each sample was treated with 3% hydrogen peroxide solution to reduce organic material content and then dried at 60 °C for 48 hrs. After drying, the samples were weighed and the bulk dry weight recorded.

Samples were then thoroughly wet-sieved to separate gravel (larger than 2mm or -1 phi) and mud (finer than 0.063mm or 4 phi). The sand and gravel fractions were transferred to separate beakers, dried at 60 °C for 48 to 72 hrs and weighed. The sum of the gravel and sand fractions was then subtracted from the sample's bulk dry weight to determine the mud fraction.

Approximately 2 g of the sand fraction was subjected to grain-size analysis using a custom built rapid sediment analyzer (RSA). This technique determines sediment grain size using an empirical equation derived by relating the fall velocity of sand grains through a fluid medium to the grain diameter (Krumbein and Sloss, 1951; Gibbs et al., 1971; Gibbs, 1974; Komar and Cui, 1984). The grain-size frequency distribution was recorded at 24 quarter-phi intervals between -2 phi (2mm) and 4 phi (0.063mm). The mean, standard deviation, skewness and kurtosis of the samples was then calculated using the moments method (Friedman and Sanders, 1978).

C. Construction of Sediment Distribution Plots

To determine cross-shore trends in sediment size, plots of the relative abundance of gravel, sand, and mud were plotted as a function water depth. The northern and southern data were plotted separately.

The grain-size data obtained from the 24 phi size intervals was then grouped according to Udden-Wentworth sand-size classes (e.g., fine, medium, course), Emery's (1960) geomorphic cross-shore zone (foreshore, shoreface, inner shelf; Figure 2) and proximity to the inlet. Plots of the average frequency of occurrence for each grain-size class were then constructed for each cross-shore zone. Three point moving averages of each grain-size class were also computed by taking the average of three adjacent data points and plotting that value at the position of the second data point. This method was used to smooth the data while preserving any significant trends (Davis, 1973).

D. Quantify Area of Inlet Influence

To establish the area of inlet influence the graphic depictions of alongshore and cross-shore grain-size data were visually inspected. A significant shift in the relative abundance of the grain-size data in the proximity of the inlet was interpreted to be a consequence of the inlet effect. The alongshore distance to this shift was then assumed to be the limits of inlet effect.

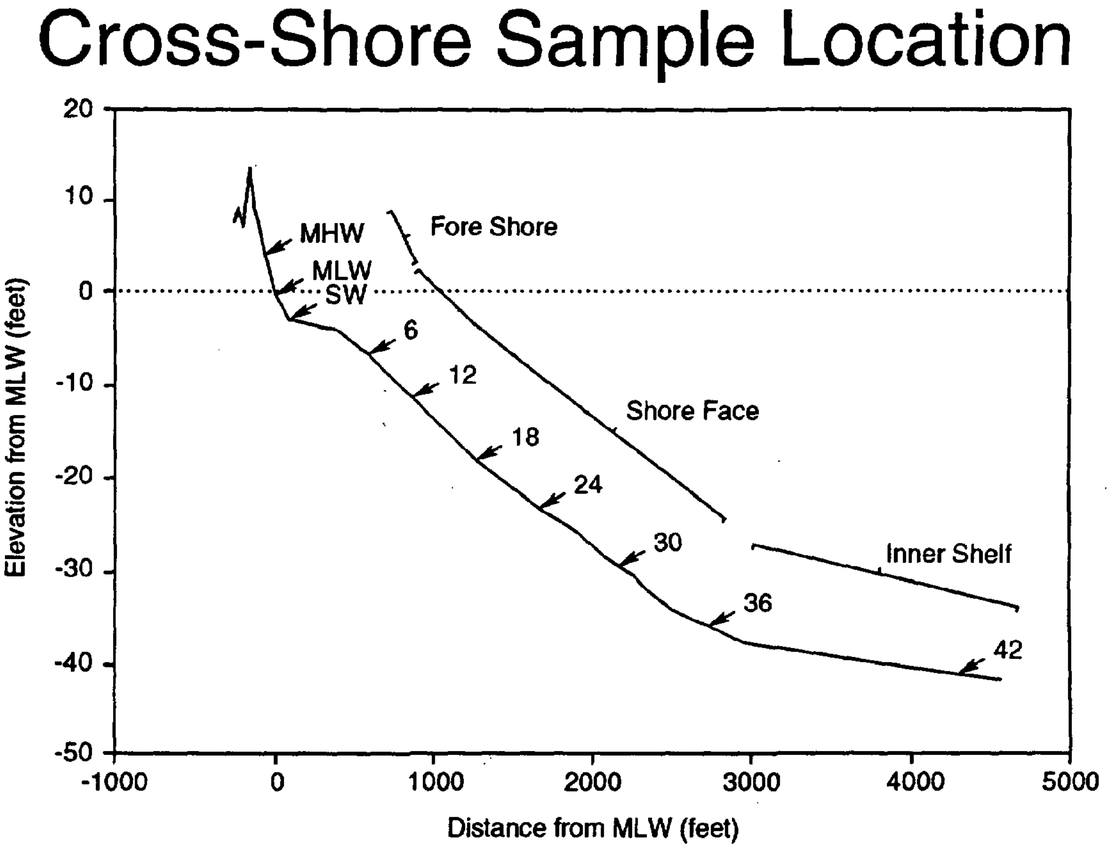


Figure 2. Generalized shore-normal profile showing location of ten sampling stations located within the three cross-shore geomorphic zones.

RESULTS

A total of 246 "summer" samples were collected over a ten day period in September of 1991. A total of 222 "winter samples were collected over a fifteen day period in April and May, 1992. Tables 1 and 2 illustrate the location of successful and unsuccessful sediment grab sample recovery. An unsuccessful recovery is defined as any location where three attempts failed to collect a sediment sample.

A. General Sediment Distribution

Figure 3 depicts the average frequency of occurrence of the gravel, sand and mud fractions for all samples plotted as a function cross-shore sample location. In both the summer and winter profiles, the sand-size fraction is the most abundant grain-size class. A typical bulk sample contains on average >90% sand-size material in the foreshore. Sand decreases in the offshore direction to minimum value of 50% at the seaward limits of the study area. The gravel fraction averages <10% in the foreshore and increases offshore to about 40%. Mud is the least abundant constituent as it is absent in the foreshore zone and gradually increases to about 10% on the inner shelf.

A textural transition zone occurs between -18 and -30 ft water depth in which there is a concomitant decrease in the abundance of sand and increase in the abundance of gravel and mud. This textural transition marks the shoreface-inner shelf boundary (Meisberger and Duane, 1971) and confirms the successful sampling of the zone of active sediment transport.

Because the sand fraction is the most abundant grain-size class within the study area, granularmetric analysis focused on this fraction. The average frequency of occurrence for each of the 24 phi intervals plotted as a function of location north and south of the inlet is presented in Figure 4. The bimodal abundances obtained during both the summer and winter sampling correspond to two of the three grain-size classes defined by Udden-Wentworth: (1) fine sand [>4.0 phi to <2.0 phi] and (2) medium sand [>2.0 phi to <-1.0 phi]. The fine-grained sand collected during this study is composed predominately of quartz, the medium sand is composed predominately of carbonate material. Coarse sand [>-1.0 phi to <-2.0 phi] was a very minor component of the surficial sediment and consisted entirely of carbonate material (shells).

