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GALVESTON DISTRICT, CORPS OF ENGINEERS
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REPLY TO
ATTENTION OF:

Planning Assistance to States Program

SECTION 22 REPORT

Galveston Beach Groinfield Maintenance Material Placement

U.S. Army Engineer District, Galveston
Southwestern Division
August 1992

GALVESTON BEACH GROINFIELD
MAINTENANCE MATERIAL PLACEMENT
(SECTION 22 REPORT)

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INTRODUCTION

This report has been prepared as part of a cooperative agreement between the State of Texas and the United States Army Corps of Engineers, Galveston District under the Planning Assistance to States Program. The lead agencies for the State of Texas have been the Texas Water Development Board under the direction of the Executive Administrator, Mr. Craig Pedersen, and the Texas General Land Office led by Land Commissioner, Mr. Garry Mauro.

AUTHORITY

Section 22 of Public Law 93-251 authorized Federal cooperation with States in the preparation of water resources related plans. This law was amended by Section 921 of the Water Resources Development Act of 1986, Public Law 99-662, which limited expenditures to $300,000 per State in any one year. Further policy decisions have imposed cost sharing between the Federal Government and States beginning in Fiscal Year 1991 to a 90-10 ratio, changing to 70-30 in Fiscal Year 1992, then to 50-50 in Fiscal Year 1993 and beyond.

PURPOSE AND BACKGROUND

The purpose of this report is to describe the various factors to be considered in the possible use of dredged maintenance material from the Galveston Harbor Channel for placement in the Galveston groinfield to increase the useable beach area for recreation purposes. One of Galveston Island's major tourist attractions is its 28 miles of beaches along the Gulf of Mexico shoreline.

A primary consideration in taking material accumulated in a navigation channel and placing it on a beach is that it be "beach quality" material. What constitutes "beach quality" material is subject to debate as there is no specifically defined criteria. Or stated in the form of a question, what sand fraction must the material have to be defined as beach quality material? The answer is somewhat subjective and is based on a number of factors including appearance of the material, how desperate the material is needed, the cost to obtain and place the material, and other non-scientific factors.

It should be noted that the consideration for placement of material from the Galveston Harbor Channel is generically referred to as a "project" in this report. However, this action is not termed a project in the same context as a Congressionally authorized and Federally funded and constructed undertaking. The content and discussions contained in this report are focused solely on the evaluation of an alternate placement site for the dredged material from the Galveston Harbor Channel.

Historically, dredged maintenance material from various segments of the Galveston Harbor Channel has contained relatively high percentages of sand. The channel material which is deposited by wave and current action, agitated by currents and ship propellers, and finally picked up by hydraulic pipeline dredges typically contain varying percentages of silts and clays, and shells and shell fragments contained within the discharged material. Similarly, material from the existing remaining natural beach along the seawall contains a small percentage of silts and clays.

Because of the nature of a pipeline dredge operating in open water conditions, some material other than shoal material from the channel bottom or sideslopes may be dredged and would result in non-beach type materials being picked up. These materials would normally be in small quantities, confined to a small area, and could either be covered or pushed into the surf zone to be sorted by wave action. These and other uncertainties are discussed later in this report.

The timing of the placement of the dredged material is critical to Galveston because of the tourist season and its importance to the local economy. The presence of silts and clays will temporarily cause a turbidity plume from the material as wave action removes the fines. This plume will be expected to last several weeks and possibly longer depending on the material properties and the intensity, direction, and duration of wave conditions. Accordingly, the winter months would be the only applicable time to place the material to avoid impacting the tourist season. Typically the tides are lower in the winter because of the series of continental air masses or cold fronts moving through the area. Should these lower tide conditions be present when the material is placed, it would allow better opportunities for shaping the material with land-based equipment.

DESCRIPTION OF THE AREA

Galveston Island is a 28-mile long barrier island, oriented in a northeast-southwest direction and varies in width from 1/2 to 3 miles. The City of Galveston virtually encompasses the entire Island. The densest developed portion of the City occupies the northeastern one-third of the Island and is protected from storm waves on the Gulf side by a concrete seawall approximately 10 miles long. The City's economy is centered around the Port of Galveston and the tourist trade which capitalizes on the natural amenities of the Island and adjacent waters of the Galveston Bay complex and Gulf of Mexico.

