A comparison of the erosion/accretion rates of five shoreline types surrounding Galveston Island, Texas

by

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ABSTRACT

This study compared the erosion/accretion rates of five shoreline types surrounding Galveston Island and Pelican Island, Texas. The shoreline types examined included sandy beach, mud flat, salt marsh, shell beach, and mud bank. Erosion/accretion rates of these shoreline types were used as a relative measure of stability. The determination of erosion/accretion rates were made by short-term direct field measurements, the examination of historical aerial photographs, and a survey of available literature. The research found that salt marsh shorelines possess erosion/accretion rates that are much less variable than those of the other four shoreline types. Location was found to be a major factor influencing shoreline stability in the study area, since it determines energy conditions and sediment input. The use of the "point-stake method" proved to be successful at most field study sites. It was also concluded that the use of both a field study and a photographic analysis is necessary for a thorough investigation of any shoreline's stability over a long period of time.

ACKNOWLEDGMENTS

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INTRODUCTION

Erosion can be defined as the natural processes that result in the loss of land to open water, while accretion is an increase in the area of land by natural processes (Adams et.al., 1978). Knowledge about erosion and accretion rates is important in planning coastal development and contruction in order to prevent economic losses caused by these processes. It is also important in the management and creation of ecological environments associated with different shoreline types.

The erosion/accretion rates of five shoreline types surrounding Galveston Island and Pelican Island, Texas were determined by a direct field study and the analysis of historical aerial photographs. The objectives of the research were four-fold. The first was determine which shoreline type in the study area is most stable. The second was to define the factors that are responsible for shoreline stability (i.e. what makes a shoreline stable or unstable). The third was to assess the usability of the "point-stake" field method for estimating the value of shoreline change. The point-stake method entails the use of wooden stakes as reference markers of shoreline position. The fourth objective was to compare the effectiveness of short-term field studies versus long-term photographic analysis. Effectiveness was based on a comparison of the advantages and disadvantages of each method.

--format based on Ecology

REVIEW OF LITERATURE

Erosion/Accretion Studies

Entire Texas Coast

A study using topographic maps between 1850 and 1966 documented that 50% of the Texas coast has a general rate of change in the "small change" category (+4 to -5 feet/year). Forty percent was classified as recessionary and ten percent as accretionary (Seeling and Sorenson, 1973).

Shepard (1960), using charts from 1870, 1880 and recent, found that barrier islands are relatively stable in position along the western Gulf of Mexico, but changes of the order of 100-500 feet have occurred in about 60 years.

The National Shoreline Study of Texas Coast Shores (1971) by the U.S. Army Corps of Engineers found that since the latter part of the 19th century there has been continuing erosion of the sand dunes on all barrier islands. This erosion is most pronounced after storms breach the weakest dunes and create wash-over cuts. Most of the shoreline erosion in bays has been along northern and western shores.

A 1977 study of the Gulf shoreline of Texas documented that approximately 60% of the Texas shoreline is undergoing erosion. This erosion is most rapid along peninsulas and deltiac headlands, and less rapid along barrier islands. They reported that barrier islands in the vicinity of 27^{o} N are stable because this is a zone of net longshore drift convergence. The study classified 60% of the Gulf shoreline erosional, 33% in equilibrium, and 7% accretionary (McGowen et.al., 1977).

Galveston Island

Significant changes in the shorelines of Galveston Island have occurred in the past few thousand years. These changes were associated with erosional and depositional processes along the bay and Gulf shorelines. The most prominent changes in the Gulf shoreline of Galveston Island have resulted from deposition associated with longshore currents in the littoral zone of the Gulf of Mexico. Although some segments of the beaches have receded during the past 50 years, the net result of the 80 years growth trend is accretion (LeBlanc and Hodgson, 1959). The greatest growth has been in the direction of littoral drift but significant progradation has also taken place seaward (Otvos, 1970).

The 1971 Corps of Engineers study classified a 65 mile beach zone including parts of Folets Island and Bolivar Peninsula and the entire seaward shore of Galveston Island. The study documented 25 miles of critical erosion, 1 mile of non-critical erosion and 39 miles of non-eroding or accreting shoreline. Erosion was classified as critical or non-critical according to economic, industrial, recreational, agricultural, navigational, and ecological factors. Two critical areas were identified on Galveston Island: 1) the area just past the west end of Seawall Boulevard; and 2) San Luis Pass. No critical erosion was classified on the backside of Galveston Island (U.S. Army Corps of Engineers, Galveston District, 1971) (See Figure 1).

The beaches along the western portion of Galveston Island have been documented as being erosional. A study by the U.S. Corps of Engineers using topographic maps between 1850 and 1966 identified that this area has retreated at a rate greater than 10 feet per year (Seelig and Sorenson, 1973).

