Planning Assistance to States Program

SECTION 22 REPORT

Galveston Beach Groinfield Maintenance Material Placement

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

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
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REPLY TO
ATTENTION OF:

Planning Assistance to States Program

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Maintenance Material Placement

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MAINTENANCE MATERIAL PLACEMENT
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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

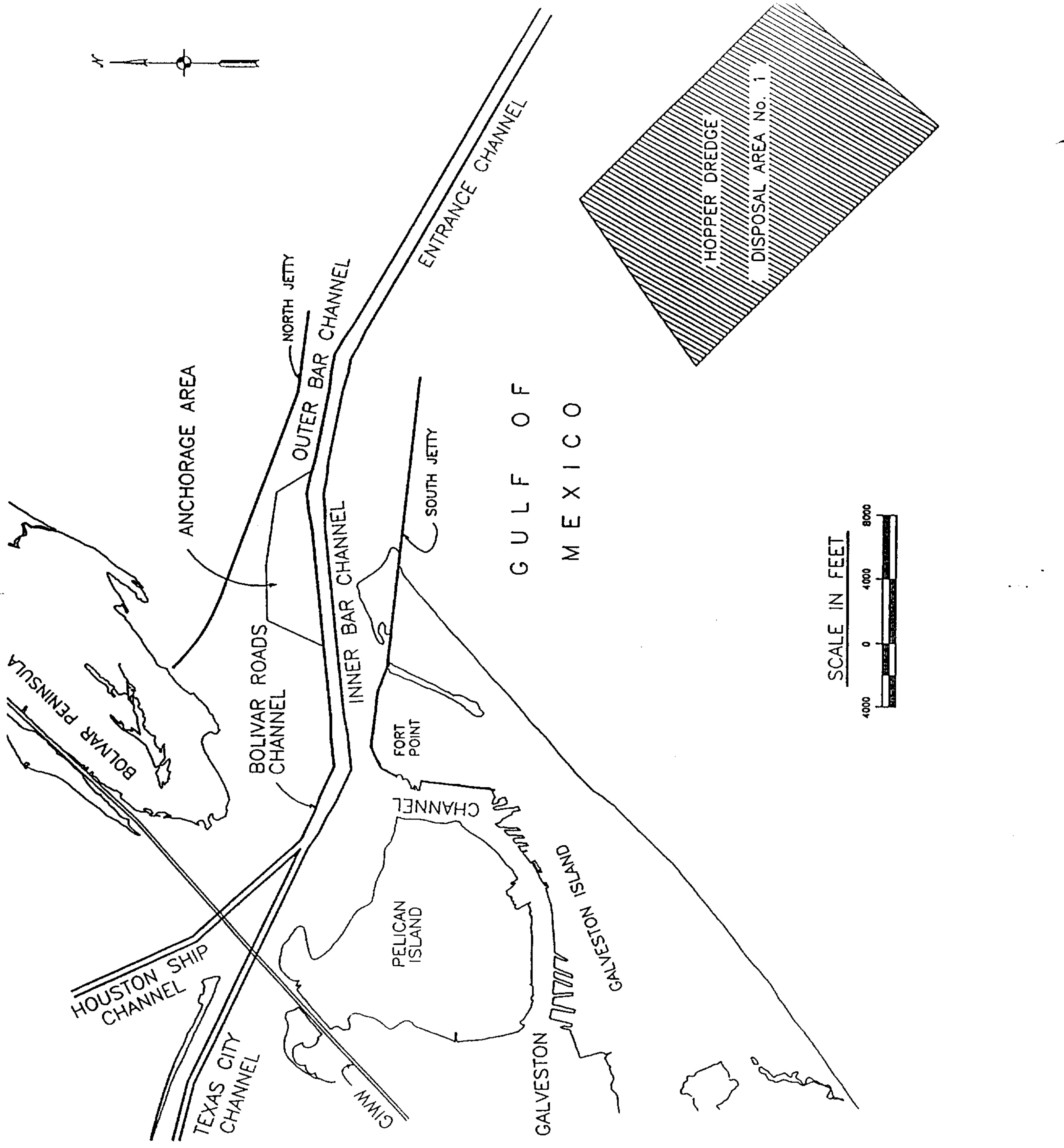


Figure 1. **STUDY AREA MAP**

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.

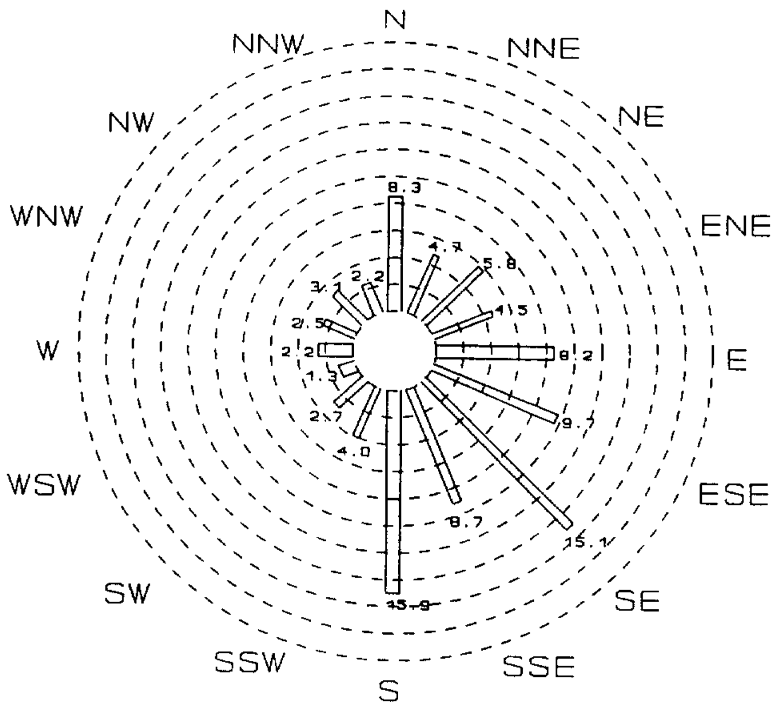
The wind has a great influence on the movement of beach materials along the shoreline as it causes surface currents. The wind varies considerably in intensity, duration, and direction. Wind speeds and direction can change rapidly because of the movement of various fronts through the area which either 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 structures by the establishment of a new prey source otherwise unavailable along a natural shoreline.

CULTURAL RESOURCES

Galveston Island has an interesting and colorful history with earliest accounts being of the Karankawa Indian inhabitants of the Island at the time of initial European contact. European settlement of Galveston Island began in 1816 when the Island became the headquarters for pirates and revolutionaries such as Aury and Mina, the LaFitte brothers, Henry Perry, and Dr. James Long. The smuggling activities of LaFitte and others induced the Mexican government to establish a garrison of Mexican soldiers and a custom house on the Island in 1830. By 1840, a town of over 3,000 had developed around a new wharf and expanded port facilities.

The only significant historic sites located along the Gulf shoreline on the eastern end of the Island were temporary Civil War fortifications and gun emplacements at the ends of several streets along the beach. These temporary fortifications scarcely outlasted the Civil War and no evidence of them remains due to erosion and Seawall construction.

Evidence of the military reservations of Fort San Jacinto and Fort Crockett remain of the large gun emplacement shore fortifications. There are numerous historical homes and other points of interest throughout the City of Galveston. The enhancement of the beaches would not be expected to impact any of the historically significant sites.

ECONOMIC RESOURCES

Economic activities for the City of Galveston are highly dependant on the Port of Galveston, the University of Texas Medical Branch, American National Insurance Company headquarters, Federal governmental agencies, the tourist industry, and related support and satellite industries. Without question, one of the primary attractions to Galveston Island is its natural features and more specifically, its 28 miles of beaches. Additional recreational beach area along the more developed portion of the City would concentrate the beach users to various business activities established to provide necessary specialized services.

SHORELINE REHABILITATION

The primary area under consideration by City and County officials to restore the beach is along a portion of the Galveston beachfront, from 10th Street to 61st Street, a distance of approximately 3.8 miles. This area coincides with the existing groin system that has been previously described.

There have been several attempts on behalf of the County and City over the past 25 years to supplement and enhance the remaining beaches in front of the Seawall. The most recent attempt was through a Federal feasibility report analysis which was completed in 1985. This study has been previously described in the "Prior Reports" Section above. The conclusion of the report involving possible nourishment of the groinfield area was that essentially all of the benefits of a beach project would be from recreational usage. The project was found to be economically feasible, however, recreational projects currently have a low Administrative priority and have not been funded. This project recommended the use of Big Reef as the borrow source.

There are insufficient quantities of beach building material entering this 3.8-mile area to offset the material that is being lost to natural processes. To rebuild a beach in this area, material must be "brought in" from off-site. This section of the report describes various alternative sources of material from a generic standpoint and the types of equipment required to add material to the beach.

MATERIAL SOURCES

There are several possible sources of fill material for renourishing Galveston Seawall beaches. All of which have specific factors which must be overcome and with some degree of risk involved. These sources include Big Reef, offshore, Fort San Jacinto disposal area, truck hauling or barging material from inshore areas, and the use of maintenance material from selected reaches from the Galveston Harbor Channel.

Big Reef

The Big Reef area is a sand spit located just inside the South Jetty between the intersection of the Seawall and Jetty and extends seaward to near the Gulf shoreline. It is about 3.8 miles from the beginning of the groinfield at 10th Street. The area is dynamic in that it is constantly changing as it is subject to various hydrodynamic and meteorological forces.

The spit area is formed by a combination of hydraulic forces from the channel area, from wind-blown deposits from the beach area, and from materials which have been transported onshore from the offshore dredged material disposal area. Because of the orientation of the Jetty system and the configuration of the channels within the tidal pass, the Big Reef area is a hydraulic nodal point. This simply means that the velocities in this area are lower than in other areas between the Jetties and sediments tend to deposit. In addition, there is a wide, flat beach area that the wind blows across moving sand across the South Jetty onto the sand spit, building dunes which become vegetated and serve as habitat for various birds and small animals.

The development process of Big Reef is that it is built-up by the hydraulic and aeolian processes described above and is torn down by storms. After Hurricane Carla in 1961, the Big Reef area consisted of only a few small emergent remnant islands. The area built back and was later damaged significantly by Hurricane Alicia in 1983. Big Reef has now recovered to its pre-Alicia condition and is continuing to expand. The destructive mechanism of a hurricane is the storm surge and the accompanying wave attack from the Gulf of Mexico. The top elevation of the South Jetty in the vicinity of Big Reef is approximately +5 feet, equivalent to +3.6 feet National Geodetic Vertical Datum. Therefore the Big Reef area is subject to storm surges with about a 2-year average return frequency.

As portions of the spit are washed away, these materials are deposited in the navigation channels, on the bay bottom, or depending on the location of the storm track, in the Gulf of Mexico. Hurricane tracks east of the Island produce the condition where counter-clockwise winds force the bay waters out the inlet and over the Jetty into the Gulf taking portions of Big Reef into the nearshore waters off the Island into deeper water within the jettied entrance.

The Big Reef area contains high quality beach material, is naturally renewable, and relatively close to the groinfield as a source for periodic nourishment for the beaches near the Seawall. At this time there is no Federal interest in building or rebuilding beaches strictly for recreational purposes, therefore, non-Federal interests would have to provide the full costs of such an undertaking.

Offshore Sources

During the feasibility phase of the Galveston County Shore Erosion Study, seismic profiles and some coring was obtained in an attempt to identify potential beach quality sand sources offshore. The inner shelf area from High Island to Freeport was surveyed and studied using high-resolution continuous seismic reflection profiles to determine the general geologic character of surface and sub-bottom sediment distribution. This effort has been documented in a Coastal Engineering Research Center publication, Miscellaneous Report No. 79-4, dated July 1979, titled "Sediment Distribution, Sand Resources, and Geologic Character of the Inner Continental Shelf Off Galveston County, Texas" by S. Jeffress Williams, Dennis A. Prins, and Edward P. Meisburger.

The results of the testing showed there is a high potential for sand that exists in 18- to 30-foot water depths in an area located just north of the offshore dredged material disposal area. However, these results are based only on two vibra-core samples and seismic profiles. The sand in this location is interbedded with muddy sand. Additional cores would be required to better define the limits and the practicality of this area as a potential borrow site for beach quality material. If all the material were recoverable and suitable for beach fill, the volume of material from this site is estimated to be 27 million cubic yards.

This site appears to have favorable potential as a borrow site, but would require additional verification. If this site was used as nourishment material for Galveston beaches, it would be entirely a non-Federal initiative based on the reasons previously stated in this report.

Fort San Jacinto Disposal Area

The Fort San Jacinto Government Reservation was converted into a leveed dredged material disposal area after World War II. Various quantities of new work construction material and maintenance material have been deposited at this location for a number of years. Material from Galveston Channel, the Inner and Outer Bar Channels, and the anchorage area have been periodically placed in this area. The material that was removed to construct the realigned Inner Bar Channel in the mid-1960's was also deposited in this area.

Historically, portions of the channels in close proximity to this disposal area have contained significant quantities of sand. The material placed in this area has been done so indiscriminately without consideration of segregating the sand materials from the silts and clays because it would have been impractical to do so. However, there are areas within the disposal area where there are significant isolated quantities of sandy material that could be selectively mined and hauled to a beach placement site. This, like the two previous alternatives, would have to be accomplished at non-Federal expense.

Inland Sources

Sand could be brought in from inland sites by truck or barge and off-loaded in the desired locations. The major disadvantage to this option, particularly from using trucks, is the transportation costs. The major advantage of this approach is that the grain size can be specified which would insure greater longevity of the beach.

By using barges which have lower per ton transportation costs than trucks, greater flexibility could be exercised in the selection of borrow sites, especially those which have water access. This could allow for versatility in grain size, color, and appearance of the beach materials.

Galveston Harbor Channel

The inner reaches of the Federally maintained Galveston Harbor Channel and anchorage basin have historically yielded material which contains a significant percentage of sand-size particles. These areas are usually dredged on a 2-year frequency and yield in the range of 1 million to 1.5 million cubic yards per dredging cycle of potentially suitable materials to be placed on a beach. The various tidal and current velocities in this area usually exceed the normal settling velocities for the smaller silt and clay particles and therefore, these smaller particles are deposited in other portions of the channel where velocities are lower. The quantities, locations, and sand percentages of the potential beach quality sand material varies considerably between dredging cycles.

The Corps of Engineers is required to dispose of maintenance materials in the least costly manner, consistent with appropriate laws and statutes. This procedure has consisted of the removal and deposition of the maintenance materials by hopper dredge in a designated offshore disposal site. The site is located on the west side of the Entrance Channel beyond the South Jetty. Additional discussions will follow on the type of dredging equipment, basic operational characteristics, etc.

As stated in the "Beneficial Uses of Dredged Material Policy" Section above, suitable beach materials may be placed on adjacent beaches if requested to do so by the State and the additional costs are borne by non-Federal interests. Under conditions where the placement of this material could result in significant storm reduction benefits, half of the additional costs could be provided by the Federal Government. However, for the Galveston beaches in front of the Seawall, there are no measurable benefits derived from storm damage reduction purposes, therefore all additional costs must be from non-Federal sources. This option would be the most advantageous for the local community. The major disadvantage of this option is that there is only limited quality control on the type of material which would be placed on the beach as the beach is being used as a disposal area and the operation is not a beach restoration project.

Summary of Borrow Sources

Based on the above options and the interest of the City, County, and State officials to restore the beach in the most expedient and cost-effective way possible, the use of maintenance material from selected reaches of the Galveston Harbor Channel would be the preferable option. This option would satisfy the desire for a timely project and would be the least costly as the local interests would only pay the costs which are over and above the least costly disposal option. However, there is uncertainty in the quality of the material which will be available during the dredging operation which translates into uncertainty as to how long the material may remain in the groinfield area.

CONSTRUCTION PROCEDURES

Historically, various portions of the Galveston Harbor Channel has been maintained by both pipeline and hopper dredges. The Entrance Channel and Outer Bar Channel are maintained exclusively with hopper dredges. The Inner Bar and Bolivar Roads Channels were maintained for many years using pipeline dredges, however, they are currently being maintained by hopper dredges.

Hopper Dredges

Hopper dredges are self-propelled seagoing ships that are equipped with propulsion machinery, sediment containers (hoppers), dredge pumps, and other special equipment required to remove material from a channel bottom. Hopper dredges have propulsion power adequate for required free-running speed and dredging against strong currents and maneuverability for safe and effective work in rough, open seas. Dredged material is raised by dredge pumps through dragarms connected to drags in contact with the channel bottom and discharged into hoppers built into the vessel. During dredging operations, hopper dredges travel at a ground speed of 2 to 3 miles per hour and can dredge in depths from about 10 feet to over 80 feet. They are normally equipped with twin propellers and twin rudders to provide required maneuverability.

Dredging is accomplished by progressive traverses over the area to be dredged. Hopper dredges are equipped with large centrifugal pumps similar to those employed by other hydraulic dredges. Suction pipes or dragarms are hinged on each side of the vessel with the intake extending downward toward the stern of the vessel. The dredged material is sucked up the pipe and deposited and stored in the hopper of the vessel. Once fully loaded, the dredge moves to the disposal site to unload before resuming dredging. Unloading is accomplished either by opening doors in the bottoms of the hoppers and allowing the dredged material to sink to the open-water disposal site or by direct pumpout through a fixed pipeline to a specific disposal site.

Direct pumpout capability would be required for placement of material on a beach. This procedure uses the dredge pumps to force the material from the hopper through the pipeline. To accomplish this, an anchored facility would be necessary to connect the dredge to the pipeline which leads to the beach discharge point. This facility could consist of a platform, a barge, or other similar structure with a manifolding system which would allow hook-up between the dredge and the pipeline. The dredge would load its hoppers from the channel, move to the off-loading facility, and pump its contents through the pipeline, repeating the process until the required channel shoaling has been removed.

Prior to selecting this as an option, there are a number of factors which must be considered on a case-by-case basis, such as the need for booster pumps, travel distance between the dredging location and the pump-out facility, time required to pump out the contents, wave exposure at the pump-out facility, and others depending on project requirements.

Pipeline Dredges

The hydraulic pipeline cutterhead suction dredge is the most commonly used dredging vessel and is generally the most efficient and versatile. The dredge is equipped with a rotating cutter apparatus surrounding the intake end of the suction pipe. Slurries of 10 to 20 percent solids (by dry weight) are typical, depending upon the material being dredged, dredging depth, horsepower of dredge pumps, and pumping distance to the disposal area. Production rates of dredges vary according to the above factors. The dredge size is often referred to according to the size of the discharge pipe diameter and therefore, similar size dredges can have significantly different production rates.

The cutterhead dredge is generally equipped with two stern spuds used to hold the dredge in working position and to advance the dredge into the cut or excavation area. During operation, the cutterhead dredge swings from side to side alternately using the port and starboard spuds as a pivot. Cables attached to anchors on each side of the dredge control lateral movement. Cutterhead dredges are not self-propelled, and forward movement is achieved by lowering the starboard spud after the port swing is made and then raising the port spud. The dredge is then swung back to the starboard side of the cut centerline. The port spud is lowered and the starboard spud lifted to advance the dredge. This procedure is repeated as the dredging operation progresses. The anchors must be moved ahead periodically to facilitate lateral movement.

For the situation where the excavated material is to be removed from the channel and deposited on a beach, a combination floating pipeline and shore pipeline would be required. The floating pipeline consists of sections of pipe mounted on pontoons and held in place by anchors. While dredging the anchorage area and the easterly portion of the 800-foot bottom width channel, a portion of the pipeline would have to be submerged by anchors to allow free passage of ship traffic.

The shore portion of the pipeline would be composed of sections of pipe added to reach the desired discharge point. For cutterhead dredging, the pipeline transport distances usually range up to about 3 miles, but with obvious loss of efficiency as the pipeline is extended. The distance from the dredging excavation location to the discharge point on Galveston beaches will be in the order of 10 miles and will require the use of additional booster pumps.

The bay dredging equipment that has been common in the Galveston District over many years is not designed to operate in waves over 2-3 feet in height. Larger waves will force the cutterhead into the sediment by wave action and create unacceptable shock loads on the dredging ladder upon which the cutterhead and suction pipe are mounted. However, there are cutterhead dredges which are available in some areas of the United States which are designed to operate in offshore waters and can function in waves up to about 6 feet. Dredging of the Inner Bar and Bolivar Roads Channels and the anchorage area have been accomplished a number of times using pipeline cutterhead dredges.

Summary of Construction Procedures

Hopper dredges with pipeline pumpout capability or cutterhead pipeline dredges could be used to renourish Galveston beaches with material from the Galveston Harbor Channel. The most economical procedure appears to be the use of a cutterhead pipeline dredge.

ENVIRONMENTAL CONSIDERATIONS AND COORDINATION

A Public Notice was distributed on January 15, 1992 to interested State, Federal, and local agencies, private organizations, news media, and individuals to assist in developing facts and recommendations concerning the proposed use of an additional placement area for material excavated during maintenance dredging in selected reaches of the Galveston Harbor and Channel project. There was no opposition to this proposal, however, the State Historical Preservation Officer pointed out the potential for a historic site in the proximity of the Seawall. This site was not considered by the State to be jeopardized by the addition of fill.

The various environmental and local interests and the public have also been involved through various open meetings concerning possible use of maintenance materials for beach augmentation in the groinfield. The major study participants have been the Texas General Land Office, Galveston County, and the City of Galveston. Various entities within the County and City have been closely involved with all activities. These groups include the Galveston County Shore and Beach Preservation Association, Galveston County Parks and Beaches Department, Galveston Chamber of Commerce, Galveston Parks Board, and others.

As part of routine maintenance pre-dredging activities, the sediments to be dredged are sampled and tested for evidence of various pollutants. The various compounds include heavy metals, pesticides, and organic chemicals. Since the maintenance material in the Bolivar Roads area could be deposited in either the Gulf or the bay, the testing requirements of both the Ocean Dumping Act and Section 404 of the Clean Water Act were addressed.

Sediment samples were collected and analyzed for the various pollutants. Levels of heavy metals and organic compounds were generally below analytical detection limits. It should be noted that there are no established criteria for sediments. It has been concluded by a committee established for the Houston-Galveston Navigation Channels project that there are no contaminant concerns related to dredging and disposal of maintenance material from the Bolivar Roads reach of the project and that no further testing of the maintenance material is required at this time. This conclusion was documented on July 8, 1992 by the various committee members. Committee representatives were from the U.S. Fish and Wildlife Service, Environmental Protection Agency, Texas Water Commission, Texas Parks and Wildlife Department, and the U.S. Army Corps of Engineers.

A Final Environmental Impact Statement for Maintenance Dredging, Galveston Harbor and Channel, Texas (Galveston Harbor Channel) was filed with the Council on Environmental Quality on October 23, 1975. The proposed addition of the groinfield area as an alternate disposal site has been coordinated with various Federal, State, County, City, and local officials through the Public Notice mechanism mentioned above. An Environmental Assessment and Finding of No Significant Impact (FONSI), or other National Environmental Policy Act compliance document, will be prepared prior to advertising of the maintenance dredging project for bids. A State Water Quality Certificate will also be obtained during this same time frame.

REAL ESTATE CONSIDERATIONS

Various real estate considerations must be completed prior to placement of material on the beach. If a pipeline is to be used to convey materials from the channel to the deposition site, a pipeline route must be established. Given the relative location of the borrow source (channel maintenance material) with respect to the disposal area (the groinfield beach), there are two more obvious primary pipeline routes. One is along the Seawall, where the Federal Government and the County have existing rights-of-way and the other is along the beach ridge line along the Gulf shoreline. In addition, the property rights of various interests within the deposition area must also be addressed.