The Galveston Harbor Channel is a natural inlet, stabilized by twin jetties, and maintained for navigation purposes for the Ports of Galveston, Texas City, and Houston. The inlet is located between the barrier complex features of Bolivar Peninsula and Galveston Island and serves as the major tidal exchange for the 550-square mile Galveston Bay estuarine system.

Figure 1 shows the general study location and the various physical features of the area that will be referred to throughout this

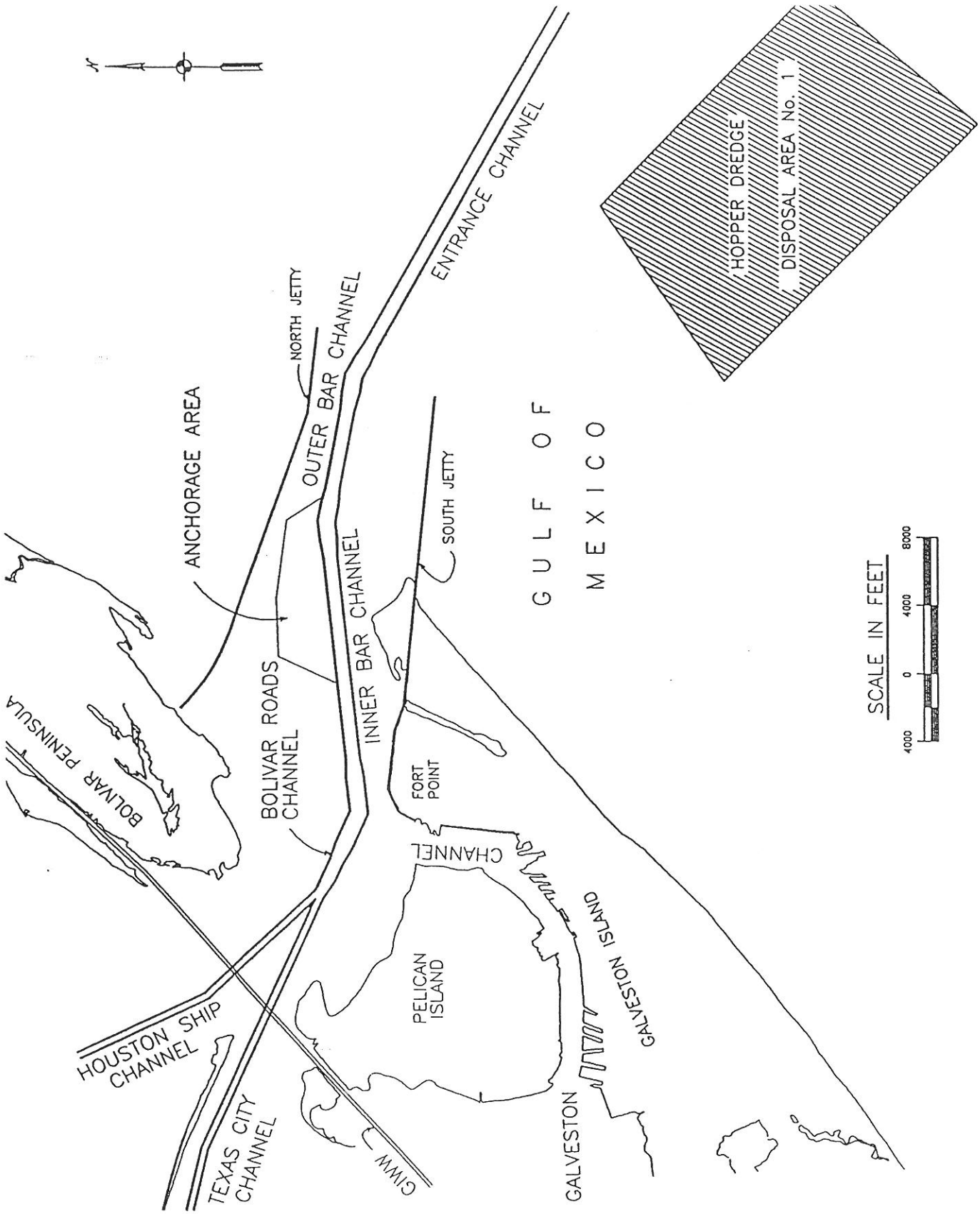


Figure 1. STUDY AREA MAP

report. The harbor area consists of the Bolivar Roads, Inner Bar, Outer Bar, and Entrance Channel segments. These collectively are referred to as the Galveston Harbor Channel. This area also contains an anchorage area adjacent to the Inner Bar Channel.

