REVIEW REPORT
GRAND ISLE AND VICINITY, LOUISIANA

SYLLABUS

Grand Isle is located along the Gulf of Mexico in Jefferson Parish, Louisiana. It is about 50 miles south of New Orleans and 45 miles northwest of Southwest Pass of the Mississippi River. Local interests desire restoration and stabilization of Grand Isle's gulf shore and protection from hurricanes.

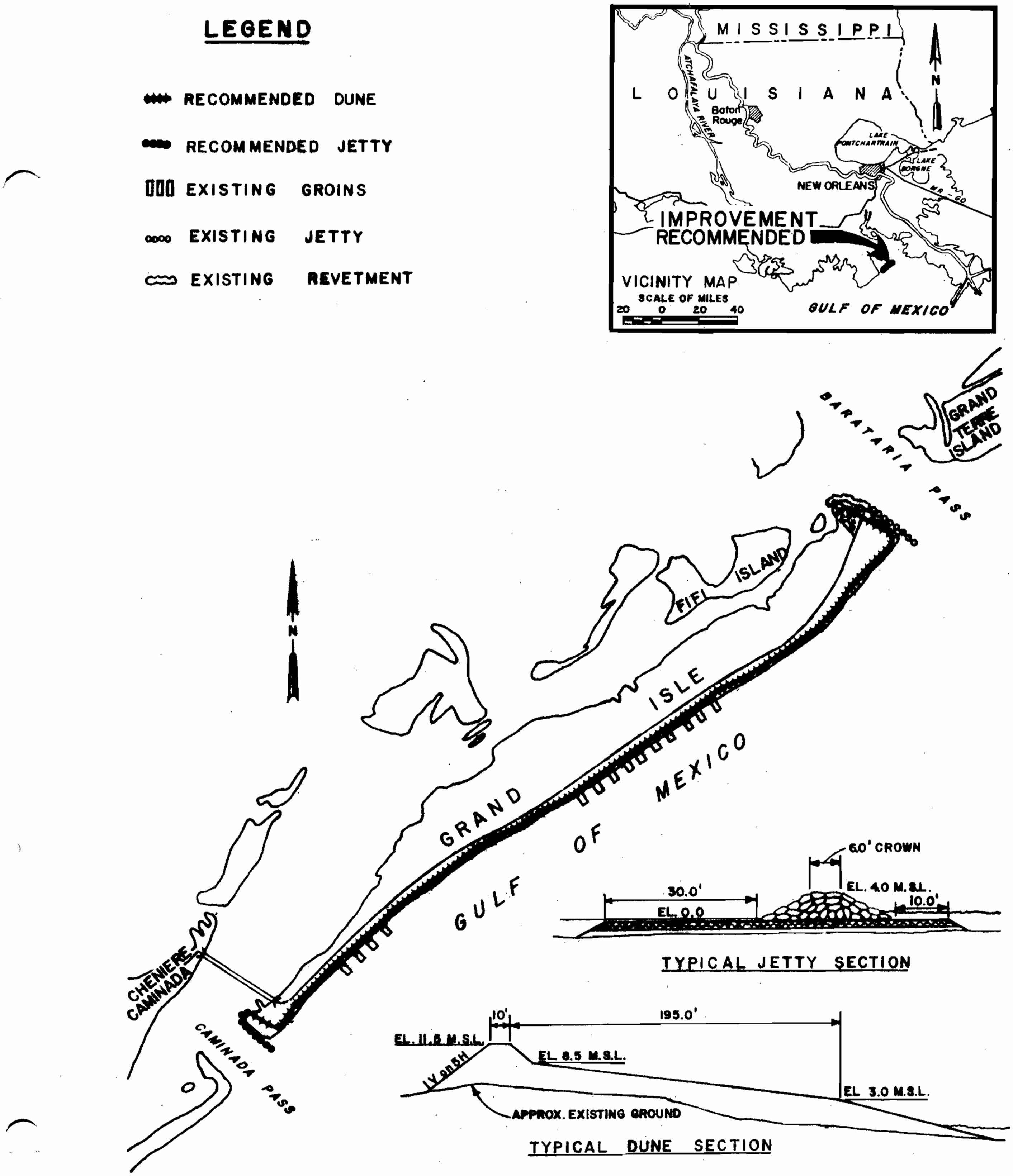
Damage and destruction occur on Grand Isle due to beach erosion and flooding by hurricane surges. In September 1965 the eye of Hurricane Betsy passed slightly to the west of Grand Isle placing the island directly in the path of very severe winds and a hurricane surge from the gulf. Stages of approximately 9 feet mean sea level (m.s.l.) covered the area causing flood damages estimated at $11,500,000. The combined effects of wind and tide destroyed approximately 85 percent of the improvements on the island, excluding industrial development.

Between March 1968 and May 1971 severe erosion resulted in the loss of approximately 35 acres of land between the western tip of the island and groin number 1. Before this erosion was halted eight houses were stranded in the gulf and several housetrailers had to be moved from their gulf front lots. The 1971 Louisiana legislature appropriated $1 million for emergency work to halt this erosion. The Louisiana Department of Public Works awarded a contract on 3 September 1971 for the construction of a jetty on the western end of the island at Caminada Pass and placement of sandfill on its Grand Isle side in accordance with the improvements of the recommended plan (plan B) described below. The jetty and placement of sandfill were completed in mid-July of 1972.

The recommended plan of improvement (plan B) is a combined beach erosion and hurricane protection plan. It provides protection from waves driven by hurricanes that have a frequency of recurrence of up to once in every 50 years. The plan consists of a berm and vegetated dune extending the length of Grand Isle's gulf shore and a jetty to stabilize the western end of the island at Caminada Pass. The dune would have a 10-foot wide crown at an elevation of 11.5 feet m.s.l., 1 on 5 side slopes, and protective vegetation. The sandfill berm would slope from an elevation of 8.5 feet m.s.l. at the toe of the dune 180 feet gulfward to an elevation of 3 feet m.s.l. and, from this point, would assume its natural slope to the offshore bottom. The jetty provided by the plan has a top width of 6 feet at an elevation of 4 feet m.s.l., 1 on 2 side slopes, and extends approximately 2,600 feet along the western end of the island at Caminada Pass.

The estimated average annual benefits for the recommended plan are $1,182,000, consisting of $289,000 for the prevention of erosion damages, $378,000 for the prevention of flood damages, $198,000 for intensified land use, and $317,000 for increased recreational use. The first cost of the recommended plan is $9,100,000, of which $4,840,000 would be Federal costs. The estimated annual charges are $678,000, and the benefit-to-cost ratio is 1.7.

It is recommended that a Federal project be authorized as described above and that the Louisiana Department of Public Works be allowed credit for expenditures for emergency preauthorization construction on the western end of the island, subject to the conditions of local cooperation specified in the report.



GRAND ISLE AND VICINITY, LOUISIANA

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

SCALE OF FEET
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REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

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DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60267
NEW ORLEANS, LOUISIANA 70160

LMNED-PR 31 October 1972

SUBJECT: Review Report, Grand Isle and Vicinity, Louisiana

Division Engineer, Lower Mississippi Valley
ATTN: LMVPD-F

SECTION I - AUTHORITY, PURPOSE, AND SCOPE

1. AUTHORITY

This report is submitted in response to the following resolutions:

"Resolved by the Committee on Public Works of the House of Representatives, United States, in accordance with Section 110 of the River and Harbor Act of 1962, that the Secretary of the Army be, and is hereby, requested to cause to be made, under the direction of the Chief of Engineers, a survey of the shores of Grand Isle, Louisiana, and such adjacent shores as may be necessary, in the interest of beach erosion control, hurricane protection, and related purposes." Adopted 26 September 1963.

"Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the report of the Chief of Engineers on Grand Isle and Vicinity, Louisiana, published in House Document Numbered 184, Eighty-ninth Congress, with a view to determining whether any modifications of the recommendations contained therein with respect to hurricane protection at Grand Isle are advisable, particularly in light of damages suffered in the recent hurricane 'Betsy.'" Adopted 5 May 1966.

2. PURPOSE AND EXTENT OF STUDY

a. Purpose. The purpose of this study is to determine the best means for restoring and protecting the gulf shore of Grand Isle, Louisiana, and to determine the most feasible method of hurricane protection to prevent loss of human life and to prevent property damages. Objectives of the beach erosion investigation are to study the factors contributing to the shoreline deterioration, estimate the rate of recession, and devise methods to halt the recession and restore the beach. Objectives of the hurricane protection investigation are to determine the characteristics of a project storm, determine the magnitude of protective works required, and select those measures most practicable and economically feasible.

b. Available data. Available data and information include the beach erosion study, pursuant to the House Resolution of 26 September 1963, which was suspended in 1966 in order to evaluate the effects of work accomplished by local interests and the restoration under Public Law 875, 81st Congress, following Hurricane Betsy; the report "Beach Erosion Control Report on Cooperative Study of Grand Isle, Louisiana," 2 April 1954, published as House Document 132, 84th Congress; the report "Interim Survey Report on Hurricane Study of Grand Isle, Louisiana and Vicinity," 11 July 1963, published as House Document 184, 89th Congress; surveys and observations of the Corps of Engineers and the Louisiana Department of Public Works, of the shoreline of Grand Isle and the non-Federal groins and jetty; aerial photographs and mosaics of Grand Isle and vicinity; quadrangle maps by the Corps of Engineers and U. S. Geological Survey; U. S. Coast and Geodetic Survey coast charts (now National Ocean Survey); U. S. Weather Bureau (now National Weather Service) records on wind and rainfall; data on stages and tides; soil borings offshore and in the Lafourche-Jump Waterway and Barataria Bay Waterway between Grand Isle and Cheniere Caminada and Fifi Island; the report "History of Hurricane Occurrences along Coastal Louisiana," prepared 29 December 1961 and revised August 1972 by the New Orleans District; Hurricanes Flossy, Carla, Hilda, Betsy, and Camille reports; and the preliminary evaluation dated 20 March 1969.

c. Additional investigations. Additional investigations made for this study include hydrologic studies to determine the nature and extent of the erosion problem; field surveys, soil borings, and soil analyses; design, cost, and benefit studies; environmental investigations and studies; consideration of non-structural alternatives; and consultation with local, state, and other Federal agencies and interested individuals.

3. PRIOR REPORTS AND EXISTING PROJECTS

Prior reports and existing projects on beach erosion control and shore protection, hurricane protection, and navigation pertinent to the study area are:

a. Initial study of Grand Isle, Louisiana. The initial study was prepared on a cooperative basis by formal application from the State Board of Engineers of Louisiana, dated 9 July 1935, and approved by the Chief of Engineers on 5 August 1935. The report on the study was made by the Beach Erosion Board and submitted to the Chief of Engineers on 28 July 1936. The study revealed that the gulf shore of Grand Isle had undergone significant material changes, that the area was subject to abrupt temporary losses and gains, and that the littoral currents along the shore were generally from east to west. The Board was of the opinion that further erosion along the western end of the island could be expected, with little serious erosion likely to occur on the eastern half. The Board believed that the complete protection of Grand Isle against tropical storms would require the construction of a massive seawall at a prohibitive cost. The report recommended, as the most practicable means of securing stabilization of the island, the construction of a single long jetty placed near Caminada Pass, approximately 900 feet west of the bridge and extending into the Gulf of Mexico perpendicular to the shoreline, to the 6-foot depth curve or 1,500 feet from the shore. The Chief of Engineers concurred in the plan presented by the Beach Erosion Board and ruled that no Federal interests were involved.

b. "Grand Isle, La., Beach Erosion Control Study," submitted to Congress 17 March 1955, and published as House Document No. 132, 84th Congress, 1st Session. The most suitable plan for stabilization of the gulf shore of Grand Isle, as developed for this study, was determined to be direct placement of suitable material in the attacked areas and periodic replacement, as necessary, and the construction of a jetty near the eastern end of the island. Investigations made during this study revealed that the littoral currents along the shore were generally from west to east. It was also determined that no part of the cost should be borne by the United States.

c. "Grand Isle and Vicinity, Louisiana," project was authorized by the Flood Control Act of 1965, in accordance with report published as House Document No. 184, 89th Congress, 1st Session. The project includes the construction of levees on each side of Bayou Lafourche connected to floodgates in Bayou Lafourche at Larose and south of Golden Meadow to provide hurricane protection for the developed areas along Bayou Lafourche from Larose to Golden Meadow, inclusive. As of 30 June 1972 planning on the project was about 37 percent complete.

d. "Bayou Lafourche and Lafourche-Jump Waterway, La.," project was authorized by the River and Harbor Act of 1935 and modified by the River and Harbor Act of 1960, in accordance with report published as House Document No. 112, 86th Congress, 1st Session. The project includes a 12- by 125-foot waterway from the Gulf Intracoastal Waterway to the Gulf of Mexico via a new channel to Leeville and Bayou Lafourche from Leeville to the gulf; a 9- by 100-foot waterway from Leeville to Golden Meadow; and a 12- by 125-foot waterway from Bayou Lafourche at Leeville to the Barataria Bay Waterway at Grand Isle. As of 30 June 1972 the total project, as modified, was about 11 percent complete.

e. "Barataria Bay Waterway, La.," project was authorized by River and Harbor Act of 1919 and modified by the River and Harbor Act of 1958, in accordance with House Document No. 82, 85th Congress, 1st Session. This project as modified includes the enlargement and realignment of the existing project to provide a 12- by 125-foot waterway from the Gulf Intracoastal Waterway to the Gulf of Mexico at Grand Isle and a 12- by 125-foot channel in Bayou Rigaud along the north shore of Grand Isle. The project was completed in November 1963.

SECTION II - DESCRIPTION

4. LOCATION AND EXTENT

Grand Isle is located on the Gulf of Mexico in Jefferson Parish, Louisiana. It is about 50 miles south of New Orleans and 45 miles northwest of Southwest Pass of the Mississippi River. Grand Isle is one of the many low, irregular islands separated by bays, lagoons, and bayous which form a part of the shoreline of Louisiana. The island extends about 7.5 miles in a generally northeast to southwest direction and is about 0.75 mile in width at the center. Grand Terre Islands are to the northeast and Cheniere Caminada, the mainland, is to the west of Grand Isle. (See plate 1.)

5. TOPOGRAPHY AND VEGETATION

The topography is typical of that found in other areas of coastal Louisiana where a well-developed marsh and beach ridge complex have formed. The dunes along the gulf shore are the principal features of relief with elevations ranging up to about 8 feet m.s.l. (mean sea level).[1] This dune was restored after Hurricane Flossy in 1956 and Hurricane Betsy in 1965. The central section of the island has elevations varying from 3 to 5. The north or bay shore, where undeveloped, is low, flat marshland indented by numerous small bays and inlets. Vegetation on Grand Isle is similar to that of other areas along the Louisiana coast. Common species growing on the beach berm are glasswort, sea-rocket, salt grass, sea ox-eye, cord grasses, and numerous annuals. High ridges or old well-developed beaches above normal wave action support a diversity of plants including trees and shrubs such as live oak, wax myrtle, marsh elder, rattle box, and various grasses. Marsh area vegetation consists primarily of salt-tolerant plants, the major species being oystergrass, salt grass, and black rush. Details of the soil characteristics of the area are given in appendix A.

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[1]All elevations shown herein are in feet mean sea level unless otherwise noted.

6. CLIMATOLOGY

a. Climate. The climate of this area is semitropical in nature. It is influenced by the proximity of the Gulf of Mexico with water temperatures along the Louisiana shore ranging from an average of 64° F. (Fahrenheit) in February to 84° F. in August. Southerly winds produce afternoon thundershowers in summer while winter storms are of the frontal type in which showers generally last the duration of the storm. The area is subject to tropical hurricanes particularly in summer and early fall.

b. Temperature. The average annual temperature of this area is 67° F., based on records of 13 to 98 years at stations in or adjacent to the study area. Monthly averages range from 83° F. in July and August to 57° F. in January. The maximum recorded temperature of 104° F. occurred at Houma on 22 June 1915, while a minimum of 5° F. was recorded on 13 February 1899 at the same location. In the period subsequent to 1949, Grand Isle experienced a maximum of 101° F. on 30 August 1954 and a minimum of 16° F. on 11 January 1962.

c. Rainfall. Precipitation is generally heavy with greatest falls recorded during the summer months due to frequent afternoon thundershowers. The average annual rainfall for the area is 62.8 inches with monthly averages ranging from 3.5 inches in October to 7.5 inches in July. This is based on records of 13 to 98 years at Weather Service stations in or adjacent to the study area. A maximum monthly rainfall of 21.1 inches was recorded at Burrwood in September 1957, while Grand Isle experienced 9.6 inches during the same period. The maximum monthly rainfall of 20.9 inches at Grand Isle occurred in September 1946. Burrwood rainfall during the same period was 16.8 inches. Measurable snow occurs infrequently. The last fall of consequence produced a maximum depth of 2.8 inches on 12 February 1958 at Grand Isle while other locations in the area reported smaller depths. Rainfall and other climatological data for this area are published in monthly and annual pamphlets by the National Weather Service titled "Climatological Data for Louisiana." A summary of these data is presented in appendix B.

7. TIDES

The normal tide along the Grand Isle coast is diurnal and has an average range of approximately 1.2 feet, with a maximum range of about 1.9 feet. Normal tidal effects are observed as far inland as 40 miles. Storm and hurricane tides reach elevations of about 10 on the coast, and strong northerly winds in the winter depress gulf levels as much as 2.6 feet below m.s.l. Tide gage readings are available at three regular locations with 16 to 23 years of record. All of these locations have recording type gages from which hourly readings may be obtained. In 1956, high water pipes were installed at several points (plate B-1) to record the maximum elevations reached by tides during tropical storms. Observed stages for regular locations are published annually in "Stages and Discharges of the Mississippi River and Tributaries and Other Streams and Waterways in the New Orleans District" by the U. S. Army Engineer District, New Orleans.

8. FLOOD PROTECTION AND DRAINAGE SYSTEMS

Grand Isle has a low degree of protection against flooding by tropical storms and hurricanes. A sand dune along the beach front affords some protection against flooding from the Gulf of Mexico, and a few discontinuous low levees afford minor protection from flooding by high tides in Barataria Bay. No drainage structures of significance exist and the island depends solely upon gravity drainage. The natural flow on the island is generally from the gulf to the bay.

9. MAPS

The area under study appears on the U. S. Army Corps of Engineers quadrangle map, Fort Livingston, Louisiana, scale 1:62,500; the U. S. Geological Survey maps, Caminada Pass, Louisiana, and Bay Tambour, Louisiana, scale 1:24,000; and the National Ocean Survey chart no. 1273 Barataria Bay and Approaches, scale 1:80,000. Recent aerial photographs and local maps of the area are available and were used as a basis for the detailed maps of the area accompanying this report.

10. ECONOMIC DEVELOPMENT

a. General. Grand Isle is a base of operations for large offshore petroleum and sulphur industries and is a commercial fishing and sportfishing center. It is also an important recreational area for residents of Louisiana and nearby states. Of the 2,340 acres on the island, there are 640 acres in residential development, 210 in industrial development, and 213 in commercial, Government, and public establishments. This latter acreage includes 126 acres of state-owned beach designated as State parks--23 acres on the western end and 103 acres on the eastern end.

b. Population. The population within the corporate limits of Grand Isle, which includes the eastern end of Cheniere Caminada, has increased from 1,190 in 1950 to 2,074 in 1960, and to 2,236 in 1970. The reduction in the growth rate between 1960 and 1970 was due to the widespread damage wrought by Hurricane Betsy in 1965. Immediately following Betsy, it was estimated that the population had been reduced to about 500 people.

c. Industry. Industries within the area include a shipyard for repair of shrimp and oyster fishing vessels and other work boats, an ice plant, seafood unloading facilities, and oil storage and barge loading facilities. Extensive facilities for oilfield servicing and for operation of an offshore sulphur mine are located on the eastern end of Grand Isle. Numerous deep-sea sportfishing charter vessels and commercial shrimping boats operate out of Grand Isle.

d. Mineral production. Extensive oil and gas fields exist in the offshore areas in the Gulf of Mexico. In terms of value, petroleum, natural gas, and natural gas liquids are dominant. Representatives of the oil companies indicate that future increases in the size of oil company installations are not anticipated and that the size of these installations should remain constant in the future.

e. Transportation. The island can be reached by traveling U. S. Highway 90 and Louisiana Highway 1 from New Orleans and by traveling Louisiana Highway 1 from Baton Rouge. Louisiana Highway 1 (two-lane asphalt and concrete) follows the west bank of Bayou Lafourche from Donaldsonville to Leeville, crossing Bayou Lafourche at this point, then continuing to the eastern end of Grand Isle. The elevation of the highway between Grand Isle and Golden Meadow ranges from approximately 2.5 to 5.0 feet. Above Golden Meadow the elevation of the highway crown increases gradually to about 7 feet at Larose. Louisiana Highway 308 (two-lane, blacktop) extends from Donaldsonville to Golden Meadow on the east bank of Bayou Lafourche. The only railroad service in the area consists of freight facilities of the Southern Pacific Line which extends down the east bank of Bayou Lafourche to the mills at Valentine. The island is also accessible by water and air. Oil companies have heliports and seaplane ramps at the eastern end of the island. There is also a private landing strip located several miles from Grand Isle on Cheniere Caminada.

f. Utilities. Natural gas, electric power, and telephone service are available to the area. Water supply is provided by Lafourche Parish Water District No. 1.

g. Recreation. Grand Isle is a significant recreation area offering camping, swimming, boating, and other water sports. Excellent deep-sea fishing in the Gulf of Mexico, surf fishing, and fishing in the numerous bays and bayous are among the principal attractions.

h. Ownership and accessibility of shore. The total length of shore fronting the gulf and passes is about 40,000 feet, of which 1,000 feet at the eastern end is Federally owned (U. S. Coast Guard Station), while about 8,000 feet are public state parks, 6,000 feet at the eastern end and 2,000 feet at the western end. There are 2,500 feet of road and street ends dedicated open to the beach. The remaining 28,500 feet of the gulf frontage is private but accessible to the general public. The old wooden highway bridge across Caminada Pass was not demolished after construction of the new concrete bridge. With the center span removed, the bridge is now used as fishing piers accessible from both ends and available to the public at no cost.

SECTION III - THE PROBLEM AND IMPROVEMENTS DESIRED

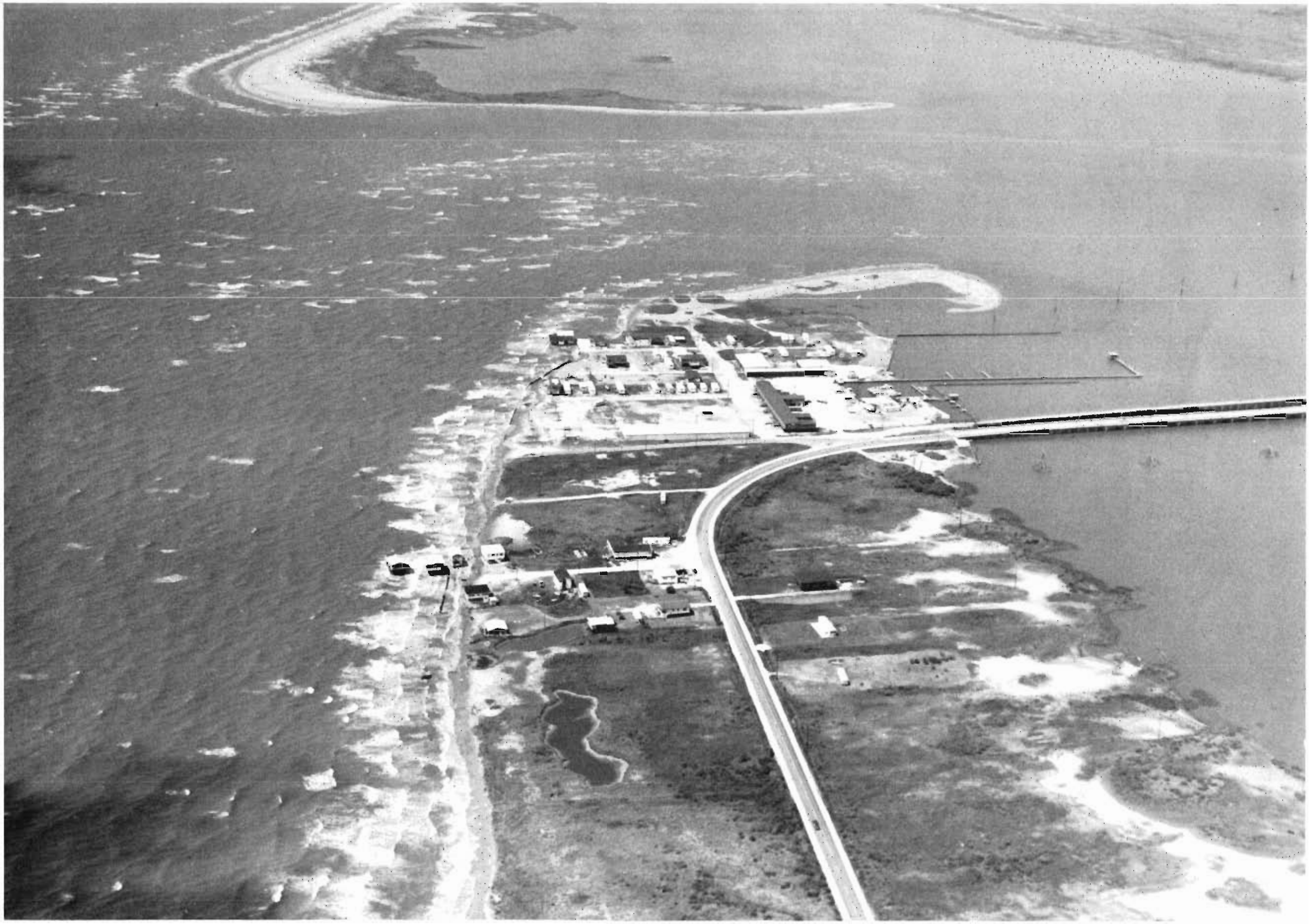
11. STATEMENT OF THE PROBLEM

a. General. Grand Isle is subject to severe damage from hurricanes since it lies fully exposed fronting on the Gulf of Mexico. Hurricanes from the south, southeast, and southwest that approach the coastline within the vicinity of the study area can cause widespread flooding and damage to the entire area by penetration of the hurricane surge inland across Grand Isle. Flooding has been experienced from both the gulf side and the bay side of the island. Hurricanes passing west of Grand Isle produce high stages along the gulf side of the island, causing inundation of the whole island. Large waves driven by hurricane winds strike the flooded improvements causing widespread devastation. The force of these waves is a very significant cause of damage on the island. Hurricanes passing east or south of the island raise the stage of Barataria Bay due to surges entering from the gulf. As the winds change direction, floodwaters and waves from the bay are swept toward the island. Hurricanes have produced stages of 9 feet at Grand Isle. Standard project hurricanes for the area would produce a stage of about 10 feet at Grand Isle. Probable maximum hurricanes for the area would produce stages averaging about 17 feet over most of the study area. Erosion of the gulf shore is also a serious and continuing problem. The sand beach area which is being eroded is particularly attractive to recreationists and is adjacent to the most heavily-developed area on the island. In addition to the loss of the valuable and scenic beachfront, many homes, business establishments, Louisiana Highway 1, and other public improvements are subject to damage resulting from erosion of the island.

b. Severe erosion of the western end of the island resulted in the loss of approximately 35 acres (March 1968 to May 1971) of land between the western tip of the island and groin number 1 (plate 2). Before this erosion was halted by the emergency work described in paragraph 25b, it had stranded eight houses in the Gulf of Mexico and caused several housetrailers to be moved from their gulf front lots. (See photographs 1 and 2.)

12. IMPROVEMENTS DESIRED

a. At the initial public meeting held for this study in Grand Isle, Louisiana, on 8 December 1966, the following improvements were requested:



Photograph 1 Critically eroding West End of Grand Isle

January 1971

Photograph 2 West End of Grand Isle after Completion of Emergency Work.

August 1972

(1) A representative of the Louisiana Department of Public Works requested that the 2,700-foot stone jetty on the eastern end of the island be enlarged and extended and that the beach be periodically nourished as needed;

(2) The Mayor of Grand Isle, expressing the consensus of Grand Isle residents, requested that a beach nourishment program and a system of rock groins or jetties tied into existing sandbars be constructed in lieu of a high (20- to 30-foot) levee;

(3) A resident of Grand Isle requested that a stone breakwater with a crown elevation of 8 or 9 feet be constructed to extend the length of Grand Isle at a distance of about 200 yards off the gulf shore;

(4) A representative of the tourist industry indorsed the request for the seawall, with a modification to include several stone jetties; and

(5) Numerous individuals, the Mayor of Grand Isle, and representatives of Grand Isle, Jefferson Parish, and the State of Louisiana, through letters and at informal meetings, requested immediate assistance to stop the rapid erosion of the western end of Grand Isle.

b. Additional requests were made by a few individuals at the second and final public meetings for any form of beach erosion and hurricane protection (subparagraphs 32a).

SECTION IV - FACTORS PERTINENT TO THE PROBLEM

13. ISLAND FORMATION

Approximately 4,000 to 5,000 years ago, sea level approached its present stand, having risen about 450 feet as a result of the melting of the Pleistocene continental glaciers. At that time, the Mississippi River began migrating back and forth across the gulfward advancing deltaic front. Approximately 1,200 years ago, the Mississippi River began to occupy the Lafourche course and to develop a delta to the south of what is now Lafourche and Terrebonne Parishes. When the Mississippi River abandoned the Lafourche course in favor of its present course to the Gulf of Mexico about 600 years ago, the effects of subsidence and erosion became the dominant process within the abandoned Lafourche delta. The gulfward edge of the abandoned delta began a landward retreat, forming arcuate, sandy delta margin islands with well-developed beaches that are the result of reworking and winnowing of the deltaic-front materials. Grand Isle, which flanks the seaward end of the abandoned Lafourche delta, is an example of these delta margin islands, having originated as a baymouth spit initially attached to the marshes at its western end.

14. LITTORAL MATERIALS

a. Characteristics. Generally Grand Isle consists of a series of low, arcuate sand beach ridges curving bayward away from the gulfward facing edge. The thickness of the fine beach sand varies from 15 to 30 feet and is underlain by a considerable thickness of silty sands. Borings taken on the island and in the surrounding area indicate that the material becomes finer with depth and with distance landward and gulfward of the island. Grain size detail and additional information concerning the characteristics of the materials comprising Grand Isle and the surrounding area are contained in appendix A.

b. Sources. The main source of sediments for development of Grand Isle has been the Recent materials winnowed and reworked through erosion of delta-front material of the old Lafourche delta located to the west of Grand Isle. The granular size of this material currently being supplied to the island is so small that it is quickly carried away by wave action and by the prevailing west-to-east littoral current. As a result, the gulfward facing beach at Grand Isle is receding at varying rates with maximum recession occurring on the western half of the island. Possible sources of sand for beach replenishment include Cheniere Caminada on the mainland and just offshore at the western and eastern ends of the island.

15. HURRICANES OF RECORD

Historical hurricanes. The Grand Isle area has experienced many severe hurricanes, but only a limited history of storms exists because records and factual documentation are lacking. Prior to 1893, there were no official meteorological records. The historical records are found mainly in newspaper accounts and, because the area was sparsely developed, accounts were limited only to dramatic stories of damage and loss of life.

a. Very little factual information is recorded for three storms that struck during the period between 1831 and 1893. The first, in 1831, inundated "Barataria Island" (probably Grand Isle) to a depth of 6 feet, destroying a fishing village and causing 150 fatalities. In 1856, a tropical storm struck the area causing extensive flooding. A storm in 1886 caused 3 feet of water to flow over Cheniere Caminada.

b. The worst storm with respect to fatalities occurred in 1893. This storm struck without warning, allowing no time for evacuation. Approximately 1,150 persons were drowned on Cheniere Caminada and 18 on Grand Isle as winds over 100 m.p.h. (miles per hour) lashed the coast. A central pressure of 28.65 inches of mercury was recorded. One hundred and fifty luggers were sunk and a shrimp processing factory was destroyed. Fort Livingston was severely damaged except for the lighthouse.

c. Another severe storm in 1909 caused considerable destruction of property because of high tides. On 20 September the storm struck the coast on a northwesterly track. The central pressure of the storm was 28.94 inches of mercury and winds of 50 m.p.h. were reported east of the area and 80 m.p.h. west of the area. The wind direction during the approach of the storm was such that a large amount of water was pushed ahead of the storm. Grand Isle experienced a very high tide and was covered by 2 feet of water. Manila, in Barataria Bay, was washed out completely.

d. The first hurricane in 1915 occurred on 17 August and had a central pressure of 28.14 inches of mercury. This hurricane approached the coast on a northwesterly track and although it struck approximately 250 miles to the west, it caused severe flooding along the entire central coast of Louisiana. The Barataria Bay area was struck by 8-foot waves. Grand Isle had water 6 feet deep in some parts. This storm illustrated that flooding of land areas by tides can result from storms which pass a considerable distance away from an area.

e. The second hurricane of 1915 struck on 29 September and passed over the study area on a northerly track with high winds. Burrwood, to the east, reported winds of 94 m.p.h. maximum velocity for 5 minutes with gusts up to 106 m.p.h. There was extensive flooding in the coastal area. Grand Isle had tides of 9 feet and was almost a total loss. Most of the livestock that survived the August storm were drowned in this one. Although 275 deaths were reported on the lower coast, the loss of life was minimized by the excellent warnings that were issued. The Weather Service in New Orleans analyzed the storm potential in time to warn the coastal areas by telegraph and telephones.

f. On 26 August 1926, a storm having a central pressure of 28.31 inches of mercury passed through the western part of the area but did not cause any appreciable damage.

g. On 7 August 1940, a storm with a central pressure of 28.76 inches of mercury passed approximately 25 miles south of the area on a westerly track. Neither winds nor tides caused much damage but the rainfall associated with the storm produced considerable damage.

h. On 24 September 1956, Hurricane Flossy struck the area causing tidal damage in the outlying islands and marshy mainland. The central pressure in this storm was 28.76 inches of mercury. Grand Isle was again flooded to a depth of several feet when water, which had been driven behind the island through Barataria Bay, moved into Caminada Bay and inundated the island from the back side with stages of 8 feet at the rear and 3.9 feet at the front.

i. Hurricane Carla, 9-14 September 1961, passed inland approximately 400 miles west of the study area. Carla, with a minimum central pressure of 27.50 inches of mercury and a large radius, was one of the most severe gulf hurricanes of this century, and caused high tides and attendant extensive inundation of the low lands along coastal Louisiana. Along this coastline, sustained winds generally were less than 50 miles per hour and tides ranged from about 3.5 to 7.5 feet. Louisiana Highway 1, which serves as the only vehicle escape route for residents of Grand Isle, was inundated from 9 to 13 September at several locations.

j. Hurricane Hilda crossed the Louisiana coast about 100 miles west of Grand Isle during the evening on 3 October 1964. At the time of entry on the coast, winds were 98 m.p.h. and the central pressure was 28.00 inches. Hilda caused heavy damage to offshore and coastal oil installations in the vicinity of Grand Isle and generated surge heights of 4.0 feet at Grand Isle and 5.5 feet to the east and west of the island. The hurricane caused considerable damage to the beach at Grand Isle and cut through the western end of the island and Cheniere Caminada.

k. The most destructive storm of record for the Louisiana coast and one of the great hurricanes of the century, Betsy, struck just west of Grand Isle on the night of 9 September 1965. Winds of 100 m.p.h. with gusts up to 160 m.p.h. were reported at Grand Isle while the island experienced a maximum surge height of 8.8 feet. The central pressure was 27.79 inches of mercury. The entire island was inundated and practically all buildings with the exception of three were either swept away, demolished, or severely damaged by the onrushing surge and waves. The entire beach and adjacent sand dunes were swept back over the island by the high surge. The coastal highway was covered with 3 feet of sand in some places and was severely eroded in others. Aerial photographs 3 and 4 and aerial mosaics numbered F-1 through F-4 in appendix F depict some of the damage caused by Betsy.

l. Other hurricanes of a minor nature struck this section in 1895, 1897, 1900, 1923, 1936, 1941, 1948, 1949, and two in 1957. The damage from these was either slight or was unassessed in any recorded report.

16. HURRICANE CHARACTERISTICS

a. General description. A hurricane is a well-developed cyclonic storm, usually of tropical origin. Hurricane characteristics are violent, counterclockwise winds, producing tremendous waves and surges and torrential rainfall. Size and duration vary with each hurricane. They generally extend over thousands of square miles, reach a height of 30,000 feet or more, and last about 9 to 12 days from origin to dissipation.

b. Origins and tracks. Hurricanes originate exclusively in the shifting zone of equatorial calms called the "doldrums" which lies between the two trade wind systems. Early in the hurricane season, June and July, there is a tendency for the storms to develop in the western Caribbean Sea, while late in the season, September and October, storms are more likely to develop in the Atlantic Ocean. While still in the initial stages of development, the storms are affected by the trade winds and begin to move toward the west or northwest. In the vicinity of 30° N. latitude, they recurve and begin to move in a northeasterly direction at an accelerated speed. This is only a very general path that hurricanes follow and actually there are many deviations. Hurricanes have been known to circle back and cross over their paths.

c. Barometric pressure and winds. Normal barometric pressures in the tropics are about 30 inches of mercury, whereas the pressures recorded in hurricane centers range between 27 and 29 inches or sometimes even lower. The wind system of a hurricane follows a counterclockwise circular pattern with the wind direction deflecting about 30° inward toward the center of the storm. At the outer limits of the storm, the winds are light to moderate; at about 35 miles from the center, they reach a maximum 5-minute average velocity of about 100 m.p.h. although higher averages have occurred. Gusts as high as 175 m.p.h. have been reported. At the center, winds are relatively calm. This calm area, called the "eye" of the storm, ranges between 7 and 20 miles in diameter. The point of lowest

Photograph 3 Damage on Grand Isle after Hurricane Betsy

September 1965

Photograph 4 Damage on Grand Isle after Hurricane Betsy

September 1965

barometric pressure is located in the vicinity of or within the eye. The lowest recorded barometric pressure for hurricanes occurring along the gulf coast is 26.35 inches.

d. Surge. The hurricane surge which inundates low coastal lands is the most destructive of the hurricane characteristics. It alone accounts for three-fourths of the lives lost from hurricanes. It is the product of meteorological and beach, shore, and inland topographic conditions. All other factors being equal, a higher surge will be produced if the hurricane path is perpendicular to shore, the velocity of forward movement is fast, or the diameter of the storm is very large. Maximum surge heights experienced along the gulf coast range between 10 and 25 feet.

e. Waves. The waves generated by hurricane winds cause extensive damage to shore structures. At sea, the waves are high and turbulent, particularly in the right front quadrant and near the eye of the storm. Near shore, wave heights which have diminished some since origin begin to increase again because of the shoaling effect of the shallow water. Further, breaking waves can run up and overtop shore structures whose crowns are higher than the wave heights. The force expended when waves break causes the most damage to shore structures.

f. Rainfall. Rainfall accompanying a hurricane usually is heavy and sometimes torrential. However, its distribution during the passage of a hurricane is not uniform. The rain may begin long before arrival of the storm. Prior to the passage of the eye, rainfall generally reaches its maximum rate, and after the eye has passed it ceases almost entirely. Rainfall is particularly heavy in the right front quadrant. Some hurricanes, however, are accompanied by little or no rainfall over considerable lengths of their paths.