There are slight differences in the shape of the frequency distribution curves for the data collected north and south of the inlet within both modes (Figure 4). These differences are minor (<2% shift) within each data set (e.g., summer, winter) and the direction of the shift (e.g., finer, coarser) is not consistent between the two data sets. However, the variations between updrift and downdrift sand-size classes suggests that the inlet is exerting an influence on the textural patterns of surficial sediment.

B. Longshore Sediment Distributions

To further examine the apparent variation in grain-size distributions north and south of the inlet, the three sand-size classes (fine, medium, coarse) were plotted for the foreshore, shoreface and inner shelf zones as a function of longshore location. In this study, distances or locations north of the inlet are referenced using negative numbers (-) and distances or locations south of the inlet are referenced using positive numbers (+).

1. Longshore Sand-Size Frequency Distribution

Figures 5, 6 and 7 are paired summer and winter plots depicting the average frequency of occurrence of coarse, medium and fine sand within each geomorphic cross-shore zone as a function of their proximity to the inlet.

Within the foreshore or intertidal zone (Figure 5) coarse, medium and fine sand show a fairly uniform distribution throughout the study area. In both the summer and winter plots medium sand is most abundant size class (averaging 90 to 95%), while fine and coarse sand are uniformly low (<10%). The distribution patterns are slightly asymmetric about the inlet with greater variability (±10%) on the downdrift beaches. A comparison between the two profiles suggests the foreshore zone is slightly finer during the winter, especially on the downdrift beaches.

Within the shoreface or subtidal zone (Figure 6), fine sand is the most abundant grain-size class, although the spatial variability is high. Medium sand is of intermediate abundance and coarse sand is uniformly low (<2%). In both profiles, the southern locations exhibit greater variability than the northern locations. Although the spatial variability of fine and medium sand is high, a decrease in fine sand and a corresponding increase in medium sand can be observed in the immediate vicinity of the inlet (approximately ±4,000 ft) in both the summer and winter profiles. Also, between +6,000 and +14,000 ft (summer and winter) a significant decrease in fine sand and a corresponding increase in medium sand can be observed. In the winter profile, the appears to be a trend of increasing fine sand and decreasing medium sand towards the inlet. A significant coarsening of updrift beaches during the winter is apparent.

The most distinct longshore grain-size distribution trends were found on the inner shelf (Figure 7). In the summer data set, medium sand has the highest abundance in the distal portions of the study area (>±6,000 ft). In the area proximal (<±6,000 ft) to the inlet the abundance of medium sand decreases concomitant with an increase in the abundance of fine sand. The abundance of coarse sand remains very low (<2%) throughout the inner shelf. The winter profiles are similar to the summer except that the inner shelf area distal to the inlet (>+6,000 ft) does not grade into medium sand; it is a mixture of fine and medium sand.

2. Three Point Moving Average

Figures 8, 9 and 10 are paired summer and winter plots depicting the three point average of the sand-size frequency plotted for each geomorphic cross-shore zone as a function of their proximity to the inlet. These plots are considerably smoother (less variability) than the average frequency plots although the general trends (discussed above) in the data set are preserved. Inferences regarding the area of inlet influence will be based upon these figures.

GRAB SAMPLE RECOVERY TABLE

Sample Depth															Summer													
42	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o
36	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o
30	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	x	x	o	o	o	o	o	o
24	o	o	x	x	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	x	x	x	x	x	o	o	o
18	o	o	x	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	x	x	x	x	o	x	x	o
12	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	x	x	x	x	o	o	x	x
6	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	x	x	o	o	o	o
SW	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o
LT	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o
HT	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	o	o	o	o	o	o	o	o	o	o	o	o
	-25		-20		-15			-10		-5					0					5		10	15		20			25

LONGSHORE DISTANCE (x1,000 feet)

Table 1. Summary of successful and unsuccessful summer grab samples arranged according to transect and station location. Successful grabs are denote by "o" and unsuccessful grabs are denoted by "x".

GRAB SAMPLE RECOVERY TABLE

Sample Depth														Winter													
42	o	o	o	x	o	o	x	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	x
36	o	x	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o
30	o	o	o	o	o	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
24	o	o	o	x	x	o	o	o	o	o	o	o	o	o	o	o	o	o	x	x	o	o	o	o	o	o	o
18	x	o	o	o	x	o	x	o	o	o	o	o	o	o	o	o	o	x	x	x	x	x	o	o	x	o	o
12	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	x	x	x	x	x	o	x	x	x
6	x	x	o	o	x	o	x	o	o	o	x	o	o	x	o	o	o	o	x	o	o	x	o	x	x	x	o
SW	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	x	x	o	o	o	o	o	o
LT	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o
HT	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o	o	o	o	o	o	o	o	o	o	o
	-25		-20		-15			-10		-5				0			5			10		15	20				25

LONGSHORE DISTANCE (x1,000 feet)

Table 2. Summary of successful and unsuccessful winter grab samples arranged according to transect and station location. Successful grabs are denote by "o" and unsuccessful grabs are denoted by "x".