PRIOR REPORTS AND STUDIES

There has been no specific study or subsequent report that addresses the use of dredged material as beach nourishment for the Galveston groinfield area. However, several studies, both Federal and non-Federal, have identified the potential use of both new work construction and channel maintenance material as sources of beach nourishment. These have included studies in connection with the Galveston Bay Area Navigation Study and a private permit action requiring channel deepening for a facility on Pelican Island. At this time, these studies have not resulted in projects that would produce potentially useable beach quality material.

A report on beach erosion control at Galveston, printed in 1934 as House Document No. 400, 73rd Congress, 2nd Session, concluded that a system of groins would effectively protect the Galveston Seawall. As a result of this report, the groins were designed and subsequently completed in 1938. Rehabilitation of the Galveston groin system was authorized by the Chief of Engineers' letter, ENGCW-OM, dated October 27, 1960. This work was completed in 1970.

In response to House Committee Resolutions dated October 10, 1974 and September 22, 1976, the Galveston District conducted a feasibility study on the eroding shorelines of Galveston County and Surfside Beach in Brazoria County. The study known as the Galveston County Shore Erosion Study was completed in May 1985. The feasibility report recommended the construction and periodic renourishment of a 3.8-mile long segment of beach in the groinfield between 10th and 61st Streets and a 0.6-mile long reach at the western end of the Seawall.

The benefits derived from the groinfield portion of the project recommended in the feasibility report was exclusively from recreation. The benefits derived from the West Beach portion of the project were from damages prevented to development, and it was determined that the non-Federal portion of the total project costs were 85 percent. The local non-Federal sponsor, Galveston County, stated that the ratio was unacceptable. Processing of the feasibility report has been discontinued because recreation is not considered to be a high priority or primary project output under current Department of the Army policy. Construction of the recommended project for the groinfield segment was estimated to cost $15,388,000 at October 1984 price levels. Of this amount, $8,441,000 were non-Federal costs. In addition, it was estimated that the periodic renourishment of the beach would cost $228,000 on an equivalent annual basis. Of this amount, $129,000 were non-Federal costs.

EXISTING PROJECTS

FEDERAL PROJECTS

Galveston Harbor and Channel

This project includes the common entrance channel into Galveston Bay which serves the ports of Galveston, Texas City, and Houston; Galveston Channel; two rubble mound jetties; a concrete seawall; and a system of groins in front of the seawall.

Galveston Harbor Entrance Channel

The Galveston Harbor Channel is a common entrance used by all deep-draft vessel traffic between the Gulf of Mexico and Galveston Bay. This common channel serves the Galveston Channel, the Texas City Channel, and the Houston Ship Channel. The Galveston Harbor Channel consists of four sections: 1) the Entrance Channel with dimensions of 25,000 feet in length, 800 feet in width, and 42 feet in depth; 2) the Outer Bar Channel with dimensions of 8,764 feet in length, 800 feet in width, and 42 feet in depth; 3) the Inner Bar Channel with dimensions of 16,864 feet in length, 800 feet in width, and 40 feet in depth; and 4) Bolivar Roads Channel with dimensions of 5,048 feet in length, 800 feet in width, and 40 feet in depth. It should be noted that throughout this paper all depths and elevations refer to the mean low tide (mlt) datum unless specifically labelled otherwise. A 36-foot deep anchorage basin is located immediately adjacent to the west side of the Inner Bar Channel.

Construction of the Galveston Harbor Entrance Channel began in the 1870's with improvement of a natural pass between Galveston Island and Bolivar Peninsula with a 15-foot channel and the South Jetty. The project was frequently modified throughout the late 1800's and into the 1900's. By 1923 the Outer Channel was 500 feet wide and the Inner Channel was 700 feet wide with depths of 35.5 feet and 32.5 feet, respectively. Dredging of the realigned Entrance and Outer Bar Channel was completed to a depth of 36 feet in 1967. The project was completed to its current dimensions in 1976.