Pipeline Route Considerations

Figure 3 shows the Seawall route and the shoreline route as potential options for laying of the shore portion of the pipeline to the beach placement site. These two routes are discussed below. Other potential routes are also discussed below.

Seawall Route

The major advantage of the Seawall route is that the Federal Government and Galveston County have existing rights-of-way which includes the toe protection to the Seawall. Another advantage to this route is that it is 0.6 miles shorter than the shoreline route. However, there are a number of disadvantages to this route. The pipeline would have to cross several well-traveled streets and access points to the beach. The line would have to be bored through the ramp embankments for each of these roadways. The road crossing problems could not be avoided whether the line ran along the top of the Seawall or along the base of the wall.

Leakage at the pipe joints would also cause problems where a spray, consisting of a mixture of salt water and dredged material, could affect traffic and pedestrians along the seawall. Leakage is not a major problem as it is commonly overcome by welding the joints.

If the line was routed along the base of the Seawall, the problem that exists is that the rock toe protection is exposed along a significant portion of the route. This is not conducive to

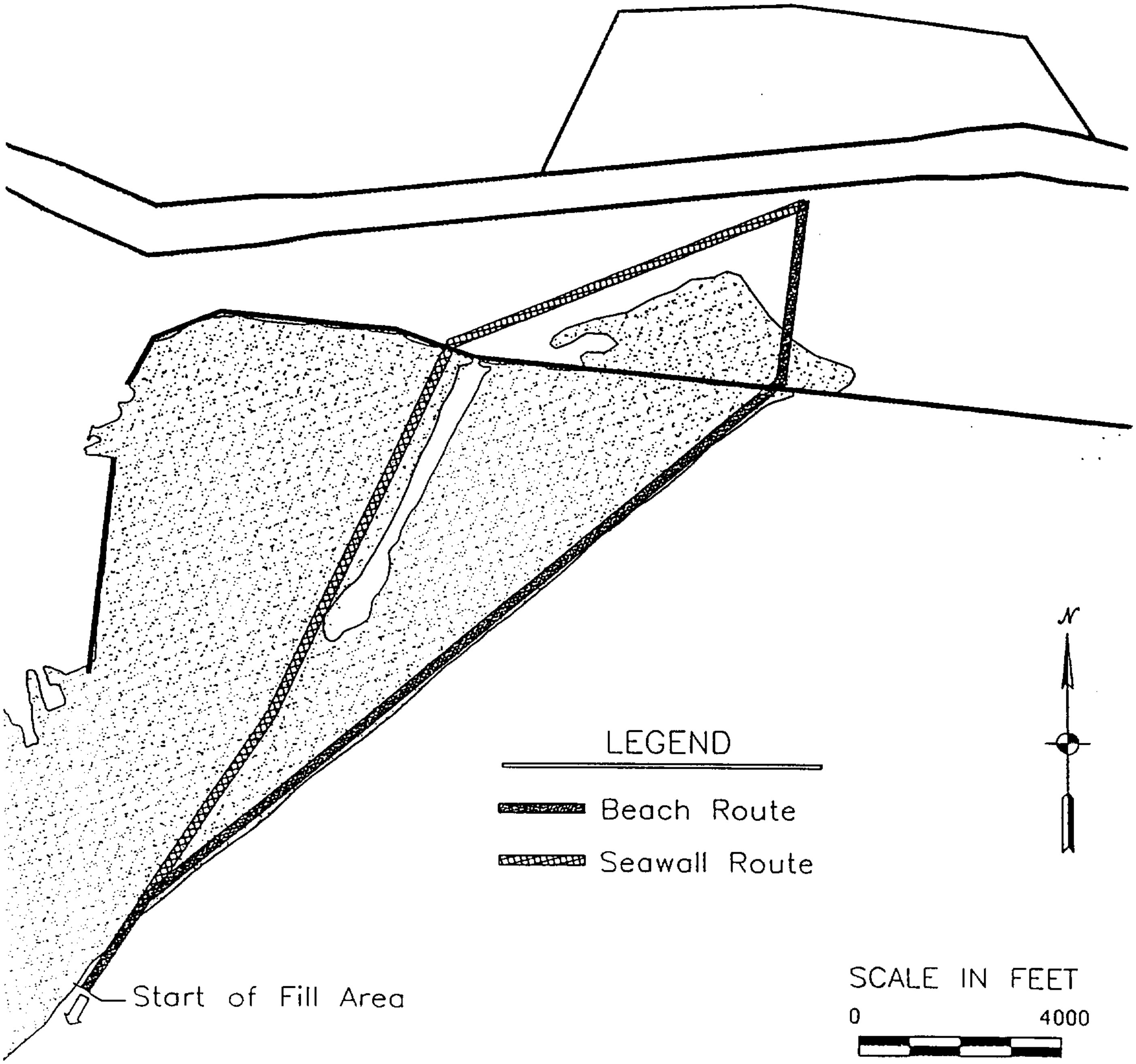


Figure 3. ALTERNATIVE PIPELINE ROUTES

connecting the joints of the pipe in order to construct the pipeline. The pipeline could be placed in a cradle to avoid the irregular rock projections, however, there would be additional fabrication required for the cradles to produce somewhat of a uniform elevation for the pipeline to traverse.

Shoreline Route

The shoreline route has the distinct advantage of not requiring the crossing of major access points along the route. There would be several access points required for emergency use and beach cleaning. Pedestrian crossings of the pipeline could be afforded by wooden stairways at various points along the route and particularly in areas which would have heavy usage. The timing of the placement of the material is such that there would be minimal disruption to the recreational beach usage. However, with the short and often mild winters in this area, there would likely be several weeks prior to completion of the dredging where there would be significant recreational beach usage. This situation has not proven to be a problem for similar projects in other areas of the United States and is not anticipated to be a problem in Galveston. The novelty of the operation along with the obvious benefit that is being accomplished minimizes potential adverse social impacts. The pipeline route, as shown in Figure 3, would involve crossing between two distinct portions of Big Reef where there is some potential for environmental disruption to various shore birds and other species. The route between these sensitive areas would be chosen rather than through them. Biological specialists would be consulted to minimize the potential impacts. This route could be coordinated with Federal and State resource agency representatives to assure proper environmental precautions are taken.

Other Routes

There are other routes which could be chosen, but each would have various problems. A route through The Lagoon would extend the water-based route of the pipeline to take advantage of using pontoons for a floating pipeline. However, there is no direct access route for the equipment being used in the channel area to construct the pipeline across the water area of The Lagoon. Therefore, additional waterborne equipment would be necessary to lay this portion of the line. In addition, The Lagoon and areas adjacent to it are prime wetlands and would be impacted by construction equipment working in the area. The impact may be temporary, but there would be long-term evidence of equipment having worked in the area. Other routes outside of The Lagoon area would involve wetlands and would also require crossing of major streets as would The Lagoon route.

Another option could be the use of a hopper dredge to dredge the channel, navigate around the South Jetty to a point offshore of the groinfield, and tie up to a pumpout facility which is connected to the pipeline. The pipeline route would be in the Gulf waters with no interference to land-based operations. The pipeline route would not be a major factor in this decision, however, the distance each load of material would have to travel would be a major factor affecting the unit cost of the material delivered to the beach.

Summary of Route Considerations

None of the logistical problems for either the Seawall or shoreline route are monumental as these problems are routinely handled on many other dredging contracts within the Galveston District. However, of the routes discussed above, the shoreline route appears to be the preferred route as it avoids the street intersection problems, there is essentially no environmental problems, and building the beach westward from 10th Street would avoid problems encountered with the rock toe protection of the seawall. The additional distance for this route over the Seawall route is not considered significant given the overall pumping distance which is in the order of 10 miles. The specific route selection will be made as detailed plans are developed.

Property Ownership in the Groinfield Area

Private ownership of properties in front of the Seawall exists and would be a major consideration in the early stages of this renourishment project. Businesses located within the groinfield include The Shrimp Boat, The Flagship, Murdoch Bathhouse, Balinese Room, the 61st Street Fishing Pier, and others. These businesses, along with other affected private property owners, should be aware of project implications and work closely with the City with their concerns. The City of Galveston, acting as sponsor, would be required to provide all necessary lands, easements, rights-of-way, and relocations for the project and ensure the specified pipeline route is obtainable. The placement area should be thoroughly researched so that real estate and legal complications are avoided.

TECHNICAL CONSIDERATIONS

BEACH PROFILES

Beach profiles have been taken at various times over the years to monitor volumetric changes in the material along the Island. Of primary concern has been the beach area in front of the Seawall for reasons stated above. Beach profiles are plots of the ground elevation along a line extending perpendicular from the general shoreline, seaward from a known reference point to some predetermined offshore depth or distance. Comparing profiles taken at the same location at various time intervals will show gains and losses along the profile as well as shifts or losses of material along a specific segment of shoreline.

Beach profiles were taken annually from 1968 to 1981 in connection with a Coastal Engineering Research Center effort under the General Investigation of Tidal Inlets program. These profiles indicated shifts in materials between the groins and a gradual loss of material west of the 61st Street groin and a significant gain in material east of the 10th Street groin extending to the South Jetty.

In February and March 1992, profiles were taken at the mid-points of each groinfield cell. Additional beach profiles were taken 100 feet inside each groin for two of the cells. These two cells were located at the extreme eastern and western ends of the groinfield. These profiles were taken at the same locations as the profiles taken in the late 1960's to the early 1980's which extended from a point on the Seawall offshore 1,000 feet. Figure 4 is a map indicating the location of the 19 profile sections.

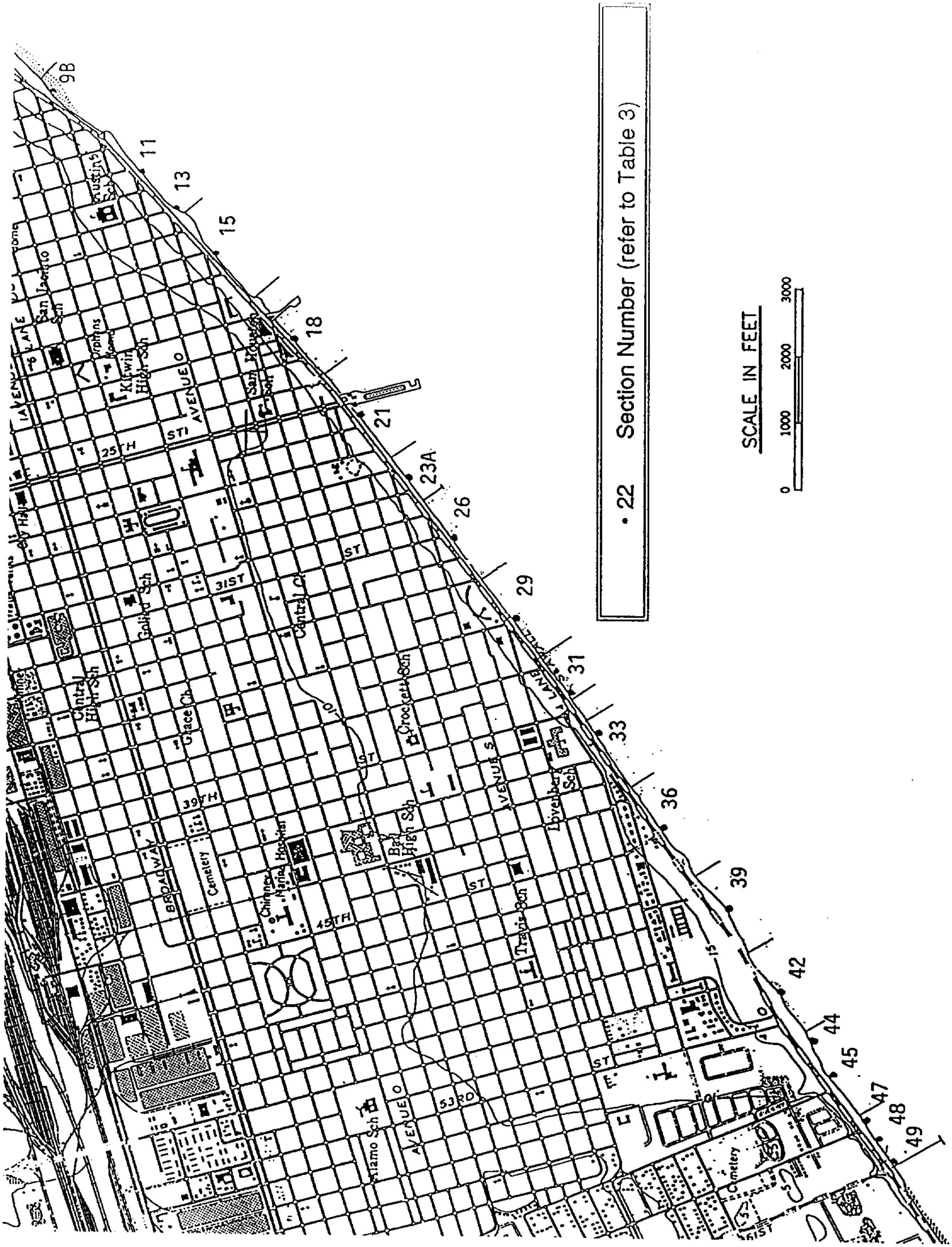


Figure 4. BEACH PROFILE TEST LOCATIONS

Beach Profile Comparison

By comparing the most recent profiles with those approximately 10 years earlier, the following general conclusions can be made. Since the profiles for the most part were taken at the mid-point of each groin cell, this may not be totally representative of what has occurred within the entire cell. Therefore, the conclusions based on the profile data should be conditioned on this basis.

The evaluation criteria involved comparing measurements of 1978-80 beach profiles with those of 1992. Portions of the 1992 profile which were found to be above the previous profile were designated as gains and those below as losses. A profile volume representing a one foot slice of beach profile perpendicular to the shore resulted. The results of the comparison are shown in Table 3.

The first and last groin cells, each with three measurements, were used to show local trends of the profile within the respective cells. The first set of measurements, taken at the easternmost groin cell at 10th Street, revealed an increase on the eastern portion, slight gain at the midpoint, and a loss on the western portion of the cell. The other set of measurements, located in the westernmost cell at 61st Street, indicated a gain on all three profiles with the largest occurring in the western portion of the cell. These results are not representative of the entire groinfield but can be used to formulate a conclusion based on the consistency of all the locations tested. Starting from the easternmost groin at 10th Street there is a tendency for beach profile loss at the western extremes of each cell coupled with slight gains on the eastern portions. This trend continues until 37th Street where slight gains occur at the midpoints and, considering the 61st Street cell, the western portion tends to gain.

Table 3
COMPARISON OF BEACH PROFILE
1978-80 and 1992
Volume (cu.ft.) per 1 Foot Beach Face

SECTION	LOCATION	GAIN (+)	LOSS (-)	TOTAL
9B	11th St.	328.03	6.45	321.58
11	14th St.	65.10	8.35	56.75
13	16th St.	0.00	171.20	(171.20)
15	18th St.	118.05	26.30	91.75
18	22nd St.	75.43	9.98	65.45
21	26th St.	2.55	177.00	(174.45)
23A	28th St.	27.90	47.60	(19.70)
26	31st St.	0.00	121.50	(121.50)
29	35th St.	13.98	95.58	(81.60)
31	38th St.	156.25	0.00	156.25
33	40th St.	110.40	5.20	105.20
36	45th St.	178.13	34.23	143.90
39	48th St.	162.85	202.38	(39.53)
42	52nd St.	185.90	1.00	184.90
44	54th St.	75.28	1.73	73.55
45	56th St.	171.13	0.00	171.13
47	59th St.	172.40	10.98	161.43
48	60th St.	118.63	6.13	112.50
49	61st St.	191.20	12.35	178.85

From these conclusions a shadowing effect of the Galveston South Jetty is indicated. These results, however, can not be used to make exact determinations of the littoral processes within the groinfield. The dynamic properties of the beach profiles are extremely complex. With the data collected, an exact volumetric loss or gain can not be calculated due to the variability of the nearshore bottom. However, comparison of the beach profiles for the different years does demonstrate that an equilibrium profile can be shown to exist.

BEACH MATERIAL CHARACTERISTICS

Existing beach material characteristics are important factors when designing beach nourishment projects. Best results are usually achieved when the fill material is similar in grain size distribution to the native beach material because of sorting action from waves. Wave action selectively redistributes sediment particles along a beach profile according to size and hydraulic properties. Construction materials are classified by grain size into clay, silt, sand, gravel, and cobble. Several classifications exist, of which two, the Unified Soil Classification and the Wentworth Classification, are most commonly used in coastal engineering. The Unified Soil Classification is the principal classification used by engineers. The Wentworth Classification is the basis of a classification widely used by geologists.

The Unified Soil Classification boundaries correspond to U.S. Standard Sieve sizes. The boundaries are between the #200 mesh sieve with openings of .074 millimeters (mm) and the #4 mesh sieve of 4.76 mm. This classification further defines sand into three categories, fine, medium, and coarse. Fine sand is that material retained on the #200 sieve but passing the #40 sieve, 0.42 mm. Medium sand is that which is retained on the #40 sieve but passing the #10 sieve, 2 mm. Coarse sand is that fraction that is retained on the #10 sieve and passing the #4 sieve.

For most shore protection design problems, typical littoral materials are sands with sizes between 0.1 and 1.0 millimeters. Approximately ninety five percent of the sand found on the native beach at Galveston is in the "fine" category, .074 mm to 0.42 mm, with a median grain size of 0.24 mm.

Material introduced to this same beach environment that is finer than the native beach will be winnowed out by wave action, leaving the coarser fraction of the material. Therefore, to obtain an equivalent volume of native beach material it would require additional quantities of new material, or "overfill", to compensate for the losses of the finer material as well as to supply the necessary coarser fraction to more closely approximate the composition of the native material.

This mechanism is particularly interesting for the Galveston groinfield. Sediment samples indicative of the beach fronting the Seawall were gathered in April 1992. A total of 13 samples were taken from 7th Street to 61st Street within the groinfield. The tests resulted in an average grain size distribution shown in Table 4. The grain size distribution of the existing material is very fine sand with the bulk between a #40 and #100 sieve (0.42 mm - 0.15 mm).

Table 4
GRAIN SIZE DISTRIBUTION
Galveston Beach, 1992

SIEVE	mm SIZE	PERCENT FINER
10	2.0	99.95
20	0.9	99.87
40	0.42	94.08
100	0.15	8.63
140	0.108	1.49
200	0.074	0.37

FINAL CROSS-SECTION

A basic beachfill template was developed during investigations for the Galveston County Shore Erosion Study and is being used for analyses purposes for this report. This template consisted of an essentially flat area or berm at an elevation of +5 feet, then a 1 vertical to 30 horizontal slope to the mean low water line (approximately +0.89 feet mean low tide elevation), and from that point a 1 vertical to 50 horizontal slope extending out into the water until it intersects with the existing beach profile. This general template is shown on Figure 5.

The volumetric requirements for two beach fill templates were computed for the placement area between 10th Street and 61st Street. The first template had a berm width of 100 feet and the other had a berm width of 150 feet. The volumes were computed using February 1992 profiles taken to wading depths and supplemented by previous profiles taken in 1980. The profiles were taken at the mid-points of the cells. The first and last cells had two additional profiles each 100 feet off from the groins within the cell. The entire length of each profile will be surveyed to current conditions prior to placement of material.

The volumetric requirements to produce the specific beach widths were determined by overlaying each design cross-section on the most recent beach profile, cross-sectional area differences computed, and volumes determined by standard end-area techniques. The 100-foot berm width would require approximately 320,000 cubic yards and the 150-foot berm width would require approximately 550,000 cubic yards. These values are volumetric requirements without consideration for losses or overfill volumes required to account for the difference in material between the borrow site and the beach area.

Figure 6 shows the eastern three cross-sections with 100-foot and 150-foot berm lines for the cell between 10th Street and 16th Street. It should be re-emphasized, that the above volume requirement does not account for losses that will occur at either end of the dredging operation. The amount of yardage removed from the channel will not equal the amount of yardage delivered to the beach. The volume of material removed from the channel is determined by the difference between before and after dredging cross-sections. At the location where the channel dredging operation is being performed, losses will occur through material displaced along the channel, outside of the cross-section by tidal

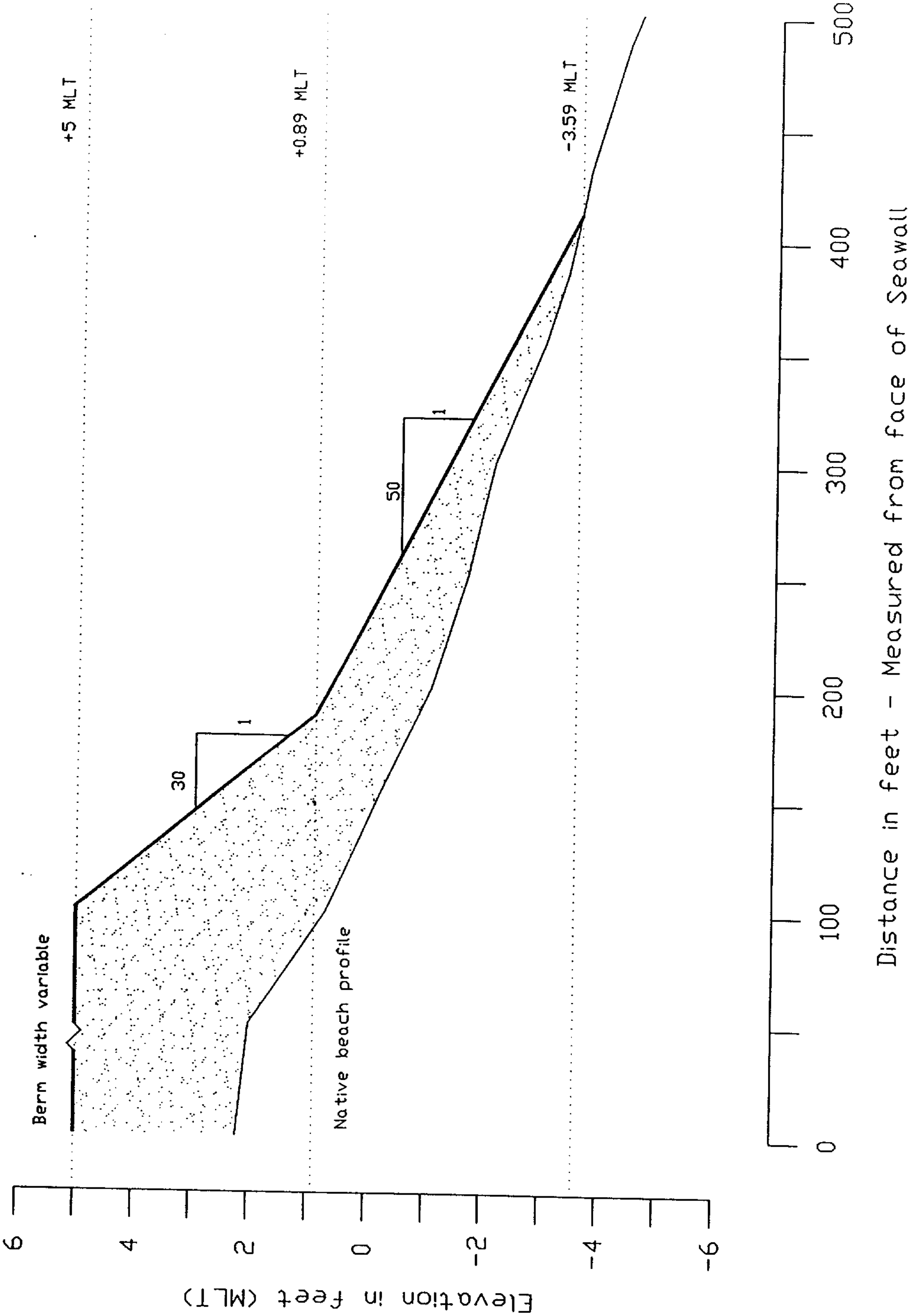


Figure 5. BEACH PROFILE TEMPLATE

action and currents and fine material resuspended and moved. At the beach deposition point, the fine material that was picked up by the dredge will likely be immediately lost through the sorting and winnowing action as the material is exposed to wave action. Losses will occur, but this process will tend to displace the finer clay and silt particles from the beach area and leave the sand. Also, apparent losses will occur where scour holes and other beach face indentations are not accounted for in the mid-point beach profiles.