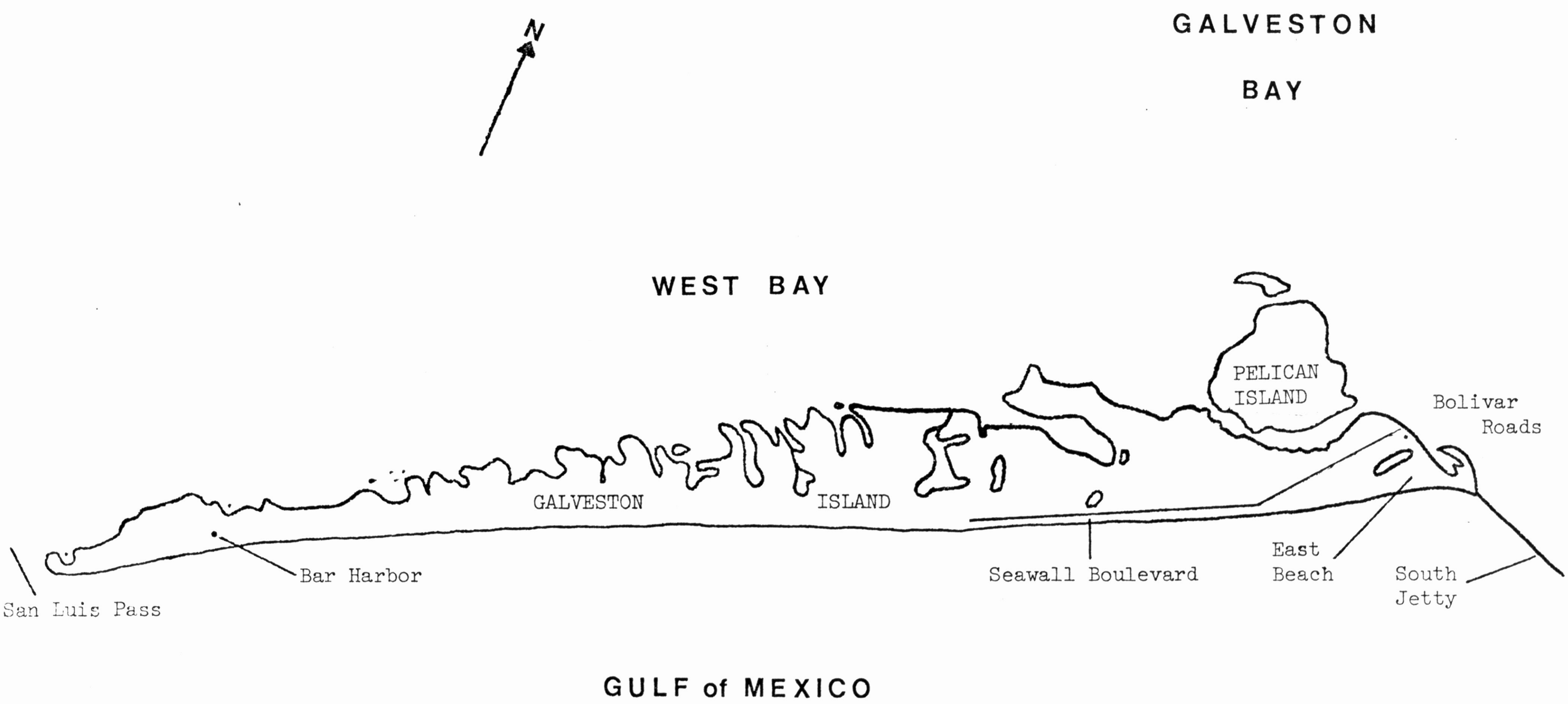

Figure 1. The study area-- Galveston Island and Pelican Island.

Between the winter of 1970 and the spring of 1973 the west end eroded at a rate of 80 feet per year (McGowen et.al., 1977). Benton et.al. (1979) reported that the placement of jetties and groins along the shore has interrupted the natural northeast to southeast littoral transport, resulting in erosion along the southward sixty-percent of the island. The report documented that the area has eroded 120 feet landward since the late 1960's and the 10 year erosion rate is at least 12 feet per year. Contrary to these conclusions, the Environmental Geologic Atlas of the Texas Coastal Zone - Galveston - Houston Area details that from the end of the seawall to Bay Harbor Subdivision is in equilibrium, despite high energy conditions (See Figure 1). This is supposedly caused by sand being pushed onshore from the inner part of the continental shelf (Fisher et.al., 1972).

The area of East Beach that is east of the South Jetty is documented as being accretional (Fisher et.al., 1972) (See Figure 1).

San Luis Pass is an area that has shown to be highly erosional (See Figure 1). Seelig and Sorenson (1973) found that between 1967 and 1972 the area retreated at a rate of 67 feet per year. Benton et.al. (1979) reported that between January, 1970 and December, 1977 the average rate of erosion was over 60 feet per year. The emergent portion of the island, however, is undergoing accretion (Fisher et.al., 1972).

Although changes related to sedimentation along the bay shorelines have been limited, the predominant process has been erosion, according to LeBlanc and Hodgson (1959). This, however, is in marked contrast to other reports. Fisher et.al. (1972) reported that the majority of this area is in depositional - erosional equilibrium, with a few segments being accretional. Otvos (1970) found that minor amounts of lagoonward progradation from wash-over deposits derived from the island is occurring.

Pelican Island

The majority of Pelican Island has been documented as being in equilibrium or accretional, with a small segment being erosional (Fisher et.al., 1972).