17. STANDARD PROJECT HURRICANE

A standard project hurricane (SPH) is one that may be expected from the most severe combination of meteorological conditions that are considered reasonably characteristic of the region. The general SPH that is characteristic of the Louisiana coast was developed in cooperation with the National Weather Service and corresponds to one having a frequency of once in 100 years in the northern gulf. This frequency is adjusted for application to the individual study area. A detailed coverage of derivation procedures and frequency computations is presented in appendix B. The specific SPH for the study area has a central pressure index (CPI) of 27.5 inches, maximum wind velocity over water of 100 m.p.h. at a radius of 35 miles, a forward speed ranging between 5 and 18 m.p.h., and a recurrence frequency of once in about 200 years. However, each location in the study area requires a particular path to produce critical effects. For critical flooding of Grand Isle from the gulf, a path similar to the September 1915 hurricane, but transposed to the west, is required. A path similar to that of Hurricane Flossy, September 1956, is critical for flooding Grand Isle from Barataria Bay. The parameters of Hurricane Betsy, September 1965, exceeded those of an SPH in all respects except CPI, and would have been more critical to Grand Isle had the path been more to the west. An occurrence of a hurricane on a critical path with SPH characteristics would produce a stage of 9.9 feet in the study area. Detailed data related to these hurricanes are presented in appendix B.

18. PROBABLE MAXIMUM HURRICANE

The probable maximum hurricane (PMH) is one that may be expected from the most severe combination of critical meteorological conditions that are reasonably possible for the region. It has an infinite recurrence period. The specific PMH for the study area has a CPI of 26.9 inches and a maximum wind velocity of 146 m.p.h. at a radius of 35 miles for forward speeds ranging between 5 and 40 m.p.h. Critical hurricane paths are identical to the ones used for the SPH. An occurrence of a hurricane with PMH characteristics would produce a maximum surge height of about 17 feet at Grand Isle. Detailed data are presented in appendix B.

19. HURRICANE FREQUENCIES

Hurricane frequencies for Grand Isle were computed, using both the observed and synthetic data, and the results obtained by both methods were in close agreement. A detailed discussion of methods used in the computation of hurricane stage-frequencies is presented in appendix B. Computed stage-frequency relationships for the Grand Isle area are shown in table 1.

TABLE 1
STAGE-FREQUENCY

Frequency	Stage (feet)
Probable Maximum Hurricane	17
Standard Project Hurricane	9.9
100-year	9.3
50-year	8.5

20. SHORE HISTORY

a. Prior corrective action and existing structures. Prior to 1951 no major effort had been made by any entity other than private property owners individually to control beach erosion.

b. The Louisiana Department of Highways made the first major effort in 1951 and 1952 to stabilize the shore with groin fields at two locations where erosion threatened Louisiana Highway 1 along the front of the island. Before this time, protection was provided privately by vertical bulkheads extending only across the gulfward front of individual lots. The bulkheads were incongruous and irregular and were constructed to suit the means and needs of the individual owner. As a whole, these isolated structures were ineffective, generally accelerating the erosion immediately gulfward of the bulkhead thus causing the structure to fail gulfward; therefore, these structures had no beneficial effect on the regimen of the shore. Fourteen timber groins were constructed by the Department of Highways at an initial cost of $480,000. Four groins, numbered 1 through 4 from west to east on plate 2, were constructed between station 342+00 and station 315+00, and 10 groins numbered 5 through 14, plates 2 and 3, were constructed between stations 200+43 and 129+29. Groins numbered 1 through 4 are 500 feet in length and numbers 5 through 14 are 250 feet in length. These timber sheet pile groins are supported by round timber piles spaced on 5-foot centers. The groins are spaced between 800 and 1,000 feet apart with a horizontal shore section constructed to an elevation of 4. The horizontal offshore section was constructed to elevation 2 with a transition slope upward to the shore section. The longer groins were placed on the western side of the field. At the time of construction, it was thought that the predominant direction of littoral drift was east to west. A previous cooperative study in 1935 determined that at least for the limited observations made in 1935 littoral currents were generally east to west. However, a later study (1954) demonstrated that the groin fields were ineffective and in fact the direction of littoral drift was from west to east. No maintenance has been performed on any of these groins since their initial construction. They are partially destroyed at the offshore ends as a result of erosion, undermining, rust, marine borers, and general rotting of the timber members. At this time no future maintenance is planned by local interests to restore the groins. Recommendations in the 1954 report provided for the placement of 1,200,000 cubic yards of suitable material within the two groin fields described above and for the construction of a jetty adjacent to Barataria Pass.

c. The State of Louisiana, Department of Public Works, placed 1,150,000 cubic yards of sand as artificial nourishment within the groins in 1954 and 1955 at a cost of $188,000. Approximately 350,000 cubic yards of sand were placed between groin numbers 1 through 4 and 800,000 cubic yards between numbers 5 and 14. Field surveys were taken in June 1954 prior to nourishment and in March 1955 after nourishment had been completed. Comparative profiles made in March 1955 indicated only a 745,000 cubic yard gain over the June 1954 survey. This indicates that 400,000 cubic yards of artificial nourishment were lost from the groin system in less than 1 year. However, the downdrift beach east of each set of groins indicated a marked gain in width and volume due to the lost material being carried eastward and being deposited along shore by wave action. See aerial photographs of the completed nourishment (photographs 5 and 6). Results of this

Photograph 5 Groins 1 through 4 after Artificial Beach Nourishment

March 1956

Photograph 6 Groins 7 through 14 after Artificial Beach Nourishment

March 1956

effort to stabilize the beach were satisfactory but in 1956 Hurricane Flossy struck, first driving a surge over the island from the gulf side thus filling Barataria and Caminada Bays to the rear of the island, then driving a surge over the island from the bay side to the gulf side. The low dunes along the beach front were not of sufficient height to prevent sheet flow over the island and erosion and scour occurred adjacent to many structures causing them to fail. Louisiana Highway 1 was undermined at many places along its length. Many residences and business establishments were totally destroyed and much of the artificial nourishment previously placed was carried away, either onshore, into the back bays, or offshore. See aerial photographs of damage caused by Hurricane Flossy (photographs 7 and 8).

d. In October 1956, Humble Oil and Refining Company constructed a timber groin on the east side of property owned by the company and placed material dredged from the offshore bottom on the west side of the groin. The groin projected 500 feet gulfward from the shoreline at station 83+00 and was similar to those previously constructed by the Louisiana Department of Highways. The shoreward 300 feet of groin was constructed to an elevation of 4 with a transition to elevation 2 for the remaining 200 feet offshore. Material used to fill the groin was dredged from the offshore bottom at a point 2,000 feet offshore. This groin generally has been more effective than those constructed by the Louisiana Department of Highways. The groin has trapped material on either side thus benefiting the shoreline for several hundred feet in either direction. No maintenance has been performed to date and this groin is in good condition.

e. Subsequent to Hurricane Flossy in 1956 the Louisiana Department of Public Works, with Federal emergency funds, placed an estimated 140,000 cubic yards of sand along 4 1/2 miles of beach in 1957 at a cost of $76,000. Initial estimates of quantities indicated 350,000 cubic yards of artificial nourishment would be needed to build the dune line; however, preconstruction surveys revealed that natural swell action following Hurricane Flossy had restored and rebuilt the beach and a much smaller quantity of material was needed to reestablish the barrier dune.

f. The Louisiana Department of Public Works constructed a jetty approximately 1,000 feet west of the eastern end of the island in 1958 and 1959 at a cost of $150,000. The jetty was approximately 935 feet long perpendicular to the shoreline at station 16+00. It was founded on a timber mattress and had a 6-foot crown width at elevation 3 and 1 on 1.5 side slopes. The 1954 cooperative study indicated that this jetty would trap a large quantity of sand at the expense of the downdrift shoreline adjacent to Barataria Pass. Within a period of 4 years following its construction, the jetty had trapped more than 1 million cubic yards west of the jetty. However, the effects of the jetty extended eastward where 30 acres

Photograph 7 Grand Isle after Sheet Flow from Hurricane Flossy

October 1956

Photograph 8 Grand Isle after Sheet Flow from Hurricane Flossy

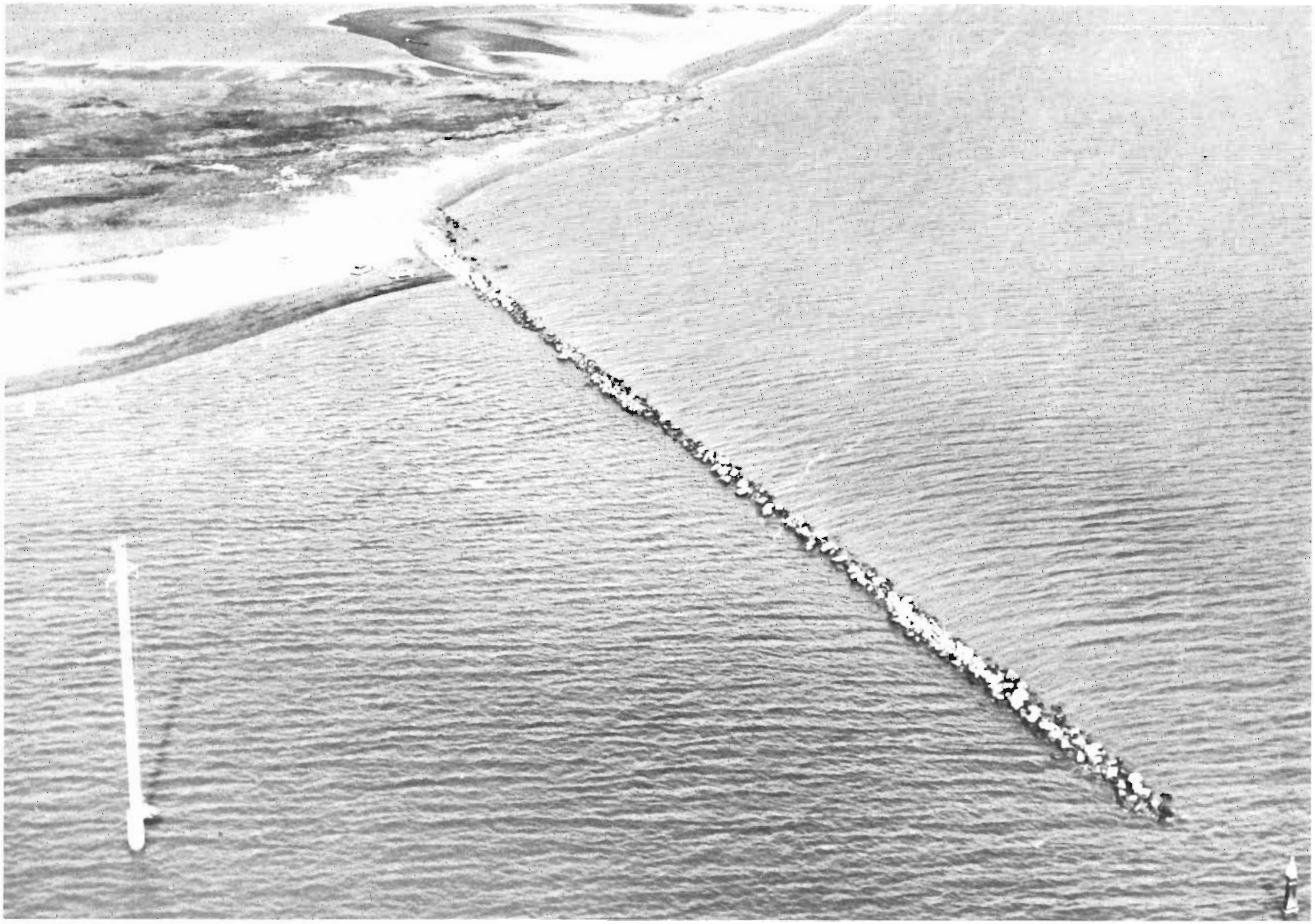
October 1956

of the island were completely lost. Aerial photograph number 9 taken in February 1960 and number 10 taken in September 1962 show the jetty and shoreline changes which took place in that time interval.

g. The Louisiana Department of Public Works placed 350,000 cubic yards of sand within the 10 groins near the center of the island in 1961 and 1962 to repair the damage done by Hurricane Carla in 1961 and supplement repairs for damages done by Flossy and several tropical storms since 1956. A study of table B-10, appendix B, indicates a significant loss occurred within the westward groin field, station 133+10 to station 196+80, during this period while the adjacent shore on both sides of the groin field was relatively stable. The cost of this work was approximately $115,000.

h. In 1964 the Louisiana Bonding and Building Commission, together with the Louisiana Department of Public Works, extended the jetty adjacent to Barataria Pass 1,400 feet. Aerial photograph 11 shows the new 1,400-foot section extending gulfward from the end of the original jetty. Essentially the same cross section was used for the extension as was used in the initial construction except for a 400-foot segment which had to be founded on a shell bedding when the contractor ran out of lumber mattresses. The extended jetty began immediately to trap sand which otherwise would have flanked the shorter jetty around its outer end. A large shoal formation east of the jetty began to erode again but the erosion was only temporary. Within 1 year the jetty had trapped sufficient sand to essentially fill the offshore bottom on the west side of the jetty and littoral drift began to flank the jetty again. The accretion caused by the jetty extended 9,000 feet to the west along shore and amounted to 1,250,000 cubic yards. The cost of this work was approximately $200,000.

i. In 1965 Hurricane Betsy caused extensive damage to the entire island. The dune line along the island, with the exception of a short segment within the westward groin field, was destroyed. Aerial photographs 3 and 4 and aerial mosaics numbered F-1 through F-4 in appendix F show changes caused by Hurricane Betsy along the western 5 miles of beach. The jetty was flanked at its shoreward end, the 400-foot segment of jetty founded on shell bedding failed, and the large shoal formation east of the jetty was scoured away by the inward flow of storm-driven tide. Following Betsy 550,000 cubic yards of sand were borrowed from the accreted area west of the jetty to restore the natural dunes which had been destroyed previously. This work was done in 1966 under Public Law 875-81 by the Louisiana Department of Public Works under a reimbursable agreement with the Federal Government through the Office of Emergency Planning. The total cost of the work was $447,000. The dune restoration was performed according to specifications determined by the U. S. Army Corps of Engineers. The dune was reconstructed to a crest elevation of 8 feet, a top width of 10 feet, a gulfside side slope of 1 on 4 to elevation 5, a 1 on 25 berm slope to elevation 3,

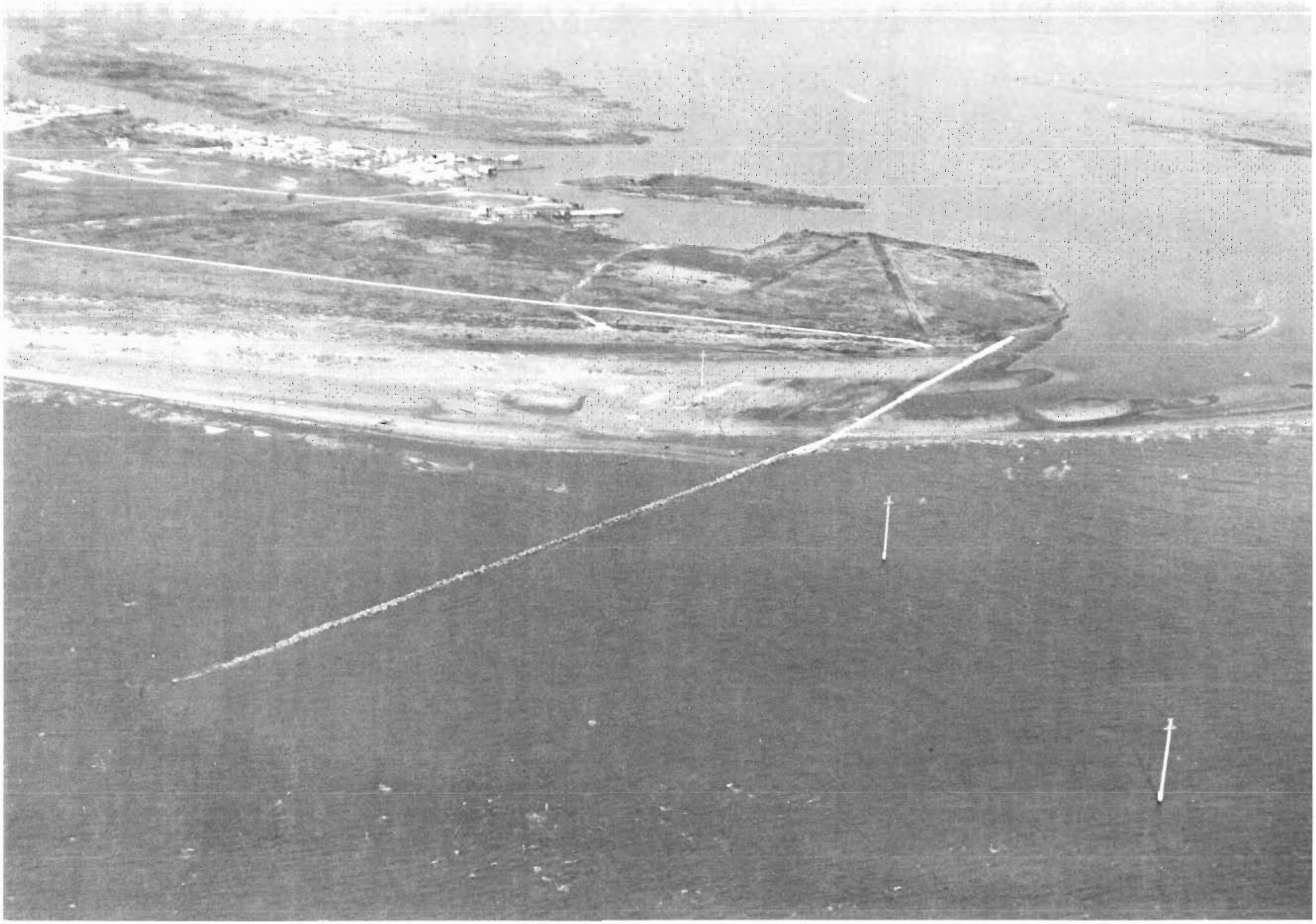


Photograph 9 Accretion on Southwest side of newly constructed jetty on East End of Grand Isle

February 1960

Photograph 10 East end jetty approximately 3 years after construction

September 1962



Photograph 11 East end jetty after its extension in 1964

August 1965

and a 1 on 15 beach slope to existing ground. The landside slopes were 1 on 4 from top of crown to elevation 5, and 1 on 15 from elevation 5 to existing ground. Since construction, the dune has been subjected to waves, wind, and rain but has remained relatively stable except near the western end of the island where serious erosion has taken place since 1969. Along the western 6,000 feet of the island, the shoreline had receded as much as 450 feet, prior to the emergency construction described in paragraph 25b, and this erosion had completely consumed the dune section within this reach and left several beach homes stranded in the gulf waters. Along the remainder of the island, natural species of beach grass and shrubbery have been established and now help trap or prevent loss of wind-blown sand.

j. Repair of the jetty was also made in 1966. Funds were provided through the Office of Emergency Planning when it was determined that the jetty would not function properly if it were not tied into the shore and repaired where failure had occurred. The cost for the tie-in and repair was $25,000 and $83,500, respectively. The Corps of Engineers contracted for the jetty repair work which was completed in April 1966.

k. As previously stated, a large shoal east of the jetty was severely eroded by Betsy. As a result of this damage, erosion east and north of the landward end of the jetty continued at a rapid rate and began to threaten the construction and continued existence of the new U. S. Coast Guard Loran Station on the eastern end of the island, photograph 12. The U. S. Coast Guard, using limited funds ($27,000) and manpower, constructed a revetment on the northeast side of the station in August 1967. The revetment was constructed along approximately 1,000 feet of existing shoreline between elevations -1 and 2.5. The material used was a pliable nylon container sewn to form individual quilted compartments or pockets. A sand-cement mixture was shot under pressure into the individual compartments after the 30- by 15-foot blankets were placed on a prepared slope. Each blanket was placed so that some overlapping occurred at each side of each blanket. The cement hardened to form a rigid shell of concrete which conformed to the contours of the graded bank slope. Inspection of the revetment in December 1968 revealed that approximately 900 feet had failed as a result of wave overtopping, uplift pressure, and leaching of the foundation which, in turn, left an unsupported shell which subsequently cracked and broke up under wave action.

l. With the failure of that revetment and continued erosion at the Coast Guard station, the U. S. Coast Guard requested assistance in the design and subsequent construction of a more permanent-type structure along the problem shore. As a consequence of detailed studies by the New Orleans District, a rubble mound revetment which would tie into the existing jetty was determined to be the most feasible method of controlling erosion. This revetment was constructed by the New Orleans District for the Coast Guard to elevation 6 along approximately 1,400 feet of pre-erosion shoreline in an effort to

Photograph 12 East end jetty and threatened U. S. Coast Guard Station

April 1969

restore the original property purchased by the Federal Government in 1965. Approximately 7.6 acres of property had been lost since the purchase. Aerial photograph 13 shows the completed revetment and the remnants of the former one. The cost of the revetment (completed in February 1970) was $176,000. This revetment was designed to protect against a 5-foot wave accompanying a storm surge having a 10-year recurrence interval and has performed satisfactorily to date. No maintenance has been necessary since construction.

SECTION V - ANALYSIS OF THE PROBLEM

21. SHORE PROCESSES PERTINENT TO THE PROBLEM

a. Littoral transport.

(1) The predominant direction of littoral transport along the central portion of the island between stations 95+00 and 350+00 is from west to east. This direction is largely determined from observations of the wind and wave climate, from studies of refraction and diffraction diagrams, from recent experience with artificial nourishment, and from observations of accretion on the west side of littoral barriers and erosion on the east side. Between stations 350+00 and 397+00 on the western end of the island, the littoral current direction is variable according to the prevailing tide, being eastward during ebb flow and westward during flood flow. This tidal current is reinforced or reduced according to the wave direction of approach prevailing at any time. This is determined from current observations made in 1935, from visual observations and aerial photographs made since 1950, and from studies of bar formation cycles in Caminada Pass and alongshore east of the pass. Aerial photographs taken in February 1965 at low tide show two separate channels through Caminada Pass--one channel following the western shore of the pass and another following the eastern shore of the pass. A large bar formation is present between the two channels, as shown on photograph 14.

(2) Along the eastern third of the island between stations 95+00 and 16+00, the predominant direction of littoral transport is toward the east. At present the direction of the ebb current is easterly about 120° and the jetty extends 2,400 feet offshore from the 1958 shoreline. Waves approaching from the east occur less than 3 percent of the time and are intercepted by the jetty; therefore, these waves have little effect on shore processes. Before construction of the jetty, the direction varied with the tidal flow, being eastward during south or southwesterly wave action and flood tide and being westward during ebb tide, opposing the littoral currents caused by south or southwesterly wave action. Southeasterly wave action tended to reinforce alongshore flood currents near the passes and reduce the

Photograph 13 East end of Grand Isle after construction of U. S. Coast Guard revetment

January 1971

Photograph 14 Offshore bar at entrance to Caminada Pass (White Water Area) and partially attached onshore bar at West end of Grand Isle

February 1965

alongshore ebb currents. This determination is a result of wave refraction and diffraction studies for waves approaching from deep water directly onshore.

(3) The only major littoral barrier of consequence in the study area other than the two passes is the jetty. Prior to its construction, the shore showed a general recession. Within 3 years after initial construction, more than 1 million cubic yards had been trapped by the jetty. This would indicate an average littoral transport rate exceeding 300,000 cubic yards annually had occurred along the island. After the 1,400-foot extension in 1964, an additional 1.25 million yards of accretion occurred along the eastern 2 miles of shore in 4 years including that lost as a result of Hurricane Betsy. Again this average would be in excess of 300,000 cubic yards per year.

(4) The variability of littoral transport along the front of Grand Isle is dependent upon two factors--the absence or presence of a trailing sand spit joining the western lip of Caminada Pass and extending into Caminada Bay (photograph 15) and the absence or presence of an onshore bar east of Caminada Pass extending eastward parallel to the shoreline for several thousand feet, photograph 14. The trailing sand spit is shown extending into Caminada Bay on the aerial mosaic, plate 2. During each hurricane or tropical storm, some material is lost to abnormal flow through the pass. Following the storm, littoral material is trapped in the trailing spit until its deficiencies are satisfied. The onshore bar forms as an offshore bar approximately in the center of Caminada Pass, as shown in photograph 16, and migrates eastward readjusting to conform to the eastern lip of the pass and the gulf shoreline, as shown in photograph 17. This offshore bar is estimated to store 1 million cubic yards over a cyclic period of 3 years before the bar finally attaches itself to the western 4,000 feet of shoreline, as shown in photograph 18. The onshore bar then proceeds to erode and nourish the downdrift shoreline. During the bar formation and subsequent to its migration toward the east, it is evident that littoral transport along the island shoreline is reduced. Photograph 1 shows the eastern lip of Caminada Pass in a critical state of erosion.

b. <u>Supply of littoral materials</u>. Experience gained from studies made after construction of the jetty at the eastern end of the island indicates that there is not a quantitative deficiency of littoral material at present. The source of littoral material to the west of Grand Isle is not yet depleted and is likely to continue to provide material for a number of years in the future. In addition, the jetty has been used effectively as a littoral trap to intercept and store material until it is needed. More than 1 million cubic yards of suitable material were available for beach restoration following Hurricane Betsy, although only 550,000 cubic yards were needed. Since 1954, more than 2 million cubic yards from various sources have been placed on the beach in efforts to restore it and stabilize problem reaches.

Photograph 15 Trailing sand spit along Western Lip of Caminada Pass

January 1971

Photograph 16 Center bar formation (Light Area) and channel along Western side of Caminada Pass

January 1971

Photograph 17 Offshore bar in process of becoming attached to West end of Grand Isle

May 1956

Photograph 18 West end of Grand Isle after attachment of bar

April 1969

c. Manner of movement of littoral material.

(1) Problem conditions in the recent past have been caused primarily by hurricanes and tropical storms, but occasionally frontal storms associated with low pressure systems and Artic air masses have raised water levels 2.5 feet or more above normal high tide and have caused limited local erosion. Table B-10, appendix B, summarizes the movement of littoral materials within the limits of the surveyed ranges between stations 72+00 and 337+00. The most significant losses have occurred within the westward groin field between stations 133+00 and 196+80. Moderate to severe storms in 1958, 1959, 1960, 1961, 1963, 1964, 1965, 1969, and 1970 were primarily responsible for eroding the beach. The eastern 2 miles of the island has experienced accretion and is relatively stable. The rapid recession of the shoreline along the western 4,000 feet of the island is the result of recent storms during August, September, and October 1970 which have caused rapid surge inflow into Caminada Bay through Caminada Pass. The unusually high alongshore currents caused by the surge rapidly eroded the unstable lip of Caminada Pass causing a loss of 15 acres in 4 months.

(2) The island is low, ranging between elevations 3 and 5. Storm surges and consequent wave action and free flow (sheet flow) work together to either drag beach material off the beach and deposit it offshore or carry the material inland and deposit it north of the highway. Results of this action are depicted vividly in photographs taken following Hurricanes Flossy and Betsy. The predominant direction of movement of beach material is determined solely by the height of the storm surge. Less severe storms which generate surges to elevations less than about 4.5 tend to degrade the beach and deposit the material offshore. Severe hurricanes, which generate surges greater than 4.5 feet, cause sheet flow and wave action to occur over the island. Both methods of degradation occur for such severe hurricanes.

d. Future shore conditions.

(1) The findings presented in the 1954 report concerning the cyclic shoreline changes along the eastern lip of Caminada Pass have been verified by studies of aerial photographs and actual observation. In the spring of 1968 an offshore bar was visible at low tide along the eastern lip of Caminada Pass. By the spring of 1969, this offshore bar had migrated eastward and had become integral with the 1968 shoreline, as shown on photograph 18. In August 1970 this bar began to erode and by February 1971 had completely disappeared. At about the same time aerial photographs flown in January 1971 showed an offshore bar in the early stages of development forming in the center of Caminada Pass (photograph 16).

(2) The island as a whole will continue to experience high surges and wave action. It is unlikely that man's efforts to control the weather will meet with measurable success in the near future.

The data presented on shoreline changes dating back to 1877 indicate that the island has changed configurations about a relatively stable midpoint or node--the eastern half accreting while the western half is eroding and vice versa. The recent construction of a jetty at the eastern end will affect the pattern along the eastern third of the island and tend to stabilize that segment. The remainder of the island including the node about which long-term changes have occurred will continue to recede at an average rate as shown in table 2. Such erosion would soon endanger the alongshore highway and stifle economic growth of the region. Littoral material from the abandoned Lafourche delta to the west of Grand Isle will likely continue to nourish the island for another 50 to 100 years. However, the occurrence of a severe hurricane such as Betsy at the same time that the eastern lip of Caminada Pass has depleted its cyclic nourishment could have disastrous results. Total erosion of the western 2,500 feet of the island could occur at the expense of total loss of any vehicular connection with the mainland.

TABLE 2
EXPERIENCED AND PREDICTED RATES OF SHORELINE EROSION
in feet[1], referenced to mean high water

Ranges	Total change 1932-1953	Annual rate	Total change 1958-1970	Annual rate	Predicted Annual rate
72+00	-180	-9	+635	+58	0
80+00	-280	-13.5	+335	+30.5	0
88+00	-360	-18	+190	+17.5	0
95+57	-300	-14.5	+139	+13	-5
133+10	-220	-10.5	-32	-3	-10
141+50	-240	-11.5	-48	-4.5	-11
149+40	-250	-12	-52	-5	-12
157+45	-240	-11.5	-40	-4	-12
165+25	-260	-12.5	0	0	-12
173+45	-230	-11	-27	-2.5	-12
181+15	-200	-9.5	-45	-4	-12
188+85	-140	-7	-3	-.5	-10
196+80	-160	-8	-14	-1.5	-8
235+26	-170	-8	+9	+1	-8
243+00	-150	-8	-4	-.5	-8
251+00	-180	-9	+20	+2	-9
259+00	-170	-8	+8	+1	-8
320+80	-90	-4.5	-38	-3.5	-5
329+00	-50	-2.5	-120	-11	-10
337+00	-20	-1	-178	-16	-16

[1]Positive numbers indicate accretion; negative numbers indicate erosion.

22. METHODS OF PROTECTING GRAND ISLE AGAINST EROSION AND HURRICANE DAMAGE

a. Beach fill. The beach at Grand Isle could be widened by artificial placement of fill material to the extent required to afford the desired protection against further destructive erosion. A wider beach would move the wave breaking point seaward for a given design and tidal elevation. The widened beach could be stabilized by periodic artificial beach nourishment. Such a widened and stabilized beach would be beneficial in view of increased recreational use as well as the provision of some protection to onshore installations against water attack. This method of stabilization was investigated in detail and is described in paragraph 24b.

b. Beach fill with groins. During preliminary studies, use of a groin system was investigated. In order for groins to be effective, without nourishment, waves must approach the shore at an angle a large percentage of the time. Waves approach Grand Isle predominately directly onshore and, therefore, render a groin system ineffective. Studies of the timber groins constructed by the Louisiana Department of Highways in 1951 and 1952 indicate that these have not provided any benefits to the beach area. These groins were constructed in two fields located approximately 2.5 miles apart. Comparison of aerial photographs and beach surveys over the last 20 years indicates that the shoreline between the two fields of groins behaves the same way as the shoreline within the fields. When the shoreline between the two fields was eroding, the shoreline within the fields was also eroding, and when the shoreline between the fields was enjoying relative stability, so was the shoreline within the field. Approximately 2 or 3 years following the construction of the groins about 1.2 million cubic yards of sand was dredged onto the beach as an emergency measure to provide erosion protection to the Grand Isle beachfront, including the area within the fields of groins. In addition, we find that the two fields of groins did nothing to help prevent the severe erosion caused by Hurricanes Flossy in 1956, Carla in 1961, Hilda in 1964, or Betsy in 1965, or to trap sand and rebuild the beach following these hurricanes. Each time the beaches had to be rebuilt by direct placement of sand. In order for a groin system with periodic nourishment to provide an adequate degree of shoreline stability, groins would have to be constructed approximately 250 feet apart, beginning at Caminada Pass and extending eastward along 6 miles of beachfront. These groins would have to be about 600 feet long to be effective. The groins for this system would cost in excess of $12 million, the initial cost for the sandfill would be about $1,500,000, and the required periodic nourishment would cost $60,000 annually. The groins would require replacement at 20-year intervals.

c. Additional beach fill and dune. Additional hurricane wave protection would be provided by a beach with a berm elevation above that required for the prevention of destruction by erosion and a dune of sufficient height to remain above the limits of the wave uprush. This method of providing protection was investigated in detail and is described in paragraphs 24c, 24d, and 24e.

d. Levees and bulkheads. A plan to provide complete hurricane protection for the island would require construction of a levee system along the bay side, with concrete bulkheads at the various docking facilities. Sand dunes along the gulf front would have to be constructed also and tied in with the levee system to constitute an unbroken barrier to water action from the gulf, passes, and bays. This system would have to be designed to protect the island from a storm which would produce tides about 6 feet in excess of those which occurred during Hurricane Betsy. This plan would cost over $30 million and is economically infeasible. Any lower degree of protection would give a false sense of security in the event that a hurricane should occur which was more severe than that designed against. This would be disastrous as the island could flood from overtopping and would be completely isolated with only the escape route inundated. No further consideration was given to this type of protective measure.

e. Breakwater. An offshore breakwater to prevent significant hurricane surges would have to be at least 13 feet above m.s.l. The cost of a structure of this magnitude would be in excess of $35 million. A breakwater at an elevation of 8 or 9 feet above m.s.l. as requested at the public meeting would not prevent damage from the significant hurricane surges and would not entirely prevent erosion of the island. The beach would still have to be initially widened as in paragraph 22a above and would still require periodic nourishment. This breakwater would reduce the amount of nourishment required but not in a sufficient amount as to justify its construction. This breakwater would function as a complete littoral barrier as far as Grand Isle is concerned and would possibly have detrimental effects upon Grand Terre Island.

f. Extension of jetty at eastern end of the island. Extension of the jetty at the eastern end of the island, as requested by the Louisiana Department of Public Works was considered in preliminary studies. It was determined that extension of this jetty would not appreciably prevent erosion of the central sections of the island, and that in the initial years after its extension it would cause a detrimental effect on Grand Terre Island by its interruption of the west-to-east littoral transport (see paragraph 20f). The enlargement was not economically justified. In light of the above and the fact that sufficient beach is now available at the eastern end of the island, no further consideration was given to extension of this jetty.

g. Jetty at the western end of the island at Caminada Pass. A stone jetty to stabilize the western end of the island at Caminada Pass was investigated and has been included as an integral part of each of the plans considered in detail for this study. This jetty is described in paragraph 24b.

h. Revetment with spur dikes at the western end of the island at Caminada Pass. A stone revetment along the western end of the island with a series of stone dikes perpendicular to Caminada Pass was also investigated as a method of stabilizing the western end. This revetment was found to be economically infeasible.

23. DESIGN HURRICANE

a. Design criteria adopted. The design hurricane adopted for this study is one which has an average recurrence interval on the order of once in 50 years in the study area. A design for a more frequent and, consequently, less severe hurricane would not provide the degree of protection desired by local interests, and damage as a result of a less frequent (more severe) hurricane, such as a standard project hurricane (SPH), could be disastrous. Although the Design Hurricane (Des H) selected is not so severe as the SPH, the difference in stillwater level, elevation 8.5 for the Des H and 9.9 for the SPH, is only 1.4 feet. The estimated recurrence interval for the SPH in the study area is approximately once in 200 years on the average. Hurricane parameters accompanying the Des H include a central pressure of 28.15 inches of mercury, a maximum overwater wind velocity of 87 m.p.h. at a 35-mile radius, and a forward speed of 13 m.p.h.

b. Design wave characteristics. For the Des H chosen, the deepwater wave height and wave period are 8.2 feet and 7.3 seconds, respectively. For the purpose of design, the incident wave is assumed to approach directly onshore from a southeasterly direction. Wave runup on the protective barrier for the design wave is 2.2 feet. Details on the methods of determining surge heights, wave characteristics, and wave runup are given in appendix B.

SECTION VI - PLANS OF IMPROVEMENTS

24. PLANS CONSIDERED

a. General. The basic plan considered most suitable to prevent erosion consists of widening the beach by artificial placement of beach fill and periodic nourishment. Stabilization of the beach would be accomplished by construction of a jetty at the western end of the island. Such a widened beach would provide benefits from increased recreational use and from prevention of damage caused by beach erosion. Protection benefits from hurricane wave damage could be obtained by raising the berm elevation and by providing a dune along the gulf front, with a crown elevation at or above the limits of wave uprush from the design hurricane. Four plans of protection have been considered in detail and are described in the following paragraphs. A discussion of the design criteria is given in appendixes A, B, and C and the plans and typical cross sections are shown on plates 2 and 3.

b. Plan A - Beach erosion protection. This plan would restore and stabilize the beach at Grand Isle to provide for increased recreational use and to provide protection from beach erosion damage. A 200-foot wide beach with a shoreward elevation of 3 and a gulfward elevation of 2 (1 on 200 slope) is the minimum section required to restore and stabilize Grand Isle's gulf shore. The beach would assume its natural slope from an elevation of 2 to the offshore bottom. It would be located gulfward of the existing dune line and would extend the length of Grand Isle's gulf shore. A jetty approximately 2,600 feet long with a crown elevation of 4, a crown width of 6 feet, and side slopes of 1 on 2 with fill placed on its Grand Isle side would stabilize the western end of Grand Isle at Caminada Pass. Material for the beach fill and periodic nourishment would have the characteristics of the sand native to the beach. Recent borings indicate that a suitable source for initial fill and periodic nourishment is available in sufficient quantities offshore of each end of the island (plate A-1). It is estimated that about 1,250,000 cubic yards of usable material would be required to provide a beach having the minimum section described above. Maximization of net benefits by analysis of other beach widths was not warranted for plan A since the 200-foot wide beach berm would provide the minimum width for beach stabilization as well as an adequate beach for recreation.

c. Plan B - Combined beach erosion and hurricane protection (dune elevation 11.5). This combined beach erosion and hurricane protection plan provides protection from gulf waves driven by hurricanes having frequencies of up to approximately once in 50 years. The plan provides for a vegetated, sandfill dune with a 10-foot wide crown at an elevation of 11.5 and side slopes of 1 on 5, and a 180-foot wide sandfill berm sloping from an elevation of 8.5 at the toe of the dune gulfward to an elevation of 3. The berm would assume its natural slope from an elevation of 3 to the offshore bottom. The jetty described under plan A would stabilize the western end of the island at Caminada Pass. The fill required to establish the dune and beach berm is estimated to be approximately

2,500,000 cubic yards. This material is available in sufficient quantities from the same sources described in plan A.

d. Plan C - Combined beach erosion and hurricane protection (dune to elevation 13). This plan would provide protection from beach erosion and from waves driven by hurricanes having frequencies of up to once every 100 years. It provides for a vegetated, sandfill dune with a 10-foot wide crown at an elevation of 13 with side slopes of 1 on 5 and a 180-foot wide sandfill berm sloping gulfward from an elevation of 10 at the toe of the dune to an elevation of 3 (slopes: 1 on 70 for 70 feet, 1 on 5 for 10 feet, and 1 on 25 for 100 feet). The berm would assume its natural slope from an elevation of 3 to the offshore bottom. The jetty described under plan A is also included in this plan. The fill required to establish this dune and berm is estimated at about 3 million cubic yards, and is available in sufficient quantities from the same sources described in plan A.

e. Plan D - Combined beach erosion and hurricane protection plan (dune to elevation 15). This plan provides protection from beach erosion and from waves driven by hurricanes having frequencies of up to once every 200 years. It consists of a vegetated, sand-fill dune with a 10-foot wide crown at elevation 15 and side slopes of 1 on 5 and a berm of the same elevation and dimensions as described for plan C. The jetty described under plan A is also included in plan D. The fill to establish this dune and berm is estimated at approximately 3,300,000 cubic yards and is available from the same sources described under plan A.

f. Nonstructural. The residents of Grand Isle have, through experience, become aware of the hurricane threat. The majority of the houses are built with first-floor elevations at or above 12 feet. The town of Grand Isle has an ordinance that requires that all residential buildings in the corporate limits be constructed on piles with no less than 8 feet of penetration and provide a clear distance of at least 8 feet between the existing ground and first-floor of the building. The town officials have an evacuation plan for the Grand Isle area. The grade of Louisiana Highway 1 from Grand Isle to Golden Meadow varies between elevations 2.5 nd 5. Because of this, evacuation must be ordered well in advance of tidal flooding. Local officials have in the past ordered evacuation of the area before the Weather Service issued evacuation advisories. None of the plans discussed above will prevent still-water flooding, and an adequate warning system as well as plans and routes for rapid evacuation are essential supplements to any of these plans in order to prevent loss of life and damage to movable property.

g. No action. Failure to construct the recommended project would allow improvements on Grand Isle to continue to be subjected to damage from erosion and hurricane-driven gulf waves and retard the residential, commercial, and recreational development of the island. Annual damages to existing development from erosion and hurricane-driven gulf waves would average $238,500 and $271,000, respectively, and benefits of $198,000 annually from intensified land use and $317,000 annually from recreational development would not be realized.