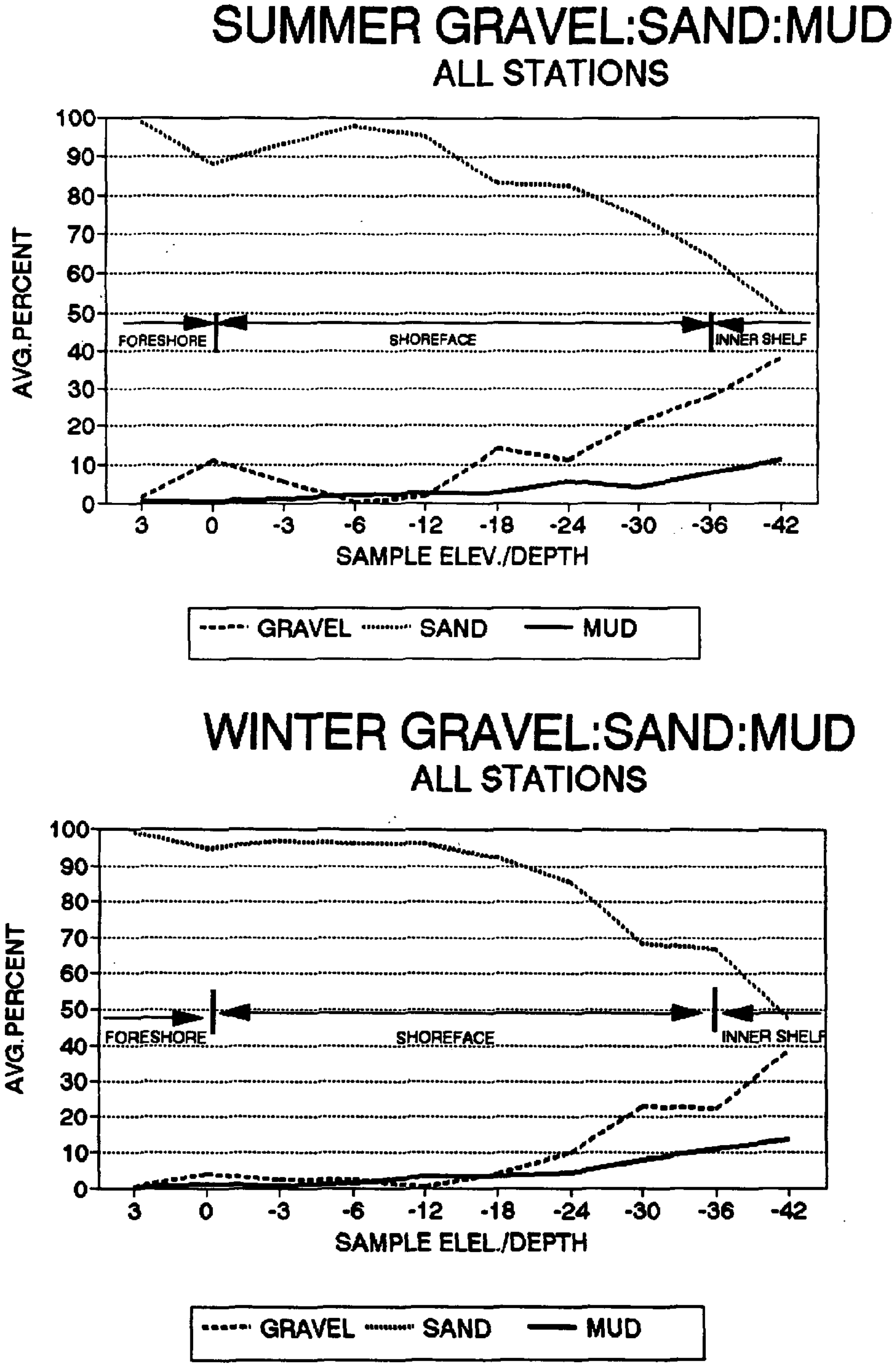
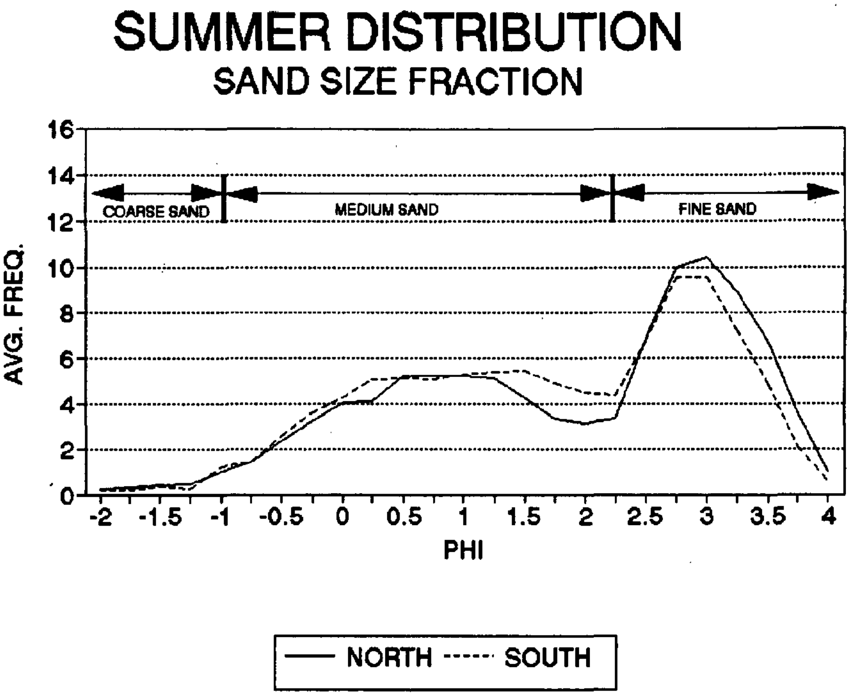
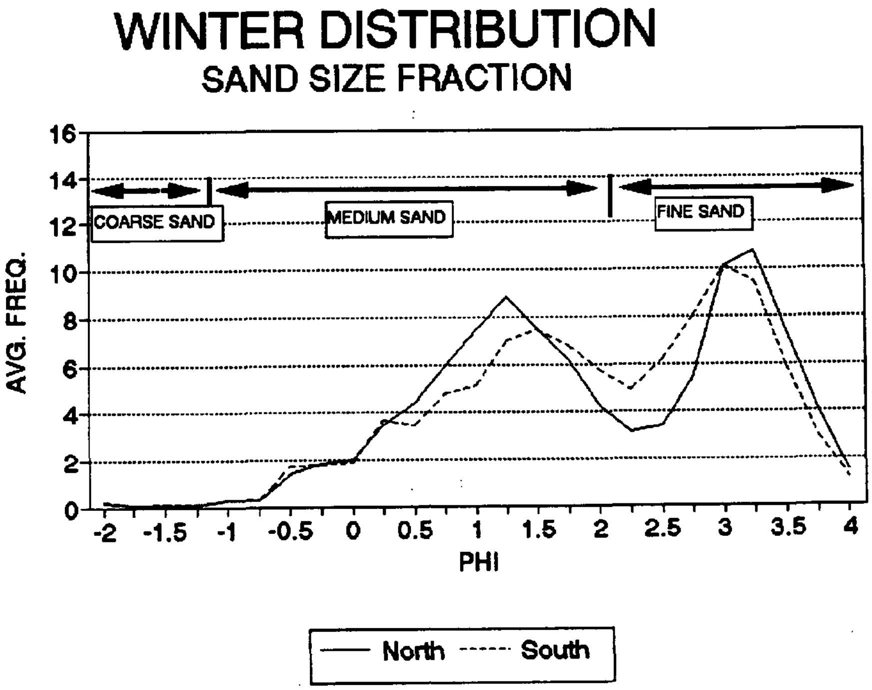


Figure 3. Shore-normal grain-size plot showing average frequency of occurrence of gravel, sand and mud fractions within the three geomorphic zones. Summer profile is shown in top panel, winter profile in bottom panel.



SUMMER DISTRIBUTION
SAND SIZE FRACTION



WINTER DISTRIBUTION
SAND SIZE FRACTION

Figure 4. Sand-size frequency distribution of entire data set plotted as a function of location north and south of the inlet. Boundaries of three sand-size classes, as defined in this study, are also indicated. Summer profile is shown in top panel, winter profile in bottom panel.