Galveston Channel

The Galveston Channel has a project depth of -40 feet and a width of 1,125 feet. Ships are turned within the channel with tug assistance. The principal commodities of the port are grain, lumber, and raw sugar. The Port of Galveston also has a full service container terminal.

Galveston Jetties

Construction of the Galveston Jetties was begun in 1887 and, after improvements and extensions during later years, was completed in 1907. The Jetties are rubble mound with single-layer cover stone consisting of 4- to 6-ton granite blocks and generally a top elevation of +5 feet. The North Jetty is 25,907 feet long and the South Jetty is 35,900 feet long.

Galveston Seawall

The 10-mile long Galveston Seawall was constructed in various increments from 1902 to 1962 by both separate and joint Federal and non-Federal actions. The seawall structure along with raising the island with dredged material, often referred to as the grade-raising, was prompted by the devastation of the September 8, 1900

Storm that killed an estimated 6,000 people on Galveston Island. City leaders decided to rebuild the prior thriving resort city of a population of 38,000 people, but to provide necessary protection from storm surges of future hurricanes. Galveston County began constructing the Seawall in 1902 that extended along the Gulf shore from 39th Street to 6th Street and then northward across the island along 6th Street to near the Galveston Channel. The Federal Government constructed a similar seawall in front of the Fort Crockett Reservation from 39th to 53rd Streets. These two sections were completed in 1905 and are known as the "Original Seawall". The 6th Street portion of the seawall which was perpendicular to the shoreline was no longer needed when the Seawall was extended to 1st Street in 1921. The end of this now abandoned section of the seawall is under a building on the University of Texas Medical Branch campus.

Other seawall extensions were completed in 1923 and 1927. The last 3-mile section of the Seawall extending westward from 61st Street was nearing completion when Hurricane Carla struck in 1961. Some damage was sustained to the uncompleted seawall. These damages were repaired and the wall was completed in 1962. Several studies have been made to further extend the wall, but no current plans are active to provide additional extension.

Table 1 shows a chronological listing of the construction of the various segments of the Seawall.

Table 1
CHRONOLOGICAL CONSTRUCTION SEQUENCE
OF THE GALVESTON SEAWALL

REACH	CONSTRUCTED BY	DATE
39th St.to 6th St.	Galveston County	1902-1904
39th St.to 53rd St. (Fort Crockett)	U.S. Government	1904-1905
6th St. to 1st St.	U.S. Government, paid for by Galveston Co.	1918-1921
1st St. to South Jetty	U.S. Government	1918-1926
53rd St. to 61st St.	Galveston County	1926-1927
61st St. westward 3 miles	U.S. Government with 35% non-Federal and 65% Fed. cost sharing	1953-1963

Galveston Groinfield

Various types and configurations of groins have been placed in front of the Seawall since its earliest construction. Several stone rubble groins were constructed prior to 1909 and additional small wooden groins were constructed by local interests at various times prior to 1922.

A cooperative beach erosion control survey, made in 1934 by the Beach Erosion Board of the Corps of Engineers, concluded that sand could best be retained Gulfward of the Seawall to provide protection to the toe of the structure by the construction of a system of groins from 12th to 61st Streets. Of a secondary nature, the Board further concluded that a groin system might also provide for an emergent beach should there be sufficient sand materials moving along this portion of the shoreline.

Congress authorized the proposed groin system in 1936, and a system of 13 groins, each 500 feet long and approximately 1,500 feet apart, between 12th and 59th Streets, was constructed from 1936 to 1939. The groins consisted of interlocking steel sheetpile with timber wales and support piles. The groins accumulated and retained considerable quantities of beach material, most of which was below mean low tide, and kept the toe of the Seawall well protected.