25. RECOMMENDED PLAN

a. The recommended plan is the plan preferred by local interests and is the combined beach erosion and hurricane wave protection plan as described above (plan B). This plan would provide both beach erosion protection and, for the greater part, protection from damage caused by hurricane wave action. The design storm, when compared with the meteorological effects of the standard project hurricane derived by the Weather Service and in light of the low probable occurrence of a storm of greater intensity, was considered to be appropriate. The dune elevation of 11.5 would not obscure the beach or gulf, in most instances, from houses built gulfward of the highway that are constructed in accordance with current building codes--first-floor elevation 8 above existing ground. The highly-developed nature of the area and the gain that would be realized upon project completion do not warrant consideration of a plan providing a lower degree of protection. A lower dune and smaller berm would greatly increase the possibility of breaching, which could result in extensive wave damage to improvements on the island and major destruction of the beach section itself.

b. Preauthorization construction by local interests. In view of the imminent danger to property on the western end of the island (see paragraph 11b) and the fact that the Corps of Engineers had no authority or funds available to construct emergency works of the magnitude required to halt the erosion, the 1971 Louisiana legislature appropriated $1 million for the emergency work. The construction of a jetty along the western end of Grand Isle and placement of sandfill on its landside in accordance with the recommended plan B was completed in July 1972 by contract of the Louisiana Department of Public Works. By letter dated 17 June 1971 the Louisiana Department of Public Wroks requested that monies spent by the state for this emergency preauthorization construction be credited toward the non-Federal share of the first cost of the proposed Federal project, when and if a Federal project is approved.

26. ENVIRONMENTAL IMPACTS

a. The principal environmental impact of the recommended plan (plan B) is the stabilization of Grand Isle's gulf shore and protection of improvements on the island from damages caused by beach erosion and hurricane-driven gulf waves. Erosion damages prevented to improvements on the island over the life of the project are projected to be $289,000, annually. Hurricane wave damages to existing and future development that would be prevented by the recommended plan are estimated to be $378,000, annually. Annual public recreation of $317,000 will be realized as a result of the improvements.

b. Grand Isle is one of the barrier islands that form a part of Louisiana's gulf shore. Stabilization of Grand Isle's gulf shore would provide the Barataria and Caminada Bay estuaries and the adjacent marshlands with continued protection against the ravaging damages of gulf waves and storm tides. Further, the checked widening of Caminada Pass would help maintain the fresh water runoff regime in the Barataria estuary which is important to sustain the level of wildlife, plant life, and fish production in the area. When passes, located in a system of barrier islands such as this system, are allowed to widen, the increased hydraulic efficiency of the passes causes a decrease in freshwater runoff time from the marsh and estuary to the gulf. The direct consequences are that nutrients, micro-organisms and sediments are flushed more rapidly from the estuary and that an important link in the food chain is broken.

c. There will be a temporary increase in turbidity in the water both adjacent to the beach where the fill material is being deposited and the area from which it will be dredged. Some of the natural living organisms of both areas will be buried by the fill or moved from their natural habitat. This alteration of the natural ecosystem is local in extent and will correct itself by natural replenishment. No endangered species will be affected. Remedial and protective measures are contained in the plan to reduce adverse environmental impacts.

d. The environmental impact of the alternatives to the recommended plan are:

(1) Beach fill. (Plan A) An artificial sandfill beach would provide beach erosion protection by moving the wave-breaking point seaward. A beach fill plan was economically feasible, but it did not provide the hurricane wave protection that the tentative plan provides. The environmental impacts are the same except that this alternative does not obstruct the view of the beach from the road.

(2) Beach fill with dune. (Plans C and D) Plans similar to the recommended plan with dune and berms constructed to higher elevations were considered and, although they provide more hurricane-wave protection than the recommended plan and were economically

feasible, they provided a greater obstruction to the view of the gulf than did the recommended plan, had higher first costs, and were therefore undesirable to local interests.

(3) Groins with beach fill. A groin system would be ineffective. See paragraph 22b. If a system of groins could effectively be used the beneficial trapping of the littorial drift on Grand Isle would be offset by concomitant beach erosion occurring along the barrier islands to the east.

(4) Levees. A complete hurricane protection plan for the island would require construction of a levee system along the bay side tied into a sand dune extending along the gulf front. It is impractical to design this plan to provide complete protection. Any degree of protection less than total would provide a false sense of security that could be disastrous if a hurricane greater than designed against were to strike since the only escape route would be inundated before overtopping occurred.

(5) Breakwater. The height required for an offshore breakwater that would prevent hurricane surges from overtopping the island would render construction too costly. This breakwater would also serve as a littoral barrier and therefore have a detrimental effect on Grand Terre Island.

(6) Extension of the jetty at the east end of the island. Extension of this jetty would not appreciably prevent erosion of the central section of the island and could be detrimental to Grand Terre Island by interruption of the west to east littoral transport.

(7) No action. The last alternative considered is to forego construction of any project in an effort to retain the existing environmental setting. Implementation of the proposed plan would not significantly alter the present development trend of the island so there is little justification to forego the protection it affords.

e. The recommended plan is favored by a vast majority of local interests. Some beachfront property owners, mostly non-residents, object to the dune and berm because it would partially obstruct their view of the gulf and create public land on the gulfside of their property.

f. No appreciable adverse effects are associated with the proposed action. It is the preferred plan of action from both the environmental point of view and the benefit to be derived by man.

SECTION VII - ECONOMIC ANALYSIS

27. ESTIMATES OF FIRST COSTS

The estimated first costs for the improvements in the recommended plan (plan B) are shown in table 3. First costs for all the plans considered in detail are summarized in table 4. Detailed project costs are given in appendix C. The estimates are based on costs for similar work in the New Orleans District in recent years and are based on prices as of July 1972. No relocations are required for construction of any of the considered plans.

July 1975 +27%

28. ESTIMATES OF ANNUAL CHARGES

The estimated annual costs, based on detailed estimates in appendix C, a 50-year project life, and an interest rate of 5 1/2 percent, are summarized in table 4. No interest during construction has been included since the period of construction should be less than 1 year.

29. ESTIMATES OF BENEFITS

a. General. The quantified benefits that result from the proposed improvements are the prevention of physical damage, recreational benefits, intensified land use, and indirect economic benefits. Detailed benefit analyses are given in appendix D. Benefits by categories for all plans considered are summarized in table 5.

b. Erosion damage prevention. Damages which will occur as a result of erosion were classified as residential, commercial, public, highways, utilties, and land. Projections of advancing erosion, using rates as shown in table B-9, were made for the period of project life to determine the area to be eroded. The existing improvements in the area were determined by detailed field surveys made in 1970. The total costs over the life of the proposed project incurred as a result of erosion were determined by computing the costs associated with existing development and adding to this the costs associated with future development projected in accordance with the growth rates as determined in appendix D. Erosion damages prevented to existing and future development over the life of the project are estimated to be $289,000, annually.

c. Hurricane wave damage prevention. The beneficial effects of the project insofar as preventing flood damages consist solely in the prevention of damages incident to high intensity waves which originate on the gulf side of the island. Stage-damage curves were developed based on existing and future

TABLE 3
COST ESTIMATE

PLAN B - Combined beach erosion and hurricane protection plan (dune elevation @ 11.5)

FIRST COST				
Item	Quantity	Unit	Unit cost	Cost
Preauthorization Construction by Non-Federal Interests:				
Jetty				
Riprap	30,700	ton	$11.50	$ 353,000
Shell	7,100	cu.yd.	7.00	50,000
Filter cloth	197,300	sq.ft.	.19	37,000
Sandfill	640,000	cu.yd.	.93	595,000
Subtotal				$1,035,000
Contingencies				259,000
Subtotal				$1,294,000
Engineering and design				86,000
Supervision and administration				110,000
Subtotal - preauthorization construction				$1,490,000[1]
Post-authorization Construction:				
Dune and berm				
Sandfill	1,900,000	cu.yd.	1.65	$3,135,000
Dune vegetation	54	acre	350.00	19,000
Subtotal				$3,154,000
Contingencies				789,000
Subtotal				$3,943,000
Engineering and design				192,000
Supervision and administration				335,000
Subtotal				$4,470,000
Easement cost				3,140,000[2]
Subtotal - post-authorization construction				$7,610,000
Total first cost				$9,100,000[3]

[1]Does not include cost of aids to navigation. The actual contract cost for this preauthorization construction, engineering and design, was $1 million.

[2]Based on 113 acres of perpetual easement at $22,500 per acre plus acquisition cost and contingencies.

[3]Does not include $105,000 preauthorization study cost.

TABLE 4
SUMMARY OF AVERAGE ANNUAL CHARGES

	PLAN A Beach erosion protection	PLAN B Combined beach erosion and hurr. protection (dune elev. @ 11.5)	PLAN C Combined beach erosion and hurr. protection (dune elev. @ 13)	PLAN D Combined beach erosion and hurr. protection (dune elev. @ 15)
	$	$	$	$
First costs[1]				
Federal	710,000	4,840,000	5,940,000	6,620,000
Non-Federal	2,260,000	4,260,000	4,260,000	4,260,000
TOTAL	2,970,000	9,100,000	10,200,000	10,880,000
Annual costs				
Interest & amortization (5 1/2%)				
Federal	42,000	285,000	350,000	391,000
Non-Federal	133,000	252,000	252,000	252,000
TOTAL	175,000	537,000	602,000	643,000
Periodic beach nourishment (5-yr intervals)				
Federal	10,000	5,000	5,000	5,000
Non-Federal	83,000	88,000	88,000	88,000
TOTAL	93,000	93,000	93,000	93,000
Post-hurricane replenishment (25th yr)				
Federal	0	0	0	0
Non-Federal	19,000	38,000	38,000	38,000
TOTAL	19,000	38,000	38,000	38,000
Dune and jetty maintenance				
Federal	0	0	0	0
Non-Federal	2,000	10,000	10,000	10,000
TOTAL	2,000[2]	10,000	10,000	10,000
Total annual costs				
Federal	52,000	290,000	355,000	396,000
Non-Federal	237,000	388,000	388,000	388,000
TOTAL	289,000	678,000	743,000	784,000

[1] Does not include $105,000 preauthorization study costs.
[2] Jetty maintenance only

TABLE 5

SUMMARY OF AVERAGE ANNUAL BENEFITS

Type of benefit	PLAN A Beach erosion protection	PLAN B Combined beach erosion and hurr. protection (dune elev. @ 11.5)	PLAN C Combined beach erosion and hurr. protection (dune elev. @ 13)	PLAN D Combined beach erosion and hurr. protection (dune elev. @ 15)
	$	$	$	$
Erosion prevention				
Existing development	238,500	238,500	238,500	238,500
Future development	50,500	50,500	50,500	50,500
Subtotal	289,000	289,000	289,000	289,000
Flood damage prevention				
Existing development	-	271,000	365,000	365,000
Future development	-	107,000	154,000	171,000
Subtotal	-	378,000	519,000	536,000
Intensified land use	-	198,000	198,000	198,000
Recreation	50,000	317,000	317,000	317,000
TOTAL	339,000	1,182,000	1,323,000	1,340,000

development for various years within the project life for four conditions--rising water only, rising water and bay-waves only, rising water and all waves (without project), and rising water and gulf waves (with plan B in place). Integration of the stage-damage relationships for the four conditions with the stage-frequency curve provided the basis for construction of the damage-probability curves. The average annual damages for each of the conditions were computed over the period 1980-2030. The average annual flood damages prevented on existing and future development with the recommended plan in place are $378,000. Details of the computation are shown in appendix D.

d. Intensified land use. These benefits, are the result of providing protection from repeated occurrences of damaging hurricane-driven gulf waves. Market values of real property and associated improvements are expected to increase. This is reflected in the benefits claimed for intensified land use. None of this increase can be attributed to the beach erosion feature since the low elevation and flat slope of the beach only plan will not provide appreciable wave protection. Computation of increase in market value of the land was made on analyses of land values within the project area and average annual benefits are estimated to be $198,000.

e. Recreational benefits. Recreational benefits are a result of increased use of the improved beach. Their net worth can be evaluated in terms of fees the public is willing to pay under existing conditions as compared to those they are willing to pay under improved conditions. It is estimated that the existing visitation and the visitation with the Louisiana State Parks and Recreation Commission interim development plan in place would be valued at $.50 per visitor-day. The increased visitation with the Corps plan in place was estimated to be worth $1 per visitor-day for the state parks (evaluated as use with minimum facilities). Annual public recreational benefits of $317,000 are expected to be realized from construction of the recommended plan of improvement.

f. Redevelopment benefits. The recommended improvements are located in Jefferson Parish, Louisiana. This parish is not currently classified by the Economic Development Administration as an area with chronic and persistent unemployment and under-employment; therefore, area redevelopment benefits are not applicable to the benefit-cost analysis under current directives.

30. JUSTIFICATION OF IMPROVEMENTS

The selected plan (plan B) which included the jetty and beach of plan A with a dune and larger berm is the most economical means of providing hurricane protection and no less costly alternative is available. This plan has a benefit-cost ratio of 1.7 (table 6).

Although this plan provides slightly less than maximum tangible excess benefits (place D-11, appendix D) over cost, it does, however, provide reliable protection under conditions where failure would not be a catastrophe. This is the plan that was endorsed by the Louisiana Department of Public Works, the town of Grand Isle (the assuring agency), the Grand Isle Civic Improvement Association, and others at the intermediate and final public meetings. The selected plan is the one favored by local interest since a project providing additional protection would require a higher dune thereby further obstructing the view of the gulf. Also, the recommended plan would provide almost complete (90%) protection from hurricane driven waves. It should be noted, however, that significant damages can occur from tidal flooding on waves from the bay side of the island. It is estimated that with recommended improvements in place residual damages would amount to about 75 percent of total damages that would be experienced without any improvements.

31. ALLOCATION AND APPORTIONMENT OF COSTS

a. Allocation of costs. The recommended plan is a combined beach erosion and hurricane-wave protection plan. First costs have been allocated to these functions by use of the separable-costs remaining-benefits method as described in appendix E. The procedure results in $7,620,000 being allocated to hurricane protection and $1,480,000 to shore protection.

b. Apportionment of costs. All costs for the recommended plan have been apportioned between Federal and non-Federal interest in accordance with the cost-sharing formula adopted in the Flood Control Act of 1958 For Narragansett Bay, R. I., New Bedford, Mass., and Texas City, Tex., projects. The costs allocated to shore protection were apportioned between Federal and non-Federal interests in accordance with the provisions of Public Law 826, 84th Congress, as amended. Apportionment ratios are derived in appendix E and resulting costs apportionments for all plans considered are shown in table 4. For the recommended plan, Federal first cost is $4,840,000, while the non-Federal first cost is $4,260,000.

SECTION IX - COORDINATION AND LOCAL COOPERATION

32. COORDINATION

a. Public meetings.

(1) This study was initiated by holding a public meeting on 8 December 1966 in Grand Isle to obtain the desires of local interests relative to beach erosion and hurricane protection for

TABLE 6

ECONOMIC ANALYSIS

	PLAN A Beach erosion protection	PLAN B Combined beach erosion and hurr. protection (dune elev. @ 11.5)	PLAN C Combined beach erosion and hurr. protection (dune elev. @ 13)	PLAN D Combined beach erosion and hurr. protection (dune elev. @ 15)
	$	$	$	$
AVERAGE ANNUAL BENEFITS:				
Erosion prevention	289,000	289,000	289,000	289,000
Flood damage prevention	-	378,000	519,000	536,000
Intensified land use	-	198,000	198,000	198,000
Recreation	50,000	317,000	317,000	317,000
Total	339,000	1,182,000	1,323,000	1,340,000
AVERAGE ANNUAL CHARGES:				
Interest & amortization	175,000	537,000	602,000	643,000
Periodic beach nourishment	93,000	93,000	93,000	93,000
Post-hurricane replenishment	19,000	38,000	38,000	38,000
Dune and jetty maintenance	2,000	10,000	10,000	10,000
Total	289,000	678,000	743,000	784,000
ANNUAL NET BENEFITS:	50,000	504,000	580,000	556,000
BENEFIT-COST RATIO:	1.2	1.7	1.8	1.7

the Grand Isle area. Approximately 130 persons attended the meeting. The improvements requested are listed in paragraph 12.

(2) A second public meeting was held in Grand Isle on 10 June 1971 to obtain the views of local interests on the three plans of improvement that were being considered for Grand Isle. The three plans considered were plans A, B, and C as described in paragraph 24. Approximately 170 persons attended including many permanent and summer residents and representatives of business and civic organizations and local state and Federal agencies. Local interests generally indorsed plan B. Others in attendance expressed no preference of plans but favored any method of providing beach erosion and hurricane protection. A few beachfront property owners objected to any plan that would deprive them of any of their beachfront rights.

(3) The final public meeting was held 28 June 1972 to present the tenative plan of improvement as recommended in this report (paragraph 25). Approximately 200 persons, consisting of permanent and summer residents and representatives of business and civic organizations, local, state and Federal agencies, were in attendance. Local interests, including the Louisiana Department of Public Works, the Mayor and Board of Aldermen of the town of Grand Isle, and the Grand Isle Civic Improvement Association, generally reaffirmed their support of plan B. A few individuals requested any form of beach erosion and hurricane protection. Approximately 60 beachfront property owners, representing about 20 percent of the private beachfront property owners and a very small percentage of all property owners on Grand Isle, expressed opposition to plan B or any plan that would deprive them of their beachfront rights.

b. Coordination with other Federal agencies. All Federal agencies listed in the pamphlet "Policies and Procedures for Distribution and Coordination of Reports Represented on the Inter-Agency Committee on Water Resources," revised July 1958, were notified of the initiation of the study by letter dated 1 December 1966 and were sent notices of the three public meetings held for this study. Copies of the draft of this report were furnished interested agencies for their review and comment. Letters from these agencies are discussed below and included in appendix G.

(1) The Bureau of Mines, by letter dated 29 December 1971, stated that mineral production and industry facilities on Grand Isle should be more clearly defined and that benefits to these industries should be included in the economic analysis. The Bureau also suggested other minor revisions. Although the mineral industry plays an important role in Grand Isle's economy, benefits to these industries that would result from the construction

of the recommended project are relatively small. Benefits to these industries have been included in the economic analysis.

(2) By letter dated 30 November 1971 the Environmental Protection Agency stated that they had no recommendations for changes to the draft report.

(3) The U. S. Fish and Wildlife Service, by letter dated 2 June 1972, agreed with recommendations in the draft report and stated that if care is exercised during construction and maintenance, damages to fish and wildlife will be minimal. They made the following recommendations:

a. Care be taken to minimize the hydraulic movement and spread of spoil material;

b. Final selection of areas for borrowing spoil materials be made in cooperation with the Louisiana Wild Life and Fisheries Commission; and

c. A safe walkway to the jetty at the west end of Grand Isle be provided.

If a Federal project is authorized, measures will be included in the general design memorandum to keep the hydraulic movement and spread of hydraulic fill to a minimum. Comments on the final plan will be requested from interested agencies, including the Louisiana Wild Life and Fisheries Commission, during preparation of the general design memorandum. A safe walkway to the recommended jetty, which was constructed prior to authorization by local interests, has been provided by landside fill (photograph 2). Surf fishermen frequent the shallow water on the Caminada Pass side of the jetty. Comments on an inclosed letter from the Louisiana Wild Life and Fisheries Commission are contained in paragraph 32c(3).

c. Coordination with local interests. This study was coordinated with local interests through the three public meetings discussed above and through informal meetings with the Louisiana Department of Public Works, the Louisiana State Parks and Recreation Commission, and officials of Jefferson Parish and the town of Grand Isle. Interested state agencies and the metropolitan clearinghouse for the area were furnished copies of the draft of this report for their review and comment. Letters from these agencies and other coordination with local interests are discussed below. The letters are included in appendix G.

(1) The Louisiana Department of Public Works, at the initial public meeting held 8 December 1966, requested extension and enlargement of the jetty at the eastern end of the island and periodic nourishment of the beach as needed. At the formulation

stage meeting on 10 June 1971 they indorsed plan B as the most suitable of the plans presented for protecting Grand Isle from damages caused by beach erosion and hurricane-driven gulf waves. At the final public meeting on 28 June 1972 the Department reaffirmed their support for plan B, the tenative plan of improvement, and requested that monies expended by the State of Louisiana for the emergency work on the western end of Grand Isle be credited toward local interests share of the first cost of the project. Several informal meetings were held with representatives of the Department of Public Works during this study. Plans and specifications for the emergency work described in paragraph 25b were reviewed and concurred with by the New Orleans District, Corps of Engineers. The Department of Public Works reviewed the draft report and by letter dated 3 January 1972 suggested various revisions. The suggested revisions (appendix G) were agreed with and appropriate changes were made in this report. By letter dated 6 September 1973 the Department of Public Works agreed to provide the required local cooperation if a Federal project is authorized. This letter is included as appendix H.

(2) This study was coordinated with the Louisiana State Parks and Recreation Commission through several informal meetings. By letter dated 23 January 1969 the Commission furnished plans for interim and long-range developments of the state parks at the eastern and western ends of the island.

(3) The Louisiana Wild Life and Fisheries Commission, by letter dated 13 January 1972, agreed with the recommended improvements as presented in the draft report but expressed concern that the jetty recommended for the western end of Grand Isle may eventually block Caminada Pass by interruption of the west to east littoral drift. They also requested that fishing conveniences be provided along the recommended jetty and that a study of the effect that the recommended improvements would have on erosion of Grand Terre Island be made. The request for a study of the effects that the recommended improvements would have on Grand Terre Island was repeated in a 13 April 1972 letter to the U. S. Fish and Wildlife Service. This letter is attached to their report (appendix G). The jetty at the western end of the island was designed to divert tidal currents away from the gulf shoreline east of the Caminada Pass and to trap littoral drift moving east to west along the gulf shore during times when waves approach from the east or southeast. The jetty was designed so that it would not extend offshore to a point where it would interfere with the predominant west to east littoral drift and therefore block Caminada Pass. Fishing conveniences along the jetty along the western end of the island are not necessary. Access to the jetty, which was constructed prior to authorization by local interests, has been provided by landside fill (photograph 2). Surf fishermen frequent the shallow water on the Caminada Pass side of the jetty. Erosion of Grand

Terre Island would not be affected by construction of any of the recommended improvements since they would not obstruct any west to east littoral drift. Erosion of Grand Terre Island could be slowed since the recommended project would help to eliminate any deficiencies of sandfill to the jetty at the eastern end of the island and would provide a larger source of littoral material immediately to the west of Grand Terre.

33. PROPOSED LOCAL COOPERATION

a. The recommended plan has features which provide both hurricane and shore protection benefits. Local interests will be required to provide cooperation generally in accordance with projects having these purposes and specific requirements are as follows:

(1) Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project;

(2) Accomplish without cost to the United States all relocations and alterations of buildings, streets, utilities, and other structures and improvements made necessary by the construction of the project;

(3) Hold and save the United States free from claims for damages due to the construction works;

(4) Assure maintenance, repairs, and periodic beach nourishment of the project after completion as may be required to serve the intended purposes in accordance with regulations prescribed by the Secretary of the Army, except that the Federal Government will contribute for an initial period of 10 years, a sum currently estimated at $11,000 toward the annual cost of beach nourishment associated with beach erosion prevention, subject to determination on the basis of conditions of public use and ownership at the time of construction of the nourishment project;

(5) Provide an additional cash contribution for the hurricane protection function in an amount sufficient to bring the local investment in cash and value of rights-of-way to 30 percent of all final first costs allocated to this function; which cash contribution is presently estimated at zero;

(6) Provide a cash contribution or perform equivalent work for the beach erosion control function, presently estimated at $120,000, the final amount to be determined at the time of project construction in accordance with cost-sharing procedures for beach erosion control defined in the report;

(7) Obtain approval by the Chief of Engineers, prior to commencement of any work on shore and beach protection phases of the project if undertaken separately from the recommended combined project, of detailed plans and specifications for the work contemplated and also the arrangements of prosecuting such work, excluding the preauthorization jetty construction;

(8) Assure continued public ownership of the shore upon which the amount of Federal participation in the beach protection phase is based, and its administration for public use during the economic life of the project and assure continued availability for public use of privately-owned shores where Federal aid is based on such use;

(9) Assure that water pollution that would endanger the health of bathers will not be permitted;

(10) Adopt and enforce appropriate ordinances to provide for the preservation of the improvement and its protective vegetation;

(11) At least annually inform interests affected that the project will not provide any substantial protection from flooding, from hurricane waves from the bay side, or from hurricane surges higher in elevation than that of Hurricane Betsy of 9 September 1965;

(12) Comply with provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646;

(13) Agree to the requirements of the Flood Control Act of 1970, Section 221, whereby damages will be paid for noncompliance of assurances furnished for the project and such assurances shall be enforceable by the United States in the appropriate District Court of the United States.

b. The Louisiana Department of Public Works concurs in the recommended plan and has agreed to furnish the required local cooperation if a project is authorized and their letter is included in appendix H.

SECTION X - STATEMENT OF FINDINGS

34. STATEMENT OF FINDINGS

a. I have reviewed and evaluated, in light of the overall public interest, the documents concerning the proposed action, as well as the stated views of other interested agencies and the concerned public, relative to the various practicable alternatives for providing beach erosion and hurricane protection for Grand Isle, Louisiana.

b. The possible consequences of these alternatives have been studied according to environmental social well-being, and economic effects, including regional and national development, and engineering feasibility.

c. In evaluation, the following points were considered pertinent:

(1) From an environmental standpoint, I have found that the benefits to the environment and to man greatly outweigh the adverse environmental effects. The recommended plan would protect Grand Isle and its improvements from damages caused by erosion and hurricane-driven gulf waves and, by stabilizing Grand Isle, would protect the valuable estuarine marshland located on the bay side of the island from the direct attack of gulf waves. Adverse environmental effects which would occur only during construction would be minor and temporary.

(2) I have found that the social well-being of the residents of Grand Isle and of the many recreationists who contribute to the local economy will be greatly benefited by the recommended project. Alleviation of the fear of damages caused by hurricane-driven waves will result in increased development of Grand Isle as a resort area and increase the standard of living of the residents of the project area.

(3) Relative to engineering feasibility, I have not maximized net hurricane protection benefits due to the reluctance of local interests to accept the higher costs and greater obstruction of the view of the Gulf of Mexico incidental to the plan that maximizes benefits.

(4) I have not recommended the best economic solution in order to provide a plan esthetically and economically acceptable by local interests.

d. I find that the proposed action, as developed in the Conclusions and Recommendations, is based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives; that wherever adverse effects are found to be involved they cannot be avoided by following reasonable alternative courses of action which would achieve the congressionally specified purposes; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations of national policy;

that the recommended action is consonant with national policy statutes, and administrative directives; and that on balance the total public interest should be best served by implementation of the recommendation.

SECTION XI - DISCUSSION AND CONCLUSIONS

35. DISCUSSION

a. Grand Isle has experienced severe erosion problems and heavy losses from recent hurricanes along its gulf shore. Hurricanes have produced surges with elevations of 9 at Grand Isle. Hurricane Betsy, elevation 8.8, caused damages in excess of $11,500,000 (1965 prices). The standard project hurricane and the probable maximum hurricane for the area would product surges with elevations averaging 10 and 17, respectively, over most of the study area. The large waves driven by the winds accompanying these hurricanes would spread wide devastation to the improvements on the island. The shore at the western end of the island had eroded so severely that camps that were once on dry land had become completely surrounded by gulf waters in less than a year's time (photograph 1). Adequate hurricane warnings and evacuation measures are effective in reducing the possibility of loss of life and damages to some movable property but are of little value in preventing damages to fixed property. The enactment of the ordinance requiring that all residential buildings constructed within the corporate limits of the town of Grand Isle be built on pilings with the first floor 8 feet above the existing ground elevation and having adequate bracing will significantly reduce hurricane damages resulting from structural inadequacies. Even with the new structures being built at this height, there is need for providing protection against hurricane damages resulting from wave action.

b. Four plans of protection have been given detailed consideration in this report. One is the basic beach erosion protection plan. The other three are combined beach erosion and hurricane protection plans that provide protection from both beach erosion and gulf waves driven by hurricanes having frequencies of once in 50 years, once in 100 years, and once in 200 years. Other plans of protection have been evaluated during the preliminary phase of the study and have been discussed briefly in this report, but none of these plans merited detailed analyses. The selected plan, plan B, as described in paragraph 24c, would not prevent flooding or damage from hurricane waves from the bay side of the island. Normal maintenance would consist of periodic rebuilding of the dune and berm to their design elevations and widths with some major restoration following larger storms comparable to Hurricanes Flossy and Betsy.

c. Additional information called for by Senate Resolution 148, 85th Congress, adopted 28 January 1958, is contained as a supplement to this report.

36. CONCLUSIONS

a. It is concluded that Grand Isle, Louisiana, has suffered severe damages in the past due to beach erosion and the action of waves accompanying storms and hurricanes, and that it is likely to suffer similar damages in the future.

b. It is further concluded that the best protection against such damages that is acceptable by local interests can be obtained by construction of improvements outlined under plan B, which will provide both beach erosion protection and protection from hurricane-driven gulf waves for the entire area of Grand Isle. The total estimated first cost of plan B is $9,100,000. This plan provides a high degree of protection and is economically justified, having a benefit-cost ratio of 1.7.

SECTION XII - RECOMMENDATIONS

37. RECOMMENDATIONS

a. It is recommended that a Federal project be authorized to provide beach erosion protection and protection from hurricane-driven gulf waves for Grand Isle, Louisiana, generally in accordance with the plan outlined in paragraphs 24c and 25 and as shown on plates 2 and 3 at an estimated first cost of $9,100,000, of which the United States would furnish $4,840,000.

b. It is also recommended that local interests be allowed credit toward the non-Federal share of the first costs for the emergency works described in paragraph 25b. The amount to be credited, not to exceed $1 million, would be determined during preparation of the general design memorandum for the project.

c. It is further recommended that prior to initiation of construction, local interests furnish assurances satisfactory to the Secretary of the Army that they will:

(1) Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project;

(2) Accomplish without cost to the United States all relocations and alterations of buildings, streets, utilities, and other structures and improvements made necessary by the construction of the project;

(3) Hold and save the United States free from claims for damages due to the construction works;

(4) Assure maintenance, repairs, and periodic beach nourishment of the project after completion as may be required to serve the intended purposes in accordance with regulations prescribed by the Secretary of the Army, except that the Federal Government will contribute for an initial period of 10 years, a sum currently estimated at $11,000 toward the annual cost of beach nourishment associated with beach erosion prevention, subject to determination on the basis of conditions of public use and ownership at the time of construction of the nourishment project;

(5) Provide an additional cash contribution for the hurricane protection function in an amount sufficient to bring the local investment in cash and value of rights-of-way to 30 percent of all final first costs allocated to this function; which cash contribution is presently estimated at zero;

(6) Provide a cash contribution or perform equivalent work for the beach erosion control function, presently estimated at $120,000, the final amount to be determined at the time of project construction in accordance with cost-sharing procedures for beach erosion control defined in the report;

(7) Obtain approval by the Chief of Engineers, prior to commencement of any work on shore and beach protection phases of the project if undertaken separately from the recommended combined project, of detailed plans and specifications for the work contemplated and also the arrangements of prosecuting such work, excluding the preauthorization jetty construction;

(8) Assure continued public ownership of the shore upon which the amount of Federal participation in the beach protection phase is based, and its administration for public use during the economic life of the project and assure continued availability for public use of privately owned shores where Federal aid is based on such use;

(9) Assure that water pollution that would endanger the health of bathers will not be permitted;

(10) Adopt and enforce appropriate ordinances to provide for the preservation of the improvement and its protective vegetation;

(11) At least annually inform interests affected that the project will not provide any substantial protection from flooding, from hurricane waves from the bay side, or from hurricane surges higher in elevation than that of Hurricane Betsy on

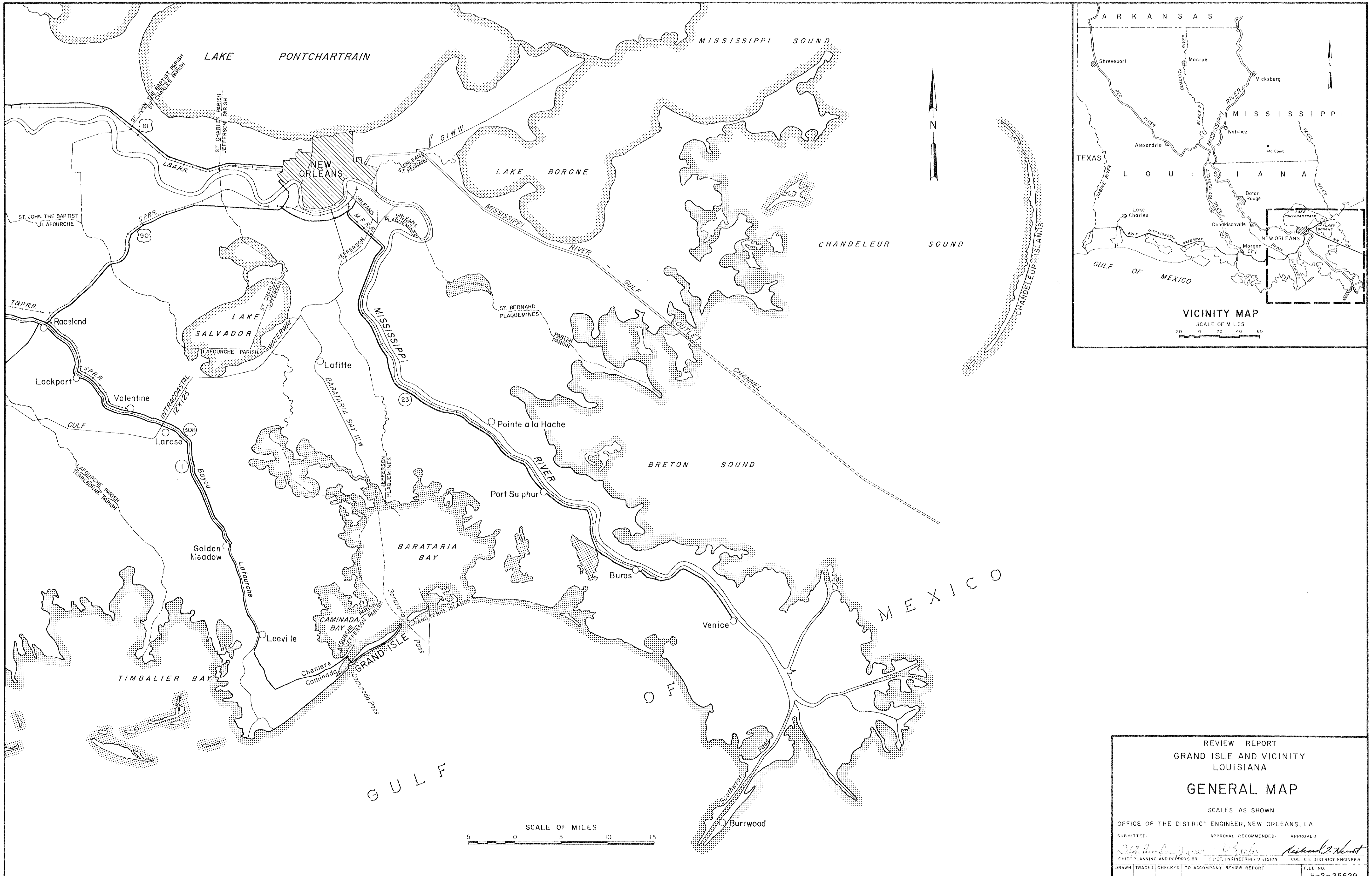
9 September 1965;

(12) Comply with the provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646;

(13) Agree to the requirements of the Flood Control Act of 1970, Section 221, whereby damages will be paid for noncompliance of assurances furnished for the project and such assurances shall be enforceable by the United States in appropriate District Court of the United States.

Richard L. Hunt

RICHARD L. HUNT
Colonel, CE
District Engineer



REVIEW REPORT
GRAND ISLE AND VICINITY
LOUISIANA

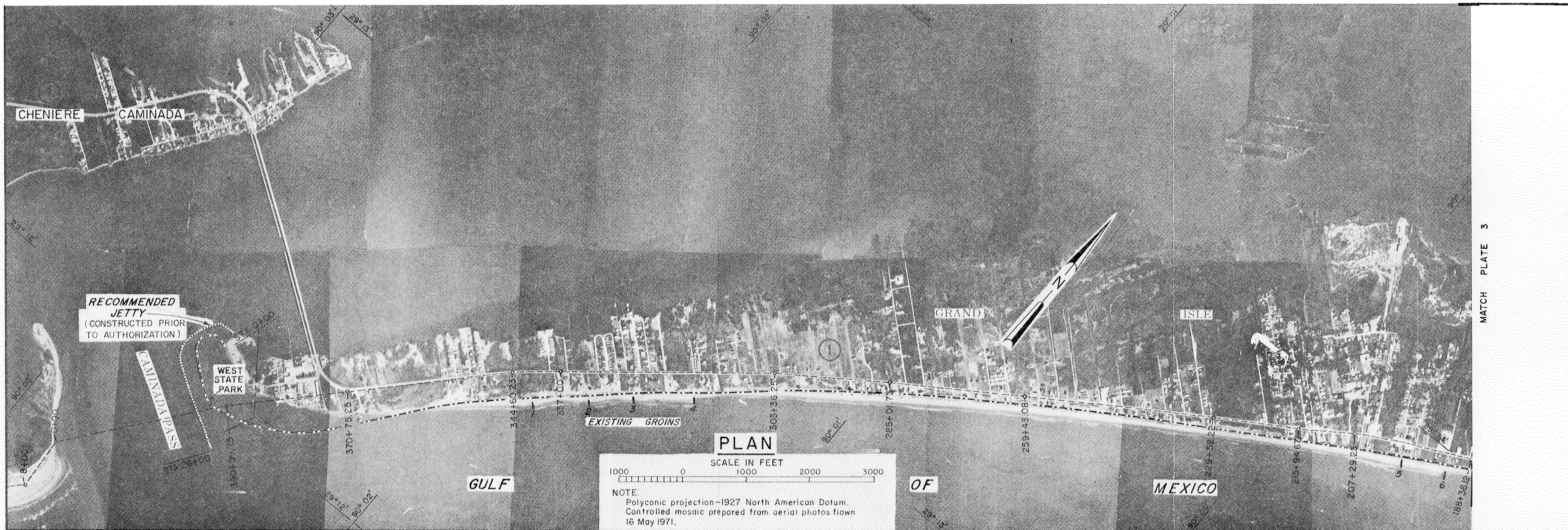
GENERAL MAP

SCALES AS SHOWN

OFFICE OF THE DISTRICT ENGINEER, NEW ORLEANS, LA.