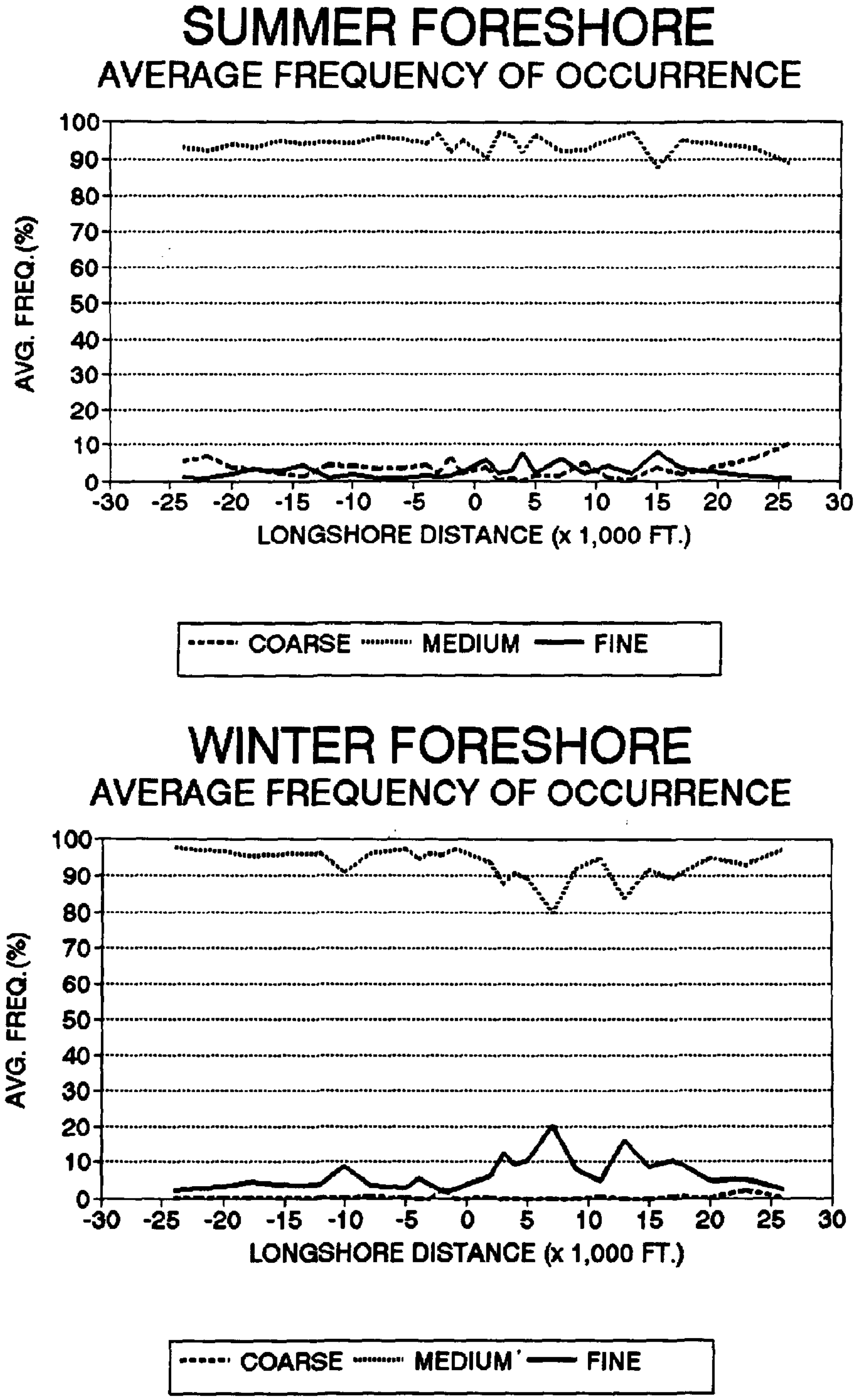


Figure 5. Average frequency of occurrence of coarse-, medium- and fine-sand classes within the foreshore. Summer profile is shown in top panel, winter profile in bottom panel.