Use of Field Studies

Field studies provide an accurate account of shoreline position. They do, however, require data collection over long periods of time and many man-hours of work. Direct monitoring also has the disadvantage of being limited to discrete points along a shoreline, thus large areas cannot be covered. Despite these disadvantages, direct monitoring of shoreline position has proved successful when permanent objects are used as reference markers (Adams et.al., 1978) (Gutman et.al., 1979). The use of wooden stakes as reference markers is not documented.

MATERIALS AND METHODS

Description of the Study Area

Location

Galveston Island is the northernmost barrier island of an almost continuous chain of barrier islands along the Gulf Coast of Texas. It is 32 miles in length and varies from one to two miles in width. The island is separated from Bolivar Peninsula on the east by Bolivar Roads, a tidal channel. San Luis Pass, another tidal channel, terminates Galveston Island on the west. Galveston Bay and West Bay separate the island from the mainland (Ditton et.al., 1979) (See Figure 2). Galveston Bay is an estuary type of bay (elongated normal to the coast) and West Bay is a lagoonal bay (elongated parallel to the coast). Both are shallow with mud bottoms (LeBlanc and Hodgson, 1959).

Pelican Island is largely a manmade island, built from dredged material. It is located on the east end, bay side of Galveston Island and is separated from Galveston Island by the Galveston ship channel (Ditton et.al., 1979) (See Figure 2).

Characteristics of Barrier Islands

Barrier islands can be separated into three zones: 1) an outer beach with a broad berm; 2) a belt of dunes; and 3) an inner flat or marsh. In general, a barrier island is a belt of sand separted from the mainland and has a straight seaward margin in contrast to a lobate lagoonal marsh shoreline. The marshes are usually intersected by channels through which water flows during high tides (Shepard, 1960) (See Figure 3).

Physical Description of Shorelines

The shorelines of Galveston Island can be separted into two general

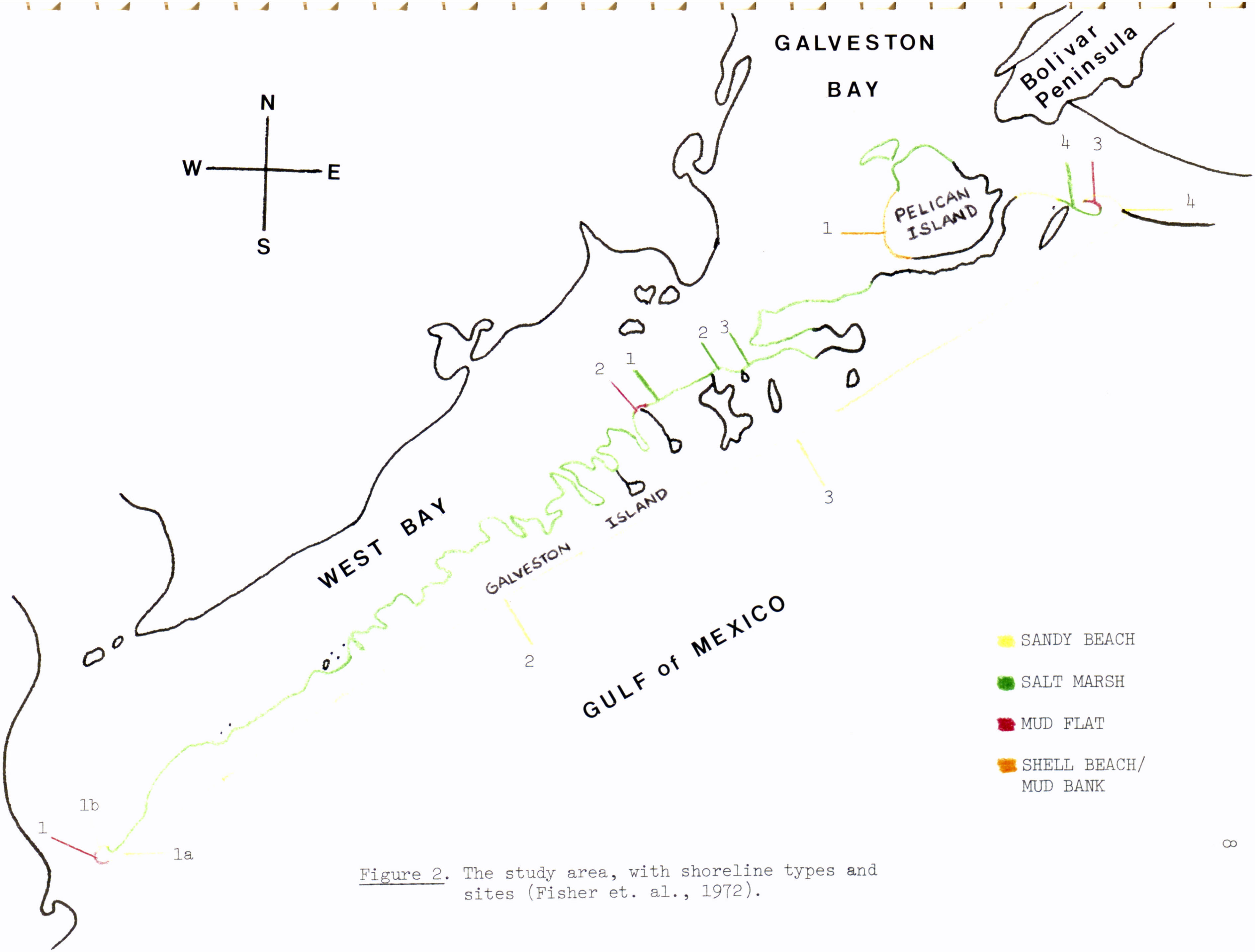

Figure 2. The study area, with shoreline types and sites (Fisher et. al., 1972).