The timber piling in the groins gradually deteriorated under attack by marine borers and the steel sheet piling succumbed to oxidation combined with the corrosive action of sea water and sand abrasion, until the structures were no longer functional and rehabilitation became necessary. The rehabilitation consisted of replacing the wood and steel sheetpile groins with rubble mound groins and reconfiguring the groinfield. Four rubble mound groins previously constructed by Galveston County as fishing piers were incorporated into the groinfield. The rehabilitated groinfield consists of 15 groins between 10th and 61st Streets. The large evenly placed cover stones of the groins permit access by sightseers and fishermen. This rehabilitation and reconfiguration was accomplished from 1968 to 1970.

The primary purpose of the groins are to retain sufficient quantities of sand adjacent to the Seawall to preclude exposure of the untreated timber piling of the Seawall foundation to prevent attack by marine borers. (The pilings under the Seawall from 61st Street westward are reinforced concrete pilings.) The groins have performed well in this regard and continue to do so as a large portion of the accretion and retention of the sand has occurred below the mean low tide elevation. A narrow beach continues to be retained by the groinfield. A secondary purpose was to build and retain a suitable beach for recreation. Because of net losses of materials during hurricanes and the lack of additional littoral materials entering the area, a recreational beach has not accreted. This does not detract from the original purpose of the groinfield.

Maintenance Dredging

From 1970 to the present, the Galveston Harbor Channel has been dredged with hopper dredges with the material deposited 5 miles offshore off of East Beach. Between 1980 and 1990, there have been 5 dredging contracts, averaging a 2-year dredging cycle. The outer portion of the Entrance Channel can not be dredged by conventional bay pipeline dredges since the dredges have little freeboard and are not designed to function in sea swells and wave conditions which are frequently encountered in the Gulf.

Material from the Outer Bar, Inner Bar, and Bolivar Roads channels and the anchorage area could be removed by other means besides hopper dredge. The potential beach quality sand is located in the interior channels and is, therefore, accessible by conventional pipeline dredges that could pump directly on the beach with the use of booster pumps. Hopper dredges with pipeline pump-out capability could be used in conjunction with facilities to connect to a pipeline to allow discharge directly on shore.

NON-FEDERAL PROJECTS

Galveston Seawall

Galveston County constructed the first portion of the Seawall beginning at 39th Street and proceeding eastward in 1902. This portion of the Seawall extended parallel along the beachfront to 6th Street and turned northward along 6th Street terminating near the Galveston Channel just south of present-day Strand Boulevard. The County also constructed the segment of the Seawall from 53rd Street to 61st Street between 1926 and 1927, paid for the 6th Street to 1st Street section which was constructed by the Federal Government, and cost-shared in the westward 3-mile extension from 61st Street between 1953 and 1963.

BENEFICIAL USE OF DREDGED MATERIAL POLICY

It is a long-standing policy of the Corps of Engineers to secure the maximum practicable benefits through the use of dredged material from authorized navigation channels and harbors, provided extra cost is not incurred. Section 145 of the Water Resources Development Act of 1976 confirmed this existing Corps policy by stating:

> "... upon the request of the State, to place on the beaches of such State beach-quality sand which has been dredged in constructing and maintaining navigation inlets and channels adjacent to such beaches, if the Secretary deems such action to be in the public interest and upon payment of the increased cost thereof above the cost required for alternative methods of disposing of such sand."

This policy was further amended by Section 933 of the Water Resources Development Act of 1986. This Section of the Act provides that the Federal Government may share up to 50 percent of the additional cost of placement of beach-quality sand on adjacent beaches provided the following requirements are met:

a. Placement of the material on a beach and Federal participation in the costs must be requested by the State in which the beach is located;

b. The added cost of such placement must be justified by the benefits associated with protection of such beach or beaches;

c. The storm damage reduction benefits resulting from the beach protection must exceed 50 percent of the total benefits, unless the placing of dredged material is economically justified based on storm damage reduction benefits alone, or on the combination of storm damage reduction benefits and an equivalent amount of incidental recreation benefits if

incidental recreation benefits exceed 50 percent of the total benefits;

d. The beaches involved must be open to the public;

e. The placement must be environmentally acceptable, pursuant to all applicable statutes and regulations;

f. Local interests must pay 50 percent of the added cost of disposal above the alternative the least costly method of disposal; and

g. Local interests must provide (without cost sharing) any necessary additional lands, easements, rights-of-way, and relocations.