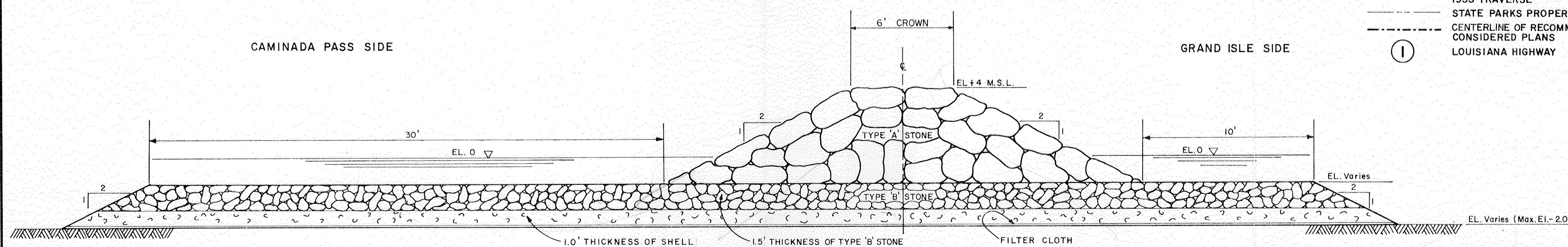
SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
CHIEF PLANNING AND REPORTS BR	CHIEF, ENGINEERING DIVISION	COL., C.E. DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REVIEW REPORT DATED: OCTOBER 1972	FILE NO. H-2-25629



LEGEND

- RECOMMENDED JETTY
- 1953 TRAVERSE
- STATE PARKS PROPERTY LINE
- CENTERLINE OF RECOMMENDED AND CONSIDERED PLANS
- (1) LOUISIANA HIGHWAY



SIZE OF PIECES

TYPE 'A' STONE 300 LBS. TO 4500 LBS.
TYPE 'B' STONE 25 LBS. TO 200 LBS.

TYPICAL JETTY SECTION

SCALE IN FEET
5' 0' 5' 10' 15'

REVIEW REPORT
GRAND ISLE AND VICINITY
LOUISIANA

PLAN AND JETTY CROSS SECTIONS

SCALES AS SHOWN

OFFICE OF THE DISTRICT ENGINEER, NEW ORLEANS, LA.

APPROVAL RECOMMENDED

CHIEF, PLANNING AND REPORTS BRANCH — CHIEF, ENGINEERING DIVISION — COL., C.E. DISTRICT ENGINEER

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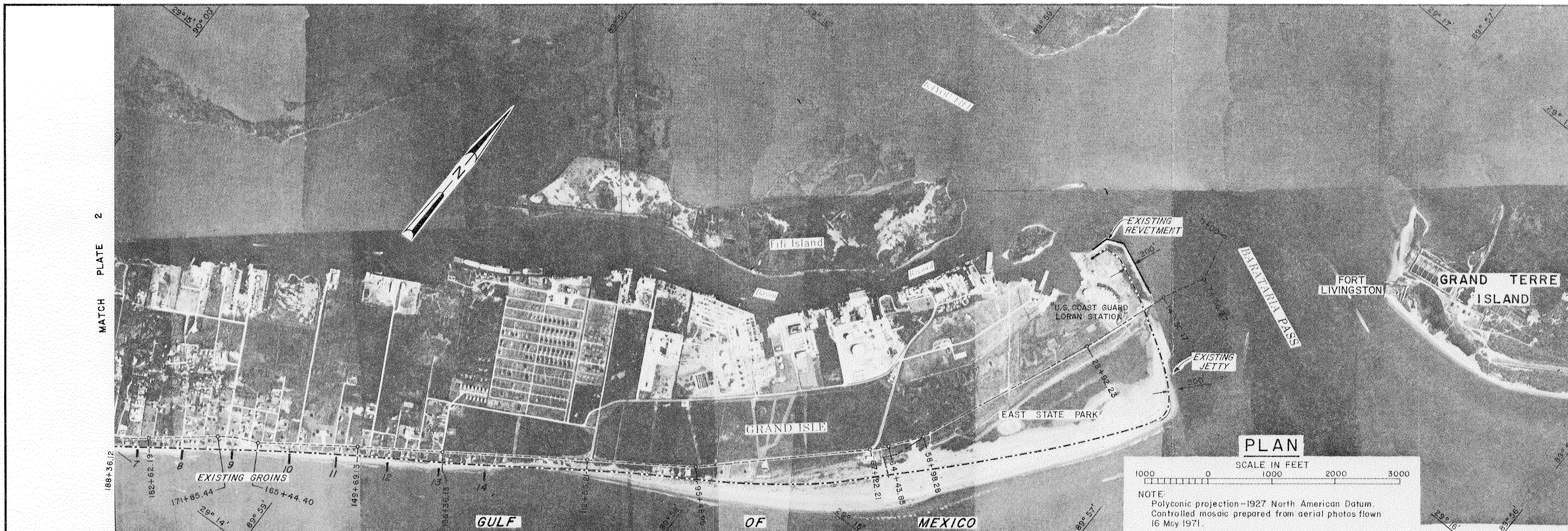
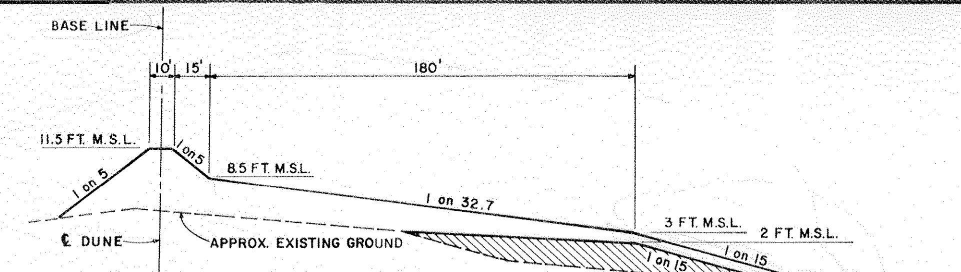
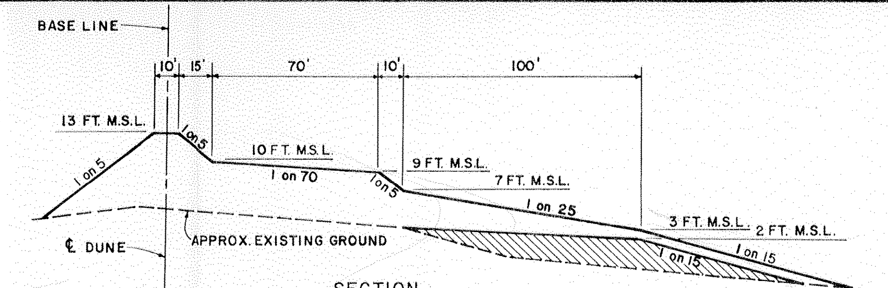




SECTION
COMBINED BEACH EROSION AND HURRICANE PROTECTION (11.5 FOOT DUNE)

PLAN B (RECOMMENDED)

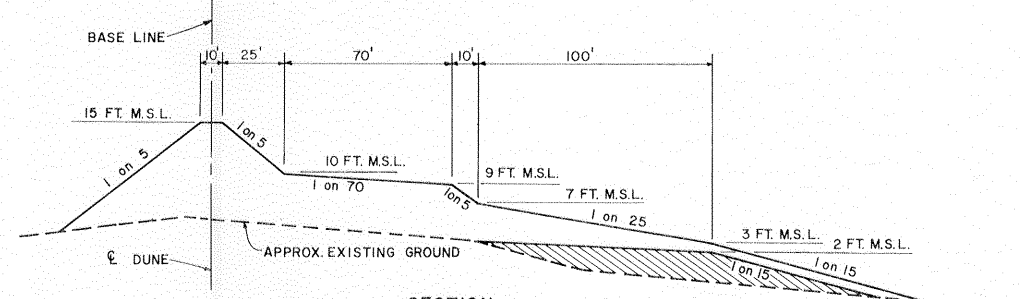


SECTION
COMBINED BEACH EROSION AND HURRICANE PROTECTION (13 FOOT DUNE)

PLAN C (CONSIDERED)

LEGEND

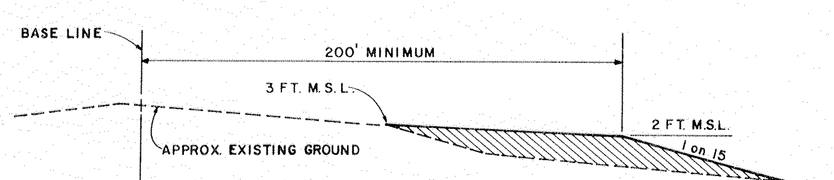
- 1953 TRAVERSE
- STATE PARKS PROPERTY LINE
- CENTERLINE OF RECOMMENDED AND CONSIDERED PLANS
- (1) LOUISIANA HIGHWAY



SECTION
COMBINED BEACH EROSION AND HURRICANE PROTECTION (15 FOOT DUNE)

PLAN D (CONSIDERED)

SCALE IN FEET
50 0 50 100 150



SECTION
BEACH EROSION PROTECTION

PLAN A (CONSIDERED)

REVIEW REPORT
GRAND ISLE AND VICINITY
LOUISIANA

PLAN AND BEACH CROSS SECTIONS

SCALES AS SHOWN

OFFICE OF THE DISTRICT ENGINEER, NEW ORLEANS, LA.

APPROVAL RECOMMENDED

CHIEF, PLANNING AND REPORTS BRANCH	CHIEF, ENGINEERING DIVISION	COL., C.E. DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REVIEW REPORT DATED: OCTOBER 1972	FILE H-2-25629

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX A
GEOLOGY AND SOILS

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX A
GEOLOGY AND SOILS

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PLATES

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX A
GEOLOGY AND SOILS

1. PHYSIOGRAPHY

The study area is located on the deltaic plain of the Mississippi River, a region of extremely low relief. Specifically, the area is situated on the northeast side of the distal end of the remnants of an ancient lobate delta of the Mississippi River known as the Lafourche delta. The principal physiographic features of the delta are the ancient course of the Lafourche stage Mississippi River; delta margin islands flanking the ancient delta; beaches along the gulfward margin of the mainland and islands facing the gulf; marshlands and inland bodies of water that lie landward of the shoreline beaches; and sand ridges--called chenieres--which locally parallel the coastline on the mainland.

Elevations range from 4 to 6 feet m.s.l. (mean sea level) along the crests of the chenieres and beach ridges to about 1 or 2 feet above sea level in the marshlands. The inland bays and lakes are very shallow.

2. GENERAL GEOLOGY

Only the geologic history in the last 4,000 to 5,000 years is significant for this study. During that time, the rise in sea level ceased, many lobate deltas were formed, and a gulfward growth of the land mass began. As the land mass advanced seaward, the course of the Mississippi River, and its associated deltas, shifted many times depositing a front of fine-grained alluvium over the entire area. After each change in the course of the Mississippi and its corresponding delta, the effects of subsidence and erosion became the dominant process within the abandoned delta. The gulfward edge of the abandoned delta began a landward retreat forming arcuate sandy delta margin islands with well-developed beaches consisting primarily of the coarser sediments of the reworked distributary deposits. Grand Isle, which flanks the gulfward end of the abandoned Lafourche delta, is an example of these delta margin islands.

3. INVESTIGATIONS PERFORMED

Twenty-six general type soil borings, extending to depths between 40 and 60 feet, were made in the general vicinity of Grand Isle at the locations shown on plate A-1. In addition to these borings, surface samples were taken at the shoreline of the beach, at the 6-foot depth line, and at the 12-foot depth line. A total of 52 surface samples were taken. Tests performed on the borings included visual classification, water content, and mechanical sieve analyses. The results of these tests and the boring logs are shown on plates A-1 and A-2. The surface samples were sieved to determine the D_{75}, D_{50}, and D_{25} grain size. A summary of the grain sizes of the surface samples is shown on plate A-1.

4. SUBSURFACE CONDITIONS

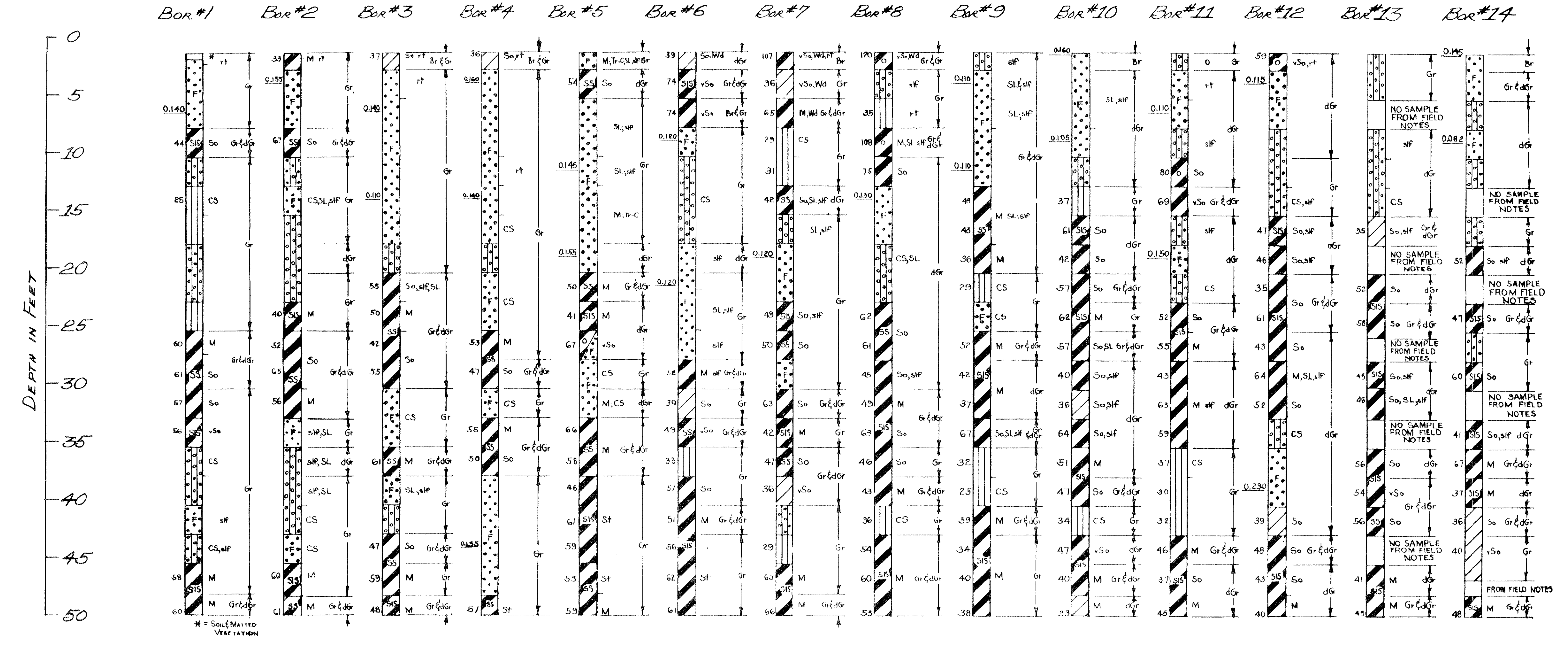
The subsurface at Grand Isle consists of Recent deposits approximately 450 feet thick. The Recent deposits are underlain by materials of Pleistocene age. Generally the Recent consists of fine beach sand varying in thickness from about 15 to 20 along the modern beach, to approximately 30 feet just northward of the modern beach. The fine sand is underlain by silty sands to a maximum depth of about 60 feet in the eastern half of the island, north of the modern beach. Generally, this sandy material wedge thins to about 20 feet at the western or Caminada Pass end of the island. The extensive depth of the sand at Grand Isle is the result of progressive settlement of the sand as the beach deposits accumulated. Underlying the sandy materials are prodelta deposits of medium clays.

5. CONCLUSIONS AND RECOMMENDATIONS

The range of the D_{50} grain size of the present beach materials is between 0.120 mm and 0.175 mm. Mechanical sieve analyses of samples from borings 1-14 (December 1964) and borings 1B-9B (November 1965) indicate that only borings 3, 4, and 5 located on the mainland in the vicinity of Cheniere Caminada, and borings 1B and 7B located just offshore at the eastern and western ends of the island, respectively, contain sands with median (D_{50}) sizes that fall within the range of the D_{50} size of the present beach material. Sands encountered in borings 3, 4, and 5 display a D_{50} size range of between 0.110 mm and 0.160 mm, while the sands encountered in borings 1B and 7B display a D_{50} size range of between 0.130 mm and 0.170 mm. Based on the median (D_{50}) size range of the sands encountered in borings 1B and 7B particularly in boring 1B where 42 feet of sand with a D_{50} size range of between 0.130 mm and 0.170 mm was penetrated, it appears that material from these areas would offer the most resistance to displacement by wave erosion and littoral currents.

Based on available geologic and soils information, no unusual problems should be encountered in constructing a levee to an elevation of 11.5 with wave berm as shown on plate 2. Erosion protection will have to be provided on the dune.

The levee could be constructed of sand obtained locally. No unusual problems relative to constructing a jetty at the western end of the island should be encountered.



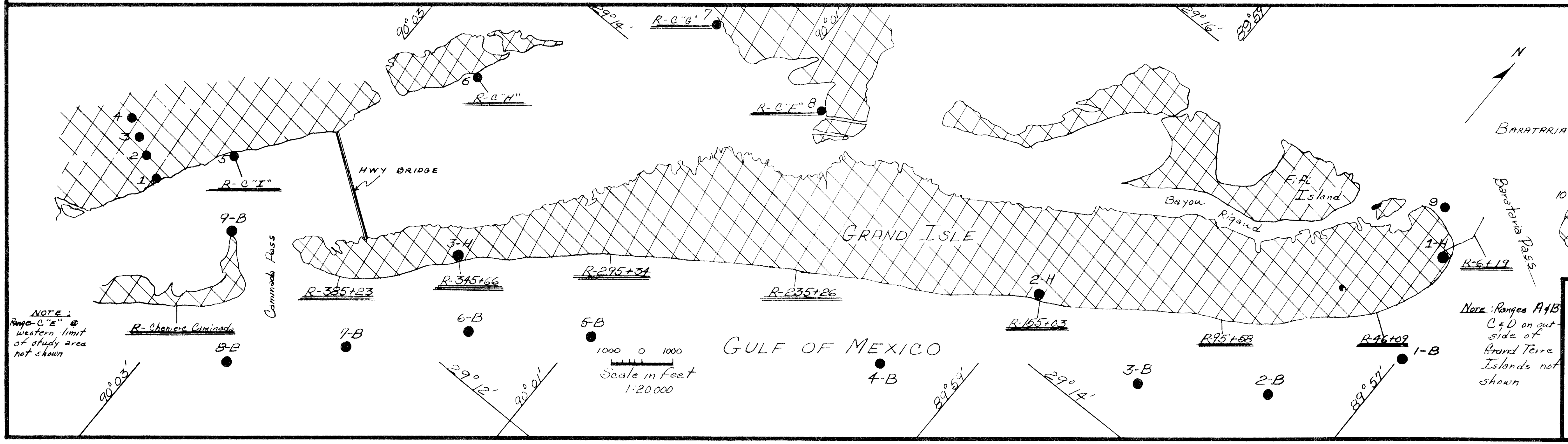
ANALYSIS OF BEACH SAMPLES

LOCATION	CLASS	D-50 (mm)
R-C "F" @ beach	SM-1-S	0.1250
R-C "F" 250' off	SM-1	0.1150
R-C "G" @ beach	Matt Veg.	No MA.
R-C "G" 200' off	SP	0.1400
R-C "G" 350' off	SM-1-S	0.1600
R-C "H" @ beach	ML-1	0.0605
R-C "H" 150' off	ML-1	0.0490
R-C "I" @ beach	SM-1	0.1250
R-C "I" 150' off	SP	0.1500
R-C "I" 300' off	SP	0.1300
R-A @ beach	SP	0.1650
R-A 6' depth	SP	0.1250
R-A 12' depth	ML-1	0.0740
R-B @ beach	SP	0.1700
R-B 6' depth	SM-1	0.0740
R-B 12' depth	SM-1-S	0.1200
R-C @ beach	SP	0.1750
R-C 6' depth	ML-2-S	0.0620
R-C 12' depth	ML-2-S	0.0640
R-D @ beach	SP	0.1750
R-D 6' depth	SM-1-S	0.1005
R-D 12' depth	ML-2	0.0560
R-6+19 @ beach	SP	0.1300
R-6+19 6' depth	SM-1-S	0.0970
R-6+19 12' depth	SP	0.1250
R-46+09 @ beach	SP	0.1400
R-46+09 6' depth	SP	0.1255
R-46+09 12' depth	ML-1	0.0670

LOCATION	CLASS	D-50 (mm)
R-95+48 @ beach	SP	0.1750
R-95+48 6' depth	SP	0.1050
R-95+48 12' depth	SM-1-S	0.1200
R-155+03 @ beach	SP	0.1900
R-155+03 6' depth	SP	0.1200
R-155+03 12' depth	SM-1	0.1050
R-235+26 @ beach	SP	0.1250
R-235+26 6' depth	SP	0.1300
R-235+26 12' depth	SM-1-S	0.1050
R-295+34 @ beach	SP	0.1700
R-295+34 6' depth	SP	0.1350
R-295+34 12' depth	SM-1	0.0890
R-345+66 @ beach	SP	0.1800
R-345+66 6' depth	SP	0.1400
R-345+66 12' depth	ML-1	0.0790
R-385+23 @ beach	SP	0.1800
R-385+23 6' depth	SP	0.1800
R-385+23 12' depth	ML-1	0.0780
R-Chen. Cam. @ beach	SP	0.1800
R-Chen. Cam. 6' depth	SP	0.1250
R-Chen. Cam. 12' depth	SM-1-S	0.0750
R-C "E" @ beach	SP	0.1750
R-C "E" 6' depth	SP	0.1700
R-C "E" 12' depth	SM-1-S	0.0940

CLASS	% SAND
SP	90-100
SM-1-S	80-90
SM-1	60-80
ML-1	45-60
ML-2-S	20-45

Bor. 1 - 14 were made in March, 1964 using an open bottom sampler.
Underlined figures to left of boring indicate D50 size in mm.
Bor. 1-B - 9-B were made in November, 1965. See Plate 2 for logs.
Bor. 1-H - 3-H were made in April, 1970. See Plate 2 for logs.

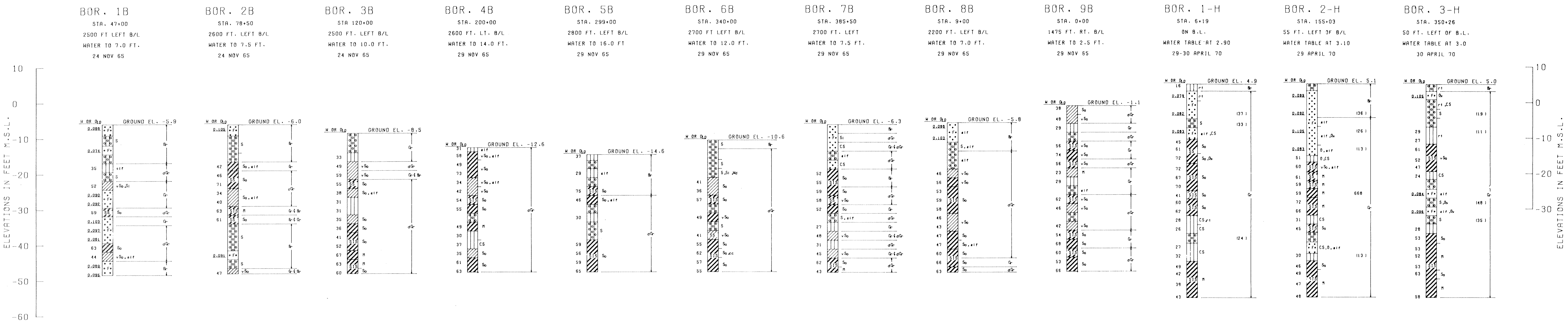


GRAND ISLE AND VICINITY
LOUISIANA

SOIL BORING LOCATION AND DATA

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



NOTE :

1. Borings 1-B thru 9-B made in Nov. 1965 with a $1\frac{7}{8}$" I.D. Core Barrel Sampler.

2. Borings 1-H thru 3-H made in Apr. 1970 with a $1\frac{7}{8}$" I.D. Core Barrel Sampler & a $1\frac{3}{8}$" Split Spoon Sampler.

GRAND ISLE AND VICINITY
LOUISIANA

SOIL BORING DATA

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION		TYPE	LETTER SYMBOL	SYMBOL	TYPICAL NAMES
COARSE - GRAINED SOILS More than half of material is larger than No. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than No.4 sieve size.	CLEAN GRAVEL (Little or No Fines)	GW		GRAVEL, Well Graded, gravel-sand mixtures, little or no fines
			GP		GRAVEL, Poorly Graded, gravel-sand mixtures, little or no fines
		GRAVEL WITH FINES (Appreciable Amount of Fines)	GM		SILTY GRAVEL, gravel-sand-silt mixtures
			GC		CLAYEY GRAVEL, gravel-sand-clay mixtures
	SANDS More than half of coarse fraction is smaller than No.4 sieve size.	CLEAN SAND (Little or No Fines)	SW		SAND, Well-Graded, gravelly sands
			SP		SAND, Poorly-Graded, gravelly sands
		SANDS WITH FINES (Appreciable Amount of Fines)	SM		SILTY SAND, sand-silt mixtures
			SC		CLAYEY SAND, sand-clay mixtures
FINE - GRAINED SOILS More than half the material is smaller than No. 200 sieve size.		SILTS AND CLAYS (Liquid Limit <50)	ML		SILT & very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
			CL		LEAN CLAY; Sandy Clay; Silty Clay; of low to medium plasticity
			OL		ORGANIC SILTS and organic silty clays of low plasticity
		SILTS AND CLAYS (Liquid Limit >50)	MH		SILT, fine sandy or silty soil with high plasticity
			CH		FAT CLAY, inorganic clay of high plasticity
			OH		ORGANIC CLAYS of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			Pt		PEAT, and other highly organic soil
WOOD			Wd		WOOD
SHELLS			Sl		SHELLS
NO SAMPLE					

NOTE: Soils possessing characteristics of two groups are designated by combinations of group symbols

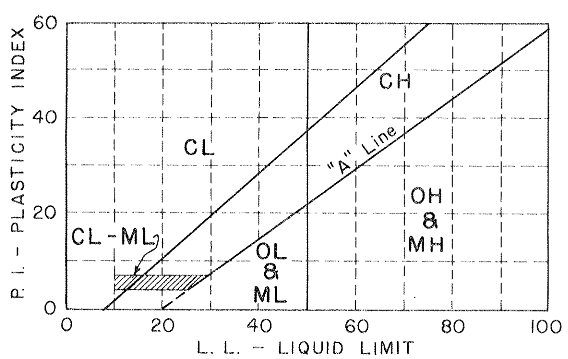
DESCRIPTIVE SYMBOLS

COLOR

COLOR	SYMBOL
TAN	T
YELLOW	Y
RED	R
BLACK	BK
GRAY	Gr
LIGHT GRAY	lGr
DARK GRAY	dGr
BROWN	Br
LIGHT BROWN	lBr
DARK BROWN	dBr
BROWNISH-GRAY	br Gr
GRAYISH-BROWN	gy Br
GREENISH-GRAY	gn Gr
GRAYISH-GREEN	gy Gn
GREEN	Gn
BLUE	Bl
BLUE-GREEN	Bl Gn
WHITE	Wh
MOTTLED	Mot

CONSISTENCY FOR COHESIVE SOILS

CONSISTENCY	COHESION IN LBS./SQ.FT. FROM UNCONFINED COMPRESSION TEST	SYMBOL
VERY SOFT	< 250	vSo
SOFT	250 - 500	So
MEDIUM	500 - 1000	M
STIFF	1000 - 2000	St
VERY STIFF	2000 - 4000	vSt
HARD	> 4000	H



PLASTICITY CHART

For classification of fine - grained soils

MODIFICATIONS

MODIFICATION	SYMBOL
Traces	Tr-
Fine	F
Medium	M
Coarse	C
Concretions	cc
Rootlets	rt
Lignite fragments	lg
Shale fragments	sh
Sandstone fragments	sds
Shell fragments	slf
Organic matter	O
Clay strata or lenses	CS
Silt strata or lenses	SIS
Sand strata or lenses	SS
Sandy	S
Gravelly	G
Boulders	B
Slickensides	SL
Wood	Wd
Oxidized	Ox

NOTES:

FIGURES TO LEFT OF BORING UNDER COLUMN "W OR D_{10}"

Are natural water contents in percent dry weight

When underlined denotes D_{10} size in mm *

FIGURES TO LEFT OF BORING UNDER COLUMNS "LL" AND "PL"

Are liquid and plastic limits, respectively

SYMBOLS TO LEFT OF BORING

- ▽ Ground-water surface and date observed
- (C) Denotes location of consolidation test **
- (S) Denotes location of consolidated-drained direct shear test **
- (R) Denotes location of consolidated-undrained triaxial compression test **
- (Q) Denotes location of unconsolidated-undrained triaxial compression test **
- (T) Denotes location of sample subjected to consolidation test and each of the above three types of shear tests **
- FW Denotes free water encountered in boring or sample

FIGURES TO RIGHT OF BORING

Are values of cohesion in lbs./sq. ft. from unconfined compression tests

In parenthesis are driving resistances in blows per foot determined with a standard split spoon sampler ($1\frac{3}{8}$" I.D., 2" O.D.) and a 140 lb. driving hammer with a 30" drop

Where underlined with a solid line denotes laboratory permeability in centimeters per second of undisturbed sample

Where underlined with a dashed line denotes laboratory permeability in centimeters per second of sample remoulded to the estimated natural void ratio

* The D_{10} size of a soil is the grain diameter in millimeters of which 10% of the soil is finer, and 90% coarser than size D_{10}.

**Results of these tests are available for inspection in the U.S. Army Engineer District Office, if these symbols appear beside the boring logs on the drawings.

GENERAL NOTES:

While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of the region are anticipated and, if encountered, such variations will not be considered as differing materially within the purview of clause 4 of the contract.

Ground-water elevations shown on the boring logs represent ground-water surfaces encountered on the dates shown. Absence of water surface data on certain borings implies that no ground-water data is available, but does not necessarily mean that ground water will not be encountered at the locations or within the vertical reaches of these borings.

Consistency of cohesive soils shown on the boring logs is based on driller's log and visual examination and is approximate, except within those vertical reaches of the borings where shear strengths from unconfined compression tests are shown.

REVISION	DATE	DESCRIPTION	BY
3	5-3-71	ADDED UPPER LIMIT LINE (P.I.= 0.9 (LL-8)) ON PLASTICITY CHART	LMVED-G LETTER D'T'D 29 APRIL 1971
2	6-8-64	SYMBOL FW, NOTE REVISED	ORAL FROM L.M.V.G.G. 5 JUNE 1964
1	9-17-63	1ST. PAR. OF GENERAL NOTES REVISED	L. M. V. D. MULTIPLE LETTER, DATED 5 SEPT., 1963

SOIL BORING LEGEND

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
FILE NO. H-2-21800

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX B
HYDROLOGY AND HYDRAULICS

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX B
HYDROLOGY AND HYDRAULICS

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GLOSSARY OF TERMS

ACCRETION - May be either NATURAL or ARTIFICIAL. Natural accretion is the gradual buildup of land over a long period of time solely by the action of the forces of nature, on a BEACH by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. Also AGGRADATION.

ADVANCE (OF A BEACH) - (1) A continuing seaward movement of the shoreline. (2) A net seaward movement of the shoreline over a specified time. Also PROGRESSION.

ARTIFICIAL NOURISHMENT - The process of replenishing a beach by artificial means, e.g., by the deposition of dredged materials.

ATMOSPHERIC PRESSURE ANOMALY - The difference between atmospheric pressure at any point within a hurricane and normal pressure at the periphery of the hurricane.

BAR - An offshore ridge or mound of sand, gravel, or other unconsolidated material submerged, at least at high tide; especially at the mouth of a river or estuary, or lying a short distance from and usually parallel to the beach.

BARRIER BEACH - A bar essentially parallel to the shore, the crest of which is above high water. Also OFFSHORE BARRIER.

BAY - A recess in the shore or an inlet of a sea or lake between two capes or headlands, not as large as a gulf but larger than a cove. Also BIGHT, EMBAYMENT.

BAYOU - A minor sluggish waterway or estuarial creek, tributary to, or connecting, other streams or bodies of water. Its course is usually through lowlands or swamps.

BEACH - The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form...or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach--unless otherwise specified--is the mean low water line. A beach includes FORESHORE and BACKSHORE.

BEACH BERM - A nearly horizontal portion of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

BEACH EROSION - The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

BEACH WIDTH - The horizontal dimension of the beach as measured normal to the shoreline.

BOTTOM - The ground or bed under any body of water; the bottom of the sea.

BREAKER DEPTH - The stillwater depth at the point where the wave breaks. Also BREAKING DEPTH.

BREAKWATER - A structure protecting a shore area, harbor, anchorage, or basin from waves.

BULKHEAD - A structure separating land and water areas, primarily designed to resist earth pressures. Also see SEAWALL.

CHANNEL - (1) A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. (2) The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation. (3) A large strait, as the English Channel. (4) The deepest portion of a stream, bay, or strait through which the main volume or current of water flows.

COASTLINE - (1) Technically, the line that forms the boundary between the COAST and the SHORE. (2) Commonly, the line that forms the boundary between the land and the water.

CONTINENTAL SHELF - The zone bordering a continent extending from the line of permanent immersion to the depth (usually about 100 fathoms) where there is a marked or rather steep descent toward the greater depths.

CONTOUR - (1) A line connecting the points on a land or submarine surface that have the same elevation. (2) In topographic or hydrographic work, a line connecting all points of equal elevation above or below a datum plane.

CONVERGENCE - (1) In refraction phenomena, the decreasing of the distance between orthogonals. This denotes an area of increasing wave height and energy concentration. (2) In wind setup phenomena, the increase in setup observed over that which would occur in an equivalent rectangular basin of uniform depth, caused by changes in planform or depth; also the decrease in basin width or depth causing such increase in setup.

CREST LENGTH, WAVE - The length of a wave along its crest. Sometimes called CREST WIDTH.

CREST OF WAVE - (1) The highest part of a wave. (2) That part of the wave above stillwater level.

CURRENT - A flow of water.

CURRENT, COASTAL - One of the offshore currents flowing generally parallel to the shoreline with a relatively uniform velocity (as compared to the littoral currents). They are not related genetically to waves and resulting surf but may be composed of currents related to distribution of mass in ocean waters (or local eddies), wind-driven currents and/or tidal currents.

CURRENT, EBB - The movement of the tidal current away from shore or down a tidal stream.

CURRENT, FLOOD - The movement of the tidal current toward the shore or up a tidal stream.

CURRENT, LONGSHORE - The inshore current moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

CURRENT, TIDAL - A current caused by the tide-producing forces of the moon and the sun, which is a part of the same general movement of the sea manifested in the vertical rise and fall of the tides.

DEEP WATER - Water of depth such that surface waves are little affected by conditions on the ocean bottom. It is customary to consider water deeper than one-half the surface wave length as deep water.

DEPTH - The vertical distance from the stillwater level (or datum as specified) to the bottom.

DIFFRACTION OF WATER WAVES - The phenomenon by which energy is transmitted laterally along a wave crest. When a portion of a train of waves is interrupted by a barrier, such as a breakwater, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

DIKE (DYKE) - A wall or mound built around a low-lying area to prevent flooding.

DIURNAL TIDE - A tide with one high water and one low water in a tidal day.

DIVERGENCE - (1) In refraction phenomena, the increasing of distance between orthogonals. This denotes an area of decreasing wave height and energy concentration. (2) In wind setup phenomena, the decrease in setup observed under that which would occur in an equivalent rectangular basin of uniform depth, caused by changes in planform or depth. Also the increase in basin width or depth causing such decrease.

DOWNDRIFT - The direction of predominant movement of littoral materials.

DUNES - Ridges or mounds of loose, wind-blown material, usually sand.

DURATION - In wave forecasting, the length of time the wind blows in essentially the same direction over the FETCH (generating area).

EBB TIDE - A nontechnical term referring to that period of tide while ebbing or at ebb; falling tide.

ENERGY COEFFICIENT - The ratio of the energy in a wave per unit crest length transmitted forward with the wave at a point in shallow water to the energy in a wave per unit crest length transmitted forward with the wave in deep water. On refraction diagrams this is equal to the ratio of the distance between a pair of orthogonals at a selected point to the distance between the same pair of orthogonals in deep water. Also the square of the REFRACTION COEFFICIENT.

EROSION - The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

FATHOM - A unit of measurement used for soundings. It is equal to 6 feet (1.83 meters).

FETCH - In wave forecasting, the horizontal distance (in the direction of the wind) over which the wind blows.

FLOOD TIDE - A nontechnical term referring to that period of tide between low water and the succeeding high water; a rising tide.

FORESHORE - The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark; that is, ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

FREEBOARD - The additional height of a structure above design high water level to prevent overflow. Also, at a given time the vertical distance between the water level and the top of the structure. On a ship, the distance from the waterline to main deck or gunwale.

GENERATING AREA - In wave forecasting, the continuous area of water surface over which the wind blows in essentially a constant direction. Sometimes used synonymously with FETCH LENGTH. Also FETCH.

GROIN (British, GROYNE) - A shore protective structure (built usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore. It is narrow in width, and its length may vary from less than one hundred to several hundred feet (extending from a point landward of the shoreline out into the water). Groins may be classified as permeable or impermeable--impermeable groins having a solid or nearly solid structure; permeable groins having openings through them of sufficient size to permit passage of appreciable quantities of littoral drift.

HEIGHT OF WAVE - The vertical distance between a crest and the preceding trough. Also see SIGNIFICANT WAVE HEIGHT.

HIGH TIDE, HIGH WATER (HW) - The maximum height reached by each rising tide. See TIDE.

HIGH WATER LINE - In strictness, the intersection of the plane of mean high water with the shore. The shoreline delineated on the nautical charts of the U. S. Coast and Geodetic Survey is an approximation of the high water line.

HURRICANE TERMINOLOGY

HURRICANE - An intense cyclonic windstorm of tropical origin in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 75 m.p.h. (65 knots) for several minutes or longer at some points. Tropical storm is the term applied if maximum winds are less than 75 m.p.h. Hurricanes of the Western Pacific Ocean are called typhoons.

HURRICANE PARAMETERS:

CENTRAL PRESSURE INDEX (CPI) - The central pressure index is the estimated minimum barometric pressure in the eye (approximate center) of a particular hurricane. The CPI is considered the most stable index to intensity of hurricane wind velocities in the periphery of the storm; the highest wind velocities corresponding to the lowest CPI.

CPI FREQUENCY - Estimated average frequency of occurrence in events per hundred years of a specified CPI in a designated geographical zone; derived from statistical analyses of recorded hurricanes supplemented by meteorological studies.

RADIUS OF MAXIMUM WINDS - Distance from the eye of the hurricane, where surface wind velocities are zero, to the place where surface wind velocities are maximum.

FORWARD SPEED - Rate of movement (propagation) of the hurricane eye in m.p.h. or knots.

HURRICANE PATH OR TRACK - Line of movement (propagation) of the eye through an area.

HURRICANE WIND PATTERN or ISOVEL PATTERN - An actual or graphical representation of near-surface wind velocities covering the entire area of a hurricane at a particular instant. Isovels are lines connecting points of simultaneous equal wind velocities, usually referenced 30 feet above the surface, in knots or m.p.h.; wind directions at various points are indicated by arrows or deflection angles on the isovel charts. Isovel charts are usually prepared at each hour during a hurricane, but for each half hour during critical periods.

HURRICANE STAGE HYDROGRAPH - A continuous graph representing water level stages that would be recorded in a gage well located at a specified point of interest during the passage of a particular hurricane, assuming that effects of relatively short-period waves are eliminated from the record by damping features of the gage well. Unless specifically excluded and separately accounted for, hurricane surge hydrographs are assumed to include effects of astronomical tides, barometric pressure differences, and all other factors that influence water level stages within a properly designed gage well located at a specified point.