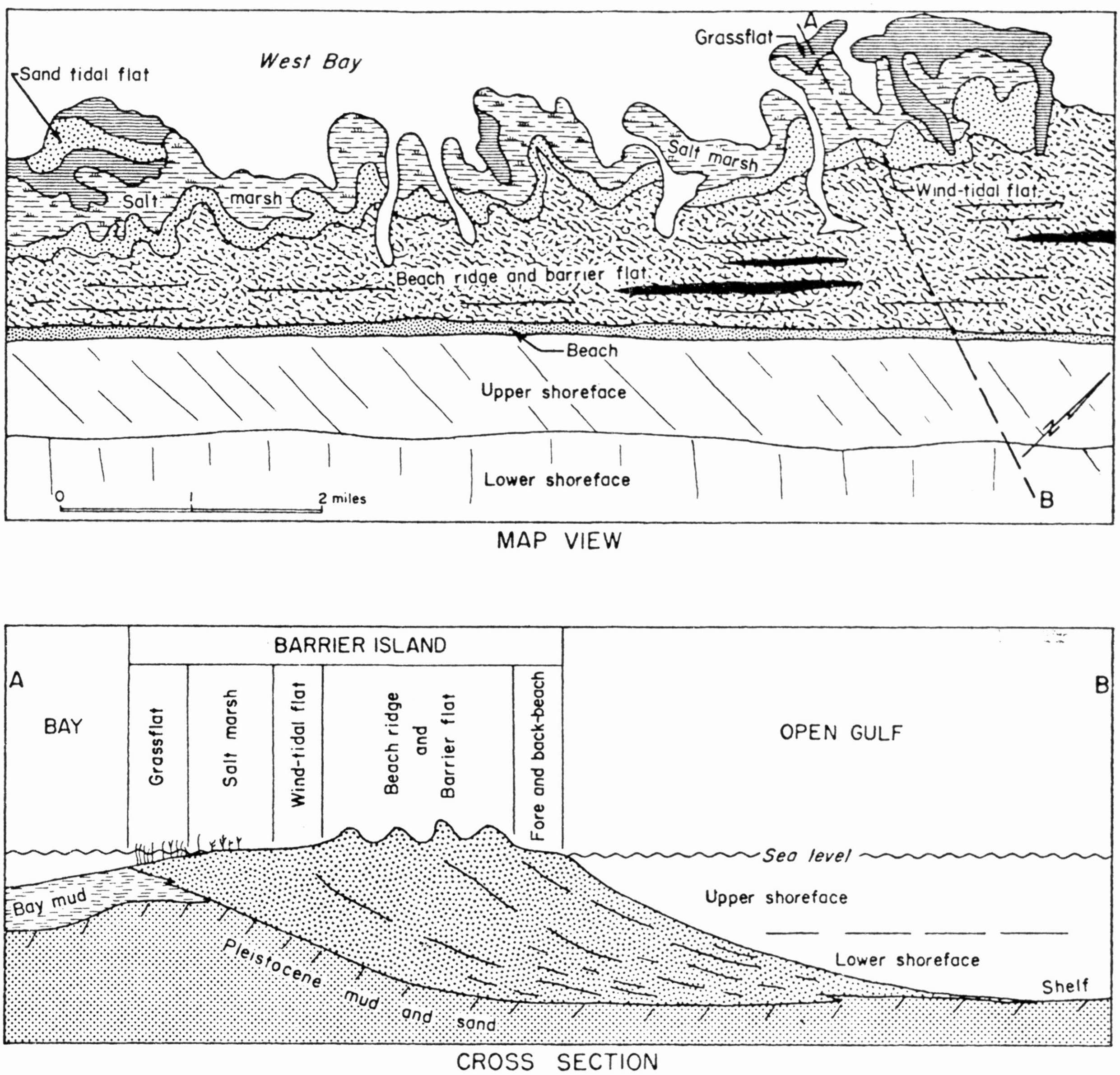

Figure 3. Features of Galveston Island.

types - Gulf and bay. The Gulf shoreline is the very smooth seaward edge of the island, with well-developed and broad beaches. The bay shoreline lies behind the island and has a serrated outline with no sand beaches. Many small lakes lie perpendicular to the axis of the abandoned beach ridges and swales in the central portion of the island. Marshes and low bluffs may be present where wave is eroding Pleistocene deposits. The shorelines of Galveston Island have been shaped predominently by marine processes, rather than deltaic sedimentation (LeBlanc and Hodgson, 1959) (See Figure 3).