The State in which the beach is located is the only acceptable non-Federal sponsor for Section 933 projects.

In the event that all of the foregoing conditions not pertain, the Corps policy is to place beach-quality material dredged during construction and maintenance of Federal navigation projects, onto beaches or nearshore waters, even though more costly than alternative means of disposal, if the State requests the material to be placed on the beach and local interests pay 100 percent of the added cost above the alternative least costly method of disposal.

EXISTING CONDITIONS

Galveston Island is a barrier island consisting of a relatively wide sand body with numerous ridges and swales. These features are evident along the undeveloped areas of the Island and particularly along the middle portion of the Island and extending westward toward San Luis Pass. Prior to construction of the Seawall and the raising of the grade, the now densely developed easterly portion of the Island consisted of a relatively low barrier island with a natural barrier ridge elevation of 6 to 8 feet above ordinary high water. These natural features were irreversibly altered in the late 1800's and early in this century by the construction of the Jetties and the Seawall.

SHORELINE CONDITIONS

East End of Island

Prior to the construction of the Jetties, the easterly end of the Island consisted of a tidal flat with numerous interconnecting channels. With the inlet stabilized by jetties, the shoreline began to grow seaward as materials accumulated adjacent to the Jetties and became stabilized by vegetation. It should be noted that the net littoral drift along the upper Texas coast is from the northeast to the southwest.

The functions of the Jetties are to control cross currents for ships entering and exiting the navigation channel into the bay system and to facilitate channel maintenance by intercepting material that would normally be deposited in the channel. The Seawall has served to limit the landward retreat of the Gulf shoreline. The affects of the Jetties and the Seawall are not totally separable, however, the greatest influence on shoreline changes in this area has been the Jetties.

A triangular fillet has been formed along the eastern end of the Island that is bounded by portions of the South Jetty, the Seawall, and the Gulf shoreline. The distance from the intersection of the Seawall and the South Jetty, measured along the Seawall to near 10th Street is approximately 3.2 miles long. Presently, the distance from the South Jetty measured along the shoreline to near 10th Street is approximately 3.8 miles. The area described above is shown in Figure 1.

The fillet has increased in size since the construction of the Jetties, most notably that portion of the triangular-shaped area measured immediately adjacent to the South Jetty. This fillet has accreted as a result of the Jetty being constructed, the Jetty's orientation with respect to the prevailing winds, the location of the offshore dredged material disposal area, and various currents generated in the vicinity of the tidal pass. The present-day shoreline is now in excess of 8,000 feet from the end of the Seawall.

The accretion rate immediately adjacent to the South Jetty has averaged in excess of 40 feet per year from 1930 to 1982. Over the same time frame, the shoreline accretion rate gradually decreases proceeding westward from the Jetty to approximately 3.3 feet per year near 10th Street.

Groinfield (10th Street to 61st Street)

The groinfield is relatively stable as is the area fronting the Galveston Seawall west of the groinfield although some areas have undergone moderate erosion particularly near the western end of the Galveston Seawall. Between 1974 and 1982 significant emergent accumulations of sand are found only in pockets adjacent to the groins. In many areas, the riprap protecting the base of the seawall is the shoreline. Current rates of erosion are lower than longer term (1933 to 1973) rates simply because no beach remains and the seawall limits additional shoreline retreat.

The area from 10th Street to 61st Street, a distance of approximately 3.8 miles, which coincides with the present groinfield, has demonstrated remarkable volumetric stability. Some material, although, has been gradually lost over the years through natural movement between groins and offshore, or has escaped to the east or west through littoral currents and various storm processes such as currents generated by varying direction, duration, and intensity.

61st Street Westward

Beyond 61st Street to the end of the Seawall, a distance of about 3 miles, there is virtually no emergent beach. This reach is void of any structures which would retard the movement of sand from the area. The area immediately west of the seawall has retreated significantly at the rate of about 15 feet per year on the average between 1956 and 1982. Progressing westward along the shoreline, the shoreline erosion rate uniformly has decreased to an essentially stable condition within about 5 miles from the end of the Seawall over this same time frame. The erosion occurring at the westerly end of the Seawall is typical of shore parallel coastal structures. The wave energy delivered to the end of the structure and adjacent beach are absorbed or reflected by the structure, but the beach must dissipate the wave energy through the displacement of sand particles. This results in beach retreat.