HYPOTHETICAL HURRICANE ("HYPO-HURRICANE") - A representative of a hurricane, with specified characteristics, that is assumed to occur in a particular study area, following a specified path and timing sequence.

TRANSPOSED - A hypo-hurricane based on the storm transposition principle is assumed to have wind patterns and other characteristics basically comparable to a specified hurricane of record, but is transposed to follow a new path to serve as a basis for computing a hurricane surge hydrograph that would be expected at a selected point. Moderate adjustments in timing or rate of forward movement may be made also, if these are compatible with meteorological considerations and study objectives.

HYPO-HURRICANE BASED ON GENERALIZED PARAMETERS - Hypo-hurricane estimates based on various logical combinations of hurricane characteristics require consideration in estimating hurricane surge magnitudes corresponding to a range of probabilities and potentialities. The Standard Project Hurricane is most commonly used for this purpose, but estimates corresponding to more severe or less severe assumptions are important in some project investigations.

STANDARD PROJECT HURRICANE (SPH) - A hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region, excluding extremely rare combinations. It is further assumed that the SPH would approach a given project site from such direction, and at such rate of movement as to produce the highest hurricane surge hydrograph, considering pertinent hydraulic characteristics of the area. Based on this concept and extensive meteorological studies and probability analyses, a tabulation of "Standard Project Hurricane Index Characteristics" mutually agreed upon by representatives of the Corps of Engineers and the U. S. Weather Bureau is available.

PROBABLE MAXIMUM HURRICANE - A hypo-hurricane that might result from the most severe combination of hurricane parameters that is considered reasonably possible in the region involved, if the hurricane should approach the point under study along a critical path and at optimum rate of movement. This estimate is substantially more severe than the SPH criteria.

DESIGN HURRICANE - A representation of a hurricane with specified characteristics that would produce hurricane surge hydrographs and coincident wave effects at various key locations along a proposed project alinement. It governs the project design after economics and other factors have been duly considered. The design hurricane may be more or less severe than the SPH, depending on economics, risk, and local considerations.

JETTY - (1) (U.S. usage) On open seacoasts, a structure extending into a body of water and designed to prevent shoaling of a channel by littoral materials and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel. (2) (British usage) Jetty is synonymous with "wharf" or "pier."

KNOT - (Abbreviation kn.) The unit of speed used in navigation. It is equal to 1 nautical mile (6,076.115 feet) per hour.

LANDFALL - The arrival of a hurricane center at the coastline.

LENGTH OF WAVE - The horizontal distance between similar points on two successive waves measured perpendicularly to the crest.

LITTORAL DRIFT - The material moved in the littoral zone under the influence of waves and currents.

LITTORAL TRANSPORT - The movement of material along the shore in the littoral zone by waves and currents.

LONGSHORE CURRENT - Current in the surf zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

LOW TIDE (LOW WATER, LW) - The minimum height reached by each falling tide. See TIDE.

LOW WATER DATUM - An approximation to the plane of mean low water that has been adopted as a standard reference plane.

MEAN DIAMETER, GEOMETRIC - The diameter equivalent of the arithmetic mean of the logarithmic frequency distribution. In the analysis of beach sands it is taken as that grain diameter determined graphically by the intersection of a straight line through selected boundary sizes (generally points on the distribution curve where 16 and 84 percent of the sample is coarser by weight) and a vertical line through the median diameter of the sample.

MEAN HIGH WATER (MHW) - The average height of the high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semidiurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

MEAN LOW WATER (MLW) - The average height of the low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All low water heights are included in the average where the type of tide is either semidiurnal or mixed. Only lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as mean lower low water.

MEAN SEA LEVEL - The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings.

MEAN TIDE LEVEL - Also called half-tide level. A plane midway between mean high water and mean low water.

NAUTICAL MILE - The length of a minute of arc, 1/21,600 of an average great circle of the earth. Generally 1 minute of latitude is considered equal to 1 nautical mile. The accepted United States value as of 1 July 1959 is 6,076.115 feet or 1,852 meters, approximately 1.15 times as long as the statute mile of 5,280 feet. Also GEOGRAPHICAL MILE.

NODAL ZONE - An area at which the predominant direction of the LITTORAL TRANSPORT changes.

NOURISHMENT - The process of replenishing a beach. It may be brought about naturally, by littoral transport, or artificially by the deposition of dredged materials.

OFFSHORE - (1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf. (2) A direction seaward from the shore.

OFFSHORE WIND - A wind blowing seaward from the land in the coastal area.

ONSHORE - A direction landward from the sea.

ONSHORE WIND - A wind blowing landward from the sea in the coastal area.

ORTHOGONAL - On a refraction diagram, a line drawn perpendicular to the wave crests.

OVERTOPPING - Passing of water over the top of a structure as a result of wave runup or surge action.

PASS - In hydrographic usage, a navigable channel through a bar, reef, or shoal, or between closely adjacent islands.

POTENTIAL ENERGY OF WAVES - In a progressive oscillatory wave, the energy resulting from the elevation or depression of the water surface from the undisturbed level. This energy advances with the wave form.

PREDICTED NORMAL TIDE - The predicted stillwater elevation of the ocean and its tidal arms at a given time and place when unaffected by abnormal phenomena; i.e., resulting only from the gravitational attraction of the moon, sun, and other astronomical bodies acting upon the rotating earth. (This term is preferable to "astronomical," whose other meaning, fabulously large, could be misleading to the uninformed.)

PROFILE, BEACH - The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

RECESSION (OF A BEACH) - (1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time. Also RETROGRESSION.

REFRACTION OF WATER WAVES - (1) The process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alinement with the underwater contours. (2) The bending of wave crests by currents.

REFRACTION DIAGRAM - A drawing showing positions of wave crests and/or orthogonals in a given area for a specific deepwater wave period and direction.

RETROGRESSION OF A BEACH - (1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time. Also RECESSION.

RIDGE, BEACH - An essentially continuous mound of beach material that has been shaped up by wave or other action. Ridges may occur singly or as a series of approximately parallel deposits. British usage, FULLS.

RUNUP - The rush of water up a structure on the breaking of a wave. Also UPRUSH. The amount of runup is the vertical height above stillwater level that the rush of water reaches.

SCOUR - Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

SETUP, WAVE - Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

SHORE - The strip of ground bordering any body of water. A shore of unconsolidated material is usually called a beach.

SHORELINE - The intersection of a specified plane of water with the shore or beach (e.g., the highwater shoreline would be the intersection of the plane of mean high water with the shore or beach). The line delineating the shoreline on U. S. Coast and Geodetic Survey nautical charts and surveys approximates the mean high water line.

SIGNIFICANT WAVE - (1) A statistical term denoting waves with the average height and period of the one-third highest waves of a given wave group. The composition of the higher waves depends upon the extent to which the lower waves are considered. Experience so far indicates that a careful observer who attempts to establish the character of the higher waves will record values which approximately fit the definition. (2) A wave of significant wave period and significant wave height.

SIGNIFICANT WAVE HEIGHT - The average height of one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one-third of a selected number of waves, this number being determined by dividing the time of record by the significant period. Also CHARACTERISTIC WAVE HEIGHT.

SIGNIFICANT WAVE PERIOD - An arbitrary period generally taken as the period of the one-third highest waves within a given group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, this is determined as the average period of the most frequently recurring of the larger well-defined waves in the record under study.

SLOPE - The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating 1 unit vertical rise in 25 units of horizontal distance; or a decimal fraction (0.04); degrees ($2^\circ 18'$); or percent (4%). It is sometimes described by such adjectives as steep, moderate, gentle, mild, or flat.

SPIT - A small point of land or a narrow shoal projecting into a body of water from the shore.

SPRING TIDE - A tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STILLWATER LEVEL - The elevation of the surface of the water if all wave action were to cease.

STORM SURGE - That rise above normal water level on the open coast due only to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. (See SETUP, WIND.)

STORM TIDE - See WIND SETUP.

SURF - The wave activity in the area between the shoreline and the outermost limit of breakers.

SURGE - (1) The name applied to wave motion with a period intermediate between that of the ordinary wind wave and that of the tide, say from 1/2 to 60 minutes. It is of low height; usually less than 0.3 foot. Also SEICHE. (2) In fluid flow, long interval variations in velocity and pressure, not necessarily periodic, perhaps even transient in nature.

TIDAL RANGE - The difference in height between consecutive high and low waters.

TIDE - The periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name TIDE for the vertical movement.

TIDE, DIURNAL - A tide with one high water and one low water in a tidal day.

TIDE, EBB - That period of tide between a high water and the succeeding low water; falling tide.

TIDE, FLOOD - That period of tide between low water and the succeeding high water; a rising tide.

TROUGH OF WAVE - The lowest part of a wave form between successive crests. Also that part of a wave below stillwater level.

WAVE - A ridge, deformation, or undulation of the surface of a liquid.

WAVE DIRECTION - The direction from which a wave approaches.

WAVE FORECASTING - The theoretical determination of future wave characteristics, usually from observed or predicted meteorological phenomena.

WAVE HEIGHT COEFFICIENT - The ratio of the wave height at a selected point to the deepwater wave height. The refraction coefficient multiplied by the shoaling factor.

WAVE STEEPNESS - The ratio of a wave's height to its length.

WAVE TRAIN - A series of waves from the same direction.

WIND, OFFSHORE - A wind blowing seaward over the coastal area.

WIND, ONSHORE - A wind blowing landward over the coastal area.

WIND SETUP - (1) The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water. (2) The difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. (3) Synonymous with WIND TIDE and STORM SURGE. STORM SURGE is usually reserved for use on the ocean and large bodies of water. WIND SETUP is usually reserved for use on reservoirs and smaller bodies of water.

WIND WAVES - (1) Waves being formed and built up by the wind. (2) Loosely, any wave generated by wind.

REVIEW REPORT
ON
GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX B
HYDROLOGY AND HYDRAULICS

SECTION I - FACTORS PERTINENT TO THE PROBLEM

1. CLIMATOLOGY

TABLE B-1
TEMPERATURE AND PRECIPITATION RECORDS

Station (Louisiana)	Map index no.[1]	Period of record Precipitation	Period of record Temperature	Collecting agency
		as of 1961		
Alvin Callender Field	2	1956 to 1960	1956 to 1960	U.S. Weather Bureau (now National Weather Service)
Burrwood	9	1907 to 1965	1907 to 1965	do
Delta Farms	5	1911 to 1944	1911 to 1944	do
Golden Meadow	7	1954 to 1967	1954 to 1967	do
Grand Isle	8	1940 to 1970	1949 to 1970	do
Houma	4	1890 to 1970	1889 to 1970	do
New Orleans	1	1836 to 1970	1871 to 1970	do
Paradis	3	1911 to 1970	1954 to 1970	do
Diamond	6	1891 to 1919	1891 to 1919	do
		1958 to 1970	1958 to 1970	do

[1]Plate B-1

TABLE B-2
TEMPERATURE DATA (DEGREES FAHRENHEIT)

	Burrwood	Delta Farms	Houma	New Orleans	Grand Isle
Maximum recorded	99	101	104	102	101
Minimum recorded	10	16	5	7	16

TABLE B-3
TEMPERATURE NORMALS (DEGREES FAHRENHEIT)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1. Mean monthly													Mean
Burrwood	57.5	58.2	61.5	67.9	75.1	81.1	82.7	82.8	80.5	74.3	65.1	59.7	70.5
Houma	56.5	58.6	62.4	68.9	75.1	80.2	81.6	81.6	78.3	70.4	61.0	57.2	69.3
New Orleans	56.0	58.2	62.8	69.7	76.8	82.3	83.4	83.5	80.2	72.6	62.0	57.1	70.4
2. Maximum monthly													Maximum
Burrwood	65.2	66.6	69.8	75.8	81.8	87.5	89.0	89.4	87.1	80.9	72.5	67.2	77.7
Houma	66.4	69.4	73.0	79.3	84.8	89.7	90.7	91.2	88.2	82.2	72.5	67.1	79.5
New Orleans	63.5	66.6	71.1	77.7	83.8	89.4	90.3	90.5	87.2	80.1	70.5	64.7	77.2
3. Minimum monthly													Minimum
Burrwood	49.0	50.1	54.1	61.4	68.8	74.4	76.1	76.8	74.9	68.8	59.2	52.3	63.8
Houma	46.1	48.2	52.2	58.4	64.1	70.1	71.8	71.4	68.5	58.7	49.4	46.5	58.8
New Orleans	48.3	47.2	54.8	61.8	68.4	74.4	75.8	76.2	73.4	65.4	54.8	48.3	62.3

Seasonal Normals	Spring	Summer	Fall	Winter
	68.8	81.9	69.3	58.9

TABLE B-4
PRECIPITATION DATA (INCHES)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1. Mean monthly													Mean
Burrwood	4.08	4.31	4.22	4.01	4.08	4.25	6.69	7.52	7.67	3.40	4.15	3.97	58.35
Houma	4.11	4.09	5.27	4.48	4.81	6.39	8.43	7.62	6.63	3.76	3.99	4.81	64.39
Paradis	4.84	5.23	6.21	5.07	5.36	6.01	7.44	6.50	5.96	3.35	4.07	5.54	65.58
2. Maximum monthly													Maximum
Burrwood	14.81	12.98	10.87	14.81	17.57	14.62	15.51	18.99	21.06	15.97	16.17	11.04	86.01
Houma	12.36	10.87	16.49	10.64	15.44	15.00	19.71	15.20	18.70	11.62	17.53	13.62	87.53
Paradis	13.45	13.17	16.40	12.97	18.00	18.00	14.64	12.17	16.40	16.15	13.85	13.65	90.10
3. Minimum monthly													Minimum
Burrwood	0.62	0.45	0.40	T	T	0.02	0.59	1.51	0.16	0.0	0.08	0.96	33.34
Houma	0.45	0.05	T	0.0	0.15	0.10	0.21	2.29	0.30	0.0	0.16	0.06	33.03
Paradis	1.37	1.12	0.25	0.0	0.46	0.0	0.24	0.79	0.0	0.0	0.25	0.30	36.79

Average Seasonal	Spring	Summer	Autumn	Winter
	4.8	6.8	4.8	4.6

T = Trace

2. LITTORAL FORCES

a. Wave climate.

(1) Height, period, and direction. Surf statistics were gathered for Grand Isle and vicinity only between 1954 and 1957, a relatively short period of time. These observations were made during a cooperative study by the U. S. Coast Guard and the Corps of Engineers Beach Erosion Board. These studies (1) (2) (3) [1] indicated that waves approach Grand Isle from the southeast 59 percent of the time, from the south 23 percent of the time, from the southwest 15 percent of the time, from the east less than 3 percent of the time, and from the northeast less than 1 percent of the time. The dominant wave heights and periods are 1 to 3 feet and 6 to 7 seconds, respectively, as shown in table B-5. Hurricane waves for one observation during Hurricane Brenda were 3 to 4 feet higher than normal and had wave periods of 1.5 seconds shorter duration than normal. The maximum wave heights observed during the period of observation were 9 feet with wave periods between 4 and 6 seconds inclusive. (3)

(2) Effects of refraction and diffraction. Wave refraction diagrams constructed for three directions of approach--south, southeast, and east--are shown on plate B-2. A wave period of 6.5 seconds was taken from observed data in reference (4) and used as a basis for computation of refraction and diffraction. The mean high-water shoreline and offshore contours at the 1 and 2 fathom depth were taken from the 1964 survey made by the Corps of Engineers. Contours at greater depths were taken from the 1957 survey by the U. S. Coast and Geodetic Survey. The procedure used in constructing the diagram is as outlined in section 1.261, paragraph a, of reference (4). Critical areas as determined from the refraction diagrams extend from stations 320+00 to 300+00, from 290+00 to 150+00, and from 133+00 to 85+00 along the 1953 baseline. A constant energy ratio was assumed between orthogonals in deep water. The ratios of the deepwater orthogonal spacing to the orthogonal spacing at the shoreline, $\sqrt{\frac{B_o}{B}}$, versus the baseline distance is plotted in the form of a bar graph on plate B-3. Areas where the ratio $\sqrt{\frac{B_o}{B}}$ is greater than unity are areas of wave energy concentrations.

(3) Direction and magnitude of wave energy. Table B-5 indicates that 59 percent of the time the alongshore wave energy component is directly onshore, that 38 percent (23%+15%) of the time the alongshore component of wave energy is toward the northeast for waves approaching from the south or southwest, and less than 3 percent of the time the component is toward the southwest. Plate B-3 demonstrates the relationship between wave energy arriving at the shore from different directions and readily indicates that for the same wave period more energy is present at the shoreline during southeasterly waves than

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[1]Publications, memorandums, references, etc., pertinent to the study are listed in SectionIV - Bibliography, and are identified in this presentation by numerals inclosed in parentheses.

TABLE B-5

YEARLY STATISTICAL SURF DATA FOR GRAND ISLE[3]

Durations given in average hours per year for 1955-1957
Height and period groupings include lower values but not the upper

Surf Height (feet)	Direction	Wave period (seconds) 3-4	4-5	5-6	6-7	7-8	8-9	Total
0-1	NE					1		1
	E				1			1
	SE			17	159	137	8	321
	S			15	147	168	11	341
	SW			6	36	34		76
Total				38	343	340	19	740
1-2	NE			5	23	8		36
	E			12	53	53	1	119
	SE		3	186	1347	622	15	2173
	S			30	571	313	6	920
	SW			4	192	279	24	499
Total			3	237	2186	1275	46	3747
2-3	NE				11	3		14
	E			4	46	3	4	57
	SE		10	239	898	242	5	1394
	S		4	53	291	63	2	413
	SW		4	39	295	113		451
Total			18	335	1541	424	11	2329
3-4	NE							
	E		4	10	7			21
	SE		11	223	275	33		542
	S			38	78	11		127
	SW	1	1	41	75	6		124
Total		1	16	312	435	50		814
4-5	NE				1			1
	E			5	5			10
	SE		2	116	49	8		175
	S		5	2	11	6		24
	SW	3	9	25	6	1		44
Total		3	16	148	72	15		254
5-6	NE							
	E			1				1
	SE		12	43	1			56
	S		3	1	1	3		8
	SW	3	5	19		1		28
Total		3	20	64	2	4		93
6-7	NE							
	E							
	SE			7	1	1		9
	S			7				7
	SW		5	4		1		10
Total			5	18	1	2		26
7-8	NE							
	E							
	SE			5				5
	S							
	SW		1					1
Total			1	5				6
8-9	NE							
	E							
	SE		1	1				2
	S							
	SW							
Total			1	1				2

from other wave directions. For waves approaching from the south a high concentration of wave energy occurs beginning in the vicinity of the last groin, station 130+00, and extending eastward to the vicinity of station 85+00. A general decrease in wave energy occurs as waves approaching from the east move toward shore.

b. Currents. In 1935[5] tidal currents through Barataria and Caminada Passes were measured on two different occasions for a spring tide at flood and one at ebb. Alongshore currents were measured simultaneously at two ranges approximately 10,000 feet away from each pass along the island shore. Results of these measurements indicated that Barataria Pass influenced alongshore currents at the point of measurement, station 100+00, but that Caminada did not appear to influence currents at station 300+00 to any significant degree. Current measurements were not made for this study; however, visual observations of tidal currents in the vicinity of Caminada Pass on 10 September 1970 and 12 November 1970 indicated that the influence of tidal currents extends eastward approximately 2,500 feet to station 375+00 where an offshore sandbar paralleling the shoreline has been cut through by high tides. The recessed area between the sandbar and the shoreline was seen to act as a channel during tidal activity. Aerial photographs and local erosion of the shore adjacent to the pass indicate that the pass is realining itself towards a more easterly direction. The 1970 tidal current tables[6] predict maximum tidal currents during spring ebb and flood tides of approximately 3.5 and 3.2 feet per second, respectively, in both Barataria and Caminada Passes. The entrance direction of flood tide in Barataria Pass is 315° and of ebb tide is 120°. The entrance direction of flood and ebb tide in Caminada Pass is 295° and 120°, respectively.

c. Winds. Observations[5] at the U. S. Coast Guard's Barataria Station from 1 December 1919 to 26 March 1936 indicate that the wind blew from the east 19 percent of the time, from the southeast 17.3 percent of the time, and from the south 12.4 percent of the time. Observations [7] from the same source from January 1944 to December 1951, inclusive, indicate that the wind blew from the east 12.1 percent of the time, from the southeast 26.4 percent of the time, and from the south 9 percent of the time. More recent observations made at Grand Isle from 1960 to 1963 indicate that winds blew from the east 11.70 percent of the time, from the southeast 18.66 percent of the time, and from the south 13.94 percent of the time. Table B-6 lists total wind duration in percent of time for the eight cardinal points and for calms for the three periods of record. Plate B-4 shows wind roses for the two more recent periods of record.

TABLE B-6
AVERAGE SURFACE WIND DURATION AT GRAND ISLE[5] [7]
IN PERCENT OF TIME

Wind direction	Period in Years 1919 to 1936	1944 to 1951	1960 to 1963
N	11.9	8.90	12.42
NE	11.9	15.90	16.86
E	19.0	12.0	11.7
SE	17.3	26.35	18.66
S	12.4	9.05	13.94
SW	7.1	12.25	10.91
W	5.6	4.15	6.22
NW	8.2	11.10	9.41
Calm	6.6	0.20	0.27

Onshore winds which cause wind-borne transport of beach material to occur include those from three directions--east, southeast, and south. Offshore winds include those from the west, northwest, and north. The island is alined generally in a northeast to southwest direction and winds blowing from these directions generally parallel the shore. Surveys of natural dunes on Grand Isle and Cheniere Caminada to the west have shown that dunes have grown to heights of 9 and 14 feet, respectively. Other proof of wind-borne transport was demonstrated recently when the dune line along the gulf shore was restored following total destruction by Hurricane Betsy in September 1965. Contract specifications called for reconstruction of the dune to elevation 8.0, including a 10-foot crown width and 1 on 4 side slopes to elevation 5.0. Grade stakes were set firmly along the alinement and the dune was constructed according to specifications except that the dune was constructed to approximately elevation 9.0 instead of 8.0. The only material available for fill was located west of the east end jetty. This material was poorly graded and ranged in size from medium sand to silt. A field visit within 2 months after the dune restoration work had been completed demonstrated that the loose sand on the crown had been blown shoreward. A comparison of surveys made at that time showed that the average elevation of the dune crown was 2 feet lower than the elevation to which it had been originally constructed, and the wind-blown sand had been deposited on the shoreward toe of the dune section.

d. Tides. The tides at Grand Isle are diurnal in nature[8] and have a mean tidal range of 1.2 feet and a maximum spring range of 1.9 feet. The maximum tidal height of record was 9.0 feet and occurred during the September 1915 hurricane. The minimum tidal height of record was -1.7 feet and occurred on two occasions--2 February 1951 and 13 January 1964. Table B-7 shows the annual highs and lows for the period of record, 1947 to 1970, at the U. S. Coast and Geodetic Survey gage in Bayou Rigaud immediately north of Grand Isle. Other station locations are shown in table B-8.

SECTION II - SHORE HISTORY

3. SHORELINE AND OFFSHORE DEPTH CHANGES

a. Shoreline changes. Shoreline changes were determined at the mean high-water shoreline for the purpose of this discussion. Shoreline changes from available surveys prior to 1954 were analyzed in connection with previous cooperative studies in 1935-36 and 1953-54 (see plate B-5). The 1935 study revealed that between 1877 and 1935 a decided change in the orientation of the mean high-water shoreline with respect to a node at the center of the island had occurred. The eastern end showed, in general, considerable accretion, while the western end showed erosion. The growth at the eastern end of the island between the survey of 1853 and that of 1935 was from about 1,250 to 1,800 feet while the recession at the western end near Caminada Pass between the surveys of 1877 and 1935 amounted to a maximum of about 1,500 feet. Between 1853 and 1877 the extreme eastern end near Barataria Pass advanced very nearly to its 1935 location, but from about 1,500 feet west of the pass to the center of the island a marked advance between the 1877 and the 1935 location occurred. This advance varies fairly regularly from zero near the eastern end of the island to a maximum of 1,000 feet approximately 8,000 feet to the west and thence to zero at the center of the island.

The recession in the western half had been almost simultaneous with the advance of the eastern half, varying from zero in the center to a maximum of approximately 1,500 feet at a point 14,000 feet west of the center. A recession at Caminada Pass between 1877 and 1935 a mounted to about 1,000 feet. The later surveys of 1932 and 1935 showed that during this 3-year period a slight accretion had taken place along the shoreline of the island except for a distance of several thousand feet from either end where slight erosion had taken place. At Barataria Pass this recession amounted to approximately 250 feet.

For the remainder of this discussion, points of accretion or erosion will be referenced to groin numbers or stationing along the 1953 baseline as shown in table B-9. From 1935 to 1953 a general recession of the mean high-water line occurred except for 6,000 feet at the western end between stations 397+00 and 337+00 where accretion took place. Here the shoreline of a barrier beach or trailing spit was at one point 1,000 feet gulfward of the 1935 shoreline. The eastern end of the barrier beach joined and was continuous with the

TABLE B-7
EXPERIENCED ANNUAL HIGHS AND LOWS IN
BAYOU RIGAUD AT GRAND ISLE
(through June 1970)

Station 884+00 Zero of gage = minus 4.70 ft. m.s.l.

Year	High Gage	High m.s.l.	Date	Low Gage	Low m.s.l.	Date
1947	9.0	4.3	19 Sept	3.5	-1.2	27 Dec
1948	-	-		3.5	-1.2	24, 25 Jan
1949	7.8	3.1	4 Sept	3.5	-1.2	1 Jan
1950	7.1	2.4	13 Feb	3.4	-1.3	10 Dec
1951	6.5	1.8	28 Mar	3.0	-1.7	3 Feb
1952	6.8	2.1	16 Jul	3.5	-1.2	7 Feb, 16 Dec
1953	7.0	2.3	25,26 Sept	3.2	-1.5	12 Jan, 17 Dec
1954	7.2	2.5	16,17 Sept	3.2	-1.5	19,20 Dec
1955	6.8	2.1	20 May	3.4	-1.3	19 Jan
1956	9.3	4.6	24 Sept	3.1	-1.6	29 Dec
1957	7.9	3.2	27 Jun	3.4	-1.3	1 Jan
1958	7.0	2.3	5,6 Sept	3.4	-1.3	2,3 Feb
1959	6.6	1.9	18 Jun	3.7	-1.0	2 Mar
1960	6.3+	1.6	2,3 Sept	3.8	-0.9	18 Dec
1961	8.2	3.5	10 Sept	3.4	-1.3	16 Jan
1962	6.5	1.8	25 Sept	3.5	-1.2	12 Dec
1963	6.5	1.8	17 Sept	3.5	-1.2	24 Jan
1964	7.0+	2.3	19 Mar	3.0	-1.7	13 Jan
1965	12.2	7.4	9 Sept	3.4	-1.3	25 Feb
1966	7.3	2.6	7 May	3.5	-1.2	4,5 Feb
1967	6.8	2.1	12,20 Jun	3.9	-0.8	5 Jan
1968	6.7	2.0	11 Mar	3.7	-1.0	14 Jan
1969	7.4	2.7	6,9 Dec	3.8	-0.9	1 Jan, 22,26 Dec
1970	7.0	2.3	20,21 May 1,2 Jun	3.3	-1.4	9 Jan

TABLE B-8
TIDE GAGING STATIONS

Location	Code no.	Map index no.[1]	Period of record	Type gage	Gage zero feet m.s.l.	Collecting agency
Bayou Lafourche						
Belle Pass, La.		13	1956-1957	HWP	4.12	NOD
Leeville, La.	82350	12	1955-1970	Rec.	0.0	NOD
			1956-1965	HWP	4.16	NOD
Bayou Barataria						
Lafitte, La.	82875	11	1955-1970	Staff	0.0	NOD
			1956-1964	HWP	3.54	NOD
Barataria, La.	82750	10	1950-1970	Rec.	-0.78	NOD
Bayou Rigaud						
Grand Isle, La.	88400	15	1947-1970	Rec.	-4.70	USC&GS
Caminada Bay						
Grand Isle, La.		14	1956-1965	HWP	4.40	NOD
Hurricane Gage						
U.S. Coast Guard Sta.						
Grand Isle, La.		8	1958-1970	Rec.	0.0	NOD

[1]Plate B-1

HWP = High-water pipe
NOD = U. S. Army Engineer District, New Orleans
USC&GS = U. S. Coast & Geodetic Survey

1953 shoreline of the island proper, decreasing in width until it reached the location of the 1935 shoreline in the vicinity of groin number 2, station 337+00. From this point eastward, the erosion gradually increased reaching a width of 350 feet in 8,600 feet, station 251+00. The width of loss then decreased to about 200 feet at the center of the island in the vicinity of groin number 5, station 200+43. From groin number 5 eastward, the width of loss again increased reaching a maximum width of about 500 feet commencing at station 145+49, groin number 12, and continuing to station 119+00, 1,000 feet beyond groin number 14. From this point to the eastern end of the island the recession was less severe, averaging between 100 and 300 feet. Plate B-6 shows comparative mean high-water shorelines for 1953 and 1964. During this period the barrier beach present in 1953 at the western end of the island dissipated. The island, however, remained essentially unchanged eastward to groin number 1, station 342+00. From groin number 1 eastward to a point 1,500 feet east of groin number 4, station 300+00, the shore accreted to a maximum width of 250 feet between groins numbers 2 and 3. From station 300+00 to station 210+00, near the center of the island, no significant change occurred. From station 210+00 eastward to the vicinity of groin number 8 accretion increased to a maximum width of 100 feet and then decreased from that point to station 133+00 near groin number 14. Between station 133+00 and station 95+57 no significant change occurred, but beginning near station 95+57 and extending eastward approximately 8,000 feet to station 16+00 at the jetty adjacent to Barataria Pass, accretion occurred extensively reaching a maximum width of 1,000 feet in the vicinity of station 35+00. East of the jetty constructed in 1958 and 1959, extensive erosion occurred. The shoreline receded rapidly after construction and by 1964 only a shoal area remained in Barataria Pass east of the jetty. Table B-9 summarizes the rates of erosion or accretion at 20 points along the island shoreline for the periods 1932 to 1953, 1958 to 1970, and August 1965 to October 1965. The period 1932 to 1953 is significant because this period represents the longest time for which accurate surveys are available and represents natural conditions because artificial nourishment was not provided during this period. The period 1958 to 1970 is significant because it represents a period during which a jetty intended to trap material at the eastern end of the island was constructed and a period during which artificial nourishment was provided on two occasions to rectify erosion caused by hurricanes. The period August 1965 to October 1965 is a before-and-after condition for Hurricane Betsy.

b. Offshore depth changes. Comparison of 6- and 12-foot depth contours, below mean low water, for the period covered by the 1878, 1891, and 1935 surveys showed that the 6-foot contour in 1935 had a decided and continuous shoreward movement on the eastern third of the island with relatively little shoreward movement in the center third. The trend of movement in a shoreward direction continued again in greater magnitude on the western third of the island, except at a point near the western end where the 1935 contour moved gulfward with the formation of an offshore bar.

TABLE B-9
SHORELINE CHANGES AT GRAND ISLE

Stations	Total changes in feet by periods[1]		
	1932 to 1953	1958 to 1970	August 1965 to October 1965
72+00	-180	+635	-80
80+00	-280	+335	-40
88+00	-360	+190	-65
95+57	-300	+139	-45
133+10	-220	-32	-65
141+50	-240	-48	-30
149+40	-250	-52	-65
157+45	-240	-40	-70
165+25	-260	0	-65
173+45	-230	-27	-40
181+15	-200	-45	-55
188+85	-140	-3	-30
196+80	-160	-14	-55
235+26	-170	+9	-60
243+00	-150	-4	-115
251+00	-180	+20	-145
259+00	-170	+8	-150
320+80	-90	-38	-25
329+00	-50	-120	-100
337+00	-20	-178	-95

[1]Positive numbers indicate accretion; negative numbers indicate erosion.

During the period 1935 to 1953 the 6-foot contour moved shoreward along the center and eastern thirds of the island an average of 300 feet. On the western end of the island the 1953 6-foot contour advanced approximately 1,400 feet westerly into Caminada Pass. From west to east along the shore of the island the 1953 contour crosses the 1935 contour approximately 1,600 feet from the western tip showing a sharp shoreward retreat from the 1935 position. This shoreward movement reaches a maximum of 1,200 feet within a distance of 400 feet gradually diminishing in an eastward direction for the next 3,000 feet until the contours again cross. The remaining shoreline on the western third of the island shows very little net change in direction of movement between 1935 and 1953.

The 12-foot contour for 1935 showed the same general movement as that indicated by the 6-foot contour in comparison with the respective contours from earlier surveys, except at the western end where there was a relatively greater recession than for the 6-foot contour, and at the eastern third of the island where the 12-foot contour moved outward toward the contour of 1878. A profile made in 1935 near the extreme eastern end indicated that the 12-foot contour continued its outward trend and that offshore from Barataria Pass there was no decided shoreward movement as noted for the 6-foot contour, except for one 300-foot segment near the west-central section of the island.

The latest complete hydrograhic survey of Grand Isle was made in 1964. Plots of the mean high-water shoreline and the 6-foot and 12-foot contours are shown on plate B-6. To facilitate comparison of movement from 1953 to 1964, the 1953 contours have been replotted on plate B-6. The 1964 survey indicates that the 6-foot contour remained essentially the same over the central portion of the island but at the two ends of the island the 6-foot contour moved gulfward significantly. This tendency at the eastern end of the island was to be expected after construction of the jetty. The 6-foot contour from a point 2,500 feet west of groin number 1 to the west end had moved outward in a bar fashion across and through the mouth of Caminada Pass. Along the portion of the island surveyed in 1953, the 1964 12-foot contour showed a definite tendency to move shoreward 1,300 feet on the average.

In 1969 six offshore ranges were surveyed to determine any significant movement since 1964. This number of ranges was insufficient to accurately locate contours along the island front; however, the three ranges surveyed along the western half (station 345+65, station 295+34, and station 235+26) indicated little change had occurred in the location of the 6-foot contour. The survey of one of the three ranges along the eastern half of the island, station 173+45, indicated the 6-foot contour moved 200 feet offshore from its 1964 location. A survey of a second range, station 95+57, indicated the 6-foot contour moved 1,600 feet offshore, and a third, station 46+08, indicated no change had occurred. The 12-foot contour moved offshore from 350 feet to 2,000 feet along the four middle ranges surveyed but the surveys indicated no change had occurred along ranges at stations 345+65 and 46+08.

c. Volumetric accretion or erosion. Table B-10 contains volumetric accretion and erosion above mean high-water datum in cubic yards annually from 1958 to 1964, and bienially from 1966 to 1970. The values in the table are arranged and tabulated in four groups corresponding to selected ranges where successive surveys have been made for the period of study. Plus and minus signs depict accretion and erosion, respectively. Values given for Hurricane Betsy in September 1965 were computed from successive surveys of August and October 1965. The net change for the period 1958 to 1970 for each group and between the ranges in each group is tabulated in the last column of the table. These values are the sums of the annual and biennial volumes excluding volumes of artificial nourishment in 1962 and 1966 and erosion caused by Hurricane Betsy in 1965. The net annual or biennial sum of accretion or erosion is tabulated in each column below values of each group. Because these computations do not include losses below the mean high-water shoreline or volumes at both ends or between each group of ranges, this table only lists changes occurring within the groups of ranges surveyed; however, the table does give an indication of the relative stability or instability of the shoreline as a whole for the period of record. More detailed estimates made immediately following Hurricane Betsy indicated a net loss of 600,000 cubic yards of sand during the hurricane. Since periodic artificial nourishment was begun on the island in 1954, 2,400,000 cubic yards of sand at an average rate of 130,000 cubic yards per year have been placed on the island. Examination of pre- and post-construction surveys and aerial photographs revealed that the annual rate of impoundment above mean high water west of the jetty adjacent to Barataria Pass was approximately 250,000 cubic yards for the years 1960 to 1961. Over an 11-year period from 1959 to 1970, the jetty has trapped 1,250,000 cubic yards above the mean high-water shoreline.

d. Profiles. The slope of the foreshore zone (between mean low water and wave runup at mean high water) varies from 1:15 to 1:40, the average slope being about 1:25. Below mean low water the slopes at the two ends of the island are flatter than at the central portion of the island. Slopes from mean low water out to the 6-foot contour vary from approximately 1:1,000 at the eastern end of the island gradually steepening to about 1:50 near the center of the island and in turn decreasing to about 1:300 near the western end of the island. Slopes between the 6- and 12-foot contours follow the same general tendencies but are flatter--approximately 1:1,200 at the eastern end of the island steepening to about 1:100 near the center and decreasing to 1:300 at the western end of the island. See plates B-7 and B-8 for representative comparative profiles.

TABLE B-10
VOLUMETRIC ACCRETION AND EROSION BETWEEN STATIONS
in cubic yards above m.h.w. (see page B-x)

	1953 baseline stations	1958 to 1959	1959 to 1960	1960 to 1961	1961 to 1962	1962 to 1963	1963 to 1964	1964 to Aug 65	Hurricane Betsy‡	1965 to 1966	1966 to 1968	1968 to 1970	Net Change
		Survey Period											
Group One	72+00												
		+13330	+6840	+7140	*	-3060	+8000	+820	-8740	†	+25560	+9190	+67820
	80+00												
		+6340	+1160	+5600		+2310	+3140	+3700	-8000		+12150	+7780	+42180
	88+00												
		+5220	+4070	-8360		+4350	-1800	+7010	-6030		+3570	+2100	+16160
	95+57												
	TOTAL	+24890	+12070	+4380		+3600	+9340	+11530	-22770		+41280	+19070	+126160
Group Two	133+10												
		-1960	+10420	-18200		-10260	-3050	+3190	-5830		+15940	-14470	-18390
	141+50												
		-2430	-2300	-3050		-10400	-2820	+510	-6800		+13750	-15140	-21880
	149+40												
		-2100	-5010	+1160		-7250	-5270	0	-10810		+9840	-14610	-23240
	157+45												
		-1130	-4880	-2430		-8260	-6460	+2530	-10180		+2890	-10180	-27920
	165+25												
		-790	-3220	-5040		-5770	-6470	+3110	-6990		-3190	-3420	-24790
	173+45												
		-1600	+30	-1880	*	+2250	-3120	+1360	-8200		-4780	+1000	-6740
	181+15												
		-1280	+3340	-60	+5890	+4730	-960	+1000	-7770		-140	-360	+12160
	188+85												
		+1270	+2770	+800	+3770	+4330	-3110	+1330	-3460		+1690	-1250	+11600
	196+80												
	TOTAL	-10020	+1150	-28700	+9660	-30630	-31260	+13030	-60040		+36000	-58430	-99200

TABLE E-10 (contd)

1953 baseline stations	Survey Period: 1958 to 1959	1959 to 1960	1960 to 1961	1961 to 1962	1962 to 1963	1963 to 1964	1964 to Aug 65	Hurricane Betsy‡	1965 to 1966	1966 to 1968	1968 to 1970	Net Change
Group Three												
235+26												
	+630	+1290	-90	+4820	+490	-1340	+3580	-20070		+2290	-3080	+8590
243+00												
	+710	-2900	+4180	+5090	+310	-1280	+3410	-20150		+2300	-1700	+10120
251+00												
	+1930	-1630	+3560	+6620	+550	+260	+3190	-24070		+3850	-1780	+16550
259+00												
TOTAL	+3270	-3240	+7650	+16530	+1350	-2360	+10180	-64290		+8440	-6560	+35260
Group Four												
320+80												
	+10390	+6200	-6010	+6500	-5990	-960	+760	-11310		-6610	0	+4280
329+00												
	+7640	+7200	-7290	+7170	-10520	-4410	+150	-22220	†	-3410	-3850	-7320
337+00												
TOTAL	+18030	+13400	-13300	+13670	-16510	-5370	+910	-33530		-10020	-3850	-3040

*Change influenced by 350,000 cubic yards of artificial nourishment
†Change influenced by 550,000 cubic yards of artificial nourishment
‡Effects of Hurricane Betsy excluded from net change computation.