The material will be deposited along the beach in slurry form and will tend to flow. However, it may also tend to be somewhat irregular and may require some grading if a uniform berm area is desired. While the material is flowing from the pipeline, the vibration of the construction equipment which is used to move the pipeline, add or subtract pipe, etc., may be sufficient to give the material a more uniform appearance.

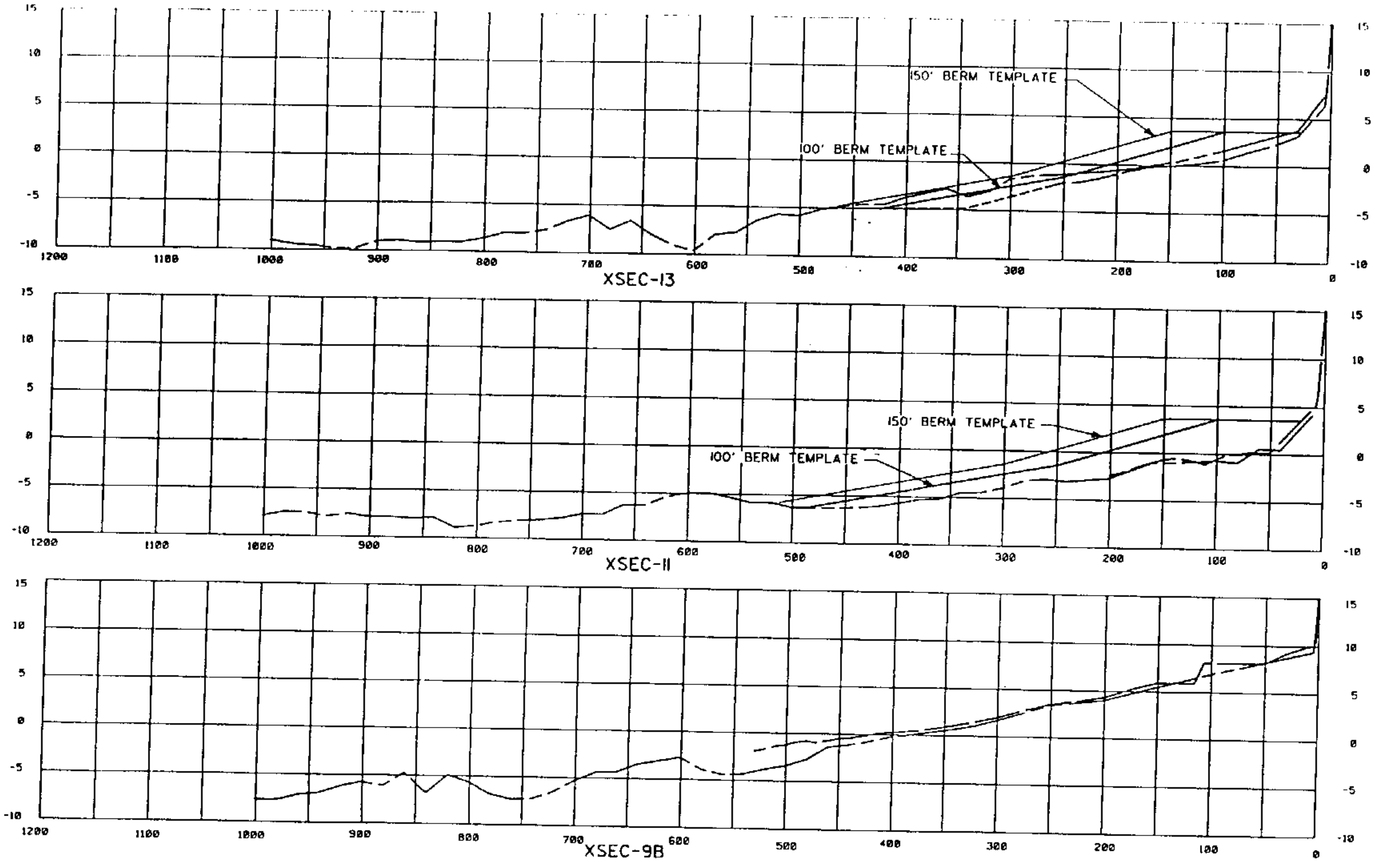
COSTS

The costs for a maintenance dredging contract are influenced by a number of factors. These factors include the type of material to be dredged, the distance the material is to be pumped, the amount of pipeline to be handled both offshore and onshore, the pipeline route, the number of booster pumps required, and the amount of final shaping and grading of the completed fill section.

The costs which will be required from the local sponsor is the difference between offshore placement of the material (the least costly placement option which is currently being used) and the placement of the material in the groinfield. This includes all additional engineering, design, and environmental considerations as well as real estate investigations. The actual amount of funds which will be transferred from the local sponsor to the Federal Government will be determined by the actual volume of material removed from the channel based on the bid price from the lowest bidder. A Government estimate will be developed for both the offshore placement option as well as the beach placement option.

This will indicate order of magnitude costs, with the final amount of funds to be transferred reckoned between the final contract pay estimate and the Government estimate for the offshore option.

The most recent costs for offshore deposition of the maintenance material from the Inner Bar Channel and Anchorage Area in the designated offshore site using a hopper dredge has averaged $2.10 per cubic yard. Using a pipeline dredge with the placement area between 10th and 61st Streets and the requirement for booster pumps is expected to increase the total costs in the range of $1.50 to $2.00 per cubic yard. The actual bid price could vary considerably because of many factors both technical and economic.



REFERENCED TO NGVD 1927, 1964 ADJUSTMENT

JAN TO MAY 1980

FEB 1992

ASSUMED LIMITS

OFFICE OF THE DISTRICT ENGINEER
U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

GALVESTON HARBOR AND CHANNEL, TEXAS

BEACH PROFILE SURVEY
WITH FILL TEMPLATES

Prepared under the direction of
John P. Basilotto, Col., C.E.,
District Engineer

SCALE: AS SHOWN

Figure 6. **BEACH PROFILE SURVEY**

DISCUSSION

There is an inherent measure of uncertainty when contemplating the restoration of beach areas. These uncertainties result from the unpredictable nature of meteorological conditions and events, the variableness of the fill material, and the fact that beach processes can not be totally described mathematically or through the use of physical models. Because these variables exist, the monitoring of the newly renourished area on a regular basis, especially in the early stages, would increase the known parameters and give insight to longevity. In other fields of engineering, site adaptation of structures and applying similar methods for similar situations are appropriate and proven to be successful. In the coastal arena, care must be exercised in applying techniques which have worked in other areas because of the many complicating factors which are involved in whether or not an undertaking is successful.

In brief, the conditions may appear similar but produce radically different and oftentimes undesirable results. These factors include offshore slopes, shelf widths, gross littoral transport, net transport direction and volume, variable wave conditions in magnitude and direction, coastline orientation, and many others. Therefore, any procedure adopted should consider all available data, collect additional data to fill critical gaps, objectively consider all of the options, and base the final decision on sound engineering judgement.

Current Federal criteria allows local interests to take advantage of the availability of channel maintenance materials from a Federal project if the fill site is relatively near the channel and non-Federal funds are available to pay that portion of the additional cost that is above the least costly maintenance method presently being used. In addition to costs, a major consideration is the compatibility of the material with the intended usage of the beach.

As in the case of Galveston where the beaches are used exclusively for recreation purposes, ideally, the material must contain a high sand content which means a low percentage of the finer silts and clays. The analysis and ultimate decision must go beyond a general statement that "the material must have a high sand content" because of the range of particle sizes that constitute what is classified as sand. As discussed previously, the native beach material in the groinfield is predominantly fine sand.

Some fraction of the materials that are deposited in the navigation channels is sand that has been moving along the shoreline beaches. Added to that sand fraction are varying amounts of silts and clays. Therefore, without some type of "washing" action occurring in the channel area to purge the silts and clays, the composition of the material which will be removed during routine channel maintenance will have varying amounts of fines. This will necessarily make the total sample finer than the native beach material. These unwanted fines can be compensated for, from a gradation standpoint, by overfilling the area to account for the losses of the finer material when exposed to wave action. If the fines make up significant portions of the fill material, it would make the beach area undesirable for recreational purposes. In summary, the above factors should be weighed in contemplating the placement of channel maintenance materials on a recreational beach.

Should the decision be to place the finer material on a beach, there are various means which could be utilized to prolong the life of the newly placed material. The groinfield slows littoral materials by trapping and retaining materials within the individual cells. Material that is removed from one cell by wave and current forces would be temporarily trapped in the adjacent cell. Some portion of the material may be lost offshore or beyond the limits of the groinfield. The material that moves offshore may be thinly spread over the Gulf bottom and essentially lost to the littoral system. Material that moves eastward beyond the limits of the groinfield will be trapped in the accreting fillet near the South Jetty.

It is anticipated that material which would move westward from 61st Street would provide some reduction in the erosion rates near the end of the Seawall and would become a part of the natural littoral system along west Galveston Island and beyond.

Another means to retard the loss of materials added to the beach could consist of covering the newly placed materials with a material with a coarser gradation. The question of how coarse should the material be is related to both its resistance to retard erosion and also aesthetic and other non-technical characteristics. This would involve the additional cost of the material, and transporting and spreading the material. Similar to any sand materials placed along the Seawall, the cover material would also ultimately be lost, but at a slower rate. A decision to use cover material would be based on the cost factors mentioned above, balanced against the extended time between renourishment events.

Other physical features could be added to the groinfield system to prolong the life of fill material. This could include various types of breakwaters either submerged or emergent to limit the amount of wave energy delivered to the new shoreline, or the modification of the existing groinfield.

The groins could be lengthened, shortened with other groins added, the seaward ends modified for greater trapping capability, or similar changes. All of these changes would be relatively costly, no guaranteed return on such an investment, and would be accomplished at local expense. The existing groinfield is performing as designed and therefore there is no current Federal interest in modifying the system.

An alternative to direct placement of materials on the beach is the use of an offshore feeder berm. At this time this technique is considered to be experimental. This procedure consists of the placement of dredged materials to build an underwater berm with the use of hopper dredges. The concept is that the berm would protect the existing beach by reducing storm wave heights, and offshore currents and wave forces would cause the berm to migrate toward the beach to eventually become part of the beach system.

Based on preliminary results from an experimental site near the Brownsville Ship Channel near South Padre Island, this shoreward migration would be very slow. This site is yielding positive results and monitoring is continuing. However, to date there are no readily observable changes in the shoreline using this procedure. If a non-Federal sponsor were willing to assume the greater financial burden for pumping the dredged materials directly onto the beach, immediate results would be evident and this would likely be the preferred option.

The placement of the material to create an offshore feeder berm would involve the difference in costs of taking the material to the berm site and the existing offshore disposal area. The type of material placed in the berm should also be monitored to place only sandy-type material. However, the type of material placed in the berm would not be as much of a concern as would the placement directly on the beach because the fines would be sorted during the placement procedure and in the offshore wave environment.

Beach-type material that is added to an erosional native beach, such as the Galveston groinfield area, will ultimately be lost or moved from the area where it was initially placed. The rate at which the material is lost depends on the type of material added and the environmental conditions the material is subjected to. If it is the desire to restore a beach, these realities must be known and expected.

The longevity of the added material is highly unpredictable, particularly with the occurrence of a hurricane or tropical storm. All or significant portions could be lost in a matter of several hours of buffeting from storm waves. There is a possibility of some natural recovery after a storm, but that also is subject to where the material is deposited, currents generated in the groinfield, and other factors related to the unique variables associated with a particular storm. These factors reinforce the need for monitoring the study site on a regular basis so that data can be utilized for further renourishment and better predictability.

There have been various formulae developed by a number of researchers over many years in attempting to determine the life of beachfill projects. Some have proven to be quite effective in predicting beach losses for a narrow range of beach conditions and wave climate. Research is continuing in this area.

In the Galveston County Shore Erosion Study report, procedures developed by W. R. James in the late 1960's and early 1970's were used to compare the Big Reef material as a borrow source to the native beach and predict the renourishment rate. The renourishment period determined using the James procedure was 15 years in the absence of a major storm event. It appears that a more reasonable, conservative time to expect the need for the beach to be renourished to maintain a given beach width would be in the order of 10 years based on Big Reef material as sampled over 10 years ago. However, using maintenance material from the Galveston Harbor Channel, the renourishment period would be predicted to be more frequent because of the expected smaller particle sizes in the channel material. Current grain size distribution data from the channel is not available for this report and therefore no specific estimate based on the above procedures can be given. However, an expected renourishment period of something less than 8 years would be considered reasonable.

CONCLUSIONS

Based on these preliminary investigations, it has been concluded that the most cost-effective approach to restore the beaches along the Galveston Seawall in a timely manner with Federal participation would be to utilize the sandy material from periodic maintenance dredging operations from the Galveston Harbor Channel. Under this option, the non-Federal sponsors would be required to pay 100 percent of the additional costs that are over and above the least costly dredge material placement alternative the Federal Government currently would pay. The City of Galveston, in corporation with Galveston County, and with the State of Texas have made arrangements to pay the additional cost and to enter into an agreement with the Federal Government to cost share in the use of maintenance materials for addition to the beach in the groinfield. The planned area to receive channel maintenance materials would extend over about a 3.8-mile distance from 10th Street to 61st Street and could require volumes in the range of 1 million to 1.5 million cubic yards of material to provide a beach berm width of approximately 150 feet. This translates into a dry beach width of more than 250 feet.

This proposed action has been found to be environmentally compatible from both social and ecological standpoints. From a beneficial uses of dredged material perspective, this would constitute a highest and best use for the material.

A number of issues and concerns have already been overcome to make the beach placement plan become a reality. Remaining issues that are being addressed include: the determination of the quantity of beach quality materials available; finalizing the required environmental documentation; completing the financial arrangements between the Federal Government and the non-Federal sponsor to provide the additional costs that are over and above the presently used least costly maintenance method employed; preparing the specific plans and specifications necessary for advertisement of the project for bids; and obtaining the required legal and real estate rights and clearances for the pipeline route and the placement area. Many of these activities are well-advanced and nearing completion, others are scheduled. Through this cooperative effort between the City, County, State, and Federal Government a functional beach area is anticipated to be enjoyed by the summer of 1993 by the local populace as well as visitors to the Island.

US Army Corps
of Engineers

Galveston Distri
Southwestern Divisi

Planning Assistance to States Program

SECTION 22 REPORT

Inlets Along the Texas Gulf Coast

August 1992

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

REPLY TO
ATTENTION OF:

Planning Assistance to States Program

SECTION 22 REPORT

Inlets Along the Texas Gulf Coast

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

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INLETS ALONG THE TEXAS GULF COAST

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

The authority for the Corps of Engineers to cooperate with States in preparing water resources related plans comes from Section 22 of Public Law 93-251. This authority was amended by Section 921 of the Water Resources Development Act of 1986, Public Law 99-662, which limits Federal expenditures to $300,000 in any one year for studies for any one State. Further policy decisions implemented cost sharing between the Federal Government and States beginning in Fiscal Year 1991 at 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 State of Texas continues to actively pursue the development of a comprehensive coastal management plan for the State's public lands. Some of the major issues which are being addressed in this plan are coastal erosion, beach access, and wetland loss. These activities are associated with or affected by coastal inlets to some extent and thus, the continued interest of the State in the subject of inlets.

The purpose of this report has been to document historical and present actions at all of the inlets along the Texas coast to serve as a basis for the State and others in evaluating overall factors and features that affect the movement of littoral materials. This report is intended to provide decision-makers background information necessary to assess the practicability of changing current practices and procedures and the compatibility of inlet sediments for potential placement on adjacent beaches.

Scientific and technical experts are quick to advise that coastal processes, in general, are complex and dynamic. Every breaking wave generates turbulence which causes materials to become suspended in the water column and move within the littoral zone. Erosion proceeds slowly under normal wave conditions but may be as great as a few hundred feet in a matter of hours under storm conditions. There are numerous other variables that promote erosion, many of which are part of the natural system.

Erosion of the Texas Gulf shoreline is recognized as a serious problem. Sixty percent of the 367 miles of the shoreline is classified as erosional, 33 percent is in equilibrium, and 7 percent is accretionary. A generic statement as to the cause of the erosion problems along the Texas coast is that there is a deficit of materials moving to and through a particular reach of shoreline. Erosion of updrift coasts does supply materials to downdrift coasts; however, the eroded volume of material from one area may not be sufficient to offset the erosion losses at all specific segments of downdrift shorelines. Likewise, the movement of materials through inlets has a direct bearing on whether the adjoining beaches are eroding or accreting, and man's actions at several of these inlets influence the way the inlet affects littoral processes. These conditions that impact on the movement of littoral materials at the inlets, both natural and manmade, are the subject of this report.

INLETS ALONG THE TEXAS COAST

A narrow barrier chain composed of islands and peninsulas extends along the entire Texas coastline except for two relatively short reaches. These exceptions are where the mainland fronts the Gulf for about 35 miles in the area southwest of Sabine Pass and for about 30 miles in the vicinity of Freeport. Behind the barrier chain lies a vast complex of shallow bays and lagoons, broken in several locations by natural and man-made inlets or passes. These openings are avenues for the movement of marine life and the nutrients on which they depend as well as sediments from inland sources. Littoral material or sediments moving along the coast causes some of these passes to migrate, contract, and occasionally, close completely. Hurricanes often temporarily create new passes, reopen closed passes, or relocate existing passes.

The inlets addressed in this report include all natural and man-made inlets or passes, regardless of whether or not they are currently open. Even though the mouths of rivers do not meet the classical definition of an inlet, they are also included since they are the primary source of new sediments to the coastal zone. The inlets discussed, beginning on the upper Texas coast and proceeding southward, are:

- Sabine Pass
- Rollover Pass
- Galveston Harbor Channel
- San Luis Pass
- Freeport Channel
- Brazos River Diversion Channel
- San Bernard River
- Caney Fork/Mitchell Cut
- Brown Cedar Cut
- Colorado River
- Greens Bayou
- Matagorda Channel
- Pass Cavallo
- Cedar Bayou
- Aransas Pass

- Corpus Christi Water Exchange Pass
- Corpus Christi Pass, Newport Pass, and Packery Channel
- Yarborough Pass
- Mansfield Channel
- Brazos Santiago Pass
- Boca Chica Pass
- Rio Grande

A map showing the location of each inlet is shown on Figure 1. A physical description is provided for each inlet below. For those inlets that have been stabilized and maintained for commercial and recreational navigation, a maintenance dredging history, including an analysis of the sediments removed during periodic maintenance dredging, and an assessment as to the potential suitability of the dredged material for placement on adjacent beaches are also presented.

Sabine Pass

Sabine Pass is a natural inlet located at the Texas-Louisiana border, approximately 58 miles northeast of Galveston. This inlet connects Sabine Lake to the Gulf of Mexico, provides an outlet for the Sabine and Neches Rivers, and is the sole tidal inlet for Sabine Lake. The Sabine-Neches Waterway is a federally-maintained project which connects the deep-draft ports of Port Arthur, Beaumont, and Orange to the Gulf through Sabine Pass.

Prior to the navigation improvements, Sabine Pass had a natural depth of about 15 feet. However, the depth of water over the outer bar was only about 6 feet, which significantly restricted navigation. The first channel improvements at Sabine Pass were constructed in 1879 and provided a channel 12 feet deep over the outer bar. Currently, the project provides a channel 40 feet deep to Port Arthur and Beaumont, and 30 feet deep to Orange. A brief chronology of the Federal improvements at Sabine Pass is shown in Table 1.