NATURAL FORCES

The shoreline area is constantly subjected to forces that are generated by the wind, tides, storms, and sea level rise. The effects of these forces can literally be measured from seconds to centuries. The results of each breaking wave as to movement of sand particles on the beach occurs within a matter of seconds. Conversely, sea level rise is gradual and quantitative projections are usually given per century or as a minimum in decades.

The wind has a great influence on the movement of beach materials along the shoreline as it causes surface currents. The wind varies considerably in intensity, duration, and direction. Wind speeds and direction can change rapidly because of the movement of various fronts through the area which either originate from the continental land mass or from the Gulf of Mexico. The wind determines the wave heights and normally the direction of the littoral currents. Because of this variability there are numerous reversals allowing an individual sand grain to be moved onshore, offshore, or laterally in either direction. The collective result of the movement of these individual sand grains over periods of time determines whether or not a specific area accretes, erodes, or is stable.

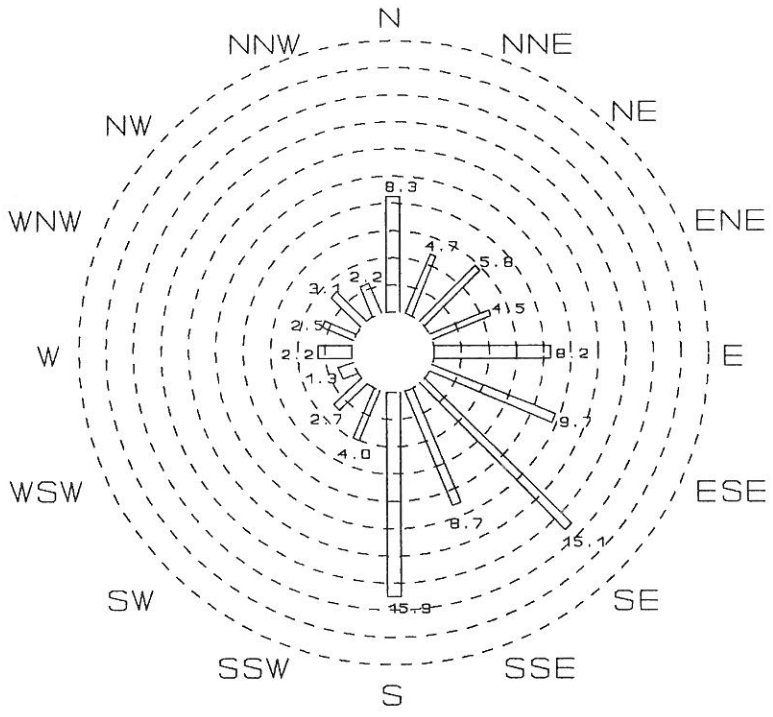
Storms and hurricanes can cause an evulsive and dramatic impact on the shoreline over a period of a matter of hours or a few days. Depending again on the intensity and duration, storms may significantly move the shoreline landward. Typically, some of the beach material is transported offshore while significant quantities may be moved inland or into a back bay. The material moved offshore will normally be in the form of an offshore bar which will migrate onshore and naturally repair some of the damage caused by the storm. However, there is inevitably a net loss in material. The material moved inshore and beyond is often permanently lost to the littoral system.

Winds

The wind affects the shoreline by generating waves and coastal currents which are the primary agents of nearshore sediment transport, causing rises in the Gulf water surface which inundates areas not generally affected by the astronomical tide. The effects of wind on the shoreline is a function of the wind velocity, direction, and duration. For the Galveston area, the wind strength is greatest from the south and southeast from March through November; however, from December through February it is greatest from the north. The yearly average wind rose shows that over 40

percent of the wind observations are from the southeast and south. A wind rose for the Galveston area for the 1958 to 1963 period is shown in Figure 2.