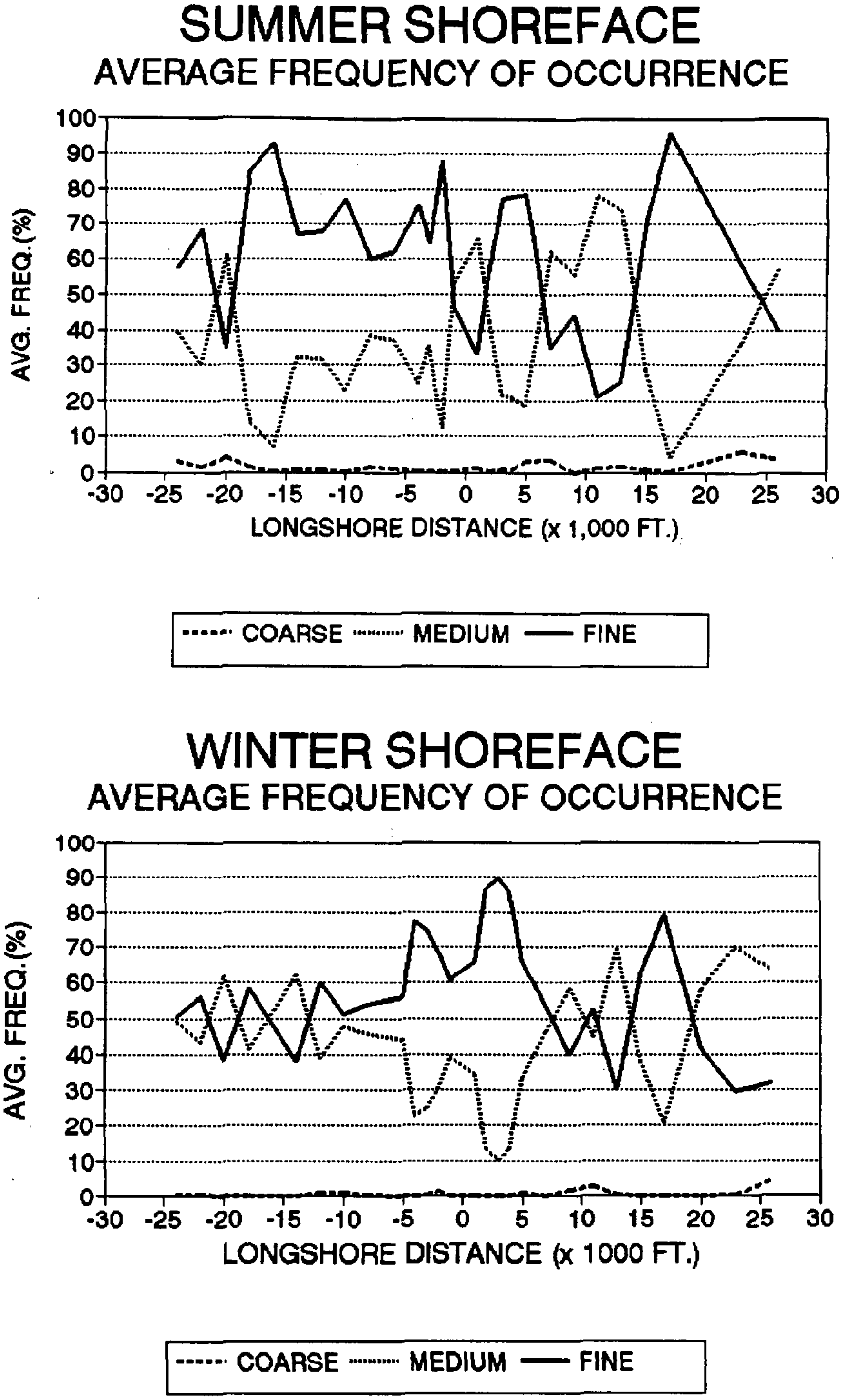
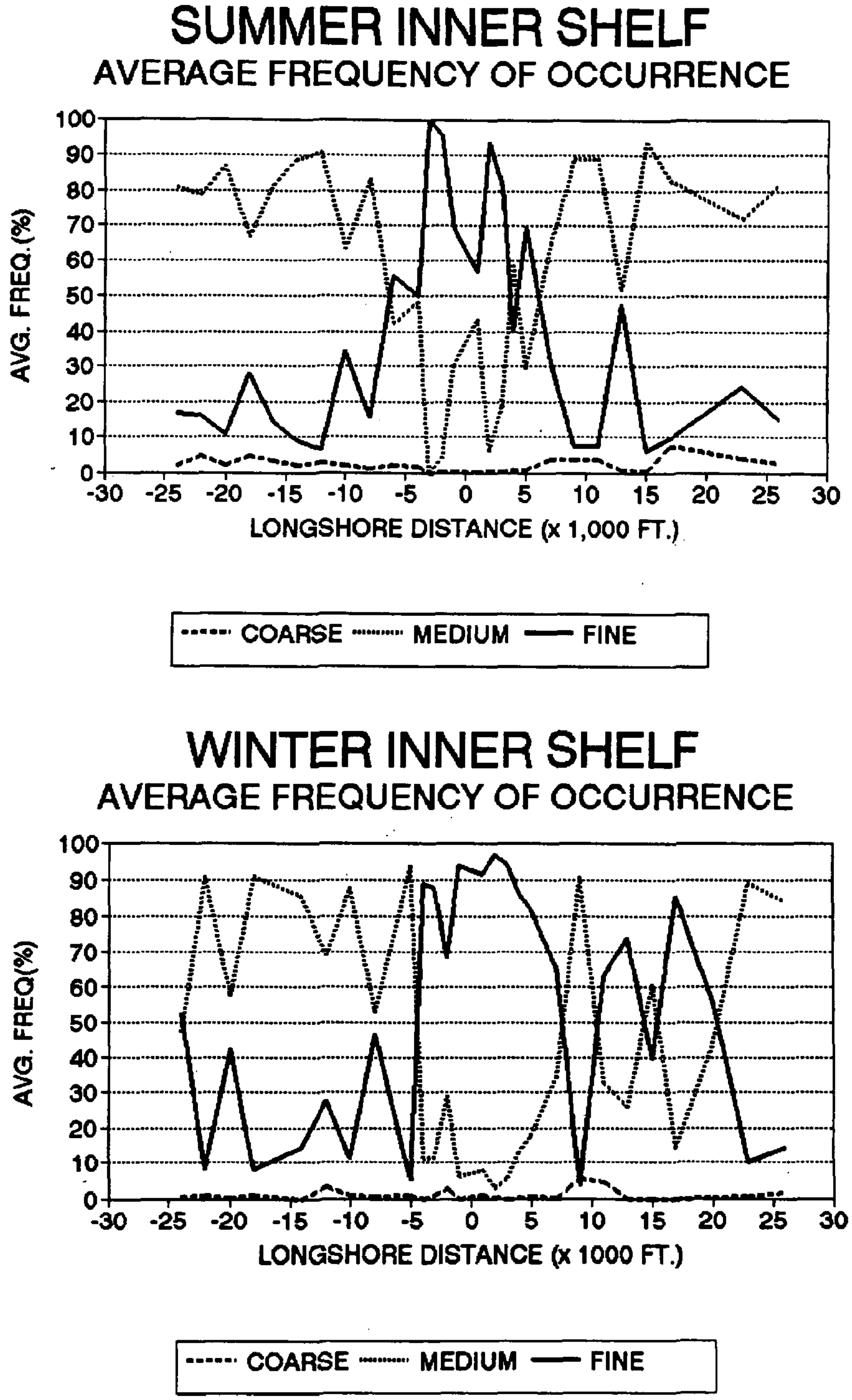


Figure 6. Average frequency of occurrence of coarse-, medium- and fine-sand classes within the shoreface. Summer profile is shown in top panel, winter profile in bottom panel.



SUMMER INNER SHELF
AVERAGE FREQUENCY OF OCCURRENCE

WINTER INNER SHELF
AVERAGE FREQUENCY OF OCCURRENCE

Figure 7. Average frequency of occurrence of coarse-, medium- and fine-sand classes within the inner shelf. Summer profile is shown in top panel, winter profile in bottom panel.