Pelican Island, being partially an artifical structure, possesses some characteristics of a bay shorelines. It does, however, have unique features such as shell beach and mud bank shorelines.

Shoreline Classification

Five shoreline types were identified in the study area: sandy beach, mud flat, salt marsh, shell beach and mud bank. Below are descriptions and characteristics of each. Table 1 shows the general features of each shoreline type.

Sandy Beach

Sandy beaches are found on the seaward side of Galveston Island in the study area (See Figure 2). They originate offshore and extend above the main high tide to the first, or primary dune (Ditton et.al., 1979). An important component of a sandy beach is its dune system. Dunes act as a barrier to high storm waves and prevent flooding of the mainland. They also act as a reserve source of sand for the beach during periods of erosion. Dune vegetation stabilizes the dune and promotes growth by trapping wind-blown sand (Bird, 1973; Fisher et.al., 1972).

Table 1. Characteristics of the five shoreline types in the study area.

Shoreline Type	Location	Energy Conditions	Sediment Content	Vegetation
Sandy Beach	Gulf shoreline of Galveston Island	high	fine to very fine sand	dune vegetation <u>Panicum</u> <u>Amarum</u> dominant
Mud Flat	Tidal passes and w/ salt marshes	variable low to high	sand, silt clay	none
Salt Marsh	Bay shoreline of Galveston Island	low	sand, silt clay	salt marsh vegetation <u>Spartina</u> <u>Alterniflora</u> dominant
Shell Beach	Artificial Pelican Island	low to variable	sand, shells	Absent or upland
Mud Bank	Artifical Pelican Island	low to variable	sand, clay shells	upland

Sandy beach profiles vary seasonally. The summer profile is typically smooth and shows accretion. The winter or storm profile has a characteristic offshore bar, the result of erosion (Smith et.al., 1976). Although beaches vary seasonally, they can be put into three categories: progradational, in equilibrium, and retreating. Progradational beaches are caused by an excess of sediment input and energy conditions that promote deposition. Beaches in equilibrium are characterized by low sediment input and low energy conditions that cause sediment transport adjacent to the coast (Coleman, 1966).

Mud Flats

The term mud flat is used here to denote two actual environments identified in the study area. The first is actually a sand tidal flat and is associated with sandy beaches. The second environment is a true mud flat and these are found adjacent to salt marshes (See Figure 2).

Sand tidal flats are barren, featureless structures that are located in association with sandy beaches with dune systems or are found adjacent to tidal passes. Consequently, they are found on the seaward side of Galveston Island (Fisher et.al., 1972).

True mud flats are depositional structures that are actually precursors of salt marshes. Thus, they are found predominantly at bayside locations in the study area. Mud flats are formed by the following process. Suspended clays in the water have a buffering effect on waves and thus reduce the effective wave energy reaching the shoreline. Under the right energy conditions, deposition of mud occurs. As deposition proceeds, vegetation appears. Once the plants are established, they act as a sediment trap and progradation increases. Within a short time the mud flat is built up to high tide level and the area is covered with salt marsh flora. By this process mud flats are created and converted into a salt marsh (Coleman, 1966). This process is also responsible for the extension of salt marshes.

Salt Marshes

Salt marshes are beds of intertidal rooted vegetation which are predominantly inundated and cleared by the rise and fall of the tide. The flat topography of the east Texas coast permits extensive marshes under low tidal range conditions (Woodhouse, 1979). In the study area salt marshes are found on the bayside of Galveston Island and along the west and north shores of Pelican Island (See Figure 2).

Salt marshes accrete by the filtering out of sediment by the vegetation as the tide rises and falls. In this way, the process of accretion is slow at the upper and lower limits of the marsh, and most rapid in the zone in between where the vegetation is the densest. Overall sedimentation is slow and the outer edge may oscillate between advance and retreat. In fact, Brittany salt marshes have been found to possess a cyclic pattern of erosion and accretion. Old *Spartina* marshes also show characteristics of a cyclic nature (Bird, 1973).

Erosion of marshes can be caused by under-cutting below the waterline, and by persistent high energy waves (Woodhouse, 1979). Also, erosion may be caused by: 1) current scour along tidal channel; and 2) strong wave action due to the lowering of the intertidal zone resulting from sediment build-up in the upper vegetated area (Bird, 1973).

It is evident that salt marsh vegetation plays an important role in shaping the depositional forms of estuaries (Bird, 1973). The main importance of salt marsh vegetation, however, is shoreline stabilization (Fisher et.al., 1972). The development of a full cover marsh can reduce or eliminate erosion by trapping sediment and damping waves (Woodhouse, 1979). Devegetation of marshes has shown to result in shoreline erosion (Fisher et.al., 1972).

Shell Beaches and Mud Banks

Natural shell beaches are developed by "northers" and are found in association with salt marshes (Fisher et.al., 1972). They are, however, only temporary structures and none were classified in the study area. Artifical shell beaches, on the other hand, were found in the study area and they can be accompanied by mud bank shorelines. Both of these shoreline types were found only on Pelican Island, a dredge spoil island (See Figure 2).