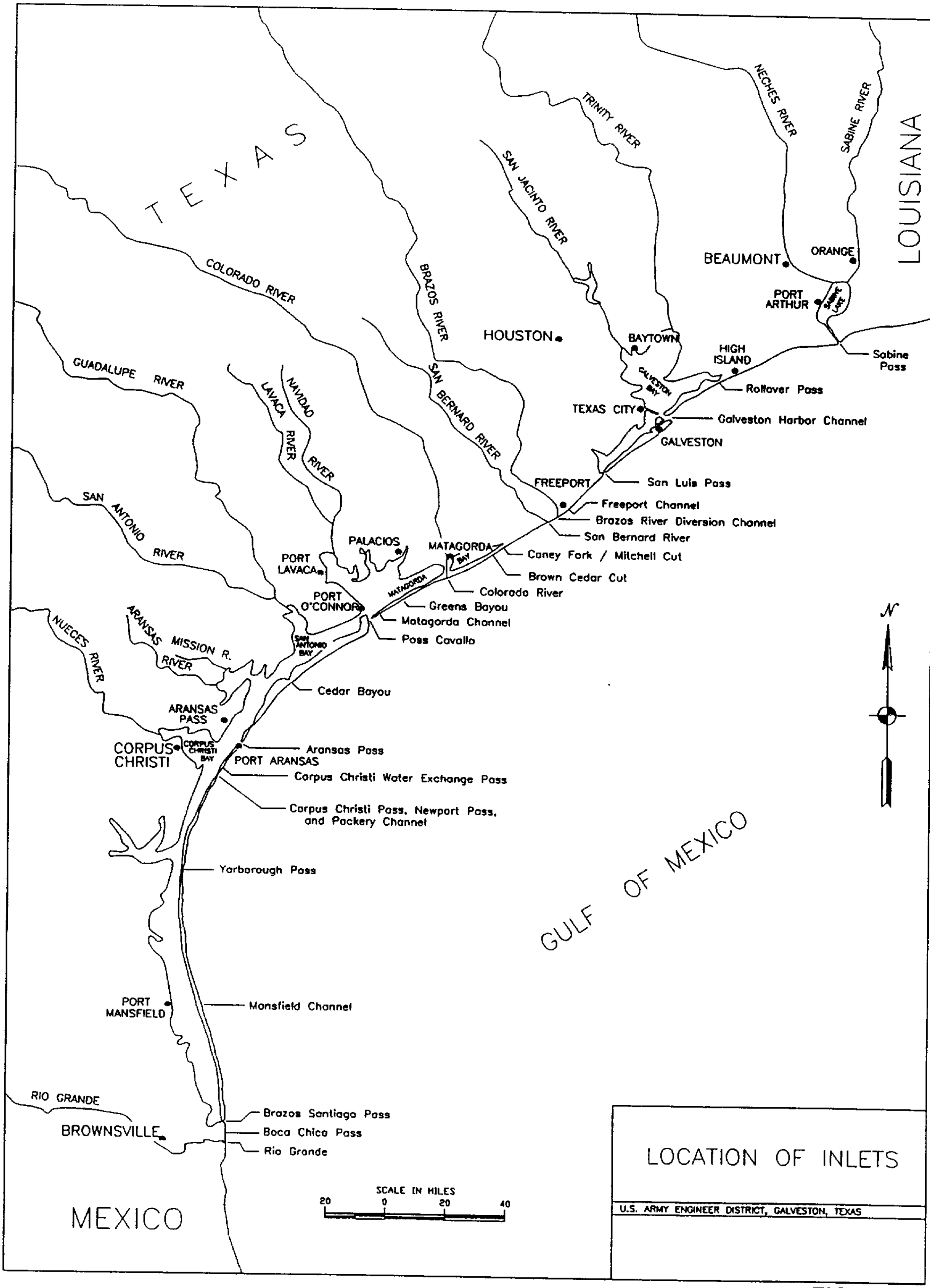

TEXAS
LOUISIANA
MEXICO
GULF OF MEXICO
COLORADO RIVER
BRAZOS RIVER
TRINITY RIVER
SAN JACINTO RIVER
NECHES RIVER
SABINE RIVER
BEAUMONT
ORANGE
PORT ARTHUR
SABINE LAKE
HOUSTON
BAYTOWN
HIGH ISLAND
GALVESTON BAY
TEXAS CITY
GALVESTON
Sabine Pass
Rollover Pass
Galveston Harbor Channel
GUADALUPE RIVER
LAVACA RIVER
NAVIDAD RIVER
SAN BERNARD RIVER
FREEPORT
San Luis Pass
Freeport Channel
Brazos River Diversion Channel
San Bernard River
SAN ANTONIO RIVER
PALACIOS
MATAGORDA
MATAGORDA BAY
PORT LAVACA
Caney Fork / Mitchell Cut
Brown Cedar Cut
Colorado River
PORT O'CONNOR
Greens Bayou
Matagorda Channel
Pass Cavallo
NUECES RIVER
ARANSAS RIVER
MISSION R.
SAN ANTONIO BAY
Cedar Bayou
ARANSAS PASS
CORPUS CHRISTI
CORPUS CHRISTI BAY
PORT ARANSAS
Aransas Pass
Corpus Christi Water Exchange Pass
Corpus Christi Pass, Newport Pass, and Packery Channel
Yarborough Pass
PORT MANSFIELD
Mansfield Channel
RIO GRANDE
BROWNSVILLE
Brazos Santiago Pass
Boca Chica Pass
Rio Grande
SCALE IN MILES
20 0 20 40
N
LOCATION OF INLETS
U.S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS

FIGURE 1

TABLE 1

CHRONOLOGY OF FEDERAL IMPROVEMENTS

AT SABINE PASS

Year	Activity
1879	Construct channel over outer bar to 12-foot depth.
1896	Construct East Jetty 19,500 feet long, West Jetty 14,875 feet long, and channel 100 feet wide and 24 feet deep.
1900	Extended East Jetty to 25,270 feet, West Jetty to 21,860 feet, and deepen channel to 25 feet.
1926	Jetty Channel improved to 30 feet deep and 200 feet wide, and Outer Bar Channel improved to 33 feet deep and 450 feet wide.
1932	Sabine Pass Channel improved to 30 feet deep and 300 feet wide, Jetty Channel improved to 33 feet deep and 300 feet wide, and Outer Bar Channel deepened to 34 feet.
1943	Sabine Pass Channel improved to 34 feet deep and 500 feet wide, Jetty Channel improved to 34 feet deep and to widths varying from 500 to 800 feet, and Outer Bar Channel improved to 36 feet deep and 800 feet wide.
1949	Sabine Pass and Jetty Channels deepened to 36 feet and Outer Bar Channel deepened to 37 feet.
1967	Established East and West Jetties to present lengths of 25,310 feet and 21,905 feet, respectively.
1972	Sabine Pass and Jetty Channels deepened to 40 feet and Outer Bar Channel deepened to 42 feet.

At Sabine Pass, the Sabine-Neches Waterway project is composed of three channel segments; Sabine Bank Channel (stations 18+000 to

95+734), Sabine Pass Outer Bar Channel (stations 0+000 to 18+000), and Sabine Pass Jetty Channel (stations 0+00 to -214+88.3). The project also includes two rubble-mound jetties, the East Jetty 25,310 feet long and the West Jetty 21,905 feet long. The Sabine Bank Channel is the portion of the Entrance Channel located the farthest gulfward. It has a bottom width of 800 feet, a depth of 42 feet and an approximate length of 77,800 feet. The Sabine Pass Outer Bar Channel is 42 feet deep, 800 feet wide, and 18,000 feet long. The Sabine Pass Jetty Channel is 21,488 feet long and has a width of 500 to 800 feet and a depth of 40 feet. Figure 2 shows the entrance portion of the Sabine-Neches Waterway and its corresponding stationing.

The maintenance dredging history for the entrance to the Sabine-Neches Waterway is shown on Figure 3. This display shows that the Jetty Channel rarely requires maintenance since dredging has only been performed once since 1981, resulting in a dredging cycle of more than 11.4 years. The Sabine Bank Channel segment has been dredged three times in the past 11 years. The Outer Bar Channel, however, has been dredged eight times over the same time period. A summary of the dredging cycle and average quantity of material removed for each part of the channel is as follows:

Location	Dredging Cycle	Avg. Quantity per Cycle
Jetty Channel	>11.4 years	1.4 million cubic yards
Outer Bar Channel	1.4 years	3.6 million cubic yards
Sabine Bank Channel	3.8 years	2.4 million cubic yards

These channels are dredged by hopper dredge and the dredged materials are placed in offshore disposal sites located west of the Sabine Outer Bar and Bank Channels. The average annual shoaling rates for the Outer Bar and Bank Channels are 2.5 million cubic yards and 622,000 cubic yards, respectively.

The materials dredged from the channels at Sabine Pass are predominantly silts and clays. The majority of the grain-size distribution curves reviewed from 1960-1976 indicated a very high percentage of fines (silts and clays), generally in the 90% range. Some exceptions to this included samples with sand ranging from 60%

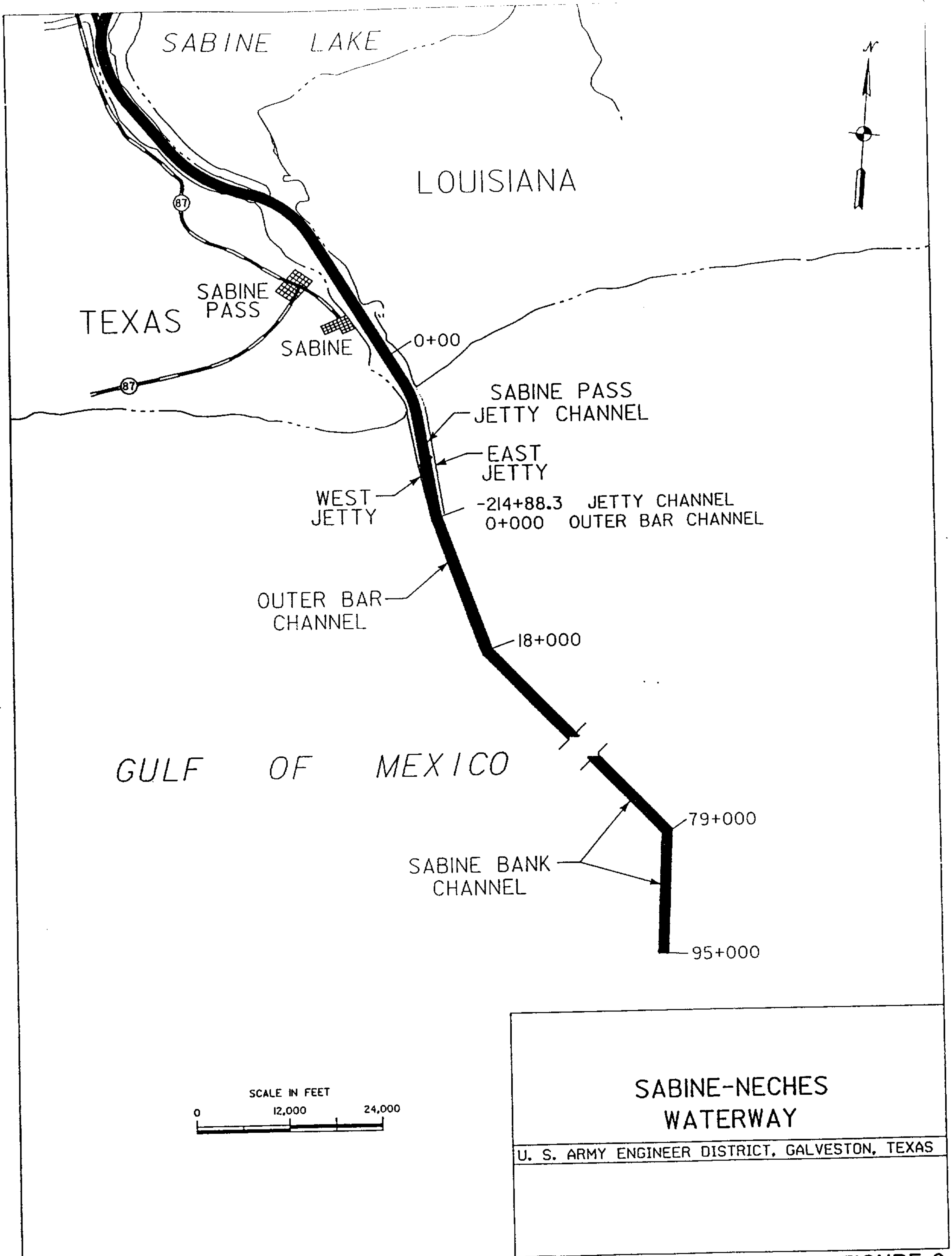
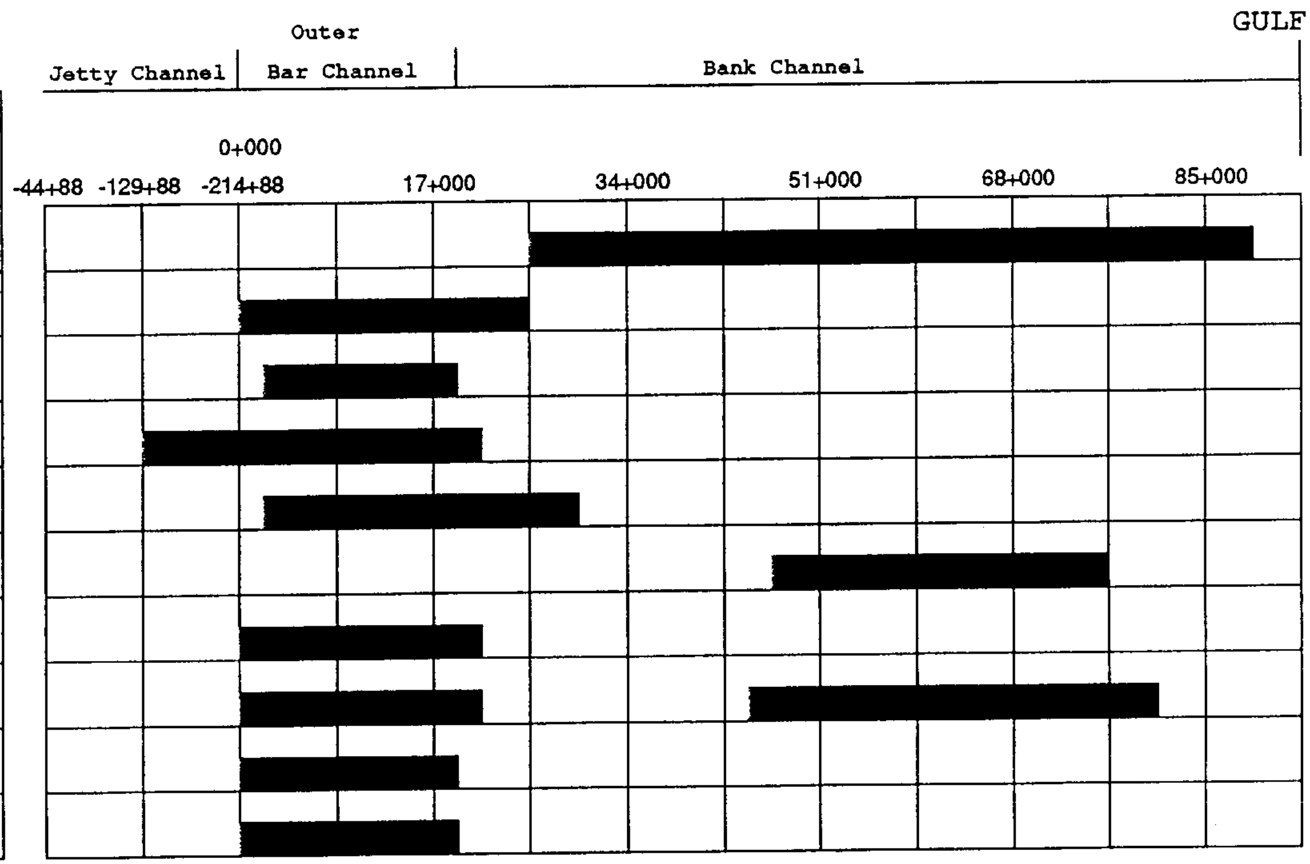

SABINE LAKE
LOUISIANA
TEXAS
SABINE PASS
SABINE
87
87
0+00
SABINE PASS JETTY CHANNEL
EAST JETTY
WEST JETTY
-214+88.3 JETTY CHANNEL
0+000 OUTER BAR CHANNEL
OUTER BAR CHANNEL
18+000
GULF OF MEXICO
79+000
SABINE BANK CHANNEL
95+000
SCALE IN FEET
0
12,000
24,000
SABINE-NECHES WATERWAY
U. S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS

FIGURE 2

FIGURE 3
MAINTENANCE DREDGING OF THE
ENTRANCE OF SABINE-NECHES WATERWAY

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
HD91-01	AUG 91 - OCT 91	1,520,027
91-0025	APR 91	5,710,000
88-0027	SEP 88 - OCT 88	3,002,319
HD87-01	JUL 87 - SEP 87	4,572,109
86-0021	MAY 86 - JUL 86	5,626,837
HD85-01	JUL 85 - SEP 85	5,353,000
84-0023	JUL 84 - SEP 84	5,601,112
HD83-01	JUL 83 - OCT 83	378,000
82-0028	MAY 82 - JUN 82	1,693,264
81-0009	MAR 81 - MAY 81	3,589,486



and 92% at several locations and at various years between 1968 and 1972. Samples from earlier and later years in the same areas indicated a greater percentage of fines. Samples taken from the channel in 1987 showed a low percentage of sand, ranging from 1% to 46%. The 1992 samples, the latest samples taken from the channel, indicated a low percentage of sand, ranging from 8% to 58%. The conclusions which can be drawn from this data are that the maintenance material that is periodically removed from this channel contains a high percentage of silts and clays that vary significantly between dredging cycles and that the material is not suitable for placement on Gulf beaches.

Rollover Pass

Rollover Pass is located 22 miles northeast of Galveston and was constructed by the Texas Game and Fish Commission, now the Texas Parks and Wildlife Department. It is one of three inlets of the Galveston Bay complex, the others being Galveston Harbor Channel and San Luis Pass. Approximately 1 percent of the tidal flow from Galveston Bay passes through Rollover Pass. Rollover Fish Pass was initially opened between October 1954 and February 1955. Although the original design called for a channel width of about 80 feet and a depth of 8 feet, tidal currents rapidly scoured the pass to a width of 500 feet at the Gulf entrance and 30 feet deep at the State Highway 87 bridge. At the same time, the downdrift beach west of the pass was severely eroded for a distance of about one-half mile. In order to control flow through the pass and minimize scour, the Game and Fish Commission constructed a steel sheetpile bulkhead across the pass immediately south of the bridge in November 1955. The tops of alternate piles were driven to a depth of about -2 feet to permit some tidal exchange between the Gulf and bay. The Commission placed approximately 6,000 cubic yards of fill along the Gulf shore west of the pass for about 1,300 feet in February 1957. However, the fill was lost by wave erosion within about 4 months after placement. Hurricane Audrey made landfall at Cameron, Louisiana, about 80 miles northeast of Rollover on the morning of June 27, 1957. Little damage was caused in the channel itself, but the Gulf shore was eroded an average of 50 to 60 feet for about 5 miles on each side of the pass. The pass was reopened in June 1958 by driving the steel sheetpiles 5 feet below mean low water.

The pass has remained open and relatively stable since 1959. The Texas Parks and Wildlife Department constructed a concrete retaining wall behind the southwest steel bulkhead in 1966 and behind the southeast bulkhead in 1972. The Parks and Wildlife Department is currently replacing the existing bulkheads. Completion of the rehabilitation project is scheduled for November 1992.

Galveston Harbor Channel

The Galveston Harbor Channel is located at the northeast end of Galveston Island, approximately 58 miles southwest of Sabine Pass. This inlet separates Bolivar Peninsula to the northeast from Galveston Island to the south and connects Galveston Bay with the Gulf. Approximately 78 percent of the tidal flow for Galveston Bay passes through the Galveston Harbor Channel.

The Galveston Harbor Channel project is a federally-maintained channel which passes through this inlet. Corps of Engineers activities to stabilize and improve the inlet for navigation were first authorized by the Congress in 1870. Activities prior to 1874 provided for dredging operations on a small scale, and were only intended to afford temporary relief to navigation.

The original project for the permanent improvement of this harbor was adopted in 1874. This project consisted of the construction of jetties which were expected to deepen the channel on the bar to 18 feet. The method used in jetty construction proved to be unsatisfactory, and a modified project was formulated for higher and longer jetties with the expectation of creating a channel at least 25 feet deep, and with a goal of reaching 30 feet deep. The modified project was authorized in 1886 and by 1900 the channel had reached a depth of 26 feet. A chronology of Federal activities at the inlet after 1900 is shown in Table 2.

TABLE 2

CHRONOLOGY OF FEDERAL IMPROVEMENTS TO GALVESTON CHANNEL

Year	Activity
1910	Jetties completed to present length, channel depth completed to 30 feet.
1922	Channel improved to 35 feet deep and 800 feet wide.
1950	Outer Bar Channel deepened to 38 feet and Inner Bar Channel and Bolivar Roads Channel deepened to 36 feet.
1967	Outer Bar and Inner Bar Channels relocated. Entrance and Outer Bar Channels deepened to 42 feet and Inner Bar and Bolivar Roads Channels deepened to 40 ft.

The Galveston Harbor Channel project, shown in Figure 4, allows for deep-draft navigation access to the ports of Galveston, Texas City, and Houston, as well as shallow-draft access to the Gulf Intracoastal Waterway (GIWW). The features of the project which are of interest to this study are: rubble-mound jetties extending from Galveston Island and from Bolivar Peninsula for distances of 35,900 feet and 25,907 feet, respectively; the Entrance Channel (stations 30+675 to 56+000) 42 feet deep, 800 feet wide, and over 25,000 feet long; Outer Bar Channel (stations 21+912 to 30+675) 42 feet deep, 800 feet wide, and over 8,700 feet long; Inner Bar Channel (stations 5+048 to 21+912) 40 feet deep, 800 feet wide, and over 16,800 feet long; the Bolivar Roads Channel (stations 0+000 to 5+048) 40 feet deep, 800 feet wide, and 5,048 feet long; and an anchorage area located north of the Inner Bar Channel (stations 12+000 to 23+400) which is 36 feet deep and has an average bottom width of 2,875 feet and an average length of 9,763 feet.

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ON: 6-AUG-1992
AT: 15:13

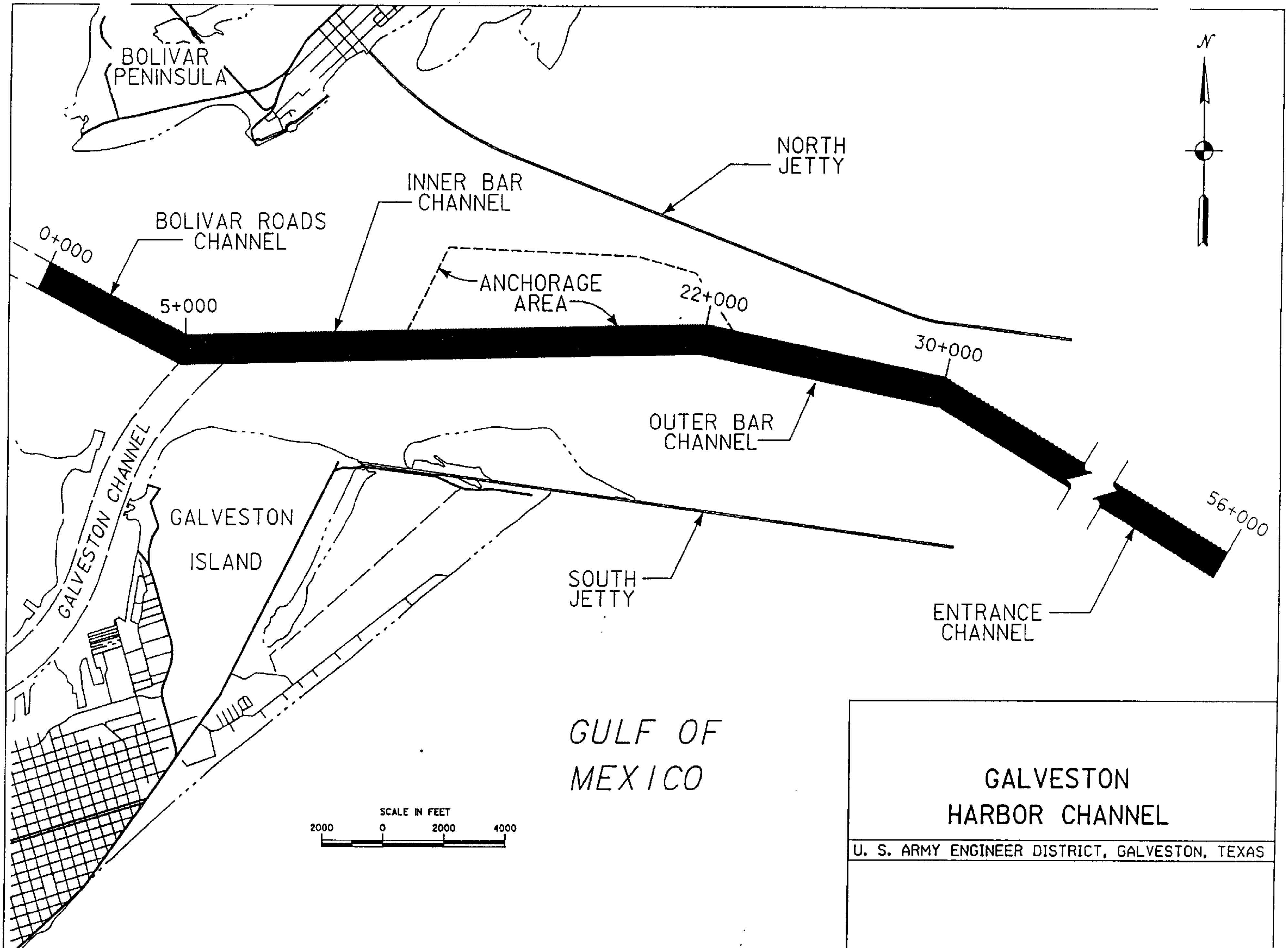


FIGURE 4

The maintenance dredging history for this project is presented in Figure 5. Shortly after the 1989 dredging contract was initiated, the Government hopper dredge experienced mechanical problems. Therefore, the dredging job was not completed, resulting in a low quantity of material removed and the exact stationing of dredging not known. The Galveston Entrance Channel, Galveston Outer Bar Channel, and Galveston Inner Bar Channel segments have been dredged seven times since March 1979 resulting in an average dredging cycle of about 1.9 years. The average quantity removed during a maintenance dredging cycle is 2.2 million cubic yards, and the average annual shoaling rate is 1.1 million cubic yards. This material is removed by hopper dredge and is placed in an offshore disposal site located south of the Entrance Channel.