SECTION III - ANALYSIS OF THE PROBLEM

4. DESCRIPTION AND VERIFICATION OF PROCEDURES

a. Hurricane memorandums. The Hydrometeorological Branch (HMB), U. S. Weather Bureau (now the National Weather Service), cooperated in the development of hurricane criteria for experienced and potential hurricanes in the study area. The HMB memorandums provided frequency data, isovel and rainfall patterns, pressure profiles, hurricane paths, and other parameters required for the hydraulic computations. Those relative to experienced hurricanes are based on reevaluation of historic meteorologic and hydrologic data. Those relative to potential hurricanes contain generalized estimates of hurricane parameters that are based on the latest research and concept of hurricane theory.

b. Historical storms used for verification. Three observed storms, with known parameters and effects, were used to establish and verify procedures and relationships for determining surge heights. These three storms occurred in September of 1915, 1956, and 1965. Isovel patterns for the hurricanes of September 1915,[(9)] September 1956,[(10)] and September 1965[(11)] are shown on plates B-9, B-10, and B-11, respectively. Tracks of these and other experienced hurricanes are shown on plate B-12.

(1) The hurricane of 28 September to 1 October 1915[(9)] had a central pressure index (CPI) of 27.87 inches, an average forward speed of 10 knots, and a maximum windspeed[2] of 99 m.p.h. (86 knots) at a radius of 29 nautical miles. This hurricane approached the mainland from the south. At Grand Isle, a high-water elevation of about 9 feet m.s.l.[3] was experienced, while Manila Village, located in Barataria Bay to the rear of Grand Isle, experienced a stage of 8 feet.

(2) Hurricane Flossy[(10)], 23-24 September 1956, had a CPI of 28.76 inches, a forward speed of 10 knots, and winds of 80 m.p.h. (70 knots) at a radius of 22 nautical miles. This hurricane approached the study area from the south and then veered northeastward. Grand Isle was flooded by waters which, after being driven over the island into Barataria Bay, reversed and inundated the island from the back side to a stage of 8 feet. The hurricane surge on the gulf side of the island was 3.9 feet.

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[2]Windspeeds represent a 5-minute average 30 feet above the water surface unless otherwise indicated.

[3]Mean sea level, the datum to which all elevations are referenced unless otherwise indicated.

(3) On 9 September 1965, Hurricane Betsy[11], the worst storm to strike the Louisiana coast in this century, entered the coast from a southeasterly direction about 10 p.m. Winds at Grand Isle were reported at 105 m.p.h. with gusts ranging up to 160 m.p.h. The storm tides swept over Grand Isle and a stage of 8.8 feet was recorded on the island. Accompanying the storm was a CPI of 27.79 inches, a radius to maximum winds of 32 nautical miles, a forward speed of 17 knots, and a maximum windspeed of 122 m.p.h. over water. Had the path of this storm been about 35 miles to the west, Grand Isle would have experienced a storm of Standard Project Hurricane (SPH) magnitude.

c. Synthetic storms. Computed flood elevations, resulting from synthetic storms, are necessary for frequency and design computations. Parameters for certain synthetic storms and methods for derivation of others were furnished by the National Weather Service. The SPH was used for all locations in the project area changing track and forward speed as appropriate. The Probable Maximum Hurricane (PMH) and Moderate Hurricane (Mod H) were derived from the SPH and differ from it only in wind velocities and CPI's.

(1) The SPH used in the study area was derived by the National Weather Service from a study of 46 hurricanes that occurred in the region over a period of 68 years. Based on subsequent studies of recent hurricanes, the National Weather Service revised the SPH wind field patterns[12][13][14]. Other characteristics of the SPH were not changed. The SPH track critical to the Grand Isle area and isovel patterns at landfall are shown on plate B-13.

(a) The SPH has a frequency of once in 100 years for the Louisiana coastal region. The CPI that corresponds to this frequency is 27.5 inches. CPI probabilities are based on the following relationship[12][15]:

$$P = \frac{100\ (M-0.5)}{Y}$$

where P = percent chance of occurrence per year
M = number of the event (rank)
Y = number of years of record

(b) Radius of maximum winds is a parameter of hurricane intensity. The average radius of 12 hurricanes occurring in the study area is 36 nautical miles. From relationships of CPI and radius of maximum winds of gulf coast hurricanes[15][16], a radius of 30 nautical miles is considered representative for an SPH having a CPI of 27.5 inches.

(c) Different forward speeds are necessary to produce SPH effects at various locations within the study area. An average forward speed of 11 knots was selected for the SPH along the gulf shore of Grand Isle.

(d) Maximum theoretical gradient wind[16] is expressed as follows:

$$V_{gx} = 73 \sqrt{P_n - P_o} - R\ (0.575\ f)$$

where V_{gx} = maximum gradient windspeed in miles per hour
P_n = asymptotic pressure in inches
P_o = central pressure in inches
R = radius of maximum winds in nautical miles
f = Coriolis parameter in units of $hour^{-1}$

The estimated windspeed (V_x)[17] in region of highest speeds is obtained as follows:

$$V_x = 0.885\ V_{gx} + 0.5T$$

where T = forward speed in miles per hour

From these relationships, an average overwater windspeed of approximately 100 m.p.h. was obtained for the SPH.

(2) A CPI of 26.9 inches was recommended for the PMH by the National Weather Service[15]. A hurricane with this CPI actually occurred at 33° N. latitude in 1935 and again in 1969 at 29° N. latitude. Other synthetic storms of different frequency and CPI are derived from the SPH. With the exception of the PMH, other CPI's for desired frequencies are obtained from the graph shown on plate B-14. V_{gx}'s corresponding to any other CPI are determined similarly by use of the method described for the SPH. Variations in CPI's of historic storms were accomplished by the same procedure[16]. Characteristics of synthetic storms and some historic storms are listed in table B-11.

TABLE B-11
HURRICANE CHARACTERISTICS

Hurricane	CPI inches	Radius of max. winds nautical miles	Forward speed knots	V_x m.p.h.
Sept 1915	27.87	29	10	99
Sept 1956	28.76	30	10	80
Sept 1965	27.79	32	20	122
PMH	26.9	30	11	146
SPH	27.5	30	11	100
Mod H	28.3	30	11	83

d. Surges.

(1) Maximum hurricane surge heights for the study area were obtained from computations made for ranges extending from the shore out to the continental shelf by use of a general wind tide formula that is based on the steady state concept of water superelevation[4] [18] [19]. In order to reach agreement between computed maximum surge heights and observed high-water marks, it was necessary to introduce a calibration coefficient or surge adjustment factor into the general equation which, in its modified form, is as follows:

$$S = 1.165 \times 10^{-3} \frac{V^2F}{D} N Z \cos\theta$$

where S = wind setup in feet
V = windspeed in statute miles per hour
F = fetch length in statute miles
D = average depth of fetch in feet
θ = angle between direction of wind and the fetch
N = planform factor, generally equal to unity
Z = surge adjustment factor

(2) Water surface elevations along a range were determined by summation of incremental wind setup above the water elevation at the gulf end of the range. Initial elevation at the beginning of each range was determined from predicted normal tide and the setup due to atmospheric pressure anomaly. Typical tidal cycles for the project area are shown on plate B-15. An adjustment was made at the shoreward end of the range to compensate for the difference in pressure setup between both ends of the range. This procedure for the determination of surge heights at the coastline was developed for an area along the Mississippi gulf coast where reliable data were available at several locations for more than one severe hurricane. The procedure was then used for the entire coastal Louisiana region. Due to dissimilar shoreline configurations, different surge adjustment factors were required at each location, but identical factors were used at a particular location for each storm. The value of the factor is apparently a function of the distance between the shoreline and deep water and varies inversely with this distance. Comparative computed maximum elevations and observed high-water elevations for the locations of the 1915 and 1947 hurricanes that were used in the development of the procedure are shown in table B-12.

TABLE B-12
HURRICANE SURGE HEIGHTS

Location	Surge adjustment factor (Z)	1915 Observed (feet m.s.l.)	1915 Computed (feet m.s.l.)	1947 Observed (feet m.s.l.)	1947 Computed (feet m.s.l.)
Bay St.Louis, Miss.	0.46	11.8	11.8	15.2	15.1
Gulfport, Miss.	0.60	10.2[1]	9.9	14.1	14.3
Biloxi, Miss.	0.65	10.1[1]	9.8	12.2[1]	12.6

[1]Average of several high-water marks.

(3) The incremental step computation was used to check experienced maximum surge heights and establish the surge adjustment factor. For hurricanes critical to Grand Isle from the Gulf of Mexico, the surge adjustment factor was determined to be 0.80. Verification of surge heights for Grand Isle are shown in table B-13.

TABLE B-13
VERIFICATION OF HURRICANE SURGE HEIGHTS

	Surge adjustment factor	Sept 1915 Observed (feet m.s.l.)	Sept 1915 Computed (feet m.s.l.)	Sept 1956 Observed (feet m.s.l.)	Sept 1956 Computed (feet m.s.l.)	Sept 1965 Observed (feet m.s.l.)	Sept 1965 Computed (feet m.s.l.)
Grand Isle	0.80	9.0	8.8	3.9	4.1	8.8	9.6

(4) The computed surge height for Hurricane Betsy, September 1965, using the Z factor for Grand Isle, was 0.8 foot higher than the observed surge height. This apparently was the effect of the high forward speed of Betsy. A fast-moving hurricane does not allow enough time for the surge heights to approach the steady state of water superelevation [4] [18] [19]. However, it was determined that the Z factors derived from the slow-moving hurricanes should be used for design purposes because this type of hurricane is more nearly representative of hurricanes in the project area.

(5) An example of the setup computation for one increment (ΔF) along a range radiating from a southwesterly direction to Grand Isle for an SPH at the critical hour of the hurricane is as follows:

(a) Initial elevation:

Normal pressure	= 30.14 inches of mercury
Pressure at beginning of range, 98 miles from center	= 29.35 inches of mercury
Deviation from normal pressure	= 0.79 inch of mercury
Pressure setup 0.79 x 1.14 feet	= 0.90 foot of water
Normal predicted tide	= 2.00 feet above mean low water (m.l.w.)
Initial elevation	= 2.90 feet (m.l.w.)

(b) Incremental setup (for setup between adjacent stations on range):

Sta. mile	ΔF miles	V m.p.h.	Cos θ	V^2Cos θ	Avg. V^2Cos θ	Depth feet m.l.w.	D=ΣS+ Avg.D+290 +ΔS/2	ΔS feet	ΣS feet
2.0		84	0.999	7049		20			6.11
	2.0				6639		19.33	0.64	
0.0		79	0.998	6229		0			6.75

$$S = 1.165 \times 10^{-3} \times \frac{6639 \times 2.0}{19.33} \times 1 \times 0.80 = 0.64'$$

(c) Setup for pressure differential:

Normal pressure	= 30.14 inches of mercury
Pressure at end of range, 34.5 miles from center	= 28.64 inches of mercury
Deviation from normal	= 1.50 inches of mercury
(1.50 x 1.14 feet)	= 1.71 feet of water
Deviation at beginning	= -0.90 foot of water
Differential setup	= 0.81 foot

(d) Final surge height:

Pressure setup at beginning of range	= 0.90 foot
Normal predicted tide	= 2.00 feet m.l.w.
Correction m.l.w. to m.s.l.	= -0.60 foot
S (wind setup)	= 6.75 feet
Pressure differential setup	= 0.81 foot
Surge height at shore	= 9.86 feet m.s.l.

(6) By using the method shown in paragraph 3d(5) above, a hurricane surge elevation of 9.86 feet was computed for the SPH at Grand Isle.

e. Wave runup.

(1) Wave runup on a protective structure depends on the characteristics of the structure (i.e., shape and roughness), the depth of water at the structure, and the wave characteristics. The vertical height to which water from a breaking wave will run up on a given protective structure determines the top elevation to which the structure must be built to prevent wave overtopping and resultant flooding of the area to be protected. Wave runup is considered to be the ultimate height to which water in a wave ascends on the proposed slope of a protective structure. This condition usually occurs when the surge is at the maximum elevation.

(2) The parameters which determine wave characteristics are the fetch length, the windspeed, duration of wind, and the average depth of water over the fetch. In determining the design wave characteristics, it was assumed that steady state conditions prevail; that is, the windspeed is constant in one direction over the fetch and blows long enough to create a fully developed sea. The windspeed (U) is an average velocity over the fetch (F) and is obtained from the isovel patterns for synthetic hurricanes critical to the location of interest. The depth of fetch (d) is the average surge height minus the average elevation of prominent subsurface features over the fetch.

(3) In order to compute wave runup on a protective structure, the significant wave height (H_s) and wave period (T) in the vicinity of the structure must be known. They were determined as described in paragraph 1.25 of reference (4). The windspeed and depth used in determining H_s and T are average values over a 5-mile fetch. Data used to determine design hurricane wave characteristics in the vicinity of the protective structures are shown in table B-14.

TABLE B-14
DATA USED TO DETERMINE WAVE CHARACTERISTICS
FOR DESIGN HURRICANE

Parameters	Grand Isle
F - Length of fetch	5 miles
U - Windspeed	79 m.p.h.
swl - Stillwater level	8.5 feet
d - Average depth of fetch	25.1 feet
d_t - Depth at toe of levee	11.5 feet

(4) Wave runup was calculated by use of model study data developed by Saville [20][21][22][23] which relates relative runup (R/H'_o), wave steepness (H'_o/T^2), and relative depth (d/H'_o). The significant wave height (H_s) and wave period (T) can be determined from the data in table B-15. The deepwater wave length (L_o) is determined from the equation:

$$L_o = 5.12\ T^2$$

The equivalent deepwater wave height (H'_o) can be determined from table D-1 of reference (4), which relates d/L_o to H/H'_o. When determining runup from the significant wave, H in the term (H/H'_o) is equal to H_s.

TABLE B-15
WAVE CHARACTERISTICS--DESIGN HURRICANE

		Characteristics	Grand Isle
H_s	-	Significant wave height	7.7 feet
T	-	Wave period	7.3 seconds
L_o	-	Deepwater wave length	272.8 feet
d/L_o	-	Relative depth	0.08876
H_s/H'_o	-	Shoaling coefficient	0.9436
H'_o	-	Deepwater wave height	8.2 feet
H'_o/T^2	-	Wave steepness	0.1539

(5) With the terms d/H'_o and H'_o/T^2 known, runup on a protective structure can be computed if the slope of the structure is known. The levee configurations used in these computations had stabilizing berms on the water side (see plate 3). These berms broke the continuity of the levee slope and Saville's[23] method of determining wave runup on composite slopes was used (see plate B-16). In using this method, the actual composite slope is replaced by a hypothetical single constant slope. This hypothetical slope is computed by estimating a value of wave runup and then determining the slope of a line from the point where the wave breaks to the estimated point of runup. The breaking point may be located by subtracting the breaking depth d_b from the stillwater elevation and extending the resulting elevation horizontally to intersect the composite slope. The breaking depth is determined from the equation:

$$d_b = \frac{0.667\ H'_o}{(H'_o/T^2)^{1/3}}$$

Using the slope of this line, which is the hypothetical slope, a value of runup is determined. If the value of runup determined is different from the estimated runup, the process is then repeated using the new value of runup to obtain a new hypothetical slope, which, in turn, determines a new value of runup. This process is repeated until the estimated value of runup agrees with the computed value of runup.

(6) Protective structures exposed to wave runup will be constructed to an elevation that is sufficient to prevent all overflow from the average highest 10 percent of all waves (H_{10}), the significant wave, and waves smaller than the significant wave accompanying the design hurricane. Waves larger than the H_{10} wave will be allowed to overtop the protective structures but such infrequent overtopping will not endanger the security of the structures. During the time of maximum surge height, the berms on the water side of the structures become submerged and waves of lesser height than the significant wave, but of the same period, break farther up the structure slope. Sometimes runup from these smaller waves reaches an elevation higher than that from the significant wave; therefore, runup resulting from these smaller waves must also be computed. The equivalent deepwater wave height for the smaller waves breaking on the berms was computed by the equation:

$$H_o' = \frac{1.84}{T} \left(d_b\right)^{3/2}$$

Wave characteristics used in computing runup from the significant wave and smaller waves are shown in table B-16. The height of the H_{10} wave is 1.27 times that of the significant wave(4). The method for computing runup is identical to that of the significant wave except for the difference in wave height and breaking depth.

5. FREQUENCY ESTIMATES

a. Procedure.

(1) Prior to 1900, information of record dealt primarily with loss of life and damage in the more densely populated areas, with practically no reference to water surface elevations caused by hurricanes. Only since 1900 has detailed information been available on flooding in coastal Louisiana and adjacent areas. Subsequent to the widely destructive September 1915 hurricane, Charles W. Okey, Senior Drainage Engineer, Office of Public Roads and Rural Engineering, U. S. Department of Agriculture, made a thorough survey of the coastal areas between Biloxi, Mississippi, and Palacios, Texas. The 1915 investigation is the only known area-wide study containing reliable stages prior to the investigation of Hurricane Flossy, September 1956. Recent data indicate that all localities along the Louisiana coast are about equally prone to hurricane attack.

TABLE B-16
DESIGN STILLWATER LEVEL, WAVE AND WAVE RUNUP DATA
DESIGN TRACK, GRAND ISLE

FOR SIGNIFICANT WAVE

Hour	S.W.L. ft.m.s.l.	Wind m.p.h.	Fetch miles	Av.depth feet	d_b feet	T sec.	H_0' feet	Hypothetical slope Vert. to Hor.	Runup el. ft.m.s.l.
-2	8.4	78	5	25.0	10.1	7.2	8.1	1 on 21	10.5
-1	8.5	79	5	25.1	10.2	7.3	8.2	1 on 21	10.7
+2	8.1	77	5	24.7	10.1	7.2	8.1	1 on 21	10.2
+4	6.6	77	5	23.2	9.7	7.0	7.8	1 on 23	8.4

FOR WAVE BREAKING AT ELEVATION 3.0 FEET M.S.L.

Hour	S.W.L. ft.m.s.l.	Wind m.p.h.	Fetch miles	Av.depth feet	d_b feet	T sec.	H_0' feet	Hypothetical slope Vert. to Hor.	Runup el. ft.m.s.l.
-2	8.4	78	5	25.0	5.4	7.2	3.2	1 on 29	9.2
-1	8.5	79	5	25.1	5.5	7.3	3.3	1 on 28	9.4
+2	8.1	77	5	24.7	5.1	7.2	2.9	1 on 31	8.9
+4	6.6	77	5	23.2	3.6	7.0	1.8	1 on 33	7.2

(2) A procedure was developed to establish synthetic stage-frequency relationships for the study area. A sufficient number of observed hurricane stages are available at Grand Isle from which a dependable observed stage-frequency curve was computed for comparison with the results of the synthetic method. Probabilities for historical data on the curve shown on plate B-17 were calculated by means of the formula:

$$P = \frac{100\ (M - 0.5)}{Y}$$

(3) The first requirement in the development of synthetic frequency relationships within the project area was to select representative critical hurricane tracks for the particular locale in question. A track from the south was selected as the critical track for Grand Isle. (See plate B-13). In the process of formulating synthetic frequency relationships, it was necessary to correlate the following hurricane parameters: central pressure indexes, tracks of approach, wind velocities, radii to maximum winds, and forward speeds of translation.

(4) Surge heights were then developed for four storms of different CPI values. Each hurricane was assumed to have the same radius of maximum winds, the same forward speed of translation, and the same adjustment for any land effects. Conversion of wind fields of hurricanes of different CPI's requisite to computing surge heights is covered in paragraph 3c(1). Surge heights for storms with other CPI values were obtained graphically by plotting the above data and reading from the resulting curve.

(5) Hurricane characteristics of area-representative storms were developed in cooperation with the Weather Service. This agency has made a generalized study of hurricane frequencies for a 400-mile zone along the central gulf coast, Zone B, from Cameron, La., to Pensacola, Fla., and has presented the results in two memorandums (12)(15). Frequencies for hurricane central pressure indexes that were presented in the report, as shown on plate B-14, reflect the probability of hurricane recurrence from any direction in the mid-gulf coastal area. In order to establish frequencies for the localities under study, it was assumed that a hurricane whose track is perpendicular to the coast will ordinarily cause high tides and inundation for a distance of about 50 miles along the coast. Thus, the number of occurrences in the 50-mile subzone would be 12.5 percent of the number of occurrences in the 400-mile zone, provided that all hurricanes traveled in a direction normal to the coast. However, the usual track is oblique to the shoreline as shown in table B of Memorandum HUR 7-97(15). The average projection along the coast of this 50-mile swath for the azimuths of 48 Zone B hurricanes is 80 miles. Since this is 1.6 times the width of the normal 50-mile strip affected by a hurricane, the probability of occurrence of any hurricane in the 50-mile subzone would be 1.6 times the 12.5 percent or 20 percent of the probability for the entire mid-gulf Zone B. Thus, 20 percent

of the Zone B frequencies shown on plate B-17 were used to represent the CPI frequencies in the 50-mile subzone that is critical for each study locality.

(6) The azimuths of tracks observed in the vicinity of landfall were divided into quadrants corresponding to the four cardinal points. In Zone B, 29 tracks were from the south, 15 from the east, 3 from the west, and 1 from the north. This indicates that approximately two-thirds of all experienced hurricanes have come from a southerly direction whereas about one-third has come from the east. The average azimuth of tracks from the south is 180° and tracks from the east had an average azimuth of 117°, while the average azimuth of all tracks is 160°.

(7) The location and physical features of Grand Isle are conducive to critical stages for a hurricane approaching from any direction. Therefore, the full 20 percent of the probabilities for mid-gulf Zone B was used for computing synthetic frequencies. Table B-17 illustrates the synthetic stage-frequency computation for Grand Isle.

TABLE B-17
SYNTHETIC STAGE-FREQUENCY
GRAND ISLE

		Frequency*	
CPI	Surge height	Zone B (400 miles)	Grand Isle (50-mile subzone)
in.	ft. m.s.l.	occ/100 years	occ/100 years
(1)	(2)	(3)	(4)
27.5	9.86	1	0.2
27.8	9.48	2	0.4
28.3	7.93	10	2.0
29.0	5.06	40	8.0

$$\text{*Frequency} = \frac{100}{\text{Return period in years}}$$

Col. (4) = 20 percent of Col. (3)

(8) The synthetic frequency curve for Grand Isle was shifted to the experienced frequency plot, maintaining as nearly as possible its general shape. Plate B-18 is a graphical presentation of the shift.

b. Relationships. Based on the above-described procedures, the stage-frequency relationship was established for Grand Isle.

6. WAVE ENERGY-FREQUENCY ESTIMATES

a. Procedure.

(1) Frequency determinations. Since Grand Isle is subject to wave attack from both its gulf and bay sides, it was necessary to develop separate wave energy-frequency curves. The development of a synthetic stage-frequency curve for Grand Isle was discussed in paragraph 5. The wave energy for the peak stage produced by each of these synthetic hurricanes was computed by procedures outlined in paragraph (2) below and then plotted at the frequency corresponding to this peak stage shown on the stage-frequency curve. Frequency estimates of the wave energy for the back side of Grand Isle were obtained by multiplying the gulf side probabilities by 50 percent. The use of 50 percent of the gulf side probability was based on the average azimuth of all hurricanes that have crossed the Zone B coastline. The average of all azimuths was found to be 160°. The selection of the average azimuth as the criteria for determining wave energy-frequency for the Barataria Bay side of Grand Isle was based on several conditions that are necessary for generation of waves critical to the backshore area. There are two basic criteria necessary for the generation of waves critical to the backshore of Grand Isle--a superelevation of the bay's normal water surface level and subsequent hurricane winds blowing towards the backshore of the island. Without the superelevation of the water surface level of the bay, the depths and fetch length available in Barataria Bay are insufficient for critical wave generation. By superimposing isovel patterns and the wind field directions associated with the synthetic hurricanes, it was found that storms having azimuths of 160° or less could not produce critical stages at Grand Isle unless these storms passed to the west of the island. A storm passing west of the island with azimuths 160° or less will have wind directions that are always blowing away from the backshore of the island. Storms with azimuths of 160° or less that pass directly over or to the east of the island cannot produce critical surge heights at Grand Isle because the projection of the Mississippi River delta into the Gulf of Mexico acts as a barrier to the storm surge, thus preventing critical stages from occurring at Grand Isle. Storms with tracks that are critical to Grand Isle cause a filling of the bay as the storm approaches the island. Winds at this time begin to blow directly onshore. As the eye of the storm passes the island, the wind direction may reverse causing critical wave generation towards the backshore of Grand Isle. The computational procedure for the bay side of the island is outlined in paragraph (2) below.

(2) Wave energy computations. In the process of determining wave energy many contributing calculations had to be performed. From prediction curves developed by C. L. Bretschneider, significant wave heights and periods for average winds and depths were determined for each of the synthetic hurricanes. These curves are given in reference (4), pages 57 through 62, and their use is explained in paragraph 1.25. For the gulf side of the island the average depths below the stillwater levels for each of the synthetic hurricanes were determined over the last 5 miles of the critical range used in generating the surges. A 5-mile fetch was used because the controlling depth in the foreshore area would cause the higher waves generated in the longer and deeper fetches to break before reaching shore. Using the criteria presented in paragraph 1.25 of reference (4) for each of the synthetic hurricanes, the deepwater wave lengths were obtained from $L_o = gT^2/2\pi$, and the equivalent deepwater significant wave heights by use of the appropriate shoaling coefficients given in Wiegel's tables, appendix D-1[(4)]. The criteria presented in paragraph 1.21 of reference (4) was used to compute the value of the forward moving wave energy, E_f, associated with the significant wave heights, H_s, for each of the synthetic hurricanes. The computational procedure used for computing wave energy on the bay side of the island was the same as used on the gulf side. The average depths below stillwater level for the bay side of the island were computed by superimposing the gulf side surge heights on the mean low-water depths existing in the bay. An effective fetch of 2 miles was used for determining significant wave heights in the bay. The average depths below stillwater level in the bay preclude using longer fetches because no significant increase in wave height can occur. The average wind velocity for the 2-mile fetch was determined by moving the isovel pattern in the direction of forward motion for the storm track until wind directions became critical to the back shore of the island.

b. Relationships. Plate B-19 shows a plot of the wave energy-frequency curves for both the gulf and bay sides of the island.

7. DESIGN HURRICANE

a. Selection of the design hurricane. Since the project area is sparsely populated, the hurricane that would produce the 50-year stage was selected as the design hurricane (Des H). A design hurricane of lesser intensity which would indicate a lower structural grade and an increased frequency would expose the protected areas to hazards to life and property that would be disastrous in the event a hurricane with the intensity and destructive capability of the Des H or the SPH occurred.

b. Characteristics. The Des H has a CPI of 28.15 inches and a maximum overwater windspeed of 87 m.p.h. at a radius of 30 nautical miles. The forward speed of the hurricane is 11 knots. The 100-year frequency hurricane, used for alternate plan C in this analysis, has a CPI of 27.8 inches and a maximum overwater windspeed of 96 m.p.h. The forward speed and the radius of the maximum winds, 130 m.p.h. and 35 miles, respectively, are identical to those of the Des H.

c. Normal predicted tide. The range of normal predicted tides in the project area is 1.2 feet. The difference in elevation of hurricane surge heights for an occurrence of the Des H at high or low tides is only a few tenths of a foot. In determining the elevation of design surge heights, it was assumed that a mean high predicted tide occurs at the initial period of surges.

d. Design tide. The hurricane surge height is the maximum stillwater surface elevation experienced at a given location during the passage of a hurricane. It reflects the combined effects of the hurricane surge, the pressure setup, and the astronomical tide. Design hurricane surge heights were computed for existing conditions.

8. DESIGN CRITERIA

a. Jetty at Caminada Pass. Tidal currents moving through Caminada Pass are the principal cause of erosion of the gulf shoreline for a distance of approximately 3,000 feet east of the pass. A study of refraction diagrams for waves approaching from the east or southeast, plate 2, indicates that littoral currents enforce the tidal flood currents near the entrance. The jetty will have two functions: (1) divert tidal currents away from the gulf shoreline east of the pass; and (2) trap littoral drift moving east to west along shore during periods when waves approach from the east or southeast. The desired effects are to retain artificial nourishment initially placed, trap and retain additional westerly drift east of the jetty, and stabilize the shoreline from the eastern lip of Caminada Pass to the vicinity of groin number one. In order to accomplish these effects, the jetty will extend from the Caminada Bay side of the island along the eastern lip of Caminada Pass and thence offshore into the gulf. The total length of jetty will be sufficient to accomplish the desired effects but should not extend offshore to a point where the jetty would interfere with the natural transfer of littoral drift from west to east across Caminada Pass. The principal entrance and exit directions of the flood and ebb tides are 295° and 120° of azimuth from north, respectively. The jetty is alined generally along the 120° azimuth measured from true north. The mean tide range is 1.2 feet above mean low water. The jetty will be constructed to +4.0 feet mean sea level datum. At mean high tide the jetty crest will be 3.6 feet above stillwater level and at spring high tide the crest will be 2.9 feet above stillwater level. The jetty will be permeable and will allow wave overtopping to occur.

b. Beach nourishment. A study of tables B-9 and B-10 indicates that the eastern 10,000 feet of the island has become stabilized to a satisfactory degree since construction of the jetty at Barataria Pass. Based on this analysis of the hydraulic regime at Caminada Pass, similar results are expected east of Caminada Pass after construction of a jetty there. This jetty will reduce the quantity of artificial nourishment needed to maintain the beach and will confine the maintenance between stations 100+00 and 327+00 along the shoreline. The maximum rate of recession shown in table B-9 for the period 1932 to 1953 within the limit of these stations is 12.5 feet per year. This period has been selected because it is representative of a period during which no severe hurricanes struck the island and no artificial nourishment was placed on the beach. An undisturbed recession rate of 12 feet per year represents 1.33 cubic yards per year per foot of beach. Because artificial nourishment is not a natural hydraulic phenomenon, the erosion rates after nourishment are likely to be locally higher than 1.33 cubic yards per foot. To compensate for this higher rate, nourishment quantities are increased 33 percent to 1.77 cubic yards per foot per year. The quantity needed for annual maintenance is 40,000 cubic yards (1.77 cu.yds./ft. times 22,700 feet) per year.

c. Frequency of nourishment. A practical frequency of nourishment would be once every 5 years initially. Experience gained during the first 5 years of operation will determine whether the frequency should be changed. The experience gained from Hurricanes Flossy, Carla, and Betsy indicates that greater quantities will be required infrequently to repair the beach. The frequency of recent storms is not representative of long-term periods. Severe hurricanes critical to Grand Isle are not likely to occur more frequently than once every 25 years. The nourishment required, plan A, to repair the beach after a severe hurricane will be approximately 500,000 cubic yards total. The fill required to repair the dune for plans B, C, and D will be an additional 500,000 cubic yards over the requirements of plan A once every 25 years on the average.

d. Design profiles.

(1) The shore protection profile was determined from a study of natural beach slopes and berm widths and elevations in the study area. The natural berm width was increased to stabilize the shoreline at a point approximately 100 feet from its present location.

(2) The hurricane protection profile was determined from an estimate of the quantity of material likely to be eroded during the occurrence of the design storm and from estimates of heights of wave runup for different dune and berm dimensions which would prevent wave overtopping of the dune through the period of maximum design storm tide elevation. The most desirable dimensions are those which provide the lowest practicable dune grade and the widest beach berm fronting the dune. The breaking point of the significant wave was placed approximately 200 feet gulfward of the dune centerline for both plans B, C, and D, so that most of the wave energy will dissipate before reaching the dune. The hurricane protection dune, for the most part, will straddle the existing dunes along the present shoreline.

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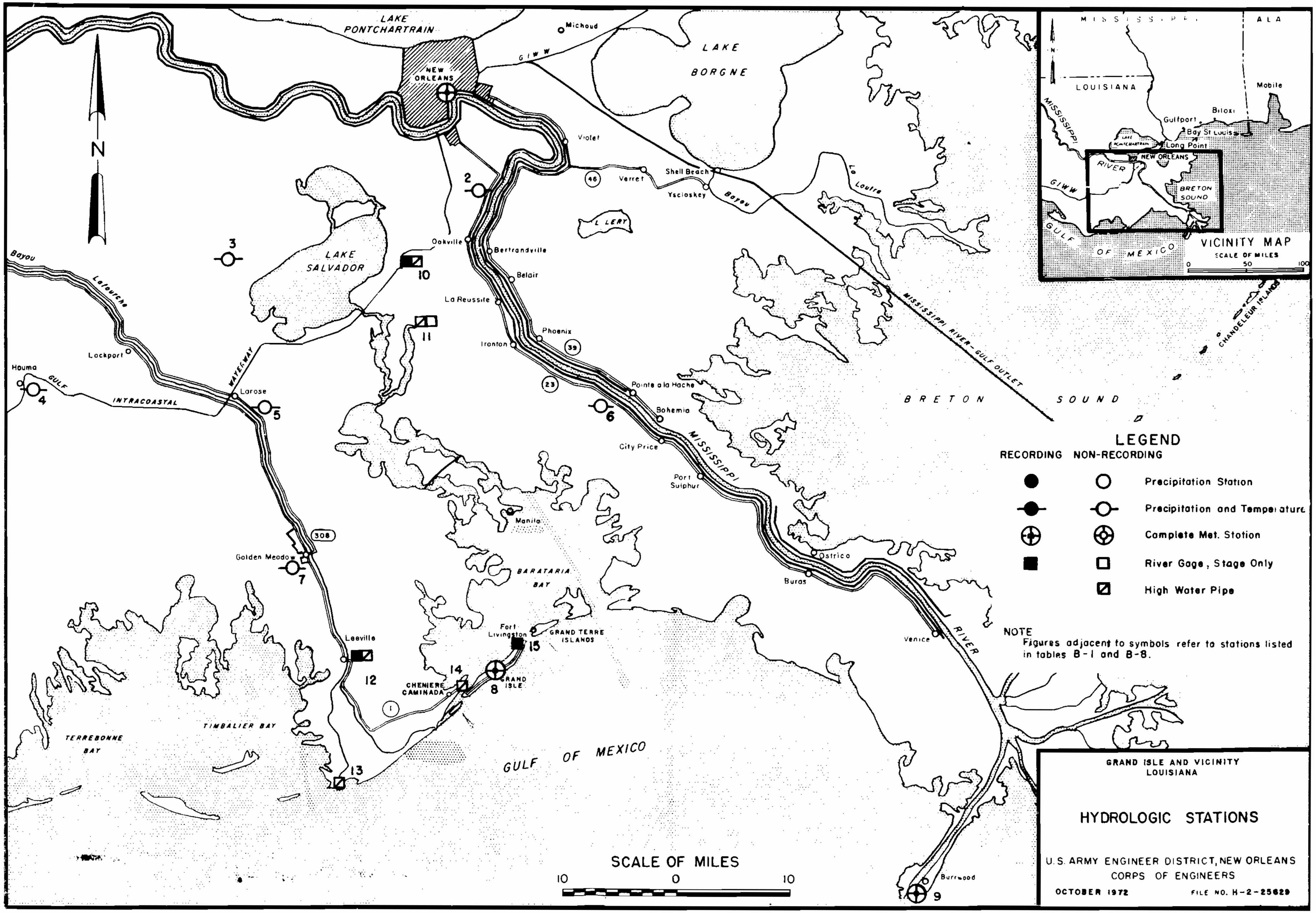
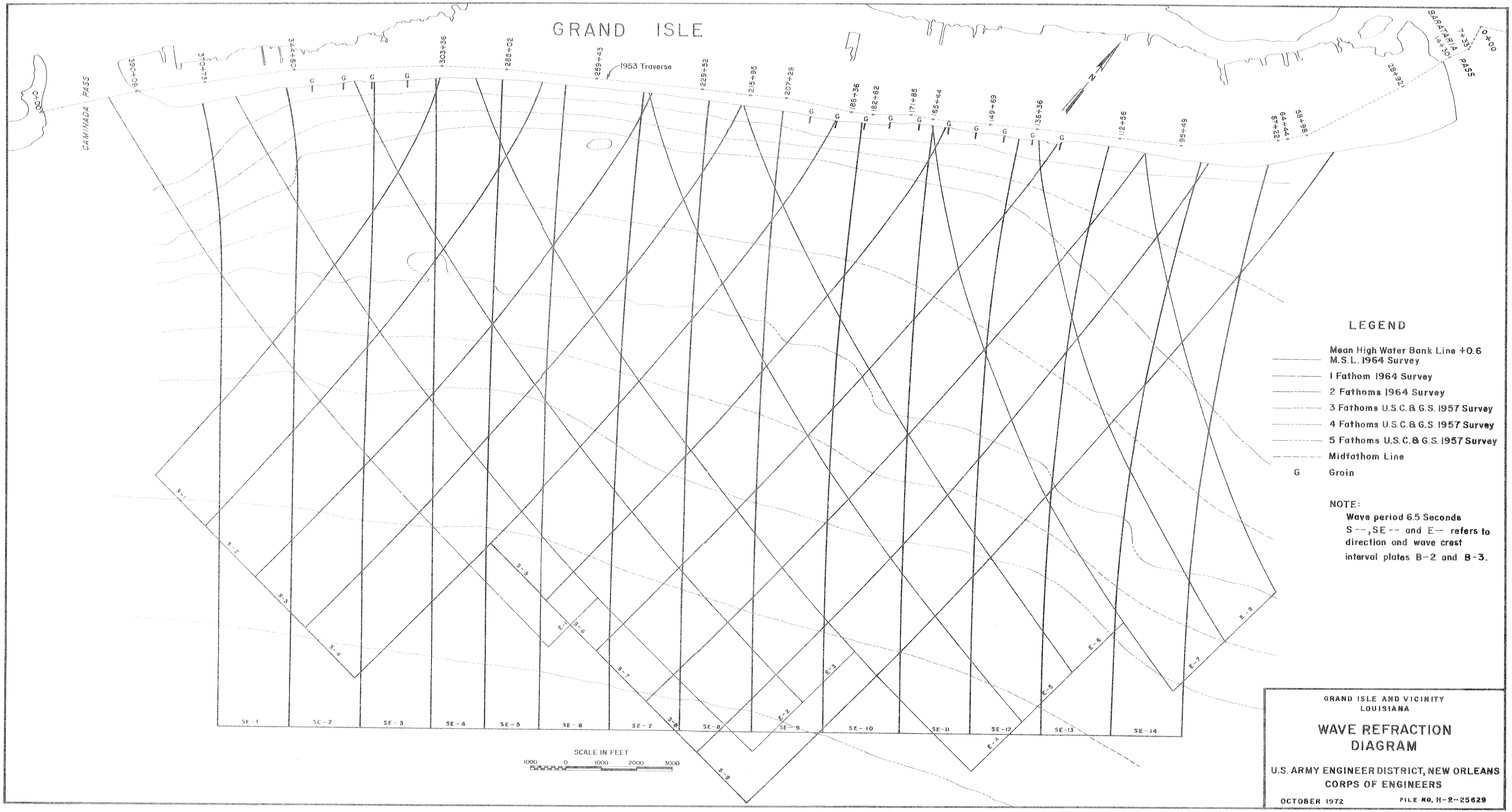