Shell beaches are beaches that contain predominantly shell material, although the sand content can be quite substantial. These beaches are characterized by being variable in outline and slope and usually become different in appearance with the passing of each tidal cycle. When shell beaches are accompanied by a mud bank, the bank is located at the edge of the high tide mark. Elevation of the bank varies from 1 foot to 8 feet.

Measurement of Erosion/Accretion

Three lines of approach were taken to compare erosion/accretion rates in relation to shoreline type - a direct field study, the analysis of historical aerial photographs, and a survey of available literature.

Direct Field Study

A six month field study was undertaken beginning in October, 1983 and continuing through March, 1984, using the "point-stake method."

This method entails the use of wooden stakes as markers for the edge of the shoreline.

Where possible, three to four replicate sites for each shoreline type were created in October at various locations in the study area. These sites are represented on Figure 2. The sites were created by placing a series of 12 stakes along the edge of the shoreline, 1-2 meters apart. Measurements of shoreline movement in relation to the stakes were taken monthly and photographs were taken at the beginning and end of the six month period to assess relative change.

Since different shoreline types have different demarcations of the shoreline edge, various methods were undertaken. For sandy beaches, the stakes were placed .5m seaward of the edge of the dune or .5m seaward of the start of upland vegetation if no dune system was present. Placement of the stakes seaward of the edge was done to prevent: 1) burial of the stake and 2) to prevent erosion caused by the stake itself. The horizontal distance from the stake to the edge was measured each month. For the salt marsh shorelines, the stakes were placed at the edge of the vegetation line and the horizontal distance from the stake to the vegetation was measured. Since mud flats have no distinct edge, the stakes were placed in the ground .15m from the top and vertical displacement was monitored. For shell beaches the stakes were put .25m-.5m seaward of the edge created by the shells, and horizontal displacement was measured. The stakes for mud bank shorelines were placed .5m or 1.0m seaward of the bank and the distance from the stake to the bank was monitored.

At the end of the six months, the measurements were converted into a yearly horizontal erosion or accretion rate in feet per year for each site.

For the mud flat shorelines, the vertical displacement was converted to horizontal using an estimated average slope of 2 degrees (Dr. Ernest Estes, personal communication, April 5, 1984).

<u>Analysis of Historical Aerial Photography</u>

Aerial photographs are useful in estimating the long-term trends of a shoreline. There are, however, limitations. Assumptions that must be made are that: 1) calculated rates of change are constant over the time interval and 2) the trend of shoreline change is also constant. If these assumptions are invalid, the calculated rates underestimate the actual rates of change (Morton, 1978). Also the use of long time intervals place more dependance on average rates and reveal less information on the periodicity of erosion or accretion (Adams et.al., 1978).

Aerial photographs were obtained from three sources, the Texas Department of Natural Resources, Dr. James McCloy and Dr. James Webb, Texas A&M University at Galveston. The years of the photographs were 1955, 1973, 1979. The 1955 and 1979 photographs were black and white; the 1973 photos were color infrared. The scales for the photographs were: 1955 - 1:10,766; 1973 - 1:2,400; and 1979 - 1:24,000. Since complete coverage of the study area was not available for all years, yearly erosion/accretion rates were made from the three following time periods: 1955-1973, 1955-1979, and 1973-1979. Rates were calculated in the units of feet per year.

Locations of shoreline investigation corresponded, where possible, to the sites of the field study (See Figure 2). On the average, three measurements were made at each location, and the results were averaged. It must be noted that the calculations represent distinct segments of the shoreline and must not be taken as an assessment for the entire area. Due to the lack of a "cliff" line and vegetation, mud flats were not considered in the photographic analysis (Morton, 1978).

Analysis of the aerial photographs was made following the procedures outlined in Standards for Measuring Shoreline Changes (Tanner, 1978). The "smallest measurable change per year" for the three time periods was calculated as 1.52 feet (1955-1973), 3.25 feet (1955-1979), and 9.95 feet (1973-1979). This implies that erosion or accretion smaller to this calculated value can not be detected and no conclusion concerning erosion or accretion within this boundary can be made. For all the photographs, radial and tilt distortion was considered negligible. Since the topography of the study area is relatively flat and the reference points chosen were commonly intersections of roads (and not elevated structures) relief distortion was also considered to be minimal. Tidal effects were also negligible, since "cliff" lines or vegetation lines were used as the edge of the shoreline (Tanner, 1978).

Literature Survey

The survey of literature pertaining to shoreline stability was conducted at the main library of Texas A&M University at Galveston. Additional materials were obtained from the personal library of Dr. James Webb.

Categories for Classifying Erosion/Accretion

Below is a classification system for yearly erosion/accretion rates that was created for the Texas shoreline by Seelig and Sorenson (1973):

+(+24) feet/year	-	extreme advance
+15-(+24) feet/year	-	high advance
+5-(+14) feet/year	-	advance
+4-(-5) feet/year	-	small change
-6-(-15) feet/year	-	recession
-16-(-25) feet/year	-	high recession
+(-25) feet/year	-	extreme recession

This classification scheme will be used here to make relative conclusions about the results obtained from the field study and the analysis of aerial phototgraphs.