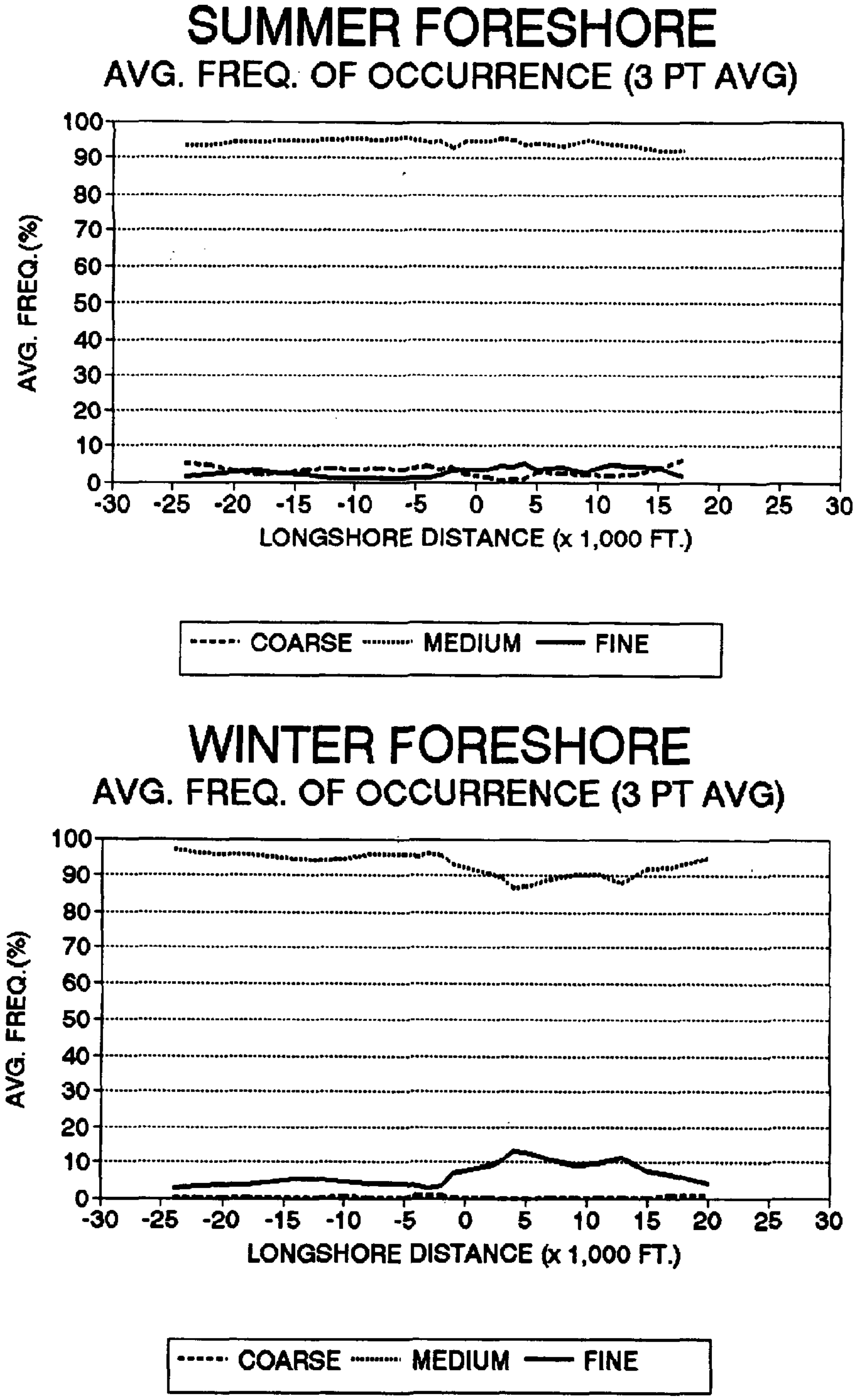


Figure 8. Three point moving average of the coarse-, medium- and fine-sand size frequency data within the foreshore. Summer profile is shown in top panel, winter profile in bottom panel.

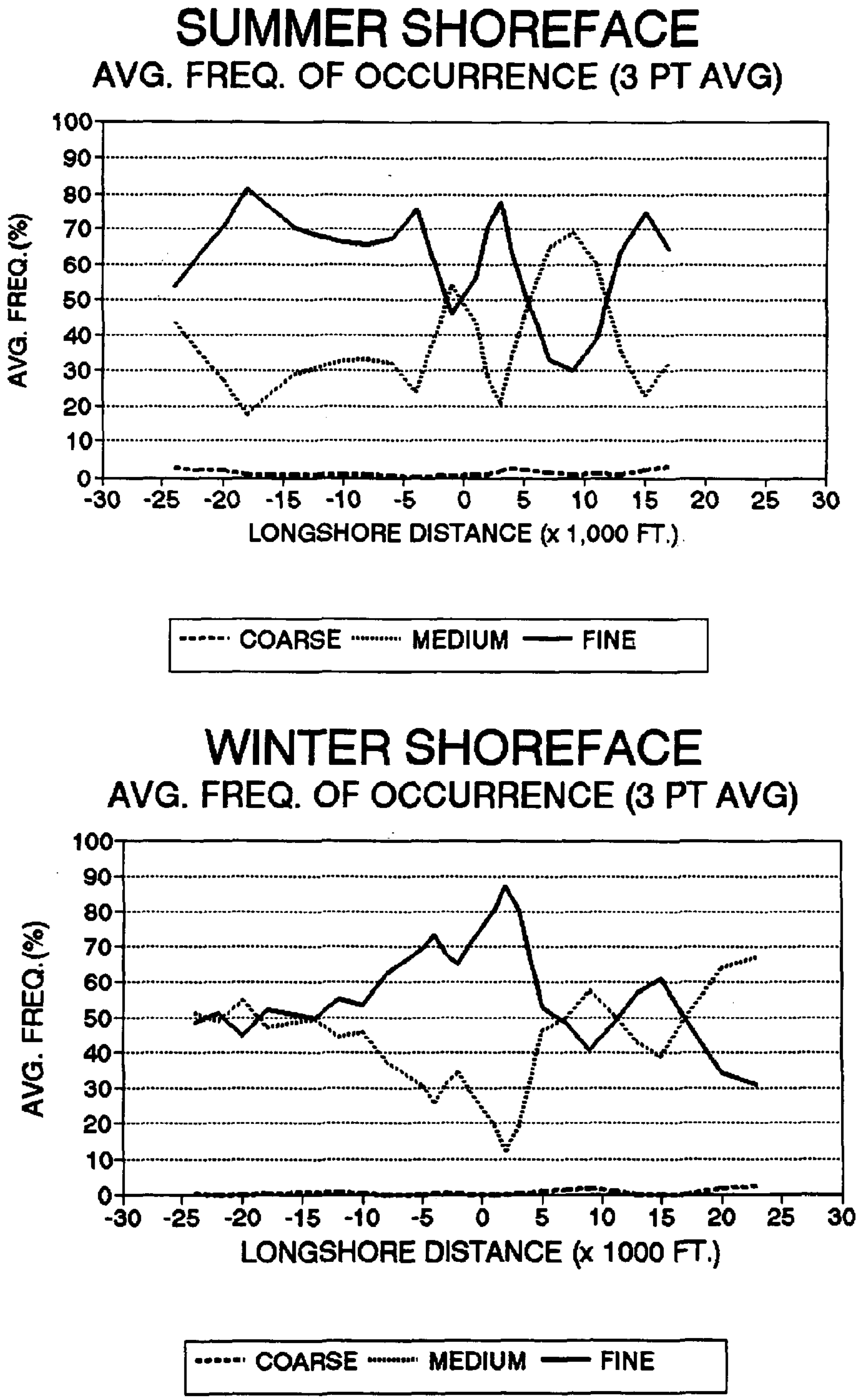


Figure 9. Three point moving average of the coarse-, medium- and fine-sand size frequency data within the shoreface. Summer profile is shown in top panel, winter profile in bottom panel.