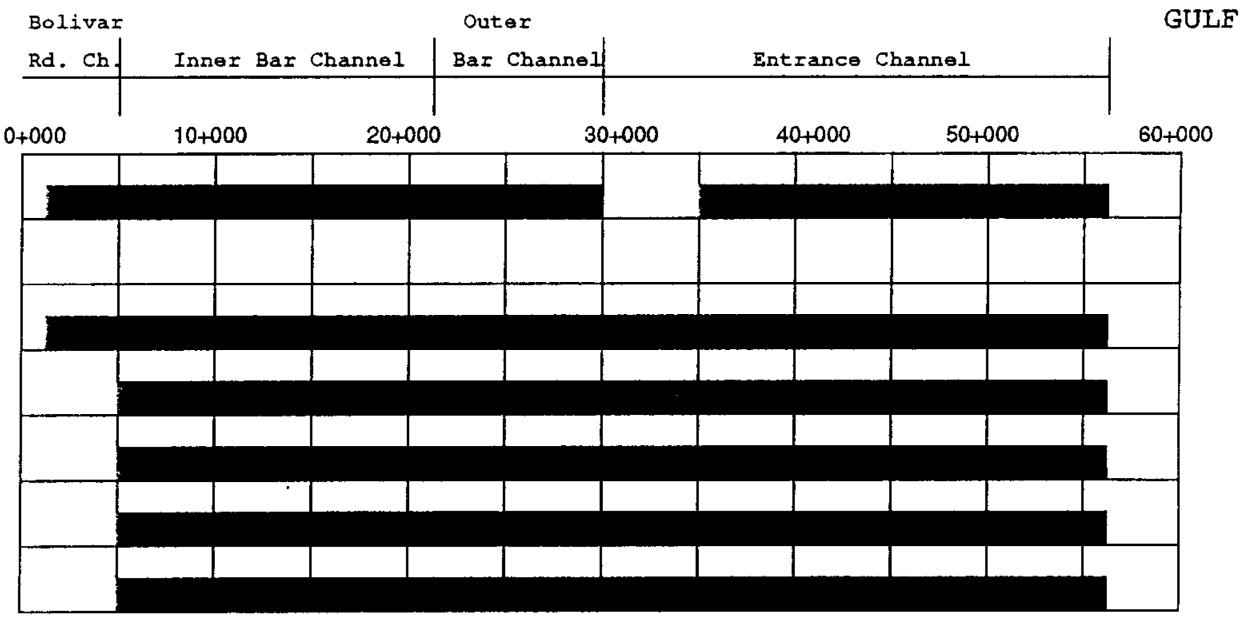
Bolivar Roads Channel has been dredged twice since March 1979, removing an average of 112,000 cubic yards of material every 6.7 years. This portion of the channel has an average annual shoaling rate of 17,000 cubic yards. The anchorage area has been dredged three times since March 1978, resulting in an average dredging cycle of about 4.8 years to remove about 786,000 cubic yards of dredged material. The average annual shoaling rate for the anchorage area is 163,000 cubic yards.

Material removed from the channel has contained some sand. From 1970 to 1977, sand percentages of samples taken from stations 8+000 to 30+000 in the Galveston Harbor Channel ranged from 88% to 97%. Samples between 1957 and 1970 for this same reach indicate a sand percentage between 9% and 97%, with the majority of samples being in the 70% to 95% range. Since 1977 samples taken from stations 0+000 to 25+000 had sand percentages ranging from 41% to 91%.

Samples taken between station 30+000 and station 38+000 from 1957 to 1977 show a sand content ranging from 40% to 88% while samples taken from station 39+000 to station 56+000 had a very low sand content. Since 1977 stations 30+000 to 56+000 have sand percentages ranging from 1% to 50% with the exception of one sample that had 79%.

FIGURE 5
MAINTENANCE DREDGING OF THE GALVESTON HARBOR CHANNEL

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
90-0031	AUG 90 - DEC 90	2,611,873
HD89-04	SEP 89	58,938 *
HD88-01	JUL 88 - OCT 88	1,038,946
86-0026	MAY 86 - JUL 86	2,212,568
84-0012	MAR 84 - MAR 85	4,487,405
80-0023	MAY 80 - JUL 80	1,170,282
79-0017	MAR 79 - SEP 79	3,812,190



* Exact Stationing Unknown

Based on this analysis, the project segment from station 0+000 to station 25+000 has the best potential source of sand for beach nourishment. This reach, which includes Bolivar Roads Channel, the Inner Bar Channel, and a portion of the Outer Bar Channel, accumulates 819,000 cubic yards of material about every 1.9 years for an average annual shoaling rate of 427,000 cubic yards.

San Luis Pass

San Luis Pass is an unjettied, natural inlet located at the southwest end of Galveston Island. It extends between the Gulf and West Galveston Bay, separating Galveston and Follets Islands with a tidal channel approximately 1 mile wide. It connects Christmas, Bastrop, and West Bays with the Gulf of Mexico. Approximately 21 percent of the tidal flow to Galveston Bay occurs through San Luis Pass. Although the first chart survey of San Luis Pass was made in 1853, there are historical records of the pass dating back to 1834. From 1853 to 1933 volume changes within the inlet were minor with some erosion of the ebb tidal delta. Historically, the deepest part of the pass has been the southwest side of the inlet. The inlet began to widen in the 1950's and the ebb tidal delta moved toward the southwest. Major changes were a result of hurricanes. The hurricane of 1959 passed directly over the pass and Carla in 1961 struck Pass Cavallo 95 miles to the southwest, producing large waves and strong currents at San Luis Pass. By 1965 the inlet width had increased to more than 4,000 feet. In 1983, the center of Hurricane Alicia moved inland directly over San Luis Pass. Although some erosion occurred on adjacent shorelines and in the pass, the overall impacts were minor. Since that time the inlet width has remained almost constant. Typical inlet changes have occurred, the ebb and flood tidal deltas have changed in volume, migration has taken place, new channels have been cut, and adjacent shorelines have eroded and accreted. Beaches southwest of the pass have accreted while those to the northeast have eroded, emphasizing the downdrift offset typical of many Texas inlets.

Freeport Channel

The Federal project known as Freeport Harbor is located on the upper Texas coast, approximately 60 miles south of Houston. The project is an improvement of the original mouth of the Brazos River and provides for a deep-draft waterway from the Gulf of Mexico to the city of Freeport. In 1929 the Brazos River was diverted from the Freeport Channel to a new outlet about 6.5 miles southwest of the original mouth by the Corps of Engineers. The diversion made Freeport Harbor entirely tidal. The project has an overall length of about 8.6 miles.

The Brazos River, the longest river in the state, sustained considerable commerce as early as the 1830's. It differs from most other Texas rivers by emptying directly into the Gulf without an intermediary tidal basin. The Brazos was not, however, an ideal candidate for dependable navigation, impeded by many rocks, shoals, bars, snags, bends, rapids, and variable water levels. A further hindrance lay in the shifting bar, fluctuating in depth from 4 to 10 feet, where the mouth of the river flowed into the Gulf.

The original project for Federal improvement at this locality was authorized by the River and Harbor Act approved June 14, 1880, which provided for construction of jetties for controlling and improving the channel over the bar at the mouth of the Brazos River. The work was started in 1881 and continued until 1886, when operations were suspended for lack of funds. Partial construction of the jetties was accomplished, but the work was not successful in obtaining an adequate depth over the bar. On March 28, 1899, the Brazos River Channel and Dock Company, under authority granted by the River and Harbor Act of August 21, 1888, started work to provide a navigable channel from the mouth of the Brazos River inland. The company was unable to finance completion of the work, and on April 25, 1899, in accordance with requirements of the River and Harbor Act of March 3, 1899, transferred all its works, rights, and privileges to the United States. A chronology of the Federal improvements made after taking over the project is shown in Table 3.

TABLE 3

CHRONOLOGY OF FEDERAL IMPROVEMENTS AT FREEPORT CHANNEL

Year	Activity
1908	Repaired jetties constructed by the Brazos River Channel and Dock Company. The jetties were 560 feet apart; the length of the North Jetty was 4,708 feet and the South Jetty 5,018 feet.
1911	Dredged 18- by 150-foot channel from outer end of jetties to railway wharf.
1919	Channel deepened to 22 feet.
1929	Dredging of Diversion Channel to relocate mouth of the Brazos River completed.
1931	Outer Bar and Jetty Channels improved to 25 feet deep and 150 feet wide.
1936	Outer Bar Channel improved to 32 feet deep and 300 feet wide, and Jetty Channel improved to 32 feet deep and 200 feet wide.
1958	Realigned Outer Bar Channel on straight alignment with Jetty Channel.
1961	Outer Bar Channel deepened to 38 feet; Jetty Channel deepened to 36 feet.
1990	Outer Bar Channel improved to 47 feet deep and 400 feet wide.
1991	North Jetty relocated 640 feet to the northeast, increasing the distance between the jetties to 1,200 feet.
1992	Jetty Channel improved to 45 feet deep by 400 feet wide.

The most recent improvements at Freeport Harbor were authorized by the River and Harbor Act of December 1970 which provided for the relocation and deepening of the Entrance Channel to 47 feet, relocation and deepening of the Jetty Channel to 45 feet, deepening and/or enlarging of inside channels and turning basins, relocation of the North Jetty, and rehabilitation of the South Jetty. This report focuses on the entrance area of this project, as shown in Figure 6.

Deepening of the Entrance Channel was completed in November 1990. The North Jetty was relocated 640 feet to the northeast in March 1991, increasing the distance between the jetties to 1,200 feet. The Jetty Channel was widened and deepened in April 1992 with work on the inner channels and basins completed in June 1992. Rehabilitation of the South Jetty and the 500-foot extension of the North Jetty is ongoing with completion scheduled for October 1993. Upon completion, total length of the North and South Jetties will be 4,200 feet and 4,600 feet, respectively. The North and South Jetties also have inshore shore protection sections of 3,500 feet and 1,460 feet, respectively. The Outer Bar Channel (station 0+00 to station -270+00) is 400 feet wide and 47 feet deep. The Jetty Channel (stations 0+00 to 60+00) has dimensions of 400 feet wide and 45 feet deep.

The maintenance dredging records shown in Figure 7 show that the entrance to Freeport Harbor has been maintained numerous times from 1970 until 1990. The maintenance record was interrupted in 1990 and 1991 when the channel was widened and deepened. The new work material removed in 1990 during the deepening project was removed by hopper and bucket dredges, whereas the new work material removed in 1991 was by a pipeline dredge.

Prior to channel modification, the average dredging cycle for the entrance at Freeport was 1.2 years to remove 1.2 million cubic yards of material. Maintenance dredging of the Freeport Outer Bar and Jetty Channels has been performed by hopper dredge and the material placed in an offshore disposal area located southwest of the Outer Bar Channel. An average shoaling rate of 960,000 cubic yards per year was calculated for this channel. The improved

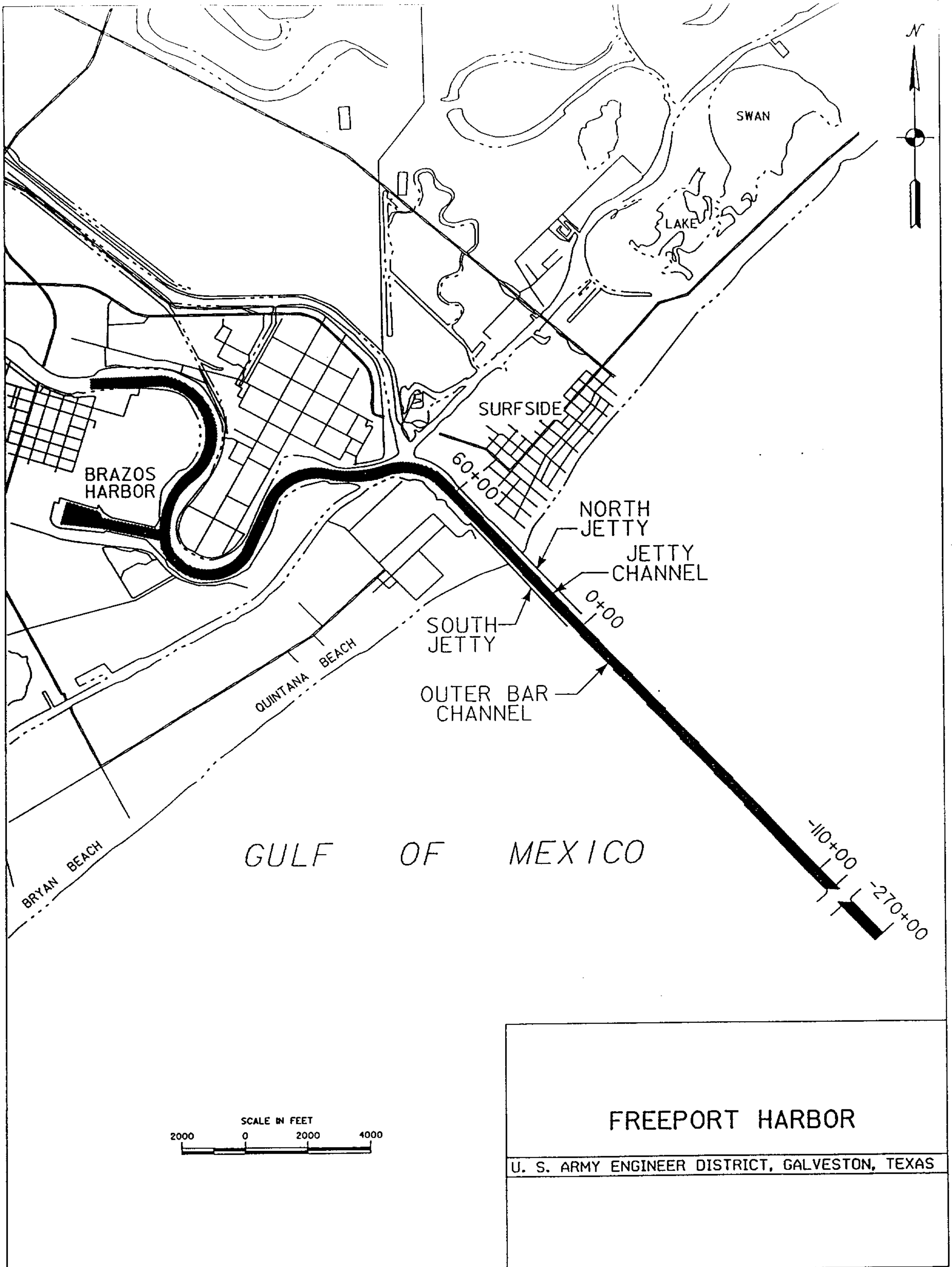
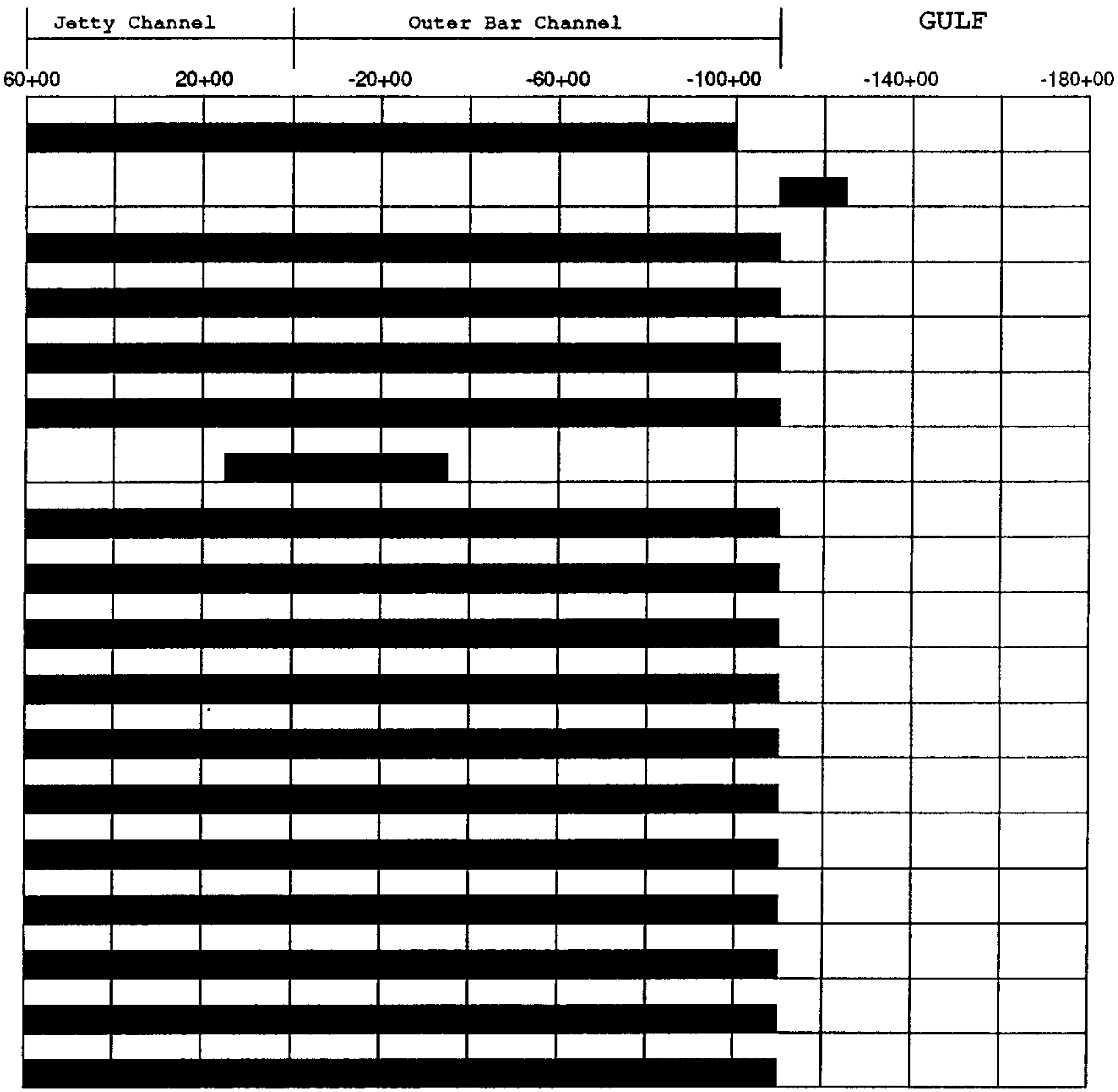

N
SWAN
LAKE
SURFSIDE
BRAZOS
HARBOR
60+00
NORTH
JETTY
JETTY
CHANNEL
0+00
SOUTH
JETTY
OUTER BAR
CHANNEL
QUINTANA BEACH
BRYAN BEACH
GULF OF MEXICO
-110+00
-270+00
SCALE IN FEET
2000 0 2000 4000
FREEPORT HARBOR
U. S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS

FIGURE 6

FIGURE 7
MAINTENANCE DREDGING OF THE
ENTRANCE OF FREEPORT HARBOR

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
88-0026	AUG 88 - SEP 88	843,940
HD87-02	SEP 87	213,773
87-0023	MAY 87 - JUL 87	1,016,286
86-0033	JUL 86 - AUG 86	925,709
85-0029	AUG 85 - SEP 85	903,748
84-0033	OCT 84 - NOV 84	1,186,135
HD84-01	OCT 84 - NOV 84	212,799
83-0016	JUN 83 - OCT 83	1,109,789
82-0027	JUN 82 - AUG 82	1,387,826
HD80-04	AUG 80 - JAN 81	1,098,920
HD80-02	DEC 79 - FEB 80	1,101,208
HD78-03	AUG 78 - OCT 78	966,648
HD76-01	SEP 75 - DEC 75	2,095,572
HD75-01	NOV 74 - DEC 74	1,010,361
-	SEP 73 - JAN 74	1,089,540
-	NOV 72 - MAY 73	868,540
-	OCT 71 - MAY 72	1,161,215
-	NOV 70 - MAY 71	1,614,436



channel has not required maintenance since its construction.

Historical records showing grain size of the material removed from the channel indicate a very low percentage of sand at all stations from 1957 through 1976, generally less than 20%. Samples taken in December 1976 had sand percentages ranging from 0% to 50% with the exception of one sample showing 71% sand at station 0+000. Samples taken in the channel from 1983 to 1989 between stations -100+000 to 50+000 show the sand content to range from 3% to 52%. From this data it was concluded that dredged material from the Freeport Outer Bar and Jetty Channels is not considered suitable for placement on beaches.

Brazos River Diversion Channel

The lower 5 miles of the Brazos River is known as the Brazos River Diversion Channel. It was completed in 1929 by the Federal Government in an effort to divert the sediment-laden waters of the Brazos River away from the deep-draft navigation facilities located at Freeport along the lower portion of the river. This was accomplished by damming the river about 7.5 miles upstream of the original mouth and rerouting the river flows through the Brazos River Diversion Channel to discharge into the Gulf of Mexico at a point approximately 6.5 miles southwest of the original mouth.

From the time the Freeport Jetties were constructed in the late 1800's, the areas adjacent to the jetties accumulated material forming a delta into the Gulf on both sides of the jetties. When the river was diverted in 1929 to its present location, the delta near the jetties began to erode, and a delta at the relocated mouth began to form. Since 1949 the new delta has been eroding because of a reduction in sediment loads on the river.

San Bernard River

Federal improvements on the San Bernard River consist of a 9-foot deep by 100-foot wide channel from the GIWW to a point 28 miles upstream authorized by the River and Harbor Act of June 20, 1938. Original plans considered for the project provided for an improved deepwater channel with jetty protection at the mouth; however, this proposal was abandoned. Federal improvements on the San Bernard River currently terminate at its intersection with the GIWW. The 1-mile reach of the river between the GIWW and the Gulf is not maintained by the Federal Government. There is not any delta building ongoing at the mouth of the river.

Caney Fork/Mitchell Cut

In May 1989 the Matagorda County Drainage District opened an inlet, Caney Fork/Mitchell Cut, between the GIWW and the Gulf through the eastern end of East Matagorda Bay. This inlet replaced McCabe Cut which was opened in 1983 to allow a direct outlet for floodwaters from the Caney Creek watershed. McCabe Cut was subsequently closed in 1989 because natural processes expanded this channel. This enlarged channel allowed strong currents to develop between the GIWW and the Gulf and became a hazard to navigation, particularly to eastbound traffic on the GIWW. This new inlet has an 80-foot bottom width and -8 foot depth. Since the Caney Fork/Mitchell Cut was constructed, the inlet has been laterally stable.

Brown Cedar Cut

The natural formation of Brown Cedar Cut near the eastern end of Matagorda Peninsula probably occurred in 1929 and has been open intermittently since that time. Historically, tidal flows and flushing through the inlet have been ineffective in keeping it open for substantial periods of time. A constantly changing inlet resulted until deposition completely closed it. It now opens during hurricanes because of storm surges from the Gulf to East Matagorda Bay or because of interior rainfall accumulations flowing from East Matagorda Bay to the Gulf.