Figure 2
GALVESTON WIND DIRECTION
Percent, Frequency of Occurrence



Data based on National Weather Service Information
December 1958 thru September 1963

Tides and Water Levels

The tides in the Galveston area are chiefly diurnal, one high and one low, with evidence of intermediary highs and lows. The typical astronomical range is from 1.8 to 2 feet along the beach front and in the inlet. Maximum monthly tidal ranges occur during June and December. Minimum ranges occur during September and March. Most of the tidal behavior is due to astronomical forces. However,

meteorological effects also cause some variation. The predominant southeasterly winds from March through November add a rise in the mean water level during these months. The predominant northerly winds from December through February cause a fall in the mean water level during the winter.

Storms

Two types of storms affect the Texas coast, northers and tropical storms or hurricanes. Because of the orientation of the island and the alignment of the Seawall, northers tend to lower the water surface thereby pushing the shoreline Gulfward. Some material may be moved offshore, but overall the impact of northers on the beach front adjacent to the Seawall is minimal.

Tropical storms and hurricanes, on the other hand, have had a significant affect on the Gulf shorelines on Galveston Island. This area has been subjected to frequent influences of hurricanes. The storms that annually threaten the Texas coast generally originate during the months of June through October in the tropical Atlantic, the Caribbean Sea, or the Gulf of Mexico. During the 20th century, hurricanes have struck the Texas coast an average of once every 2-1/2 years. A total of 12 hurricanes have made direct landfall between Sabine Pass and Freeport on the upper Texas coast between 1900 and 1991.

Table 2 shows the relationship between various water level elevations and their corresponding return frequencies.

Table 2

WATER SURFACE ELEVATION AND

CORRESPONDING RETURN FREQUENCY

Return Frequency	Still Water Level Elevation (Feet NGVD)
2-year	3.2
5-year	4.8
10-year	6.1
25-year	8.2
50-year	10.0
100-year	12.0

Sea Level Rise

Long-term changes in the mean sea level can be caused by a variation in the absolute sea level or by land subsidence. Both cause the average sea level to rise in relation to the land with erosion resulting. Land subsidence can be caused by either localized influences such as excessive groundwater withdrawals or from geologic compaction processes.

Long-term records interpreted by several researchers have determined that the relative sea-level rise ranges from 0.013 to 0.020 feet per year or 1.3 to 2.0 feet per century along the Texas coast. The National Research Council's publication "Responding to Changes in Sea Level: Engineering Implications," shows the extreme projection (Curve III) to be on the order of 0.6 meters or about 2.0 feet during the next 50 years. The placement of material on the beach would not be expected to be affected from sea level rise.

BIOLOGICAL RESOURCES

Usually only a few species of animals are found on the Gulf beaches and these fauna are highly specialized to adjust to the highly variable and dynamic environment. The ghost crab is characteristic of the drier beach sand. Large numbers of coquina clams inhabit the intertidal area of the foreshore zone and are an important food source for fish, crabs, and shore birds. Common bottom inhabitants include such fauna as hermit crabs and blue crabs which can rapidly adapt to a changing bottom configuration. The sand dollar, sea star, sea pansy, and several boring organisms are also found in the shallow, bottom habitat at the Gulf shoreline.

A variety of bivalves occupy the nearshore area where waves break and also the calmer water just seaward of the breaker zone. Their shells and shell fragments wash ashore and contribute to beach building. A variety of birds such as gulls, terns, plovers, and sandpipers feed and scavenge on small marine organisms found washed onto the Gulf beaches.

The shallow waters of the Gulf beach environment support a large number of small fish which include the young of larger, deeper-water species. Important species are the scaled sardine, Florida pompano, Atlantic threadfin, Atlantic bumper, bay anchovy, striped mullet, the tickwater silverside, and several species of killifish. Many larger fish are also found just off the Gulf beaches including red drum, black drum, Gulf whiting, sea catfish, flounder, pompano, sand seatrout, and Atlantic croaker.

The stone, rock, and rubble of the groins which are in the splash, tidal, and subtidal zones serves as attachment substrate below mean high water for a community of fouling and encrusting organisms such as algae, oysters, barnacles, hydroids, bryozoans, etc. These hard features of the groins contribute to the ecological diversity of the shoreline area by providing stable habitat for motile organisms such as snails, false limpets which graze the algae, and scavengers such as rock lice and crabs. Predators such as oyster drills, crabs, shrimp, and fish also benefit from these artificial