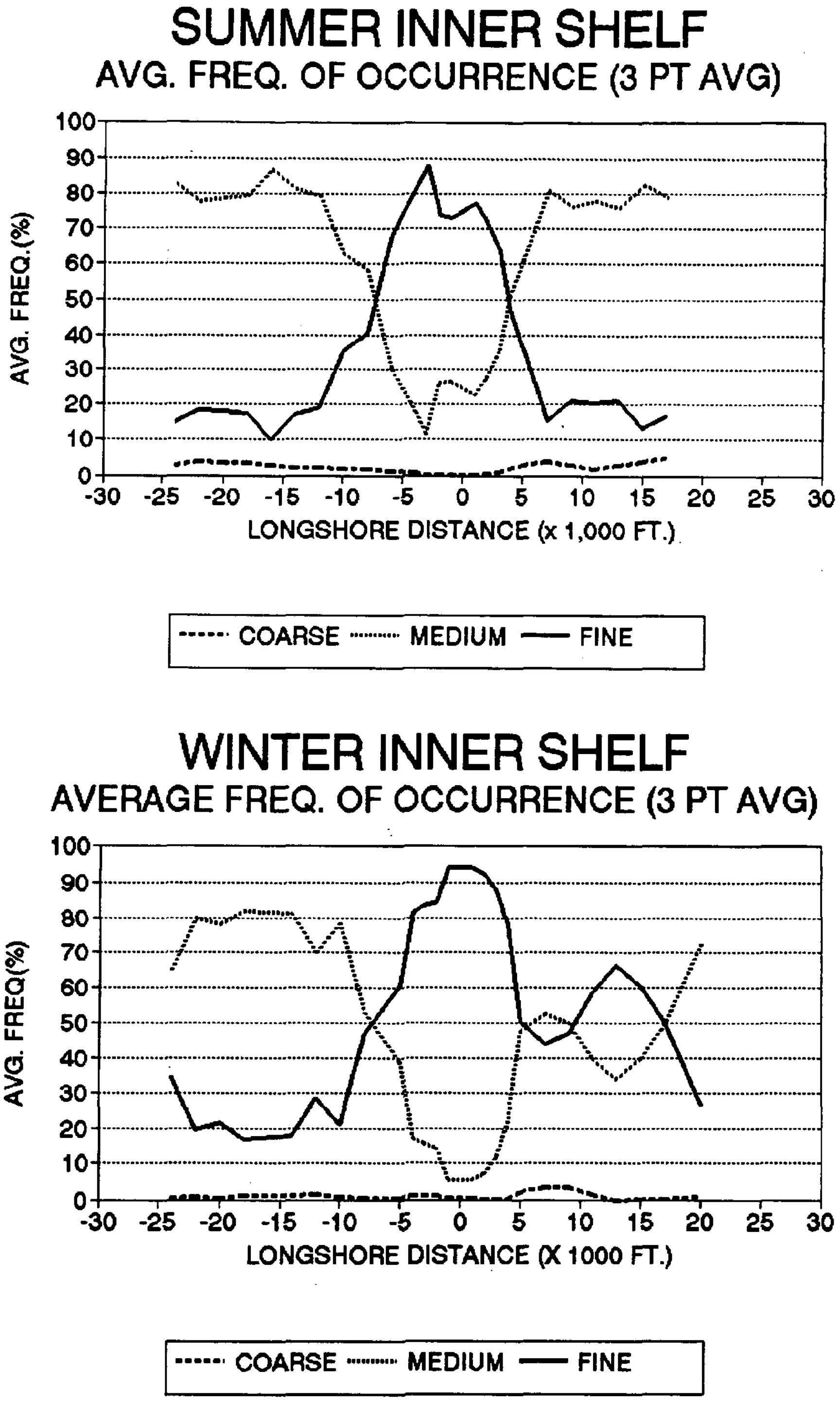


Figure 10. Three point moving average of the coarse-, medium- and fine-sand size frequency data within the inner shelf. Summer profile is shown in top panel, winter profile in bottom panel.

DISCUSSION

A. Area of Inlet Effect

The cross-shore distribution of gravel, sand and mud recognized during this study (Figure 3) correlates well with the sediment distribution patterns documented on Florida's shelf by Meisburger and Duane (1971). It is also consistent with the erosional shoreface retreat model of a transgressive barrier island system as presented by Swift et al. (1971).

The foreshore, located between mean high water and mean low water, is a high energy zone, dominated by the swash and backwash of breaking waves (Komar, 1976). Within the study area it is characterized by a high concentration of coarse and medium sand, as well as a relatively high (10%) concentration of gravel. Mud is scarce (<2%) within this zone.

The shoreface extends 2,500 ft seaward of the foreshore to a maximum depth of approximately 30 ft. Fine sand is the most abundant sediment type in this zone, which is dominated by wave driven flow associated primarily with shoaling waves. The asymmetry of shoaling waves leads to differential net transport. This favors the onshore migration of larger particles and the offshore movement of finer material, generating a graded textural pattern (Carter, 1988). This is confirmed by the abundance of coarse and medium sand within the foreshore and the abundance of fine sand within the shoreface. Coquina outcrops occur within this zone, providing a local source of coarse- and medium-sand sized shell material.

The inner shelf is located seaward of the modern sand prism in water depths greater than approximately 36 ft. The inner shelf is a low energy zone characterized by a decrease in the abundance of sand and an increase in the abundance of gravel (up to 40%) and mud (up to 10%). The gravel and mud deposits are primarily produced during erosional shoreface retreat (Civil, 1990) although modern biological productivity contributes some coarse-skeletal material to these palimpsest beds (Swift et al., 1971). Therefore the inner shelf gravel is comprised of both relic broken, bored and oxidized shell material as well as modern, well preserved shell material.

The three geomorphic cross-shore zones are oriented parallel to the shoreline throughout the study area except in the vicinity of the inlet (Figure 11). In this area, a lobe of fine-grained sand approximately 10,000 ft wide and centered on the inlet protrudes 4,000 ft out from the shoreface and into the inner shelf zone. In addition, a 6,000 ft wide zone of medium-grained sand protrudes approximately 3,000 ft out from the foreshore and into the shoreface zone. The presence of these seaward protruding sediment lobes, identified on the basis of grain size, is consistent with the tidal jetting hypothesis presented above. The lobe of fine-grained sand is a direct effect of the strong tidal currents which jet this material out from the shoreface and onto the inner shelf. Fine-grained sand is also selectively transported into the inlet where it accumulates within the flood shoal complex (Stauble et al., 1987). The medium-grained sand lobe identified within this area is interpreted to be a lag deposit of slightly coarser material not mobilized by tidal jetting.

If this fine-grained sand is jetted seaward and deposited below wave base or just within wave base it may not return to the shoreface or, if returned, the process may be very slow (Dean and Walton, 1973). Based upon the sediment budget of Wang et al. (1992) the loss of littoral drift to the inner shelf appears to be insignificant. Therefore, most fine-grained sand deposited on the lower shoreface and inner shelf must be migrating landward at the same rate as it is being jetted seaward.

Tidal currents are not 100% effective in winnowing fine sand from littoral drift. Between +3,000 and +5,000 ft the abundance of fine-grained sand on the shoreface is equivalent to updrift shoreface values (Figure 9). This zone corresponds to the location of the shore connected ebb shoal. Athough the crest of the shoal is comprised of medium-grained sand (Parkinson, 1990) the flanks and surrounding area are blanketed with fine-grained sand. Studies conducted by Hubbard (1975) and Dean (1988) have suggested that the presence of a shore connected ebb shoal is indicative of the effective transfer of littoral sediment across the inlet opening. Therefore, based upon the distribution of medium-grained sand on the shoreface and the location of the shore connected ebb shoal, approximately 6,000 ft of downdrift shoreface is directly affected by inlet hydraulics.

Within the shoreface area extending approximately +6,000 to +14,000 ft, a reduction in fine-grained sand and corresponding increase in medium-grained sand is observed (Figures 9 and 11). Outcropping coquina of the Anastasia Formation occurs in this area and this material may be providing a local source of medium- and coarse-grained sand to produce higher abundances of these grain-size classes. The outcrops could also cause localized turbulence (breaking waves) which may winnow and remove fine-grained sand from the area. A similar sediment coarsening is observable at approximately -20,000 ft. This area also hosts outcropping coquina rock (Figure 11). The presence of coquina rock may also be responsible for the greater degree of grain-size variability noted in the foreshore and shoreface cross-shore grain-size plots (Figures 5, 6, 8 and 9).