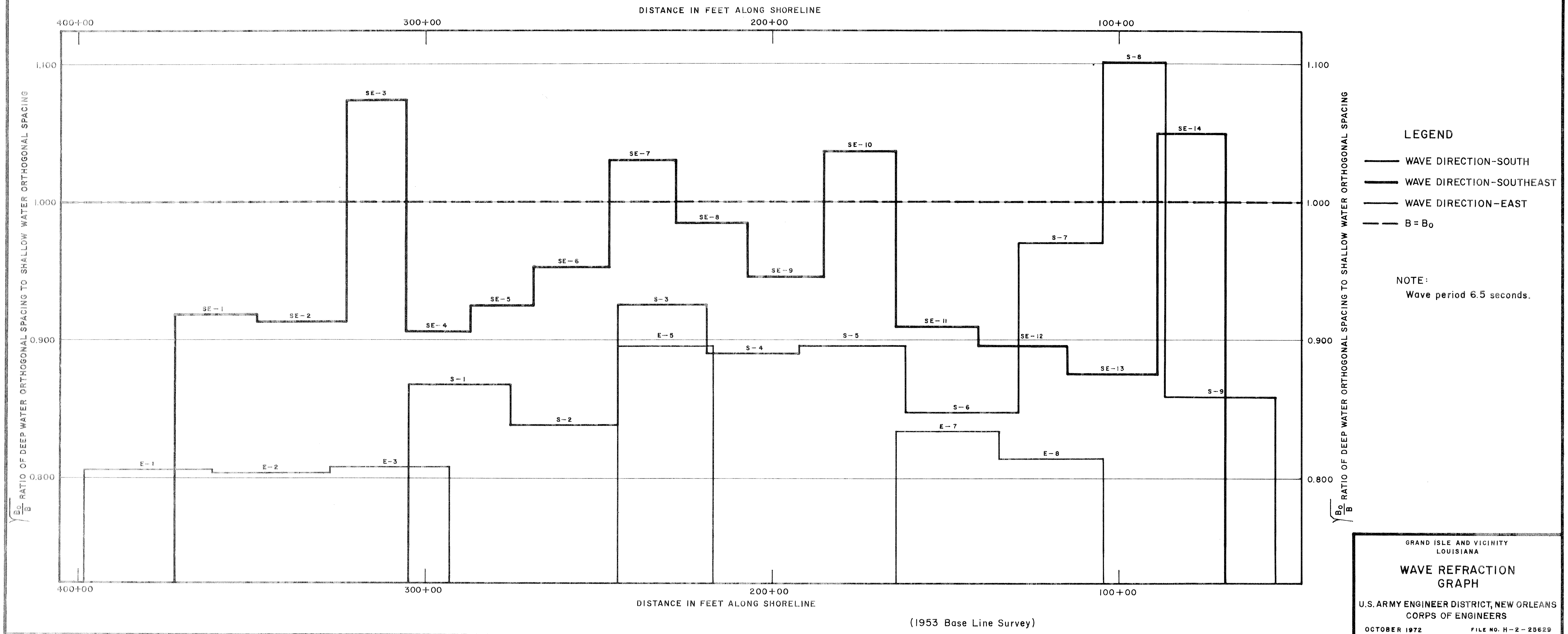
GRAND ISLE AND VICINITY
LOUISIANA

HYDROLOGIC STATIONS

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629


GRAND ISLE
CAMINADA PASS
BARATARIA PASS
1953 Traverse
N
0+00
360+06
370+75
344+60
303+36
285+02
259+43
229+52
215+95
207+29
188+36
182+62
171+85
165+44
149+69
136+36
112+56
95+49
67+22
64+44
58+98
28+92
14+30
7+33
0+00
G
S-1
S-2
S-3
S-4
S-5
S-6
S-7
S-8
S-9
E-1
E-2
E-3
E-4
E-5
E-6
E-7
E-8
SE-1
SE-2
SE-3
SE-4
SE-5
SE-6
SE-7
SE-8
SE-9
SE-10
SE-11
SE-12
SE-13
SE-14
SCALE IN FEET
1000 0 1000 2000 3000
LEGEND
Mean High Water Bank Line +0.6 M.S.L. 1964 Survey
1 Fathom 1964 Survey
2 Fathoms 1964 Survey
3 Fathoms U.S.C.& G.S. 1957 Survey
4 Fathoms U.S.C.& G.S. 1957 Survey
5 Fathoms U.S.C.& G.S. 1957 Survey
Midfathom Line
G Groin
NOTE:
Wave period 6.5 Seconds
S--, SE-- and E-- refers to direction and wave crest interval plates B-2 and B-3.
GRAND ISLE AND VICINITY
LOUISIANA
WAVE REFRACTION DIAGRAM
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
OCTOBER 1972
FILE NO. H-2-25629

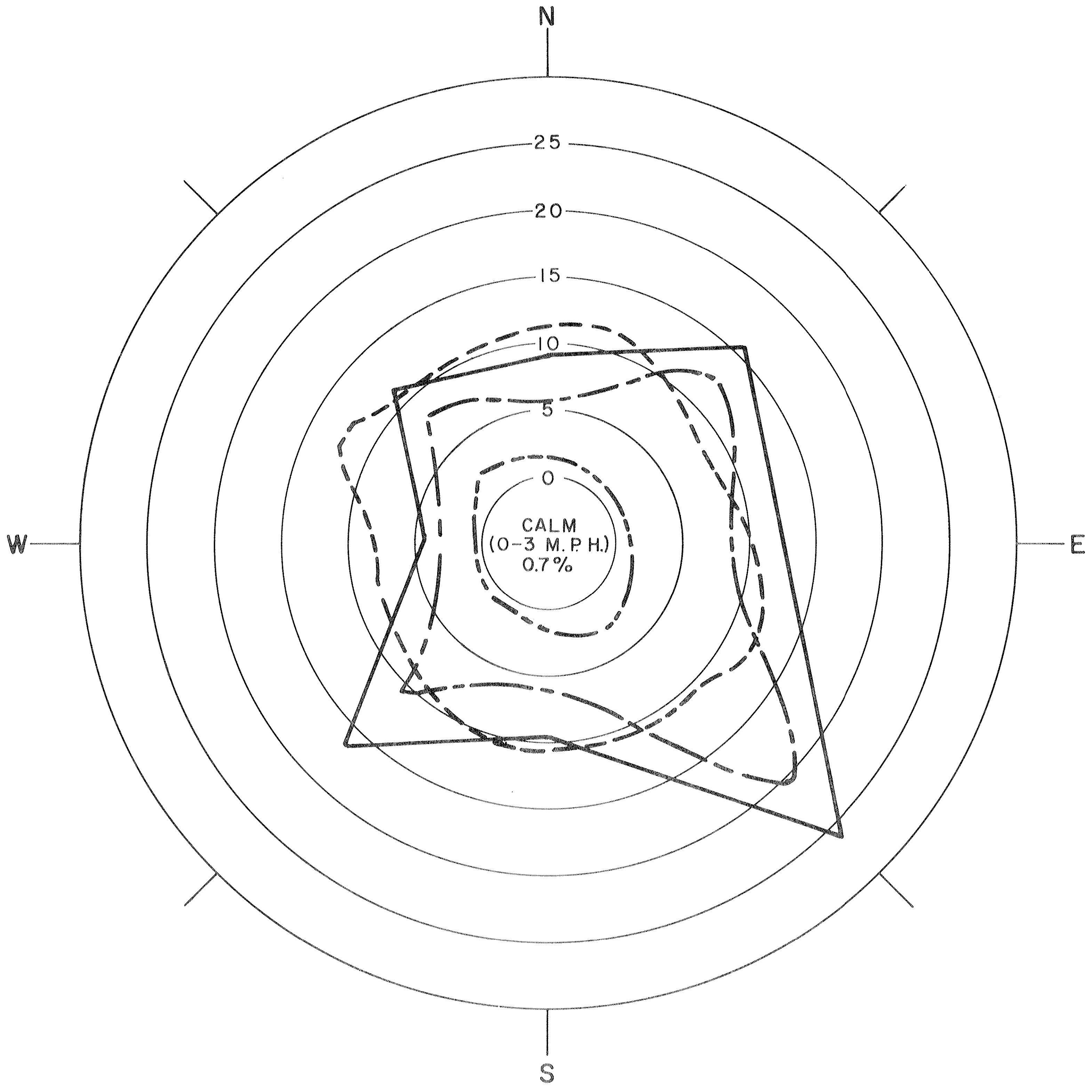


GRAND ISLE AND VICINITY
LOUISIANA

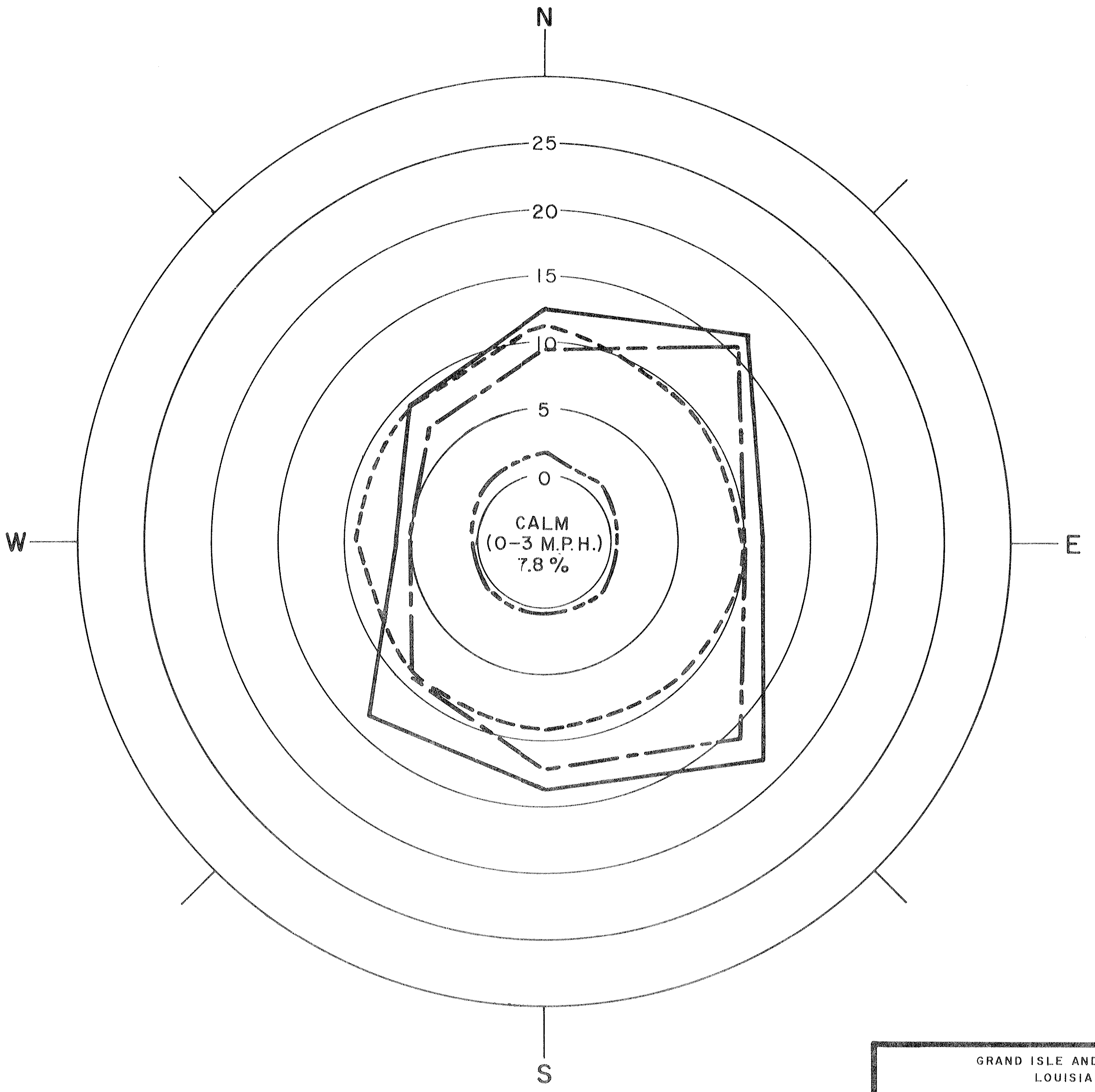
WAVE REFRACTION GRAPH

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



1944 — 1951



1960 — 1963

LEGEND

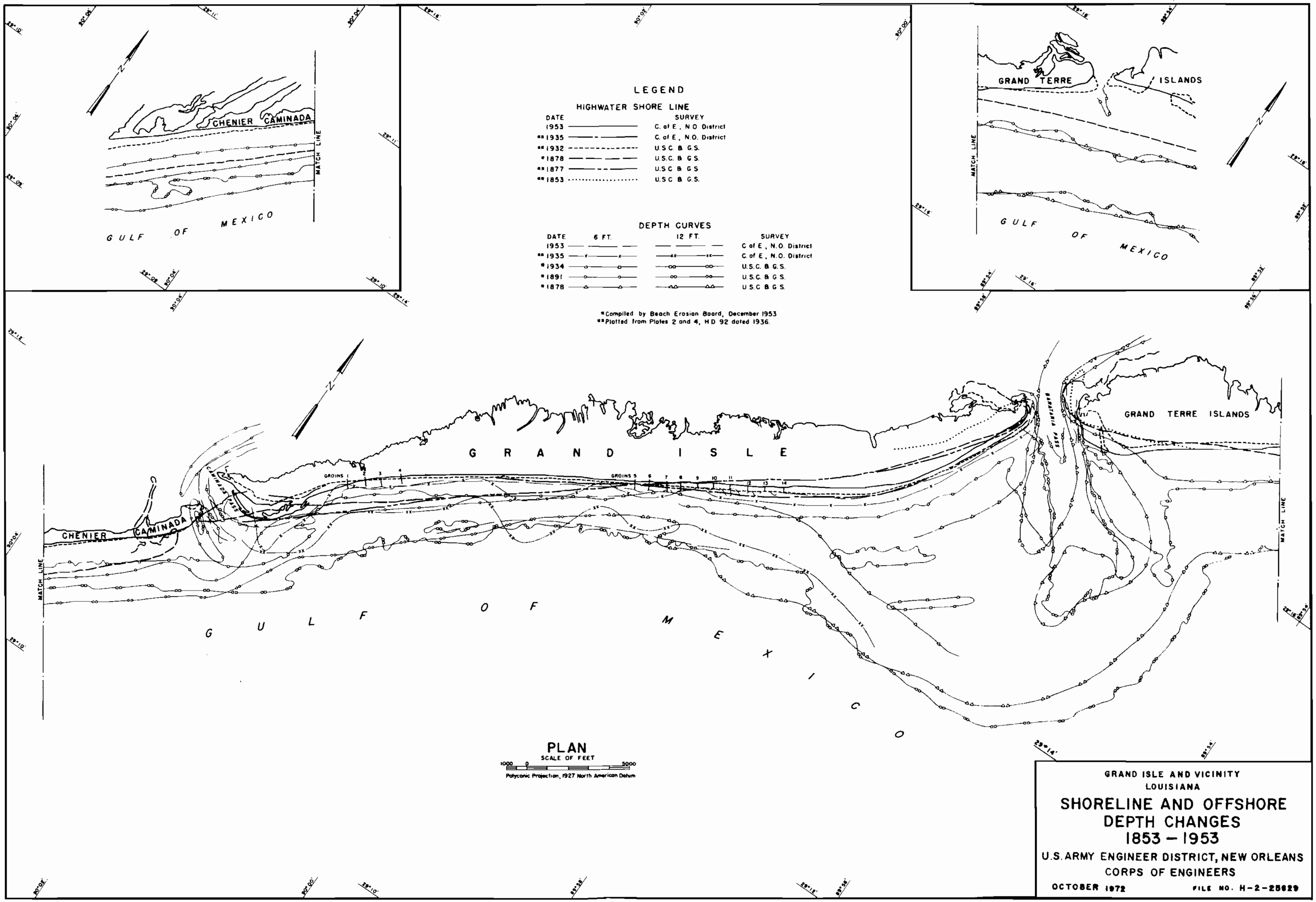
AVERAGE SPEED IN M.P.H.
WIND DURATION IN PERCENT
PERCENT OF TIME WIND BLEW 4-15 M.P.H.
PERCENT OF TIME WIND BLEW 16-31 M.P.H.

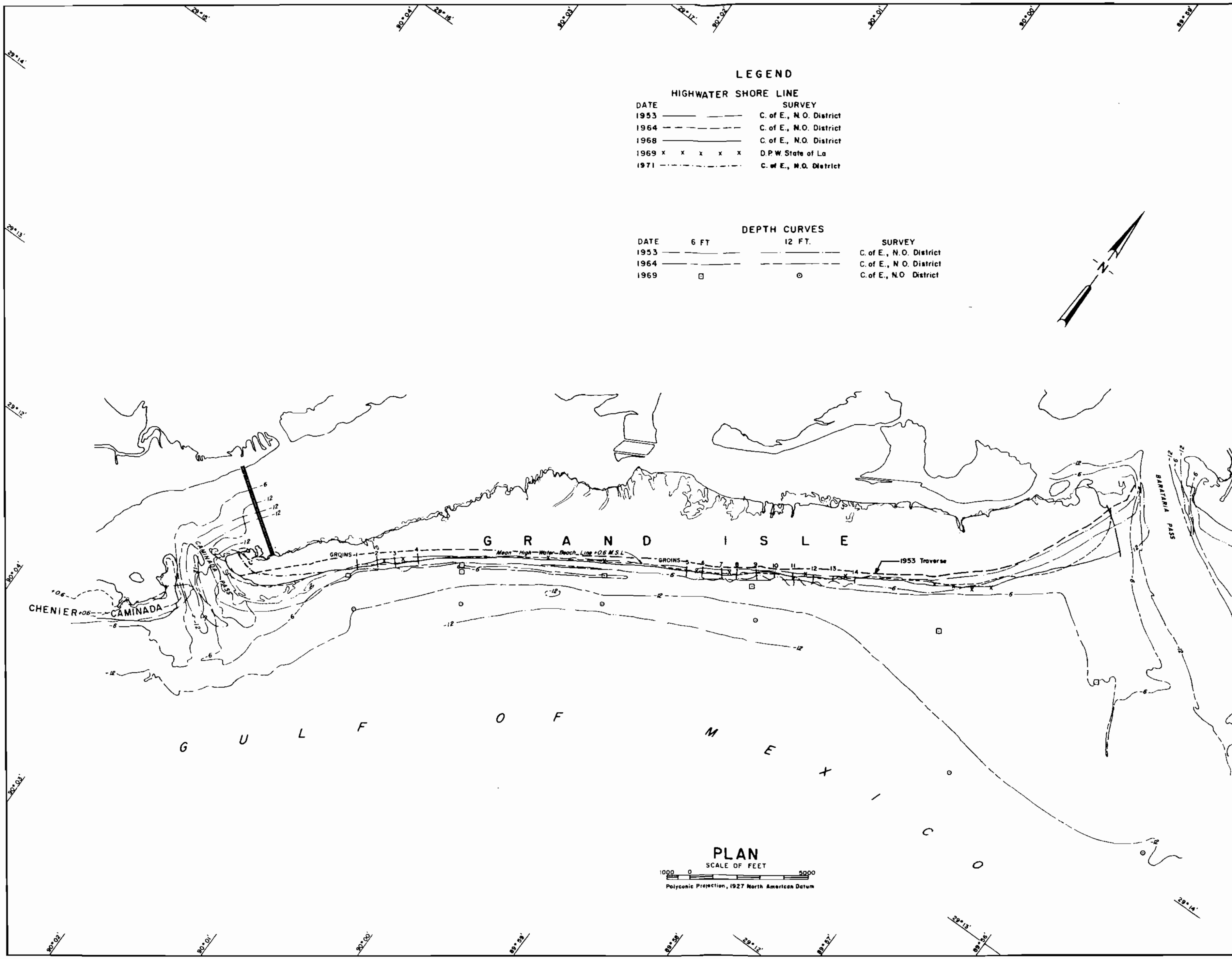
GRAND ISLE AND VICINITY
LOUISIANA

WIND ROSES
U.S. COAST GUARD STATION,
GRAND ISLE, LA.

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629


CHENIER CAMINADA
MATCH LINE
GULF OF MEXICO
GRAND TERRE
ISLANDS
MATCH LINE
GULF OF MEXICO
LEGEND
HIGHWATER SHORE LINE
DATE SURVEY
1953 C. of E., N.O. District
**1935 C. of E., N.O. District
**1932 U.S.C. & G.S.
*1878 U.S.C. & G.S.
**1877 U.S.C. & G.S.
**1853 U.S.C. & G.S.
DEPTH CURVES
DATE 6 FT. 12 FT. SURVEY
1953 C. of E., N.O. District
**1935 C. of E., N.O. District
*1934 U.S.C. & G.S.
*1891 U.S.C. & G.S.
*1878 U.S.C. & G.S.
*Compiled by Beach Erosion Board, December 1953
**Plotted from Plates 2 and 4, H.D. 92 dated 1936.
GROINS 1 2 3 4
GROINS 5 6 7 8 9 10 11 12 13 14
GRAND ISLE
CHENIER CAMINADA
CAMINADA PASS
BARATARIA PASS
GRAND TERRE ISLANDS
MATCH LINE
MATCH LINE
GULF OF MEXICO
PLAN
SCALE OF FEET
1000 0 5000
Polyconic Projection, 1927 North American Datum
GRAND ISLE AND VICINITY
LOUISIANA
SHORELINE AND OFFSHORE
DEPTH CHANGES
1853 – 1953
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
OCTOBER 1972 FILE NO. H-2-25829

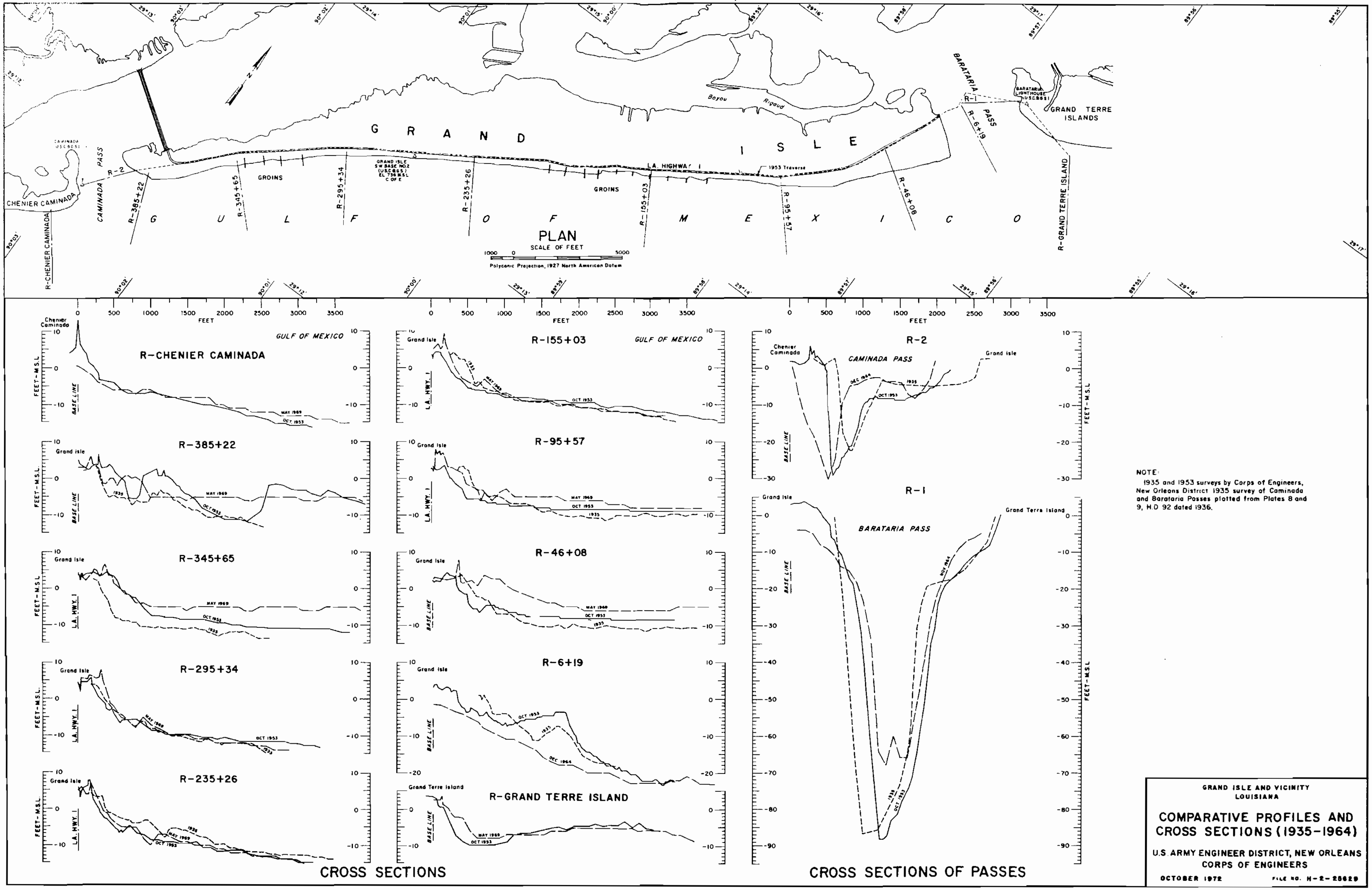


GRAND ISLE AND VICINITY
LOUISIANA

SHORELINE AND OFFSHORE DEPTH CHANGES 1953 – 1971

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



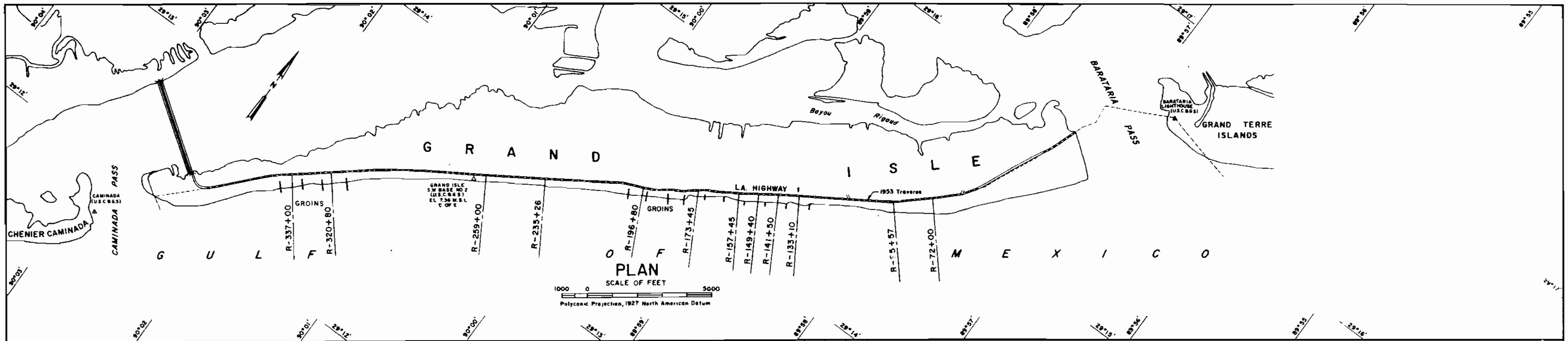
NOTE:
1935 and 1953 surveys by Corps of Engineers, New Orleans District 1935 survey of Caminada and Barataria Passes plotted from Plates 8 and 9, H.D. 92 dated 1936.

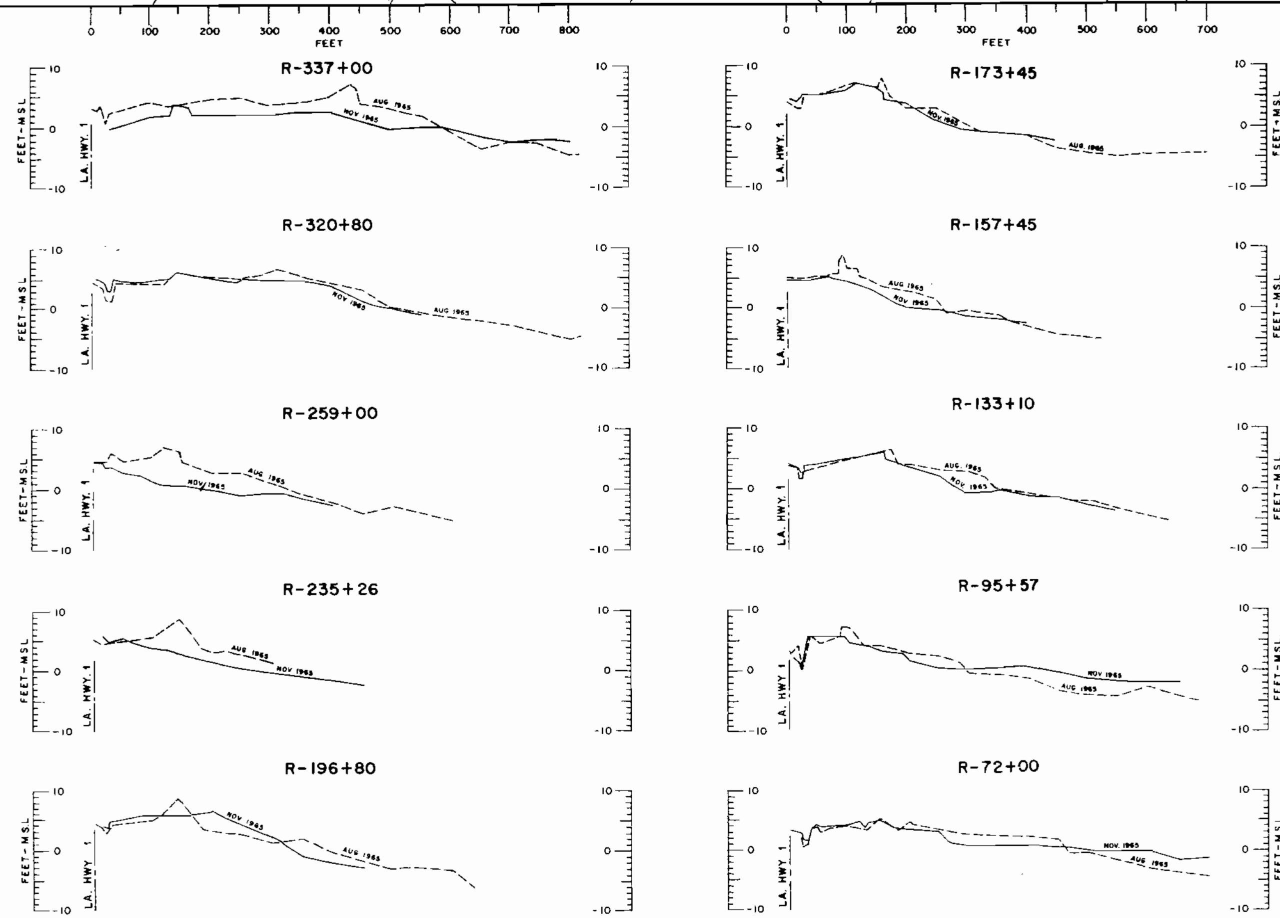
GRAND ISLE AND VICINITY
LOUISIANA

COMPARATIVE PROFILES AND CROSS SECTIONS (1935-1964)

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629





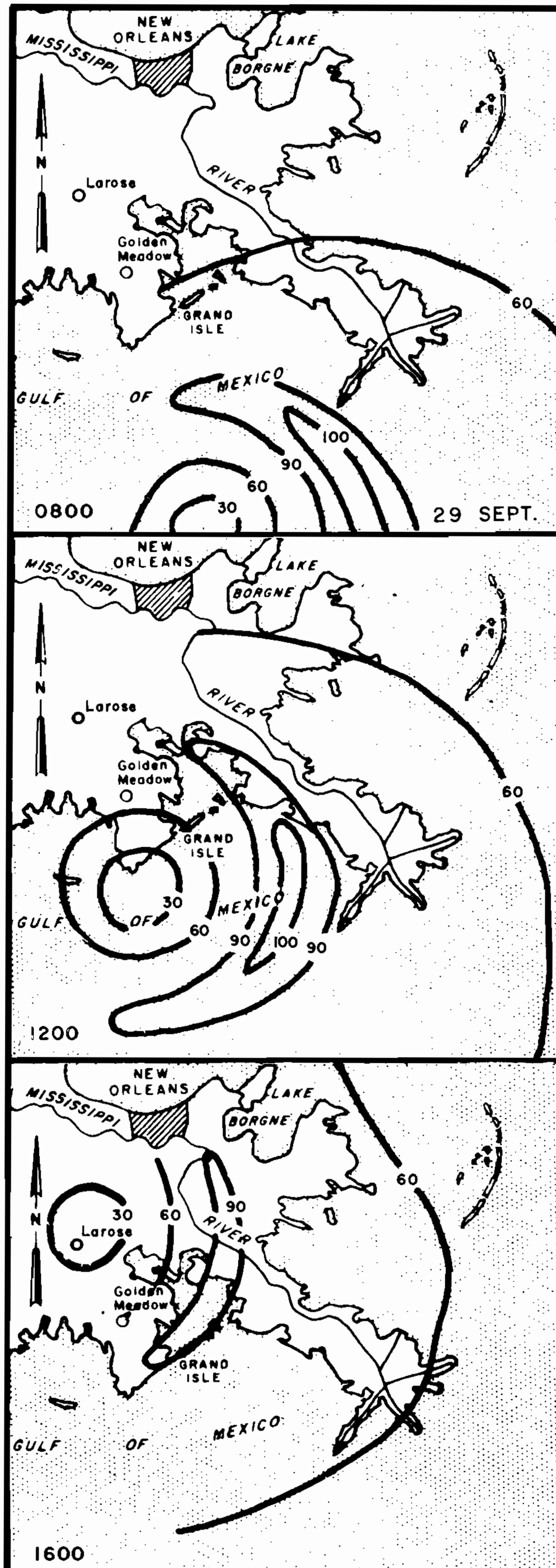
BEFORE & AFTER CROSS SECTIONS — HURRICANE "BETSY"

GRAND ISLE AND VICINITY
LOUISIANA

COMPARATIVE PROFILES AND CROSS SECTIONS (1965-1970)

U.S ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



LEGEND

30 Average Wind Velocity (MPH)

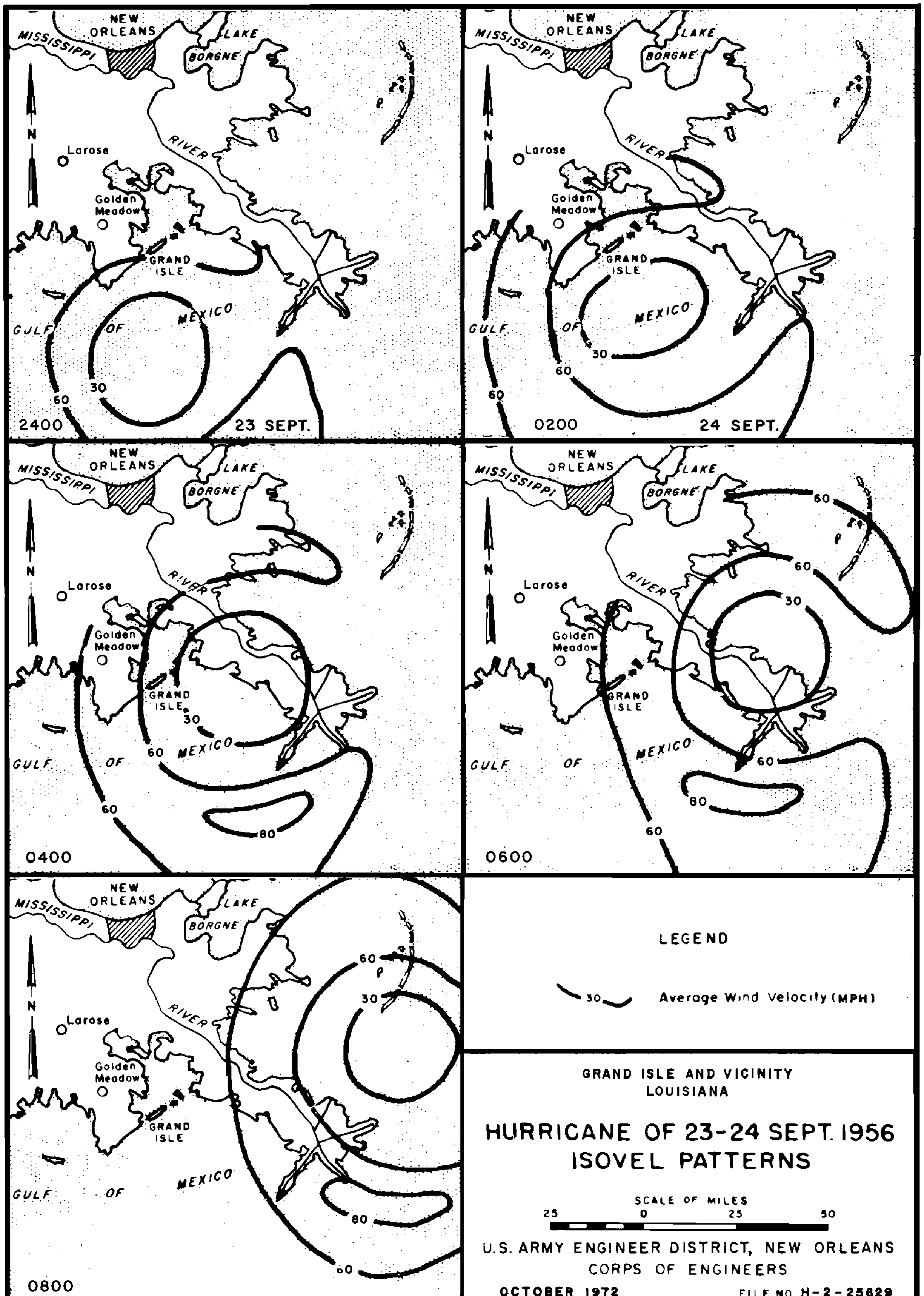
GRAND ISLE AND VICINITY
LOUISIANA

HURRICANE OF 28 SEPT.-1 OCT 1915
ISOVEL PATTERNS

SCALE OF MILES
25 0 25 50

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



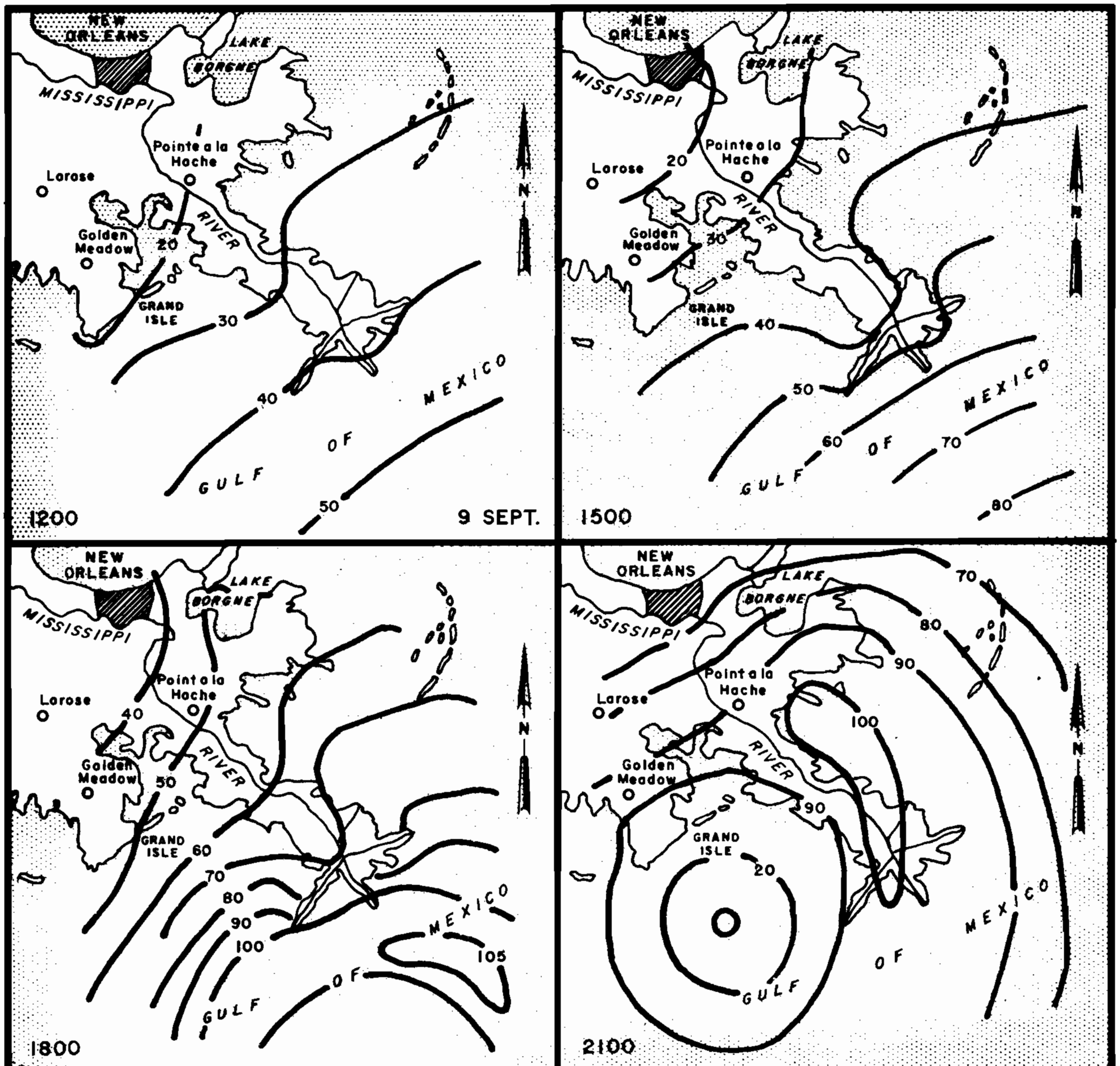
GRAND ISLE AND VICINITY
LOUISIANA

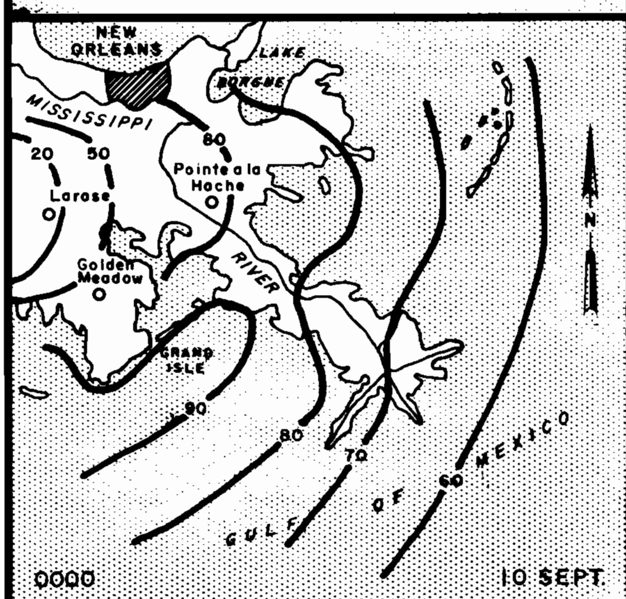
HURRICANE OF 23-24 SEPT. 1956
ISOVEL PATTERNS