RESULTS

Table 2 shows the results of the field study and the analysis of the historical aerial photographs. Each site can be located on Figure 2, where they are denoted by the same number.

In general, the sandy beach sites showed highly variable erosion/accretion results, ranging from high advance to extreme recession. This is in marked contrast to the salt marsh sites, which generally were in the small change category. Mud flats also showed greater variability than salt marshes, with sites in the advance and recession categories. Like the salt marshes, the shell beach and mud bank shorelines were in the small change category.

The sandy beach at San Luis Pass (Site 1a) showed recession at a rate of -39 feet/year. This estimate is relatively close to those made by others (Seelig and Sorenson, 1973; Benton et.a., 1979). These authors reported erosion at a rate of over 60 feet/year. The sandy beach at site 1b, however, was found to be in the small change category (-.62 feet/year). This is similar to the conclusion made by Fisher et. al. (1972) that the southwest tip of the island is undergoing accretion.

The sandy beach at Jamaica Beach Subdivision (Site 2) was found to be in the small change category (-.16 feet/year). This figure is in disagreement with other studies that found erosion rates of 10-12 feet/year (Seelig and Sorenson, 1973; Benton et.al., 1979).

Table 2. Erosion/Accretion rates of the five shoreline types based on the field study and photographic analysis.*

Shoreline Type/Location	Field Study (Feet/Year)	Aerial Photography (Feet/Year)**	Category***
Sandy Beach			
1a. San Luis Pass	--	-39.9 (73-79)	extreme recession
b. San Luis Pass	-0.6	---	small change
2. Jamaica Beach	-0.2	-4.2 (73-79)	small change
3. West End of Seawall	-0.4	-4.2 (73-79)	small change
4. East Beach	--	+21.9 (73-79)	high advance
Mud Flat			
1. San Luis Pass	+9.2	---	advance
2. Sportsman's Road	-5.6	---	recession
3. East Beach	+5.7	---	advance
Salt Marsh			
1. Sportsman's Road	-3.1	---	small change
2. 103rd Street	-5.2	+4.2 (73-79)	recession
3. Airway Lane	+0.6	+3.4 (55-73)	small change
4. East Beach	+2.7	+2.1 (73-79)	small change
Shell Beach			
1. Pelican Island	+2.7	---	small change
Mud Bank			
1. Pelican Island	-0.2	+2.0 (55-79)	small change

* Plus signs denote accretion; minus signs denote erosion

** Aerial photography results that are underlined are those which are significant according to the "smallest measurable change per year" calculations. Those not underlined must be disregarded.

*** Categories based on the classification system created by Seelig and Sorenson (1973).

The sandy beach in the area immediately west of the end of Seawall Boulevard (Site 3) was an area of critical erosion classified by the U.S. Army Corps of Engineers, Galveston District in 1971. The field study, however, found a change rate of -.42 feet/year (small change category).

The field study at East Beach (Site 4) (the only sandy beach site in the study area with a prominent dune system) was unsuccessful. Placement of the stakes in front of the dune most likely acted as a barrier and resulted in their burial. The stakes were replaced twice and after the loss of the second set, the site was abandoned. The photographic analysis found the same area of East Beach (northeast of the South Jetty) to be accretional with a rate in the high advance category (+21.87 feet/year). This is consistent with other studies that found the area to be accretional (Fisher et.al., 1972).

Mud flats were also found to be rather variable. The sand tidal flats associated with tidal passes were found to be accretional in the advance category. San Luis Pass (Site 1) and East Beach (Site 3) tidal flats has accretion rates of +9.18 and +5.74 feet/year, respectively. The true mud flat at Sportsman's Road (Site 2) showed erosion at a estimated rate of -5.15 feet/year (recession category). Since all mud flats lack a visible "cliff" line or vegetation line, photographic analysis is impossible (Morton, 1978) and was not attempted.

The field study of the salt marsh shoreline at the west end of Sportsman's Road (Site 1) found the area to be erosional, but in the small change category (-3.1 feet/year). In support, this area has been reported as being accretional or in depositional - erosional equilibrium (Fisher et.al., 1972). Due to the lack of coverage of the area on two sets of aerial photographs, the photographic analysis was not possible.

The salt marsh at the north end of 103rd Street (Site 2) is in the recession category (-5.24 feet/year), according to the field study. This figure is in disagreement with reports of depositional - erosional equilibrium in the area (Fisher et.al., 1972).

Both the field study and photographic analysis for the area of Airway Lane (Site 3) found that the marsh falls in the small change category. The field study result was +.55 feet/year; the aerial photography result was +3.4 feet/year. This area has been documented as being in depositional-erosional equilibrium (Fisher et.al., 1972).

The field study of the East Beach salt marsh (Site 4) found the area to be accretional, but in the small change category (+2.69 feet/year). This is consistent with other reports (Fisher et.al., 1972).

Overall, the shell beach/mud bank shoreline of Pelican Island (Site 1) is accretional, according to the field study. The data, however, falls into the small change category (shell beach: 2.73 feet/year, mud bank: -.17 feet/year). This is in agreement with reports made by Fisher et.al. (1972) that the west shore of Pelican Island is accretional.