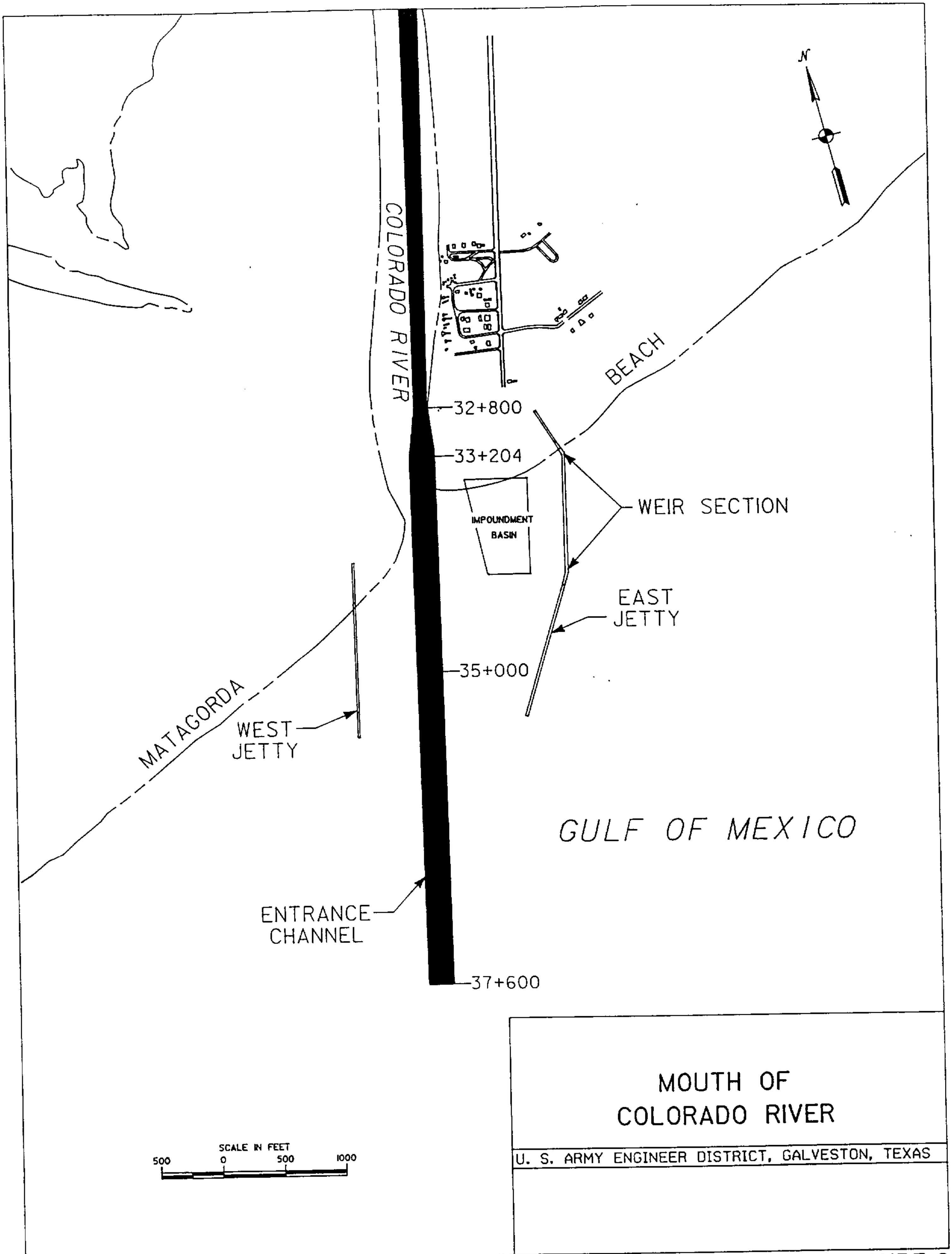
Colorado River

The Colorado River discharges into the Gulf of Mexico about 80 miles southwest of Galveston. The Mouth of Colorado River project is located in the delta portion of the Colorado River and extends from the river's mouth to the town of Matagorda. The existing project to divert the Colorado River flows into Matagorda Bay is an effort to reestablish historical flows of the river into the bay.

Sediment transported by the Colorado River was hindered in the mid and late 1800's by a log raft. It is uncertain when this particular raft originated as log jams were characteristic of the lower Colorado River. References have been made to a raft in 1824, 1831, 1837, and 1875. By 1926 the raft extended 46 miles upstream from Matagorda and formed a lake which also impounded coarse sediment.

Dredging of a pilot channel through the raft was initiated in March 1925 and completed in 1929. Growth rate of the delta changed little until June 1929 when a major flood carried large quantities of sediment and logs into Matagorda Bay. Additional sediment was also contributed by bank erosion and adjustment of the river channel after the log raft was removed. After 1929, the delta grew rapidly and by 1935 had prograded across Matagorda Bay.

The navigation features of the project include dual jetties into the Gulf with the East Jetty consisting of a weir to allow sediments to accumulate in a constructed impoundment basin between the jetties; the Entrance Channel (stations 33+200 to 37+600) 15 feet deep and 200 feet wide; a 12-foot deep by 100-foot wide navigation channel from the Entrance Channel to the GIWW which generally follows the Colorado River Channel, and a harbor and turning basin. The Impoundment Basin is located between stations 33+404 and 34+204. The project also includes recreational facilities adjacent to the East Jetty and features to restore the Colorado River outfall to Matagorda Bay. This project is shown in Figure 8. Construction of the Jetty and Entrance Channel was completed in April 1990. The remaining project features are scheduled for completion in mid-1994.



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ON: 4-AUG-1992
AT: 08:20

FIGURE 8

Maintenance dredging records are shown in Figure 9. In April 1991, the Entrance Channel from stations 30+600 to 36+600 was dredged. Approximately 62,000 cubic yards of material removed from the impoundment basin was used to construct a dam in Tiger Island Channel, closing the cut between Matagorda Bay and the Colorado River. This material was not analyzed to determine the percentage of sand.

Because of the short length of time since the channel and impoundment basin were completed, an average maintenance cycle and quantity could not be developed. However, the impoundment basin is scheduled to be maintained again in 1992. This material will be dredged by a pipeline dredge and pumped to the downdrift shore beyond the South Jetty to avoid interrupting the littoral transport downcoast. This procedure is incorporated into the project's Environmental Impact Statement.

Dredging of the channel to divert the Colorado River into Matagorda Bay was completed in May 1990. After the dam is completed in the Colorado River downstream of the diversion channel, the Colorado River will no longer discharge into the Gulf of Mexico.

Greens Bayou

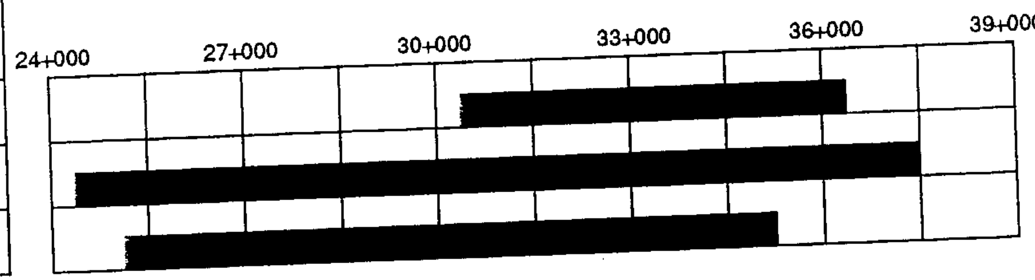
Greens Bayou is a natural hurricane washover channel located on Matagorda Peninsula between the Colorado River and the Matagorda Ship Channel. When open, this channel connects Matagorda Bay and the Gulf. It is opened by hurricanes and closed by natural processes.

Matagorda Channel

The Matagorda Ship Channel is a federally-maintained channel located 80 miles northeast of Corpus Christi. The channel extends across Matagorda Peninsula, connecting Matagorda Bay to the open Gulf. Approximately 44 percent of the tidal flow between the bay

FIGURE 9
MAINTENANCE DREDGING OF THE
MOUTH OF COLORADO RIVER

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
91-0022	APR 92 - MAY 91	62,077
89-0038	SEP 89	New Work
73-0133	JUL 73 - NOV 73	781,668



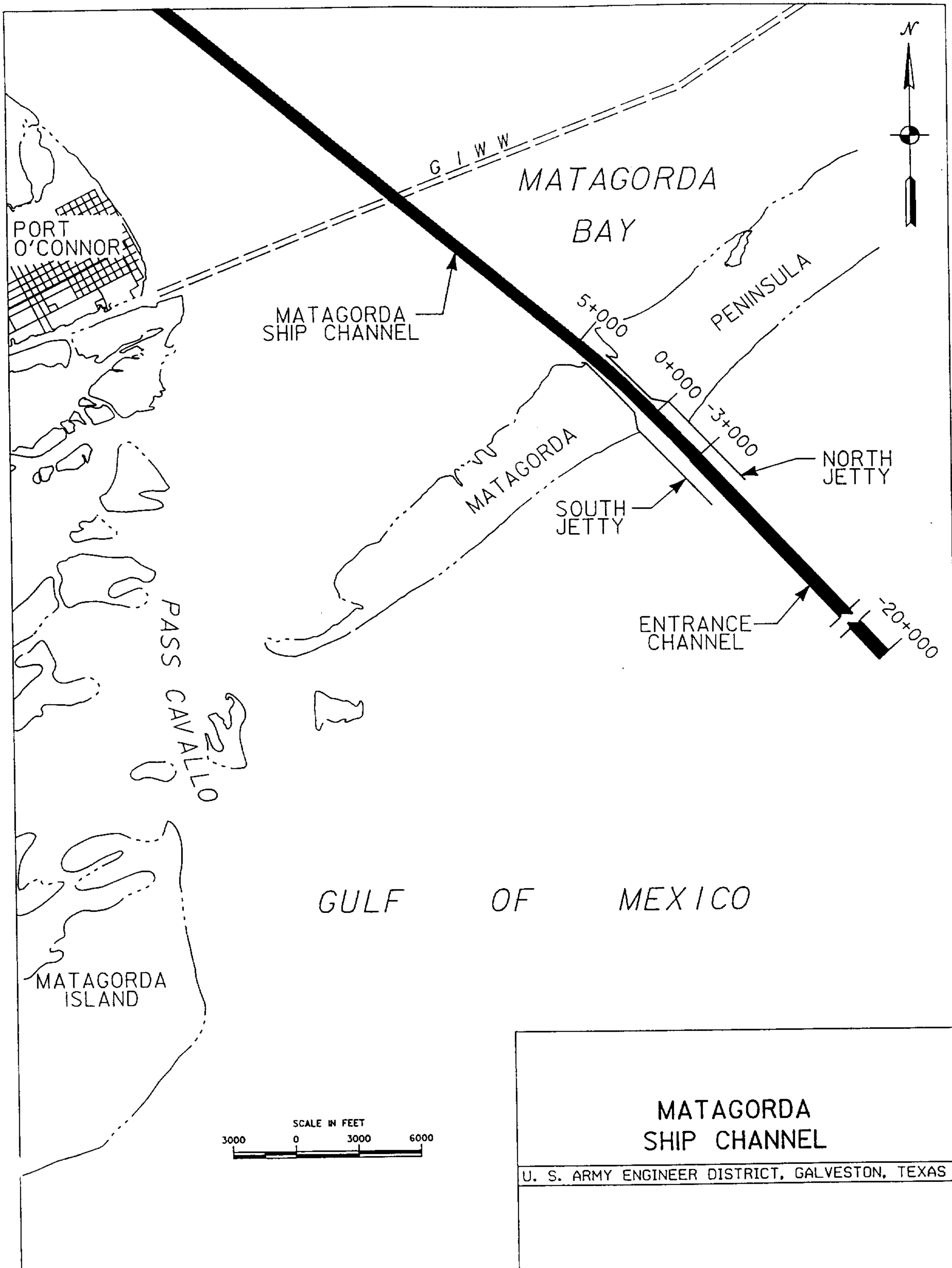
and the Gulf passes through the Matagorda Entrance Channel. The remaining 56 percent passes through Pass Cavallo.

In 1958, Congress authorized the construction of a deep-draft navigation channel from the Gulf of Mexico through Pass Cavallo, 38 feet deep, 300 feet wide and about 6 miles long; an inner channel 36 feet deep, 200 feet wide and about 22 miles long across Matagorda and Lavaca Bays; a turning basin at Point Comfort 36 feet deep and 1,000 feet square; and dual jetties at the channel entrance. The authorization also provided for enlargement of the shallow-draft channels near Port Lavaca. During preconstruction project design, a fixed-bed hydraulic model was constructed as an aid in developing sound engineering design of the project. The results of the model tests showed that the location of the Entrance Channel should be moved from Pass Cavallo to a man-made cut across Matagorda Peninsula. The relocated Entrance Channel would provide a shorter and straighter entrance, shorter jetties, a lesser length of channel in which current velocities would be relatively high, and the probability that periodic maintenance dredging would be less.

Dredging was initiated in July 1962, and construction of the jetties began early in 1963. The channel across Matagorda Peninsula was completed in September 1963. Dredging of the inner portion of the Entrance Channel and construction of the South Jetty were completed early in 1966; however, dredging on the outer portion of the Entrance Channel and construction of the North Jetty were not completed until October 1966.

This report focuses on the Entrance Channel (stations 0+000 to -20+000) and the North and South Jetties which are 5,900 feet and 6,000 feet long, respectively. The project is shown in Figure 10.

The maintenance dredging history for the entrance of the Matagorda Ship Channel is shown on Figure 11. Maintenance dredging records indicate that the Matagorda Jetty Channel is dredged by hopper dredge and the material is placed in an offshore disposal site located southwest of the channel. Portions of the Jetty Channel have been dredged ten times since October 1970, resulting in a 2.2-



MATAGORDA SHIP CHANNEL

U. S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS

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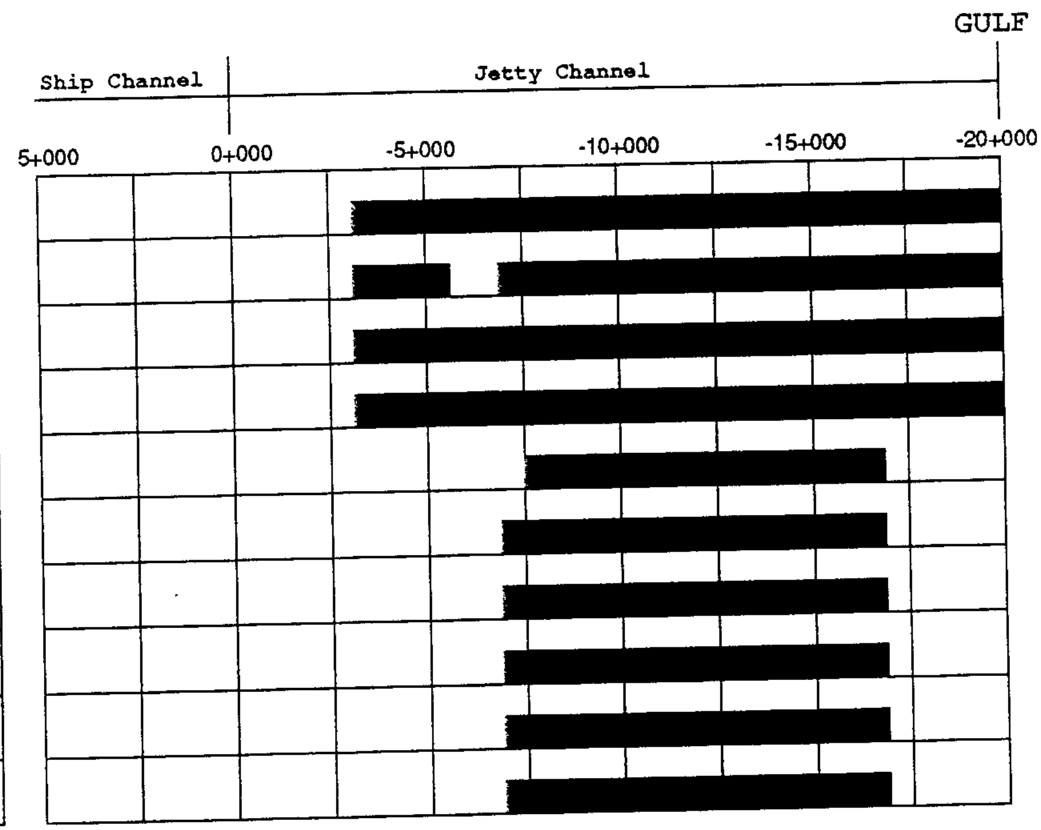
PLOTTED BY: RICK
ON: 4-AUG-1992
AT: 14:48

FIGURE 10

FIGURE 11
MAINTENANCE DREDGING OF THE
ENTRANCE OF MATAGORDA SHIP CHANNEL

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
89-0015	JAN 89 - FEB 89	498,040
84-0009	JAN 84 - MAR 84	908,933
80-0056	AUG 80 - DEC 80	1,790,548
79-0034	AUG 79	539,891
HD78-02	DEC 77 - JAN 78	290,000
HD76-02	JAN 76 - FEB 76	943,112
HD75-02	DEC 74 - MAY 75	1,463,473
HD73-02	MAR 73 - APR 73	547,000
HD72-02	MAR 72 - APR 72	484,560
HD71-02	OCT 70 - AUG 71	1,135,825



year average dredging cycle. The average quantity removed per cycle is 860,000 cubic yards. The average annual shoaling rate for this channel is 395,000 cubic yards.

For the period 1963 through 1976 sand percentages of dredged material ranged from 18% to 99%. Samples taken between stations -3+000 and -11+000 indicated a high sand content varying from 64% to 99%. Samples taken in 1977, 1979, and 1983 indicated a percentage of sand ranging from 7% to 94% from stations 0+000 to -20+000. The most recent samples taken in December 1988 also indicated a high sand content. Stations -10+000 to -20+000 had a sand percentage ranging from 81% to 98%. Based on this analysis, dredged materials from stations -3+000 to -20+000 are considered a potential source of sand for beach nourishment.

Pass Cavallo

Pass Cavallo is a natural inlet located between Matagorda Peninsula to the northeast and Matagorda Island to the southwest. It provides continuous, significant tidal flow between Matagorda Bay and the Gulf, accounting for 56 percent of the tidal exchange.

Among the first to be used for navigation in Texas, Pass Cavallo at the entrance into Matagorda Bay was the last to be successfully improved. According to shipping interests in the 1800's, Pass Cavallo was the second best natural pass on the Texas coast; Galveston was ranked first. To secure a 12-foot channel depth across the bar, a single jetty was begun in 1881 at the south side of the pass, designed to extend 7,600 feet from Matagorda Island. Construction proceeded over the next 5 years, marked by the usual problems of inadequate funds and work suspensions. In 1888 the attempt to improve Pass Cavallo was abandoned.

After abandonment of the project, no improvement was attempted between the Gulf and Matagorda Bay for many years. Pass Cavallo served in its natural state to accommodate the shallow-draft vessels using its channel. The pass had remained in a stable position for more than 200 years and the channel depth between the inner and outer bars ranged from 20 to 42 feet. Opening of the Colorado River Flood Discharge Channel across Matagorda Peninsula in the mid-1930's reduced the flow through Pass Cavallo and, gradually, its navigability.

By 1949, the outer bar posed a drastic problem, even for the small fishing and oil exploration vessels that needed to cross it. Navigation required calm weather and was limited to boats drawing less than 6 feet. As an emergency measure to relieve this restricted situation, the Corps of Engineers cut a 3,000-foot long channel, 17 feet deep by 135 feet wide. Completed in September 1949, the channel shoaled rapidly to a depth of 10 feet within 2 months, largely because of a hurricane in November 1949, and by March of 1952 had deteriorated to 8 feet. No further attempts were made to dredge Pass Cavallo.

Cedar Bayou

Cedar Bayou is a natural tidal inlet which connects the Gulf with Mesquite Bay and separates Matagorda Island and San Jose (formerly St. Joseph) Island. It is located about 40 miles northeast of Corpus Christi.

Cedar Bayou is the smallest of the natural inlets along the Texas coast that stays open on a regular basis. It is approximately 3 miles long and has maximum depths of 10 to 12 feet. When open, the depth of the pass at the Gulf is about 2 feet. Cedar Bayou is a relatively undisturbed natural pass, mainly because of its accessibility only by boat and its distance to major population centers.

Cedar Bayou is alternately opened and closed according to dominating tidal and shoreline processes. When open, it is the only tidal connection through the barrier island system for about 76 miles of coastline from Pass Cavallo at Matagorda Bay to Aransas Pass at Corpus Christi Bay. Its orientation is north-northeast by south-southwest which is the stable configuration for the inlet. Based on a comparison between the earliest available hydrographic chart (1860) and more recent aerial photography, the pass's position has not changed. This orientation is controlled in part by the strong ebb tidal currents operating during northers that scour the channel and transport sediment seaward.

A study, conducted by Turner, Collie & Braden, Inc., dated 1967, of the feasibility of reopening Corpus Christi Pass provided pertinent information on historical openings and closures of Cedar Bayou. Records dating back to 1906 indicate the pass was closed by hurricanes in 1915, 1929, and 1934. The pass was opened by a hurricane in 1919, and opened naturally in 1930. In 1939, the pass was opened artificially by dredging and remained open for 16 years, closing naturally in 1955. In 1959, the pass was again opened artificially and remained open until 1979 when the pass was closed with sand to prevent spilled oil from the IXTOC offshore oil platform from entering the bays. At the time of the oil spill, the pass appeared to be in the process of closing itself naturally. The pass remaining open for this 20-year period (1950-1979) can probably be attributed to the large number of hurricanes affecting the area (Carla, 1961; Beulah, 1967; Celia, 1970; and Fern, 1971). The force of Hurricane Allen in 1980 reopened the sand-filled pass.

The Texas Parks and Wildlife Department led efforts to improve the mouth of Cedar Bayou to provide a migration route for fish as well as to help moderate salinity levels in Mesquite Bay in the mid-1980's. The 80- to 100-foot wide by 6- to 8-foot deep channel was completed in October 1988, and the inlet remains open at this time.

Aransas Pass

Aransas Pass is a natural inlet located approximately 20 miles east of Corpus Christi between San Jose and Mustang Islands, connecting Corpus Christi Bay and Redfish Bay with the open Gulf. The entrance to the federally-maintained Corpus Christi Ship Channel project traverses the pass. This channel, in addition to providing deep-draft access to the port of Corpus Christi, allows shallow-draft access through the Channel to Aransas Pass and the Lydia Ann Channel.

Prior to channel improvements, Aransas Pass had depths over the outer bar which varied from 7 to 9 feet and a shifting channel 100 to 500 feet wide. Aransas Pass was extremely unstable during the middle to late 1800's. Relocation of the channel axis, changes in channel depth of several feet, and shifting of the inlet-mouth bars accompanied southerly migration of the inlet. Frequent changes caused navigation problems for trade vessels traveling over the outer bars and through the inlet. Because of the importance of Aransas Pass as a route for commercial vessels and because of the continuous changes in channel position and depth, numerous efforts were made by governmental and private interests to stabilize the channel and maintain navigable depths.

The first attempt at improvement was made in 1868 when a 600-foot dike was constructed on the southern end of San Jose Island; however, this dike was destroyed by storms within 3 years.

The first Federal improvements were completed in 1885. A chronology of activities at Aransas Pass since 1885 is shown in Table 4.

TABLE 4
CHRONOLOGY OF IMPROVEMENTS
AT ARANSAS PASS

Year	Activity
1885	In April, the Federal Government completed improvements including seven groin jetties on south side of pass, breakwater, mattress revetment along channel face of Mustang Island, and sand fences on the heads of both islands to reduce erosion. Also included jetty known as Mansfield Jetty or Old Government Jetty 5,500 feet long on south side of pass, constructed of brush mattresses and stone and portions capped with piles and stones. Jetty damaged seriously in September storm.
1889	Completion of riprap protection 2,725 feet long from high water to the bottom of the channel along Mustang Island.