The presence of outcropping coquina rock within the shoreface zone south of the inlet has been attributed to the inlet and it's influence on the littoral sediment budget. Wang et al. (1992) have indicated that significant downdrift shoreline erosion (averaging 5 ft per yr) occurred between the years 1947-1970. This erosional interval is attributed to the reopening and stabilization of the inlet in 1946. However, between the years 1970-1986 downdrift shoreline erosion slowed to an average of 1.5 ft per yr (Wang et al., 1992). This reduction in the rate of shoreline retreat and the development of a stable (Wang et al., 1992) shore connected ebb shoal strongly suggests the inlet has reached a state of equilibrium in which most of the littoral drift effectively bypasses the inlet opening.

Beyond +14,000 ft, the abundance of fine sand in the shoreface zone increases and is similar to values observed north of the inlet (Figure 6 and 9). This increase is probably the result of (1) onshore return of fine-grained sand jetted out onto the inner shelf and (2) the absence of coquina outcrops, which locally coarsen the surficial sediments.

The area of inlet effect can also be estimated using the inner shelf data. Based upon the surficial sediment grain-size distributions obtained from this zone during the both the summer and winter the area inlet influence appears to be approximately ±5,000 ft (Figures 7 and 10).

B. Summer vs Winter Sediment Distribution Patterns

Because the east-central Florida coastline is wave dominated, a comparison was made between winter and summer seasons to determine whether the inlet effect persists throughout the year or is masked by a strong seasonal signal (e.g., winter storms). Variations in the grain-size data which can be attributed to the inlet are present in both of the data sets. Therefore, the inlet effect is not masked by winter storm conditions although the textural pattern of surficial sediments is modified. During the winter the updrift distal shoreface coarsens while the downdrift distal inner shelf fines. These shifts are consistent with seasonal cross-shore sediment transport (Komar, 1976). A coarsening of the shoreface would generate a surplus of fine-grained sand which could accumulate in downdrift (southern) inner shelf areas.

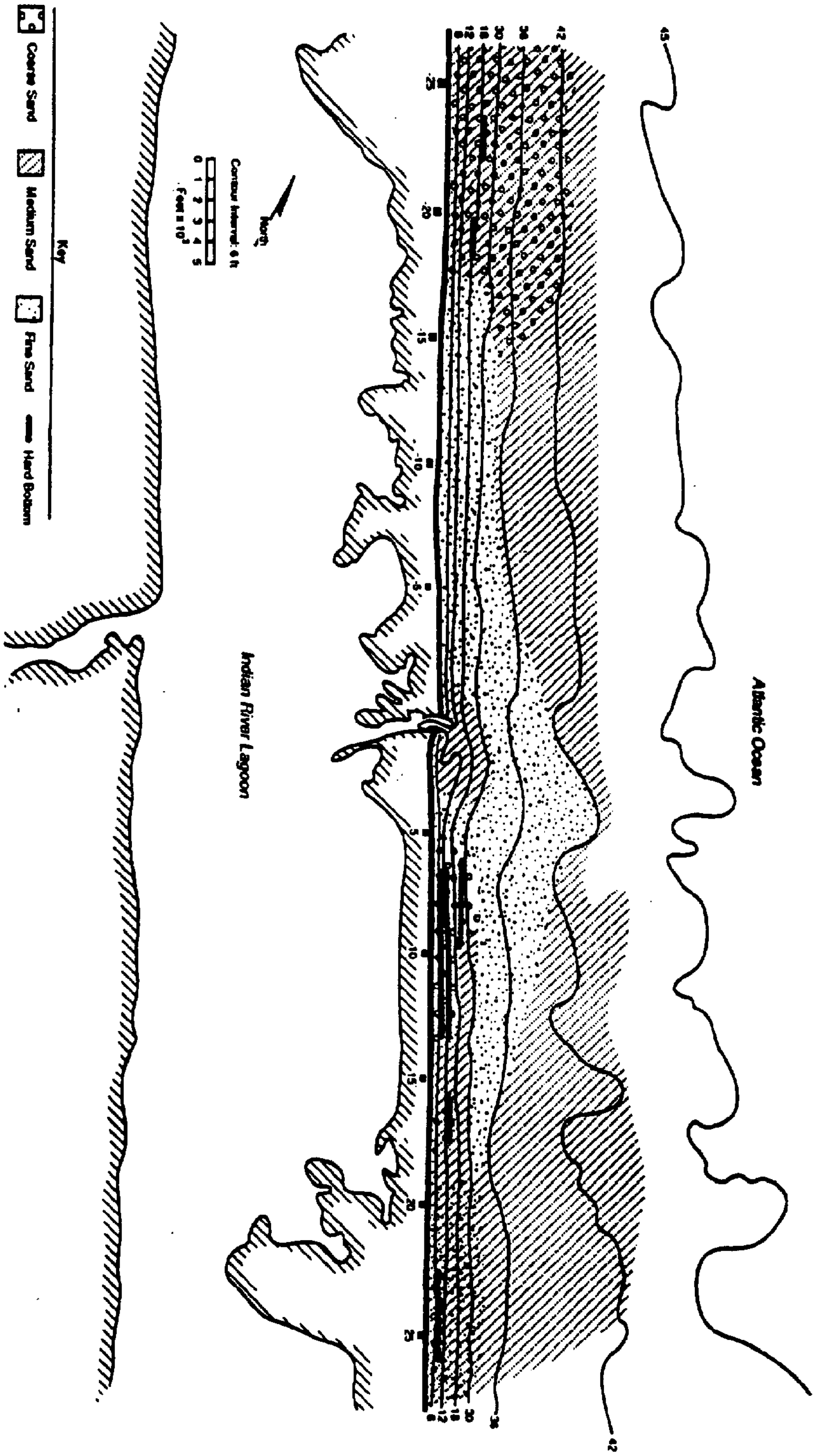


Figure 11. Idealized summer surficial sediment distribution map of coarse-, medium- and fine-sand classes. Map is representative of both summer and winter conditions.

CONCLUSIONS

(1) This study has demonstrated that textural distribution patterns of surficial sediments can be used as a method to delineate the area of inlet influence. Within the Sebastian Inlet area the presence of coquina rock outcrops in downdrift areas proximal to the inlet has resulted in highly variable grain-size distribution patterns which have hampered quantification of the area of inlet effect.

(2) The hypothesis that strong tidal currents jet fine-grained sediment offshore is supported by the decreased abundance of fine-grained sand within the shoreface and increased abundance of fine-grained sand on the inner shelf adjacent to the inlet as well as within the flood-shoal complex.

(3) The grain-size surficial sediment distribution pattern within the study area suggests the area of inlet influence within the shoreface is approximately -5,000 ft (updrift) to +6,000 ft (downdrift). Inner shelf sediment patterns suggest the area of influence is also approximately ±5,000 ft.

(4) The area of inlet influence is not masked by winter storm conditions although the elevated wave climate did coarsen the distal updrift shoreface. A fining of the distal

downdrift inner shelf was also noted and may be genetically related to the shoreface coarsening.

(4) It should be noted that the estimates of inlet effect presented herein are based upon the surficial sediment grain-size distribution patterns. Therefore, these estimates can only be used to delineate the limits of hydrodynamic influence. The data presented herein can not be used to infer how this hydrodynamic activity has effected the local sediment budget and therefore coastal accretion or recession rates.

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