When the data for the field study and photographic analysis is compared for all shoreline types and locations, large disagreement is evident. In general, the calculations from the photographic analysis were higher than those from the field study. It must be remembered, however, that most of the aerial photography data must be disregarded, since they are not significant.

DISCUSSION

There are several factors that are related to shoreline stability. Some of these are: sediment supply, littoral transport, vegetation, and climate. Since the rivers of the upper Texas coast do not carry significant volumes of sediment (U.S. Army Corps of Engineer, Galveston District, 1971), Galveston Island must get the majority of its sediment from littoral transport. Net littoral transport along the island is from northeast to southwest (Benton et.al., 1979). Vegetation is also important in shoreline stability since it plays a role in trapping wind blown sand or sediment suspended in the water column. The roots of vegetation also act to hold the sediment in place. Periodic storms and hurricanes can also be important since they can cause major erosion to take place in a very short time. A stable shoreline is usually characterized by an adequate sediment supply, abundant vegetation, and energy conditions that promote at least a depositional - erosional equilibrium. An unstable shoreline can be caused by the absence of any one combination of these factors.

In regard to the field study and photographic analysis, the sandy beach sites showed highly variable rates of erosion and accretion. The primary factor concerned here is location, which governs sediment supply. The East Beach sandy beach (Site 4) is located north of the South Jetty (See Figure 2). Consequently, it traps the northeast to southwest littoral drift and accretion occurs. By the time the currents reach San Luis Pass (Site 1) the flow has been interruped by a series of jetties and groins and sediment input is insufficent. The reason for the extreme differences in erosion/accretion rates between site la and lb at San Luis Pass is also due to location. Site la is on the Gulf shoreline and thus receives little sediment, while site lb is on the bay shoreline and get an excess of sediment from the tidal channel (See Figure 2).

The results of the field study at sandy beach sites 2 and 3 are very contradictory to previous reports. Jamaica Beach and the west end of Seawall Boulevard have been documented as being highly erosional, yet the field study found that they fall in the small change category. Two explanations are possible. The first deals with Hurricane Alicia that devastated the area two months before the start of the field study. It is a common occurance that after a period of high erosion, there is a natural accretionary period that follows to compensate for the losses. This accretionary period may have fallen within the study period and thus altered the results, causing the normal trends to be shadowed. The second explanation is that the six months of field study was not long enough to show the actual long term trends that are present.

The field study found that mud flats are also highly variable. The results suggest that they too vary with location. The sand tidal flats were found to be advancing, while the true mud flat associated with a salt marsh was undergoing recession. It must be noted that this trend is probably not actually occurring. This is because the estimation of slope to convert to horizontal distance most likely introduced large errors. Nevertheless, it can be concluded that mud flats are highly variable and often shifting environments.

The salt marsh sites were found to be relatively stable environments, usually in the small change category. This is quite different than the results for sandy beach and mud flat shorelines. This stability has to do with their presence in low energy environments, as well as their ability to buffer waves and trap sediment. Salt marsh stability, however, also seemed to vary with location. Marshes at Airway lane (Site 3) and East Beach (Site 4) are more protected from waves than those at Sportsman's Road (Site 1) and 103rd Street (Site 2) (See Figure 2). Consequently, the six months of monitoring may not be representative of the actual annual processes. Another explanation is that the exposure of the area to higher waves has actually resulted in the beginning of a long-term erosional trend.

The shell beach/mud bank shorelines showed overall accretion in the small change category. However, if dredge spoil disposal is still active along this shoreline, the results may not indicate the real trends. Nevertheless, shell beaches show highly variable shapes and outlines over a single tidal cycle.

In general, salt marsh shorelines were found to be the stablest shoreline type in the study area. Erosion is possible, but the rate is usually low. Sandy beaches and mud flats were found to be capable of accretion as well as erosion, but the rates are much more variable than for salt marshes. Although shell beach/mud bank shorelines showed overall slight accretion, there shape is quite variable. Therfore, for coastal management purposes, the creation of salt marshes where possible can stabilize a shoreline. In addition, construction in the vicinity of these other shoreline types must be carefully planned.

The use of the "point-stake method" for monitoring shoreline position proved to be successful for most of the shoreline types in the study area.

It is not recommended that this method be used along sandy beaches with dune systems and along shell beaches, since burial of the stakes is almost guaranteed. The use of field studies and aerial photographs each have their own advantages and disadvantages. These can be seen in a comparison of the data from the two methods. Field studies provide accurate data, but are limited to discrete points along the shoreline and only show short-term trends. Conversely, aerial photographs can determine long-term trends, but reveal less information on the periodicty of erosion or accretion and are less accurate. Thus, any thorough investigation of shoreline stability should involve the use of both of these methods.

CONCLUSIONS

The research found that salt marsh shorelines are the most stable shoreline type in the study area, since their erosion/accretion rates are much less variable than those of different shorelines. The most important factor effecting shoreline stability in the study area is location, which determines sediment input and energy conditions. The use of the point-stake method proved to be successful at most field study sites. It was also concluded that the use of both a field study and a photographic analysis is necessary for a thorough investigation of any shoreline's stability.

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