TABLE 4 (cont'd)

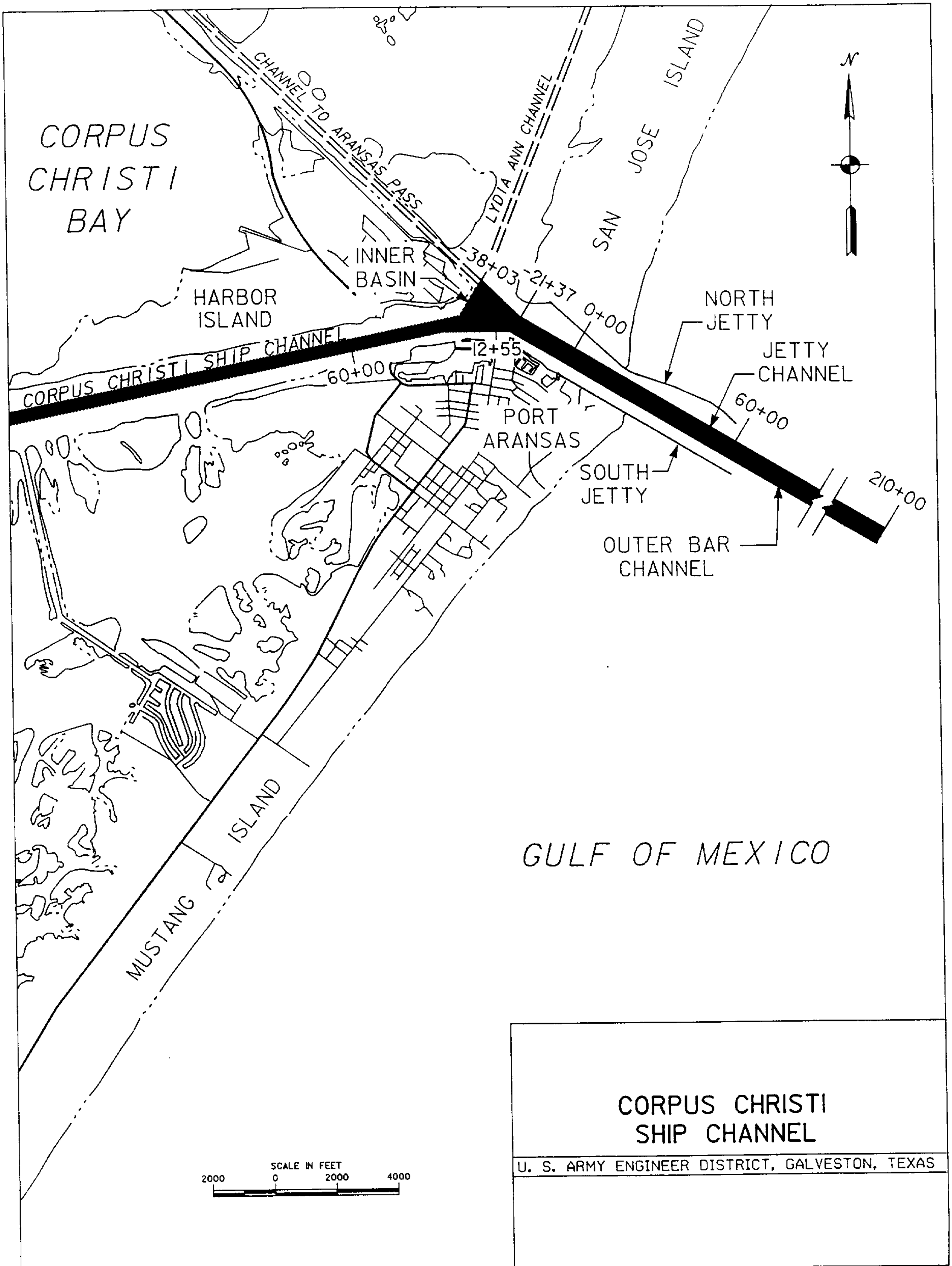
Year	Activity
1892	Since no Federal funding was available, Aransas Pass Harbor Company built South or Nelson Jetty 600 to 1,000 feet nearer the channel than the Mansfield Jetty.
1896	Aransas Pass Harbor Company completed about three-quarters of work on construction of North or Haupt Jetty. This effort failed to create anticipated depth.
1899	Responsibility of North Jetty transferred to Federal Government.
1906	Completion of Haupt Jetty in accordance with original plans and specifications.
1911	Completion of South Jetty to 6,400 feet long and North Jetty to 9,241 feet long with channel between jetties naturally deepened to 20 feet.
1912	Channel through jetties dredged to 20 feet deep and 150 feet wide. Completion of stone dike 10,000 feet long on San Jose Island.
1916	Channel between jetties dredged to 23 feet deep and 100 to 400 feet wide. Extended stone dike to a total length of 20,991 feet. South Jetty constructed to length of 7,385 feet.
1922	Four spurs projecting right angles from the North Jetty into Aransas Pass constructed in order to straighten the channel and move it southward away from jetty.
1931	Inner and Outer Bar Channels dredged to 30 and 33 feet, respectively.
1935	Channel deepened to 35 feet between jetties and 37 feet over outer bar.

TABLE 4 (cont'd)

Year	Activity
1956	Channel deepened to 36 feet between jetties and 38 feet over outer bar.
1966	Completion of project consisting of Jetty Channel 40 feet deep and Outer Bar Channel 42 feet deep.
1970	Present lengths of North and South Jetty established to 11,190 feet and 8,610 feet, respectively.
1975	Completion of channel to 45 feet between jetties and 47 feet over the bar.

For the purposes of this study, the project consists of two stone jetties, a stone dike, and the entrance portion of the Corpus Christi Ship Channel. The jetties extend into the Gulf from San Jose and Mustang Islands for distances of 11,190 and 8,610 feet, respectively, and a 20,991-foot long stone dike on San Jose Island extends from the North Jetty in a northeasterly direction along the centerline of the island. The Outer Bar Channel (stations 60+00 to 210+00) is 47 feet deep, 15,000 feet long, and has a bottom width of 700 feet. The Jetty Channel (stations 60+00 to -21+37) has dimensions of 45-foot depth, 600-foot bottom width, and 8,137-foot length. The Inner Basin extends from station -21+37 to station -38+03 (the beginning of the Channel to Aransas Pass) and has a width of 730 to 1,720 feet and a depth of 45 feet. The portion of the Corpus Christi Ship Channel which has been analyzed begins at station 12+55, the intersection of the Inner Basin, and extends to station 60+00. It has a width which varies from 400 to 600 feet and a depth of 45 feet. This project is shown in Figure 12.

The maintenance dredging history for the entrance of the Corpus Christi Ship Channel is shown in Figure 13. The Jetty Channel has required maintenance dredging eight times since 1976, resulting in an average dredging cycle of 2.1 years removing 335,000 cubic yards of material. The Outer Bar Channel was also dredged a total of



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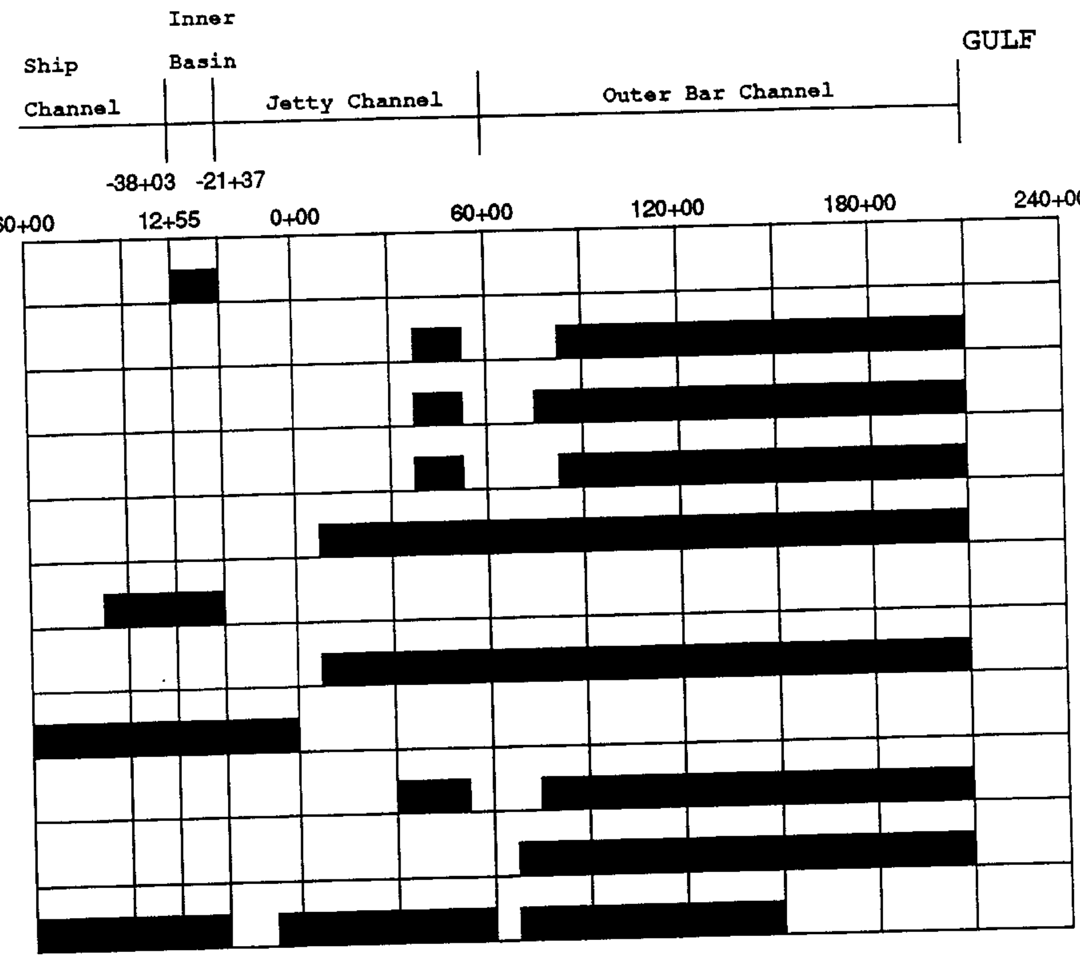
PLOTTED BY: RICK
DN: 4-AUG-1992
AT: 14:40

FIGURE 12

FIGURE 13
MAINTENANCE DREDGING OF THE ENTRANCE OF CORPUS CHRISTI SHIP CHANNEL

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
89-0018	APR 89	201,671
HD89-01	OCT 88	261,343
HD86-01	JUL 86 - SEP 86	1,340,540
HD84-02	AUG 84 - OCT 84	1,208,800
82-0036	AUG 82 - OCT 82	1,748,754
81-0051	OCT 81 - APR 82	310,784
HD80-03	AUG 80 - MAR 81	4,223,334
78-0034	MAY 78 - AUG 78	561,475
HD78-04	APR 78 - AUG 78	337,704
HD77-04	APR 77 - MAY 77	671,622
HD76-02	OCT 75 - OCT 76	2,071,293



eight times from 1976 to the present. This portion of the channel has a dredging cycle frequency of 2.1 years and on average has 1.1 million cubic yards of material removed. The average annual shoaling rates for the Jetty Channel and the Outer Bar Channel are 159,000 cubic yards and 520,000 cubic yards, respectively. The Inner Basin (station -21+37 to station - 38+03) and the Ship Channel (station 12+55 to station 60+00) required maintenance dredging four times since 1976, resulting in an average dredging cycle of every 4.2 years and removal of about 375,000 cubic yards. This section of the channel has an average annual shoaling rate of 89,000 cubic yards.

The Outer Bar Channel and Jetty Channel are normally dredged by hopper dredge and the material placed in an offshore disposal site located southwest of the channel. The Inner Basin and Ship Channel are dredged by pipeline dredge and the material is placed in disposal areas adjacent to the North Jetty on San Jose Island or immediately north of the Ship Channel. An exception to this was the maintenance of the Inner Basin and Ship Channel in 1976 which was performed by hopper dredge. In 1978 a portion of the Jetty Channel was dredged at the same time as the Inner Basin and Ship Channel and, therefore, was dredged by pipeline.

The dredged material samples taken from 1957 to 1975 from stations 0+00 to 210+00 in the Jetty Channel contained high percentages of sand. The sand content varied from 60% in the vicinity of station 210+00 to 90% in the vicinity of station 30+00. The dredged material samples taken in 1982 and 1984 in the Jetty Channel from stations 0+00 to 150+00 ranged from 71% to 90% sand. Samples from the Corpus Christi Ship Channel (station 0+00 to station 60+00) showed approximately 96% sand from 1965 to 1975. In 1988 samples from stations -32+00 to -36+00 (the Inner Basin) had sand content ranging between 81% and 97%. From these data, the Entrance Channel, Inner Basin, and the portion of the Corpus Christi Ship Channel from station 12+55 to station 60+00 are potential sources of sand for beach nourishment.

Corpus Christi Water Exchange Pass

The Corpus Christi Water Exchange Pass is a manmade inlet located about 10 miles east of Corpus Christi. Motivated by the intermittent opening and closing of Corpus Christi Pass, Newport Pass, and Packery Channel as discussed below, this jettied fish and water exchange pass across Mustang Island was opened by the Texas Parks and Wildlife Department in August 1972, connecting Corpus Christi Bay with the open Gulf. Its purpose was to control the high salinities in Corpus Christi Bay and the Laguna Madre and to allow for greater fish migration. The inlet was 150 to 300 feet wide and 10,000 feet long from the bay mouth to the tips of the jetties, extending 875 feet into the Gulf. The original depth was 8 feet. This project was never maintained and closed from natural processes by 1979.

Corpus Christi Pass, Newport Pass, and Packery Channel

These three passes are natural tidal inlets located within a 4-mile segment of southern Mustang Island. Documentation of the historical migration and closures of these channels is difficult because Corpus Christi Pass, identified on an 1881-1882 topographic chart, was later referred to as Packery Channel.

Corpus Christi Pass is the most northern of the three passes, approximately 2 miles south of the Corpus Christi Water Exchange Pass. In 1928 a 1-foot deep, 20-foot wide channel was dredged through Corpus Christi Pass. This channel was dredged three times during that summer but shoaled in within a few days after each dredging. The pass was dredged again in 1938 and a bulkhead was built on the south side of the pass. The pass remained opened until 1943 when it once again shoaled closed. All three inlets are periodically opened by hurricanes but close shortly thereafter from natural processes.

In 1965 the Corps of Engineers conducted an experiment on dune growth at these three inlets. These experiments utilized junk cars and picket fences to trap sand and initiate dune formation to develop a natural barrier against hurricane surges. These experimental dunes were destroyed by Hurricane Beulah in 1967.

Yarborough Pass

Yarborough Pass is a manmade inlet located along Padre Island 30 miles downcoast of Corpus Christi Pass. Initial dredging of Yarborough Pass, also called Murdoch's Landing Pass, was completed in 1941 to improve water circulation in the Laguna Madre. It was closed by littoral processes within 5 months of its opening. Between 1942 and 1952 several unsuccessful attempts were made to reopen the pass. Since that time, the pass has remained closed and the dunes have reestablished themselves, approaching conditions that existed prior to dredging.

Mansfield Channel

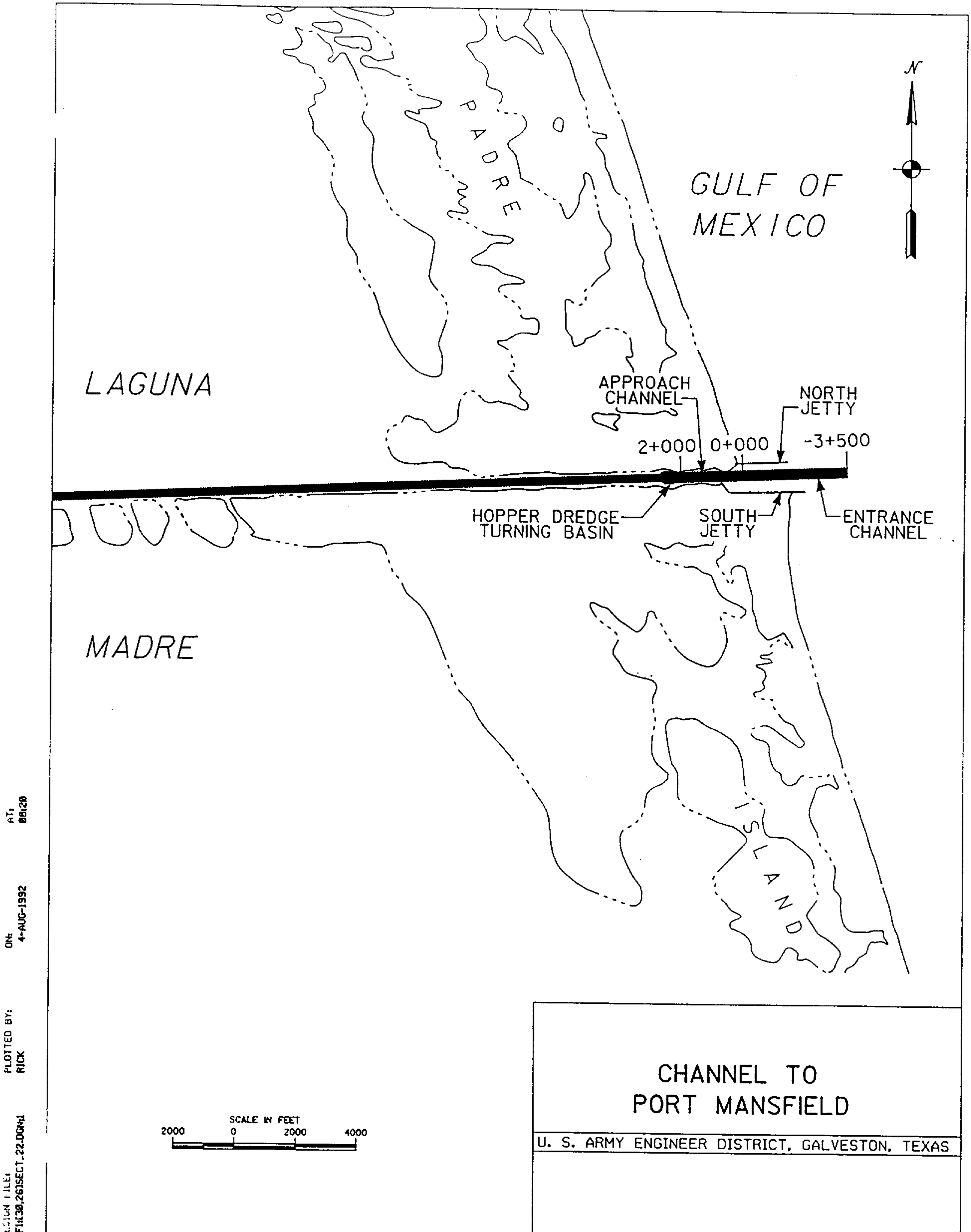
The Channel to Port Mansfield project is a federally-maintained, man-made inlet located along the south Texas coast about 93 miles south of Corpus Christi. It crosses Padre Island and connects the Laguna Madre with the Gulf. The tributary channel connecting the GIWW with the community of Port Mansfield, completed in 1949, preceded other developments at that location. Around the middle 1950's, Willacy County dredged an outlet to the Gulf 10 feet deep by 100 feet wide across Padre Island and a 16-foot deep by 250-foot wide channel from the gulfside of Padre Island to the 16-foot depth contour and constructed dual jetties. A brief chronology of the improvements at Mansfield Channel since 1957 is shown in Table 5.

TABLE 5
CHRONOLOGY OF IMPROVEMENTS
AT MANSFIELD CHANNEL

Year	Activity
1957	Local interests completed construction of tetrapod jetties in September. Jetties destroyed by storms in November.
1961	Extensive subsidence of tetrapods permitted complete closure of channel entrance by shoaling.
1962	Federal maintenance of locally dredged Jetty Channel 16 by 250 feet and construction of two new parallel jetties, the North Jetty 2,300 feet long and South Jetty 2,270 feet long. Reach from Entrance Channel to hopper dredge turning basin initially dredged to 26 feet deep to accommodate government hopper dredge. Channel presently maintained to 14-foot depth.

The Channel to Port Mansfield project is shown in Figure 14 and has a jettied entrance with a 2,300-foot long North Jetty and a 2,270-foot long South Jetty. The Entrance Channel (stations 0+000 to -3+500) has dimensions of 16 feet deep by 250 feet wide and is 3,500 feet long. The Approach Channel (station 0+000 to station 2+000) is 14 feet deep and 100 feet wide.

The maintenance dredging history for the entrance of the Channel to Port Mansfield is shown in Figure 15. The Port Mansfield Jetty Channel has been dredged 12 times since 1971 resulting in a 1.8-year dredging cycle and 175,000 cubic yards of material removed on average. The average shoaling rate is 97,000 cubic yards per year. The Approach Channel has been dredged 10 times since 1970 with an average dredging cycle of 2.2 years, an average quantity of material removed of 73,000 cubic yards, and an average annual shoaling rate of 34,000 cubic yards. All of these dredging contracts were performed by pipeline dredge with the exception of two contracts for the Jetty Channel and one contract for the Jetty and Approach Channels. In 1983 and 1986, the maintenance material

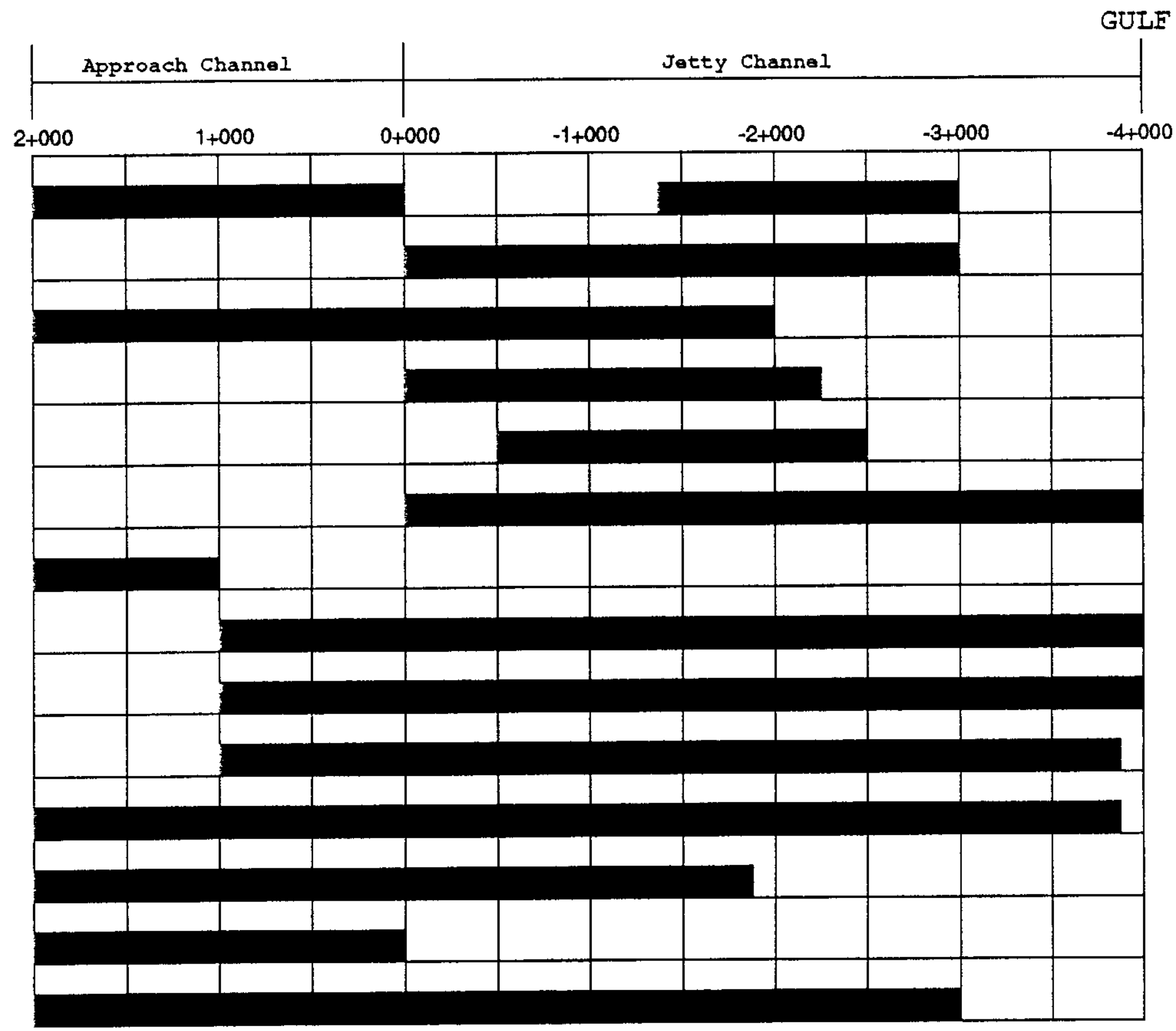


PADRE
ISLAND
GULF OF MEXICO
LAGUNA MADRE
N
APPROACH CHANNEL
NORTH JETTY
2+000
0+000
-3+500
HOPPER DREDGE TURNING BASIN
SOUTH JETTY
ENTRANCE CHANNEL
SCALE IN FEET
2000 0 2000 4000
CHANNEL TO PORT MANSFIELD
U. S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS
PLOTTED BY: RICK
ON: 4-AUG-1992
AT: 08:20

FIGURE 14

FIGURE 15
MAINTENANCE DREDGING OF THE CHANNEL TO PORT MANSFIELD

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
91-0031	AUG 91 - SEP 91	192,271
90-0016	MAR 90 - MAR 91	128,700
89-0005	NOV 88 - DEC 88	138,438
88-0014	MAR 88 - JUN 88	132,937
86-0013	APR 86 - MAY 86	104,196
83-0009	MAY 83 - JUL 83	372,765
81-0007	NOV 80 - MAY 81	62,232
80-0020	NOV 80 - DEC 80	302,181
79-0049	JUL 79 - AUG 79	369,116
HD78-01	AUG 78 - SEP 78	226,296
77-0070	SEP 77 - OCT 77	509,307
74-0073	MAR 74 - SEP 74	26,382
71-0142	APR 71 - JUN 71	44,565
71-0160	JAN 71 - AUG 71	223,232



in the Jetty Channel was removed by hopper dredge and placed in an offshore disposal site located north of the channel. The Jetty and Approach Channels were dredged by hopper dredge in 1978. When maintained by pipeline dredge, the material is generally placed on the beach adjacent to the North Jetty as a beneficial use of dredged material and to prevent flanking of the jetty.

Analysis of dredged material samples for the period 1962 through 1973 from the Port Mansfield Jetty Channel reveals a very high sand content for dredged material in the entire Jetty Channel. June 1979 samples showed 85% to 87% sand at stations -2+500 and 0+000, respectively. The most recent samples, taken in January 1983, show an 86% sand content at station -2+500 and a 19% sand content at station 0+000. Although 19% sand content is too low for beach fill, the potential for using material as beach nourishment should not be based on one sample. The material has been placed on the beach during previous dredging projects although no monitoring of these projects was performed. Therefore, the dredged materials from stations -3+500 to 2+000 of this channel are still considered a possible sand source for beach nourishment.

Brazos Santiago Pass

Brazos Santiago Pass is a natural inlet between Padre Island and Brazos Island which connects Laguna Madre with the Gulf. The entrance to the federally-maintained Brazos Island Harbor project is located approximately 20 miles east of Brownsville and 118 miles south of Corpus Christi. It passes through Brazos Santiago Pass and allows access to the ports of Port Isabel and Brownsville.

Prior to navigation improvements, Brazos Santiago Pass had a natural depth over the bar which varied from 6.5 to 11 feet at mean low tide and a narrow shifting channel. There also existed a small deep-water anchorage with a maximum depth varying from 27.5 to 40 feet at the throat of the pass. Laguna Madre had a natural depth of about 5 feet.

Existence of Brazos Santiago Pass was first documented by Alonso Alvarez de Pineda in 1519. The first Federal improvement of the pass was initiated in 1878 with the removal of a shipwreck from the channel. In 1882 construction was begun on the South Jetty which consisted of brush mattresses weighted down with clay bricks. This work was halted in 1884 because of lack of funds and the South Jetty was destroyed by storms in 1887.

The first channel improvements at Brazos Santiago Pass were constructed in 1927 and provided a 18-foot by 400-foot Entrance Channel through the pass. Currently, the project provides channels 36 feet deep to Brownsville and Port Isabel; however, construction is underway to deepen the project to 42 feet. A brief chronology of the Federal improvements at Brazos Santiago Pass since 1927 is shown in Table 6.

TABLE 6
CHRONOLOGY OF FEDERAL IMPROVEMENTS
AT BRAZOS SANTIAGO PASS

Year	Activity
1927	Completion of experimental project to dredge channel 18 by 400 feet through pass and a 16-foot by 100-foot channel from pass to turning basin at Port Isabel. Project included two short stone dikes extending into Gulf (north side 1,700 feet, south side 1,400 feet). Experimental project discontinued in 1928 because of rapid reshoaling.
1935	As authorized in 1930, completion of North Jetty to 5,600 feet long, South Jetty to 3,600 feet long, and construction of rock groins to protect inner end of jetties.
1936	Channel dredged to 25 feet deep by 300 feet wide through Brazos Santiago Pass and 25 feet deep by 100 feet wide inland of the pass.

TABLE 6 (cont'd)

Year	Activity
1940	Jetty Channel deepened to 31 feet and inner channel and turning basins to 28 feet.
1947	Completion of channel through pass to 35 feet deep and Channel to Brownsville and turning basins to 32 feet deep.
1960	Completion of channel through pass to 38 feet deep and 300 feet wide (in 1957) and all other channels and basins to 36 feet deep.
1961	Construction of erosion protection of North Jetty.
1966	Completion of major rehabilitation of North and South Jetties.
1978	Extended shore protection of North Jetty resulting in total length of 6,770 feet.
1986	Deauthorization of 1,000-foot extension of North Jetty, authorization of enlargement of the Entrance Channel to 44 feet deep and 400 feet wide.
1992	Dredging of Entrance Channel to 44 feet deep completed in March.

The project consists of a dual jettied entrance with the North Jetty being 6,770 feet long and the South Jetty 4,917 feet long, including shore protection sections. The Entrance Channel (stations 0+000 to -12+000) has depths varying from 36 to 38 feet MLT, a 300-foot bottom width, and 12,000-foot length. Figure 16 shows the Brazos Island Harbor project.

The maintenance dredging history for the entrance of the Brazos Island Harbor project is shown in Figure 17. The Brazos Island

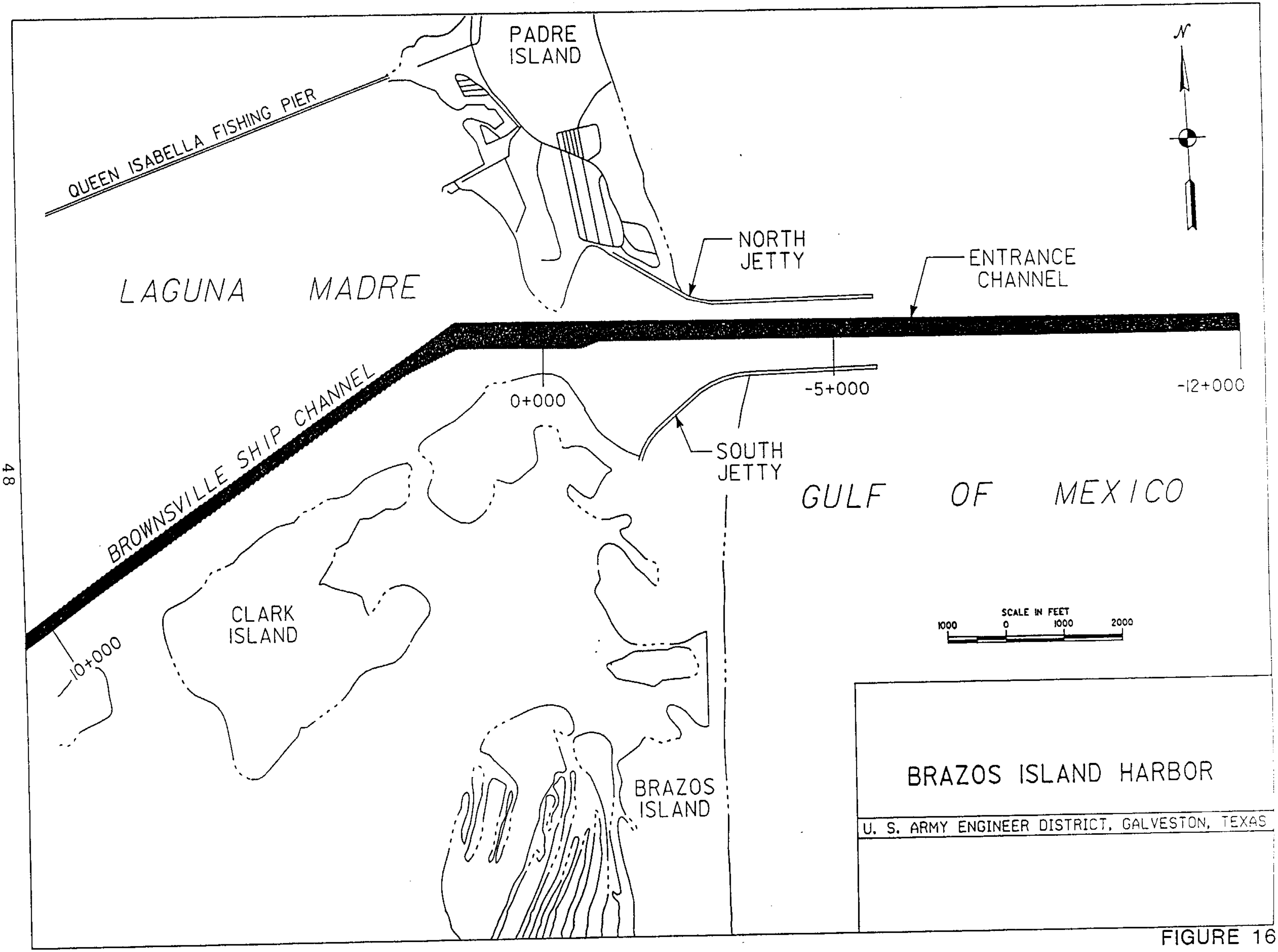
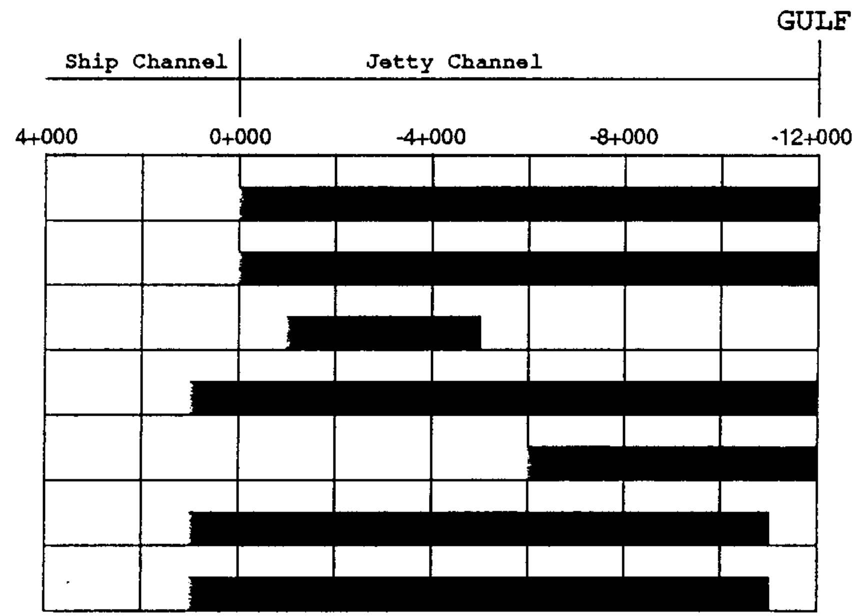

PADRE ISLAND
QUEEN ISABELLA FISHING PIER
NORTH JETTY
ENTRANCE CHANNEL
LAGUNA MADRE
BROWNSVILLE SHIP CHANNEL
0+000
-5+000
-12+000
SOUTH JETTY
GULF OF MEXICO
CLARK ISLAND
10+000
SCALE IN FEET
1000 0 1000 2000
BRAZOS ISLAND
BRAZOS ISLAND HARBOR
U. S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS

FIGURE 16

FIGURE 17
MAINTENANCE DREDGING OF THE ENTRANCE TO BRAZOS ISLAND HARBOR

CONTRACT NO.	CONTRACT PERIOD	VOLUME (C.Y.)
91-0016	MAR 91 - APR 91	576,931
88-0035	NOV 88- JAN 89	731,545
86-0013	APR 86 - MAY 86	333,693
83-0030	AUG 83 - SEP 83	886,343
HD82-01	OCT 81 - FEB 82	1,016,000
HD80-01	OCT 79 - DEC 79	847,000
HD78-01	NOV 77 - DEC 77	761,523



Harbor Jetty and Outer Bar Channel has been dredged seven times since 1977. The average maintenance calculations were based on data from 1977 until January 1992 (the beginning of the new work to deepen the channel). The dredging cycle is 2.0 years and the average quantity of material removed is 736,000 cubic yards. The average annual shoaling rate is 364,000 cubic yards. The material is removed by hopper dredge and placed in an offshore disposal area located north of the channel.

A high percentage of sand was noted in the Brazos Island Harbor Jetty Channel samples from station -10+500 to station 1+000 during the years 1971 to 1976. In fact, all samples except for one contained more than 80% sand and the exception contained 61% sand. Samples taken in 1979 showed stations 0+000 to -10+000 with a sand content higher than 51% with the exception of one sample at station 0+000 with 8% sand content. In 1988 and 1990, samples taken from stations 0+000 to -18+000 (beyond the end of the channel) had a sand content higher than 63% and at some stations the sand content was higher than 90%. Therefore, the dredged material between stations 0+000 and -12+000 is considered a potential sand source for beach nourishment.

Boca Chica Pass

Boca Chica Pass is a hurricane washover channel located approximately 5 miles south of Brazos Santiago Pass. It crosses Brazos Island and connects the South Bay of Laguna Madre with the open Gulf. Historic records show the pass was open in the mid 1800's and required a bridge over it for access to an army depot on Brazos Island. It remained opened until the pass was dammed in 1868. Since that time Boca Chica Pass has infrequently opened during storms only to close through natural processes shortly thereafter.

Rio Grande

The mouth of the Rio Grande is the southernmost of the Texas inlets and the river forms the border between Texas and Mexico. From 1854 until 1958 the mouth of the Rio Grande migrated northward, reaching its northernmost position in 1958. From 1958 until 1962 the mouth of the river then moved southward. During Hurricane Carla in 1961, the river made a new course, shifting approximately 4,000 feet south. Beginning in 1962 the mouth again migrated to the north. During Hurricane Beulah in 1967 the river again shifted its course to the south.

SUMMARY

Of the 24 inlets along the Texas coast discussed in this report, eight are federally maintained, five are manmade and either maintained by others or not maintained at all, and the remaining eleven are natural. Other than the maintained inlets, the fate of littoral materials moving along the coast is virtually controlled by natural processes. If the natural processes are accepted as the base condition with no consideration to change, then the opportunities to modify the overall system lies solely with those channels which are undergoing periodic modification through dredging operations.

For the federally-maintained channels, the dredging frequency, average quantity of material removed per cycle, and type of dredge routinely used are shown in Table 7. These data were developed from historical records which ranged in length from 11 to 22 years, and included the most recent maintenance dredging cycle.

Prior to dredging contracts, sediment samples are taken along the channel and analyzed for various pollutants as well as to determine the physical characteristics of the material to be removed. These physical tests include a determination of the grain size distribution of the particles within the sample. The percentages of clay, silt, and sand particles and the sample's location are recorded. From these test results, a preliminary assessment as to the potential that specific reaches of a channel would be suitable for placement on nearby beaches was made and the reach identified.

Of the eight federally-maintained channels, only the material being removed from two channels, the entrance to the Sabine-Neches Waterway and the entrance to Freeport Harbor, is considered unsuitable for placement on adjacent beaches. The reason being their high silt and clay content. The remaining six channels contain various length reaches which are potential sources suitable for beach replenishment.

It is a long-standing policy of the Corps of Engineers to secure the maximum practicable benefits through the use of dredged

TABLE 7
SUMMARY OF MAINTENANCE
FEDERALLY-MAINTAINED CHANNELS

	STATIONING	DREDGING FREQUENCY (years)	AVERAGE QUANTITY PER CYCLE (cubic yards)	TYPE OF DREDGE	POTENTIAL FOR NOURISHMENT	STATION	AVERAGE ANNUAL SHOALING RATE (cy/yr)
Sabine-Neches Waterway							
Jetty Channel	0+00 to -214+88.3	>11.4	1,362,260	Hopper	no		
Outer Bar Channel	0+000 to 18+000	1.4	3,571,290	Hopper	no		
Bank Channel	18+000 to 95+734	3.8	2,371,191	Hopper	no		
Galveston Harbor Channel						0+000 to 5+048	17,000
Bolivar Roads Channel	0+000 to 5+048	6.7	111,967	Hopper	yes		163,000
Anchorage Area	12+000 to 23+400	4.8	785,640	Hopper	yes		
Inner Bar Channel	5+048 to 21+912						
Outer Bar Channel	21+912 to 30+675	1.9	2,166,895	Hopper	yes	5+048 to 25+000	427,000
Entrance Channel	30+675 to 56+000						
Freeport Harbor							
Jetty Channel	0+00 to 60+00	1.2	1,175,403	Hopper	no		
Outer Bar Channel	0+00 to -270+00						
Mouth of Colorado River *							
Entrance Channel	33+204 to 37+600	----	------	Pipeline	yes	------	------
Impoundment Basin	33+404 to 34+204						
Matagorda Ship Channel							
Entrance Channel	0+000 to -20+000	2.2	860,138	Hopper	yes	-3+000 to -20+000	395,000
Corpus Christi Ship Channel							
Ship Channel	12+55 to 60+00	4.2	374,682	Pipeline	yes	12+55 to 60+00	89,000
Inner Basin	-21+37 to -38+03					-21+37 to -38+03	
Jetty Channel	-21+37 to 60+00	2.1	335,393	Hopper	yes	-21+37 to 60+00	159,000
Outer Bar Channel	60+00 to 210+00	2.1	1,094,424	Hopper	yes	60+00 to 210+00	520,000
Channel to Port Mansfield							
Approach Channel	0+000 to 2+000	2.2	72,974	Pipeline	yes	0+000 to 2+000	34,000
Entrance Channel	0+000 to -3+500	1.8	175,240	Pipeline/Hopper	yes	0+000 to -3+500	97,000
Brazos Island Harbor							
Entrance Channel	0+000 to -12+000	2.0	736,148	Hopper	yes	0+000 to -12+000	364,000

* This material is currently being placed on the beach as a part of the project. No average dredging frequencies and quantities could be developed because of the short time since implementation of the project.

material from authorized navigation channels provided extra cost is not incurred. Placement of beach quality sand on adjacent beaches is consistent with this policy objective. The initial step in this process is a request from the State to place the material on the beach.

The channel reach that shows the potential for yielding significant quantities of beach quality material would then be more intensely sampled and tested to confirm the quality of the material as well as defining the extent and location of the most suitable material. This channel material would then be compared to the native beach material to be able to approximate the expected life of the fill material on the beach. If the material to be placed on the beach is substantially finer than the existing beach materials, rapid erosion could be anticipated.

If additional costs would be required to place the material on a nearby beach over the least costly alternative of material disposal, a non-Federal sponsor would have to be identified to provide the difference in costs. Under special circumstances where the material may be used to provide storm reduction benefits, the Federal Government can provide half of the increased costs after approval from the Assistant Secretary of the Army for Civil Works.

CONCLUSIONS

It is evident that there is diversity of shoreline conditions which exist along the Texas coast. These conditions vary from erosional, to accretional, to stable. The erosional and accretional shorelines vary considerably in degree, from gradual to extreme. The usual approach when addressing coastal shorelines is to focus on a problem area, which usually means that erosion is affecting manmade improvements or some other economic loss is involved. However, the entire system must be evaluated including the stable areas, but particularly the areas that are accreting. One cannot just accept the gain (accretion) and concentrate on the loss (erosion). Gains and losses will occur at any interruption of the shoreline whether it is a natural inlet, river, or a modified and controlled inlet.

There are numerous factors which affect shoreline response other than inlets. Many of which are meteorological, such as storms, others are global or regional, such as sea level rise, and neither of which can be controlled, but must be considered. Inlets are only one shoreline feature which affect updrift and downdrift beaches. The affects of inlets with structures, such as jetties, are often much more pronounced than inlets without structures.

Opportunities exist to alter shoreline impacts at inlets, particularly where there are ongoing and periodic modifications through dredging operations. Various bypassing alternatives are available although most would require significant initial capital outlays as well as costs for future operation and maintenance of the facility. Direct bypassing typically is limited to those inlets where beach quality sand is accumulating on the updrift side of the inlet and can be collected and deposited on the downdrift beaches. Implementation of these opportunities is driven by economics, regardless of whether the initiative is at the local, State, or Federal level. Under any circumstances the costs for such an investment would have to be offset by the benefits derived.

The current dredging practices at the eight inlets that are Federally maintained for navigation purposes employ an indirect form of bypassing by placement of material in offshore placement areas located on the predominant downdrift side of the channel. These areas are generally located in deep water to allow full loading and unloading of the larger hopper dredges. Incorporation of new techniques, some of which are in the experimental stages, for beneficial uses of dredged material are also being tried. Other changes are being implemented as the base of knowledge increases in the coastal processes and coastal engineering fields. No authority is presently available to address bypassing at rivers and other inlets where there is no Federal project.

On the Texas coast, most of the material that accumulates in the inlet channels has high percentages of silts and clays. Placement of this type of material in offshore areas allows the underwater currents to separate the sand particles from the remaining material. Some portion of this material becomes part of the active littoral system although there is no specific information available as to what portion of the sand materials ultimately reach the nearshore area for each of the several offshore sites.

To summarize, the results of these investigations show that potential opportunities exist to use channel maintenance material from six of the eight federally-maintained channels. They are Galveston Harbor Channel, Mouth of Colorado River, Matagorda Ship Channel, Corpus Christi Ship Channel, Channel to Port Mansfield, and Brazos Island Harbor. Through further examination of current practices at these respective inlets and other inlets, a more comprehensive strategy can be developed to utilize available maintenance material more effectively to address coastal erosion losses. The next step would entail undertaking development of a more comprehensive plan. The information provided herein is intended to aid the State and other involved agencies in such an undertaking.