SCALE OF MILES
25 0 25 50

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629





LEGEND

60 — Average Wind Velocity (Knots)

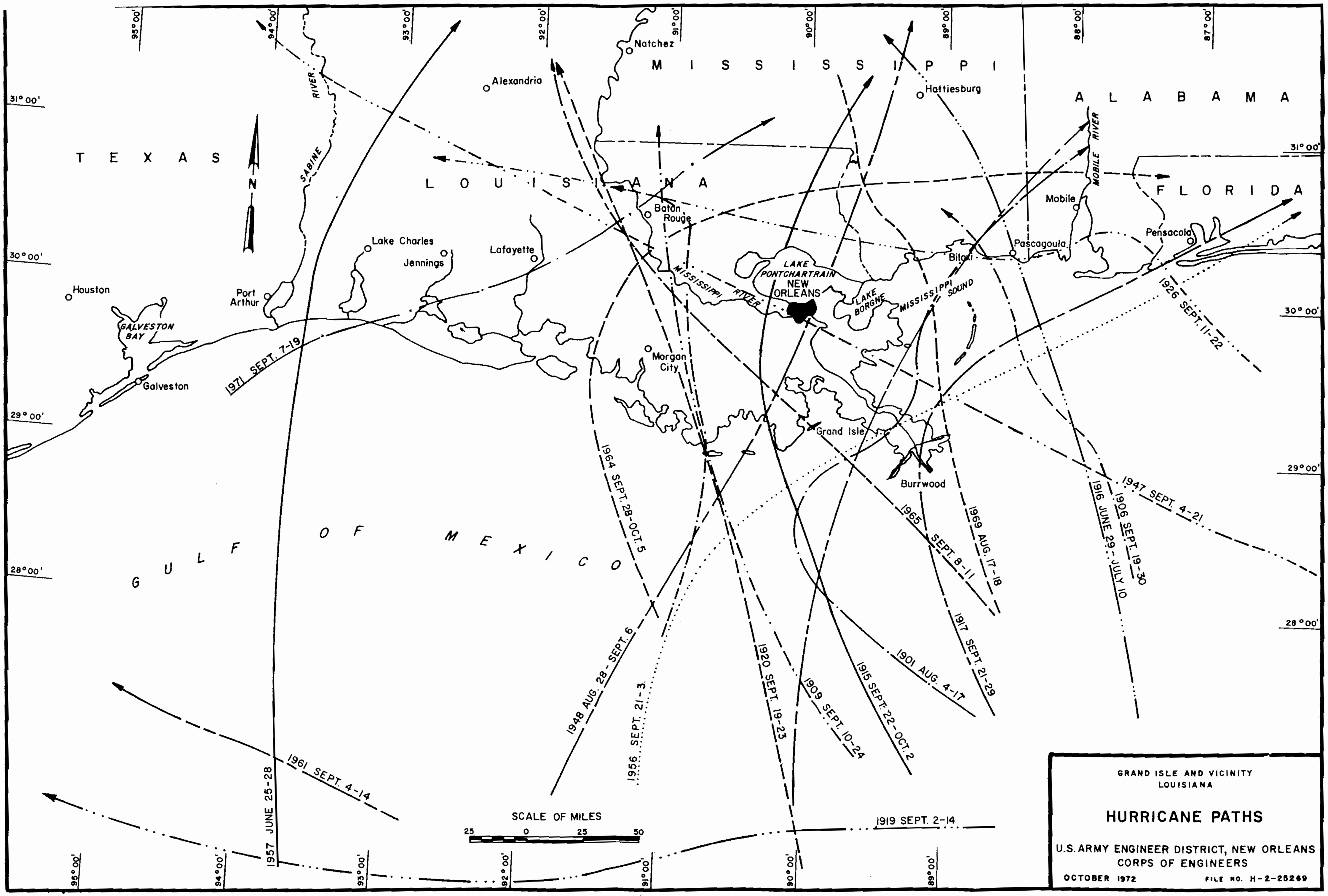
GRAND ISLE AND VICINITY
LOUISIANA

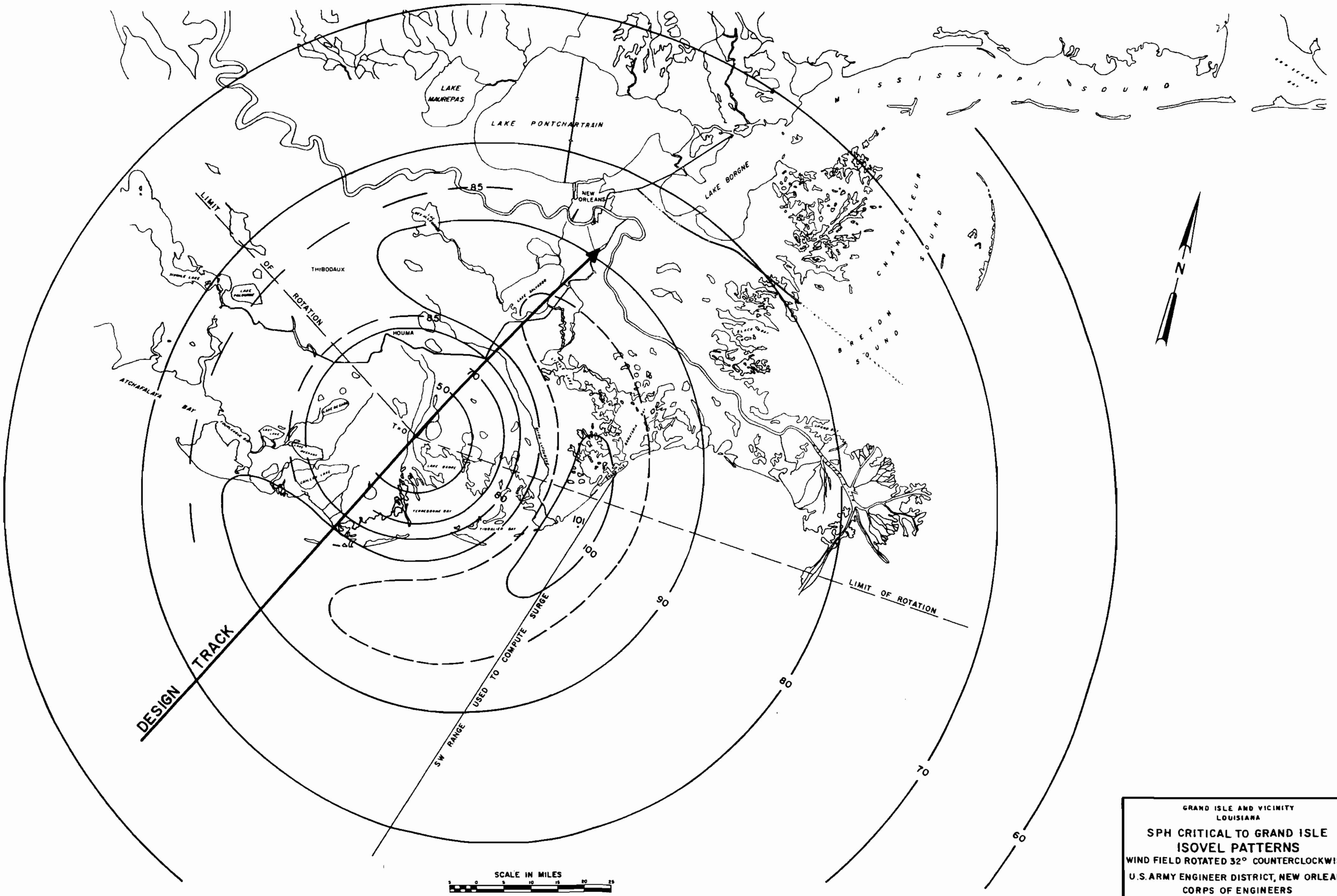
HURRICANE "BETSY"
9-10 SEPT. 1965

SCALE OF MILES
25 0 25 25

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629


GRAND ISLE AND VICINITY
LOUISIANA
HURRICANE PATHS
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
OCTOBER 1972
FILE NO. H-2-25269
TEXAS
LOUISIANA
MISSISSIPPI
ALABAMA
FLORIDA
GULF OF MEXICO
N
SCALE OF MILES
25 0 25 50
Natchez
Alexandria
Hattiesburg
Baton Rouge
Lake Charles
Jennings
Lafayette
Houston
Port Arthur
Galveston
GALVESTON BAY
Morgan City
NEW ORLEANS
LAKE PONTCHARTRAIN
LAKE BORGNE
MISSISSIPPI SOUND
MISSISSIPPI RIVER
SABINE RIVER
MOBILE RIVER
Mobile
Pascagoula
Biloxi
Pensacola
Grand Isle
Burrwood
1971 SEPT. 7-19
1957 JUNE 25-28
1961 SEPT. 4-14
1964 SEPT. 28-OCT. 5
1948 AUG. 28 - SEPT. 6
1956 SEPT. 21-3.
1920 SEPT. 19-23
1909 SEPT. 10-24
1915 SEPT. 22-OCT. 2
1901 AUG. 4-17
1917 SEPT. 21-29
1965 SEPT. 8-11
1969 AUG. 17-18
1916 JUNE 29 - JULY 10
1906 SEPT. 19-30
1947 SEPT. 4-21
1926 SEPT. 11-22
1919 SEPT. 2-14
31° 00'
30° 00'
29° 00'
28° 00'
95° 00'
94° 00'
93° 00'
92° 00'
91° 00'
90° 00'
89° 00'
88° 00'
87° 00'

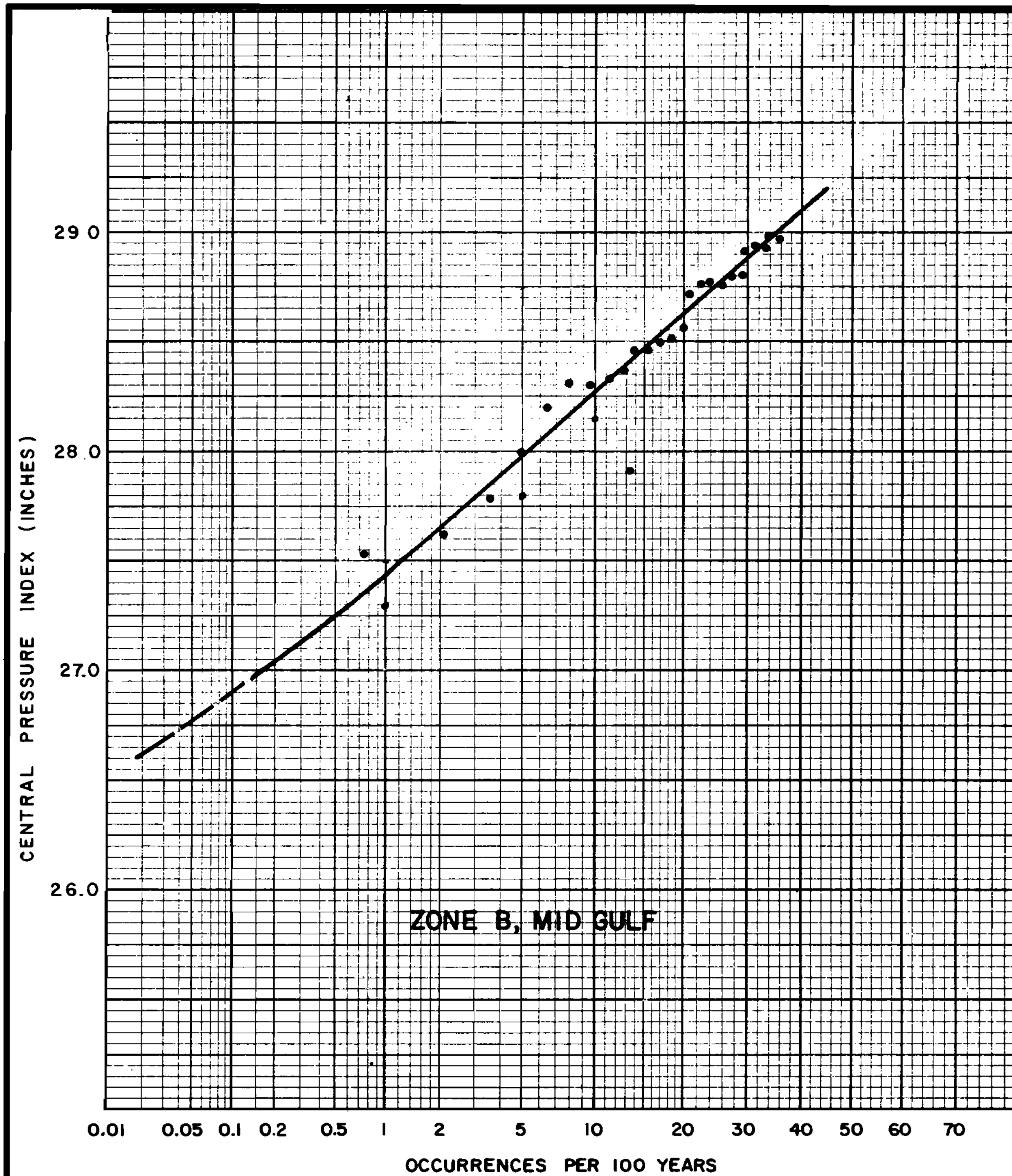


GRAND ISLE AND VICINITY
LOUISIANA

SPH CRITICAL TO GRAND ISLE
ISOVEL PATTERNS
WIND FIELD ROTATED 32° COUNTERCLOCKWISE

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

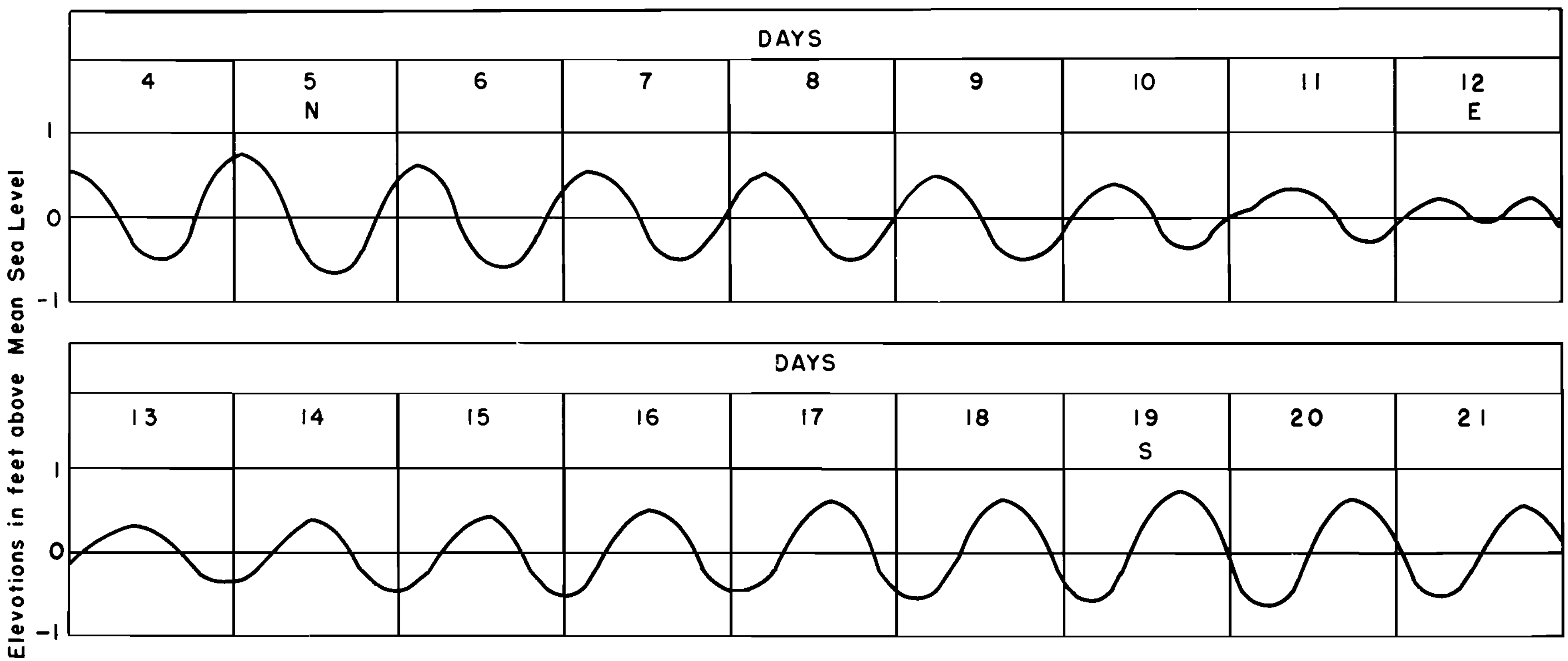


GRAND ISLE AND VICINITY
LOUISIANA

FREQUENCY OF HURRICANE CENTRAL PRESSURES ZONE B, MID GULF

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



LEGEND

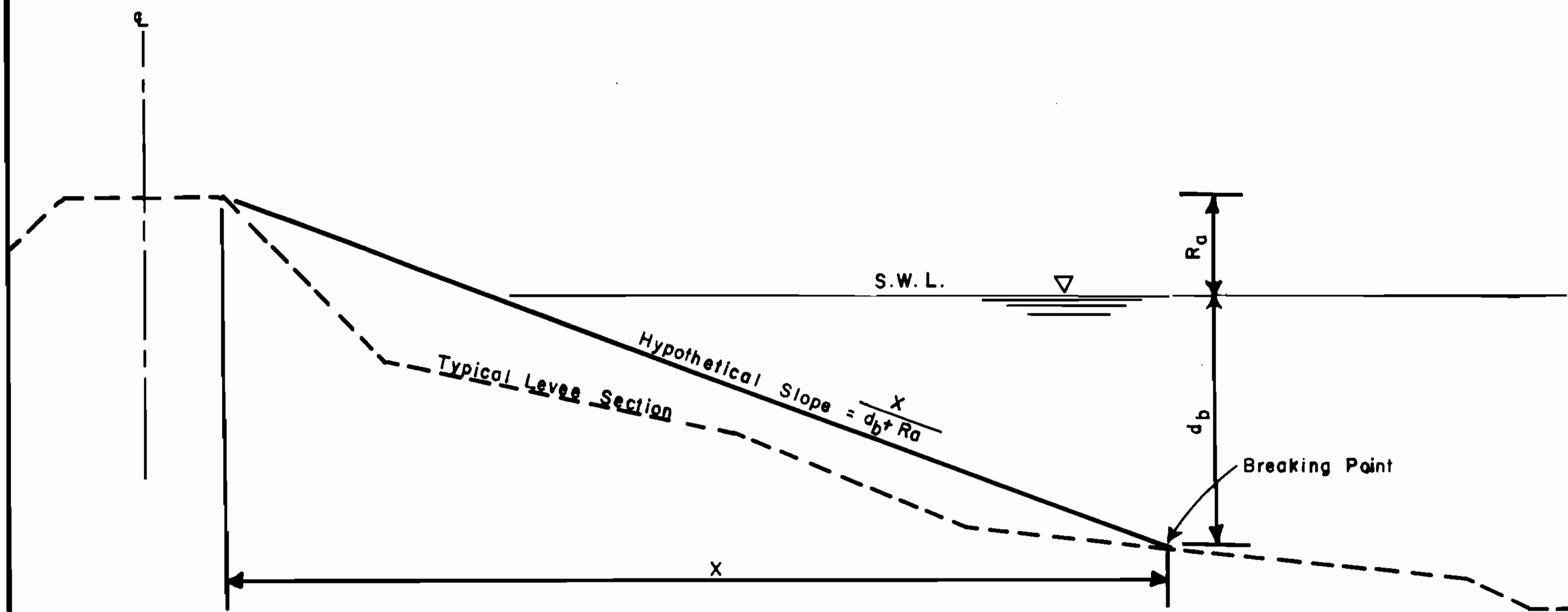
E, moon on the equator
N, S, moon farthest north or south of the equator

GRAND ISLE AND VICINITY
LOUISIANA

TYPICAL TIDAL CYCLES

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



LEGEND

R_a = assumed runup

d_b = breaking depth of wave

X = horizontal distance from breaking point to elevation at runup

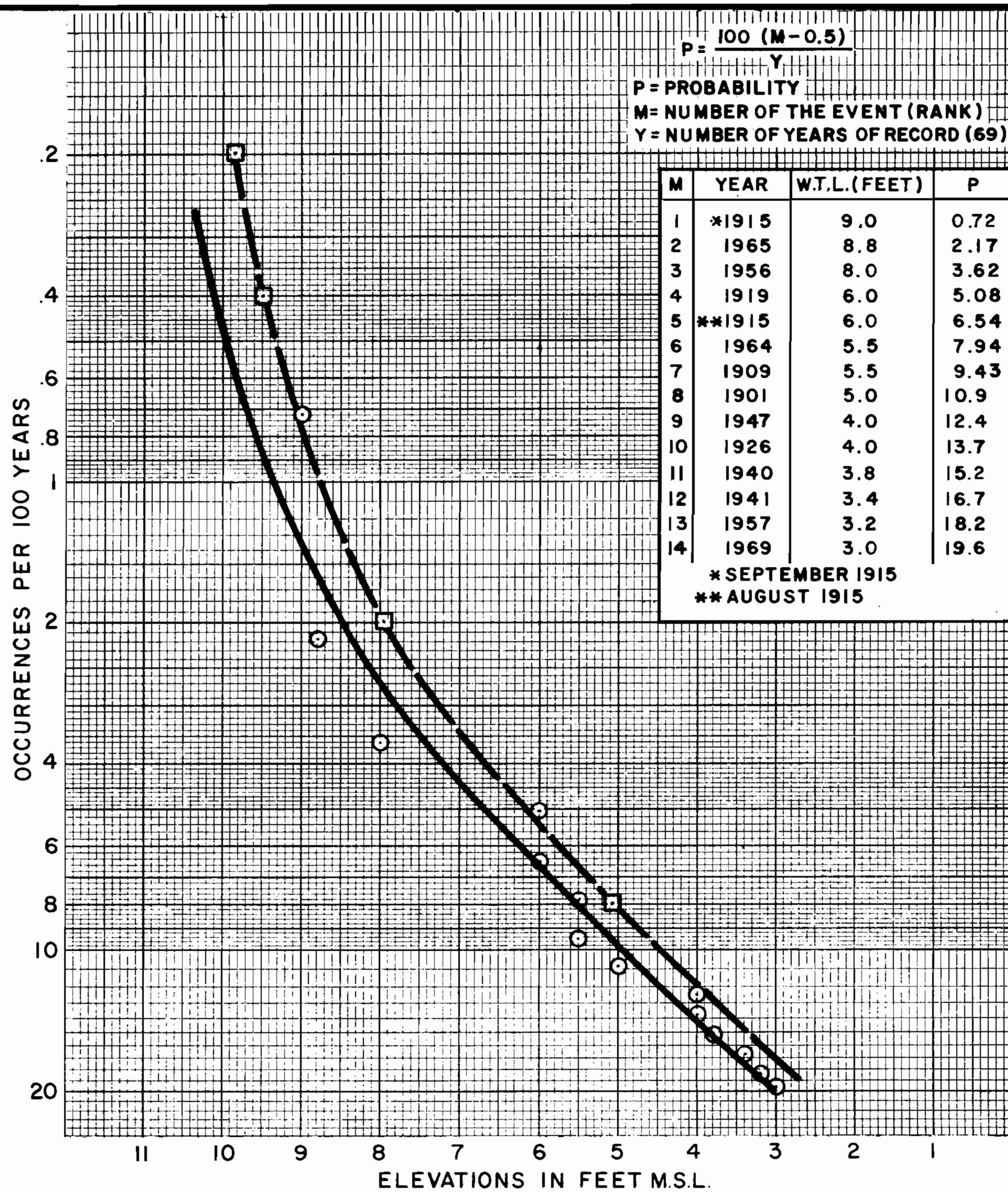
S.W.L. = stillwater level

GRAND ISLE AND VICINITY
LOUISIANA

DETERMINATION OF HYPOTHETICAL SLOPE

U.S. ARMY ENGINEER DISTRICT NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972



M	YEAR	W.T.L. (FEET)	P
1	*1915	9.0	0.72
2	1965	8.8	2.17
3	1956	8.0	3.62
4	1919	6.0	5.08
5	**1915	6.0	6.54
6	1964	5.5	7.94
7	1909	5.5	9.43
8	1901	5.0	10.9
9	1947	4.0	12.4
10	1926	4.0	13.7
11	1940	3.8	15.2
12	1941	3.4	16.7
13	1957	3.2	18.2
14	1969	3.0	19.6

*SEPTEMBER 1915
**AUGUST 1915

LEGEND

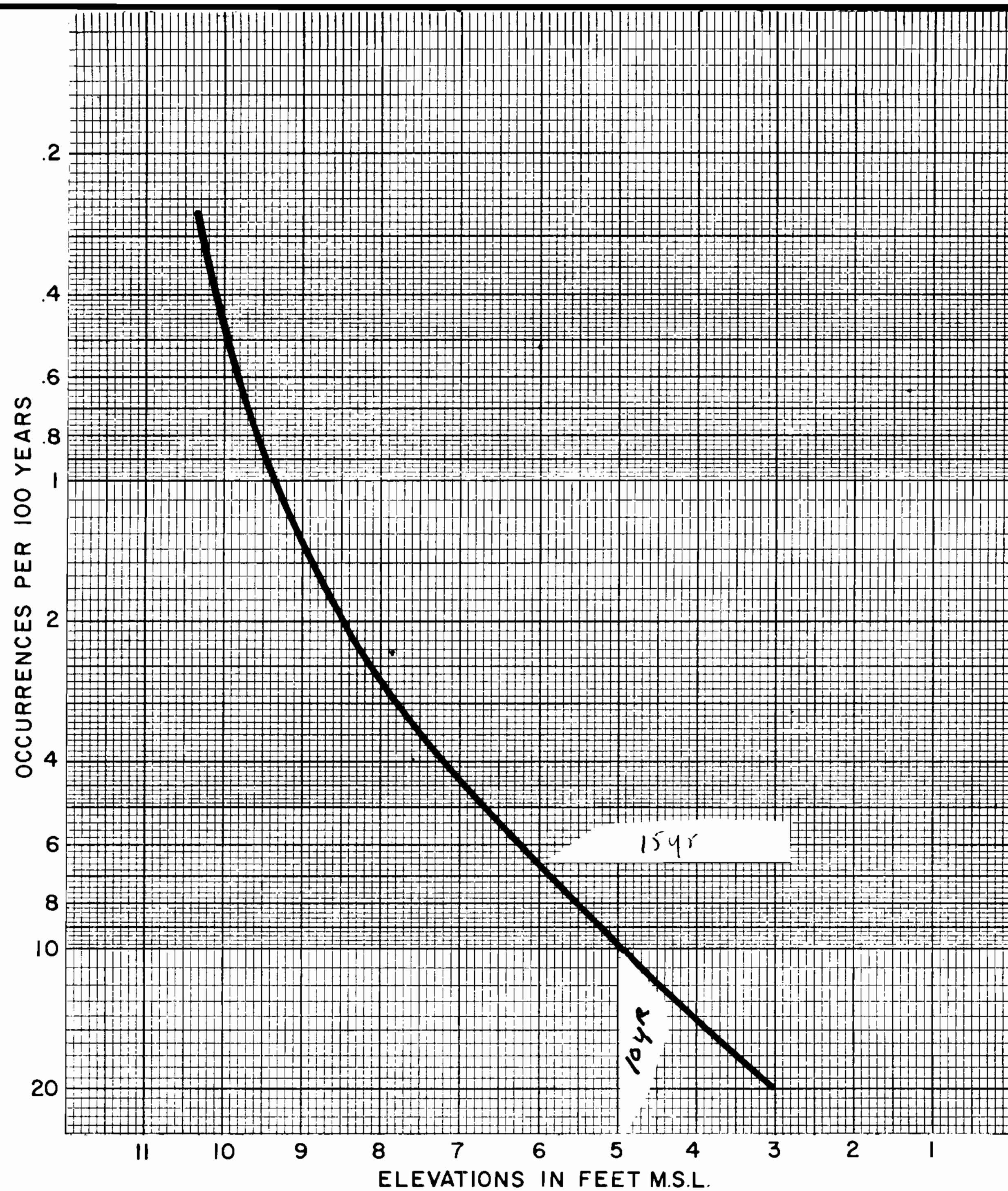
- (dashed line) SYNTHETIC STAGE FREQUENCY
- (solid line) SHIFTED TO EXPERIENCED FREQUENCY PLOT
- ⊙ EXPERIENCED STAGE FREQUENCY
- ⊡ 20% ZONE B SYNTHETIC STAGE FREQUENCY

GRAND ISLE AND VICINITY
LOUISIANA

STAGE – FREQUENCY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

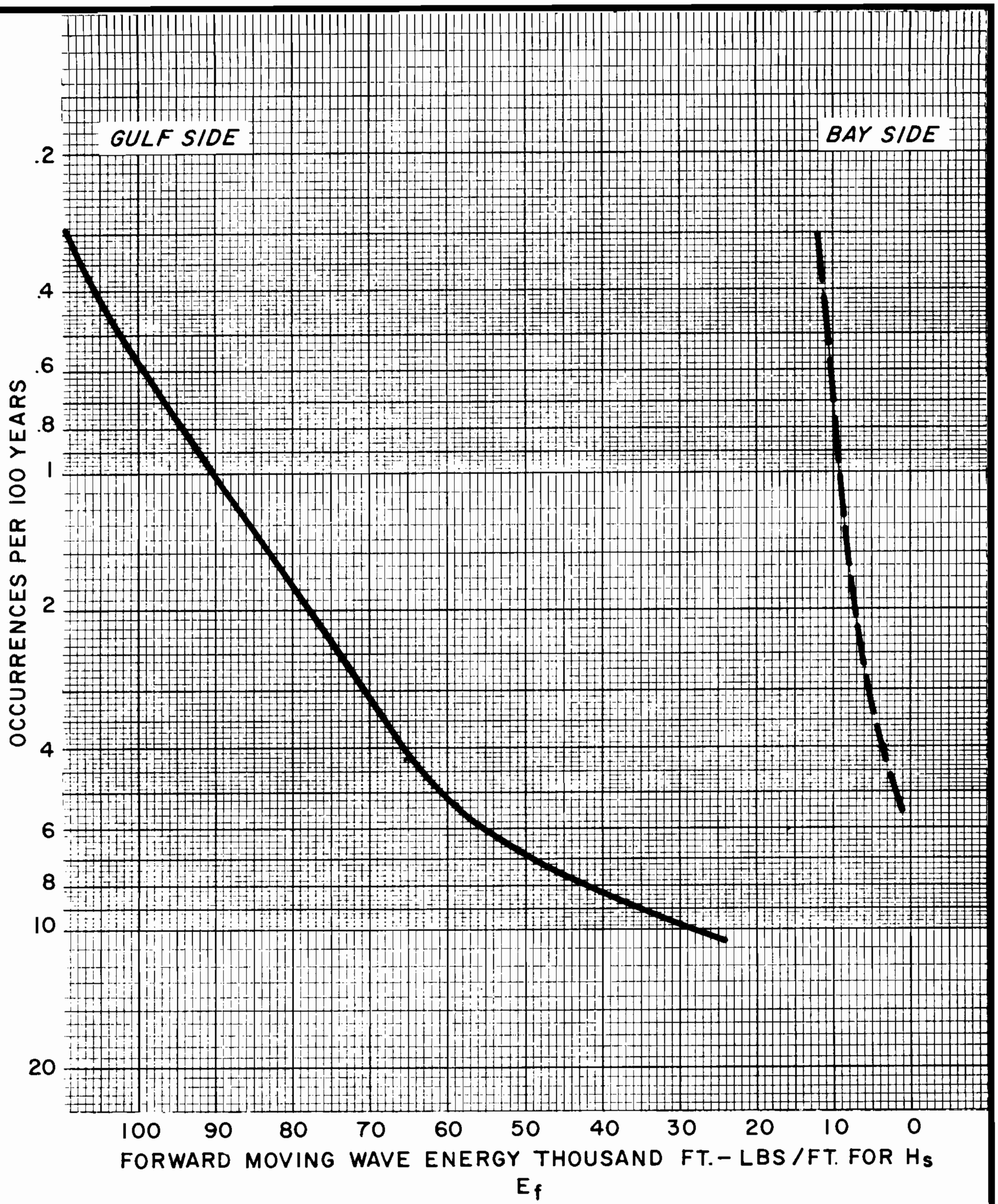


GRAND ISLE AND VICINITY
LOUISIANA

STAGE – FREQUENCY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H–2–25629



GRAND ISLE AND VICINITY
LOUISIANA

WAVE ENERGY - FREQUENCY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX C
DESIGN AND COST ESTIMATES

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX C
DESIGN AND COST ESTIMATES

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REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX C

DESIGN AND COST ESTIMATES

1. DESIGN

a. General. Plan A, the beach erosion protection plan, and plans B, C, and D, the combined beach erosion and hurricane protection plans, are described in paragraph 24 of the main report. Design criteria for the four plans are discussed in paragraph 8 of appendix B, and the alinements and cross sections of their features are given on plates 2 and 3.

b. Plan A - Beach erosion protection plan.

(1) Beach fill. Plan A would require sand fill from the 3-foot contour gulfward to provide the minimum section. Sand fill would not be placed where the minimum section exists such as near the east end jetty where considerable accretion has occurred. Sand fill quantities were computed by superimposing the minimum section on May 1969 profile data.

(2) Jetty.

(a) General. The jetty for plan A is also included in plans B, C, and D. This jetty was designed to stabilize the western end of the island and maintain the minimum beach width (see paragraph 8a of appendix B).

(b) Armor stone. The size for the cover layer of armor stone required was determined as prescribed in Technical Report No. 4 of the Coastal Engineering Research Center, "Shore Protection, Planning, and Design." The stone size was determined by the Hudson rubble mound stability formula:

$$W_{50} = W_r H_b / K_{RR} (S_r - 1)^3 \cot \alpha$$

where:

W_{50} = Minimum weight of 50% of stone (lbs.)

W_r = Unit weight of stones (165 lbs./cu.ft.)

H_b = Design wave height of structure (4.68 ft.)

K_{RR} = Stability coefficient of stone (1.7)

S_r = Special gravity of stone (2.58)

cot α = cotangent of angle of slope, measured from horizontal (2)

$$W_{50} = \frac{(165)(4.68)^3}{(1.7)(2.58-1)^3(2)} = 1260 \text{ lbs.}$$

(c) Easement. An easement was not required for the jetty since it was constructed in the state-owned waters of Caminada Pass.

c. Plans B, C, and D - Combined beach erosion and hurricane protection.

(1) Dune and berm.

(a) Alinement. The alinement for the dune of plans B, C, and D would be generally along the existing dune line except at the East and West State Parks where the alinement would be modified as shown on plates 2 and 3 to provide protection for the recreational support facilities. At the east end of the island along the jetty and revetment and at the west end of the island along the jetty at Caminada Pass the dune would be located 200 feet landward of the structures to provide the minimum berm for the dissipation of hurricane waves. The berm would be located immediately gulfward of the dune.

(b) Dune vegetation. The dune would be stabilized with vegetation to retard its erosion by wind and rain under normal conditions and gulf waves during hurricanes. The vegetation would be a rapidly spreading perennial with an extensive root system. Several grasses suitable to the Grand Isle area are:

Common name	Scientific name
Glasswort	Salicornia
Salt grass	Distichlis spicata
Sea-oats	Uniola paniculata
Sea ox-eye	Borrichia frutescens
Sea rocket	Cakile edentula

(c) Sand fill. The design criteria for the dune and berm sections are discussed in paragraph 8d of appendix B. The quantity of sand fill required for each of the three combined protection plans was estimated from the cross sections of the plans superimposed on May 1969 profile data.

(d) Easement. The easement required for the dune and berm would be the same for each of the three combined protection plans since an alinement landward of that required for the smallest dune (plan B) would require costly relocations. An easement would be required along the approximately 28,500 linear feet of privately owned beachfront. The easement area was computed from May 1969 profile data.

(e) Drainage. Drainage on Grand Isle is from the natural dune ridge on the gulf side of the island which is the alinement of the existing and recommended dunes to the bayside of the island. Therefore, no drainage structures through the dune are necessary.

(2) Jetty. The jetty for plans B, C, and D is described in paragraph 1b of this appendix.

2. COST ESTIMATES

a. General. Estimates of first and annual costs for plans A, B, C, and D are given in tables C-1, C-2, C-3, and C-4, respectively. Unit costs are based on similar work in the U. S. Army Engineer District, New Orleans, adjusted to July 1972 levels.

b. Estimates of first costs.

(1) Sand fill. Unit costs for sand fill for the four plans excluding fill for preauthorization construction are based on dredging and pumping the fill from borrow areas located approximately 2,000 feet offshore of each end of Grand Isle. Fill for preauthorization construction was dredged and pumped from Caminada Pass on the western end of the island.

(2) Jetty. The jetty included as an integral part of each plan was constructed prior to authorization by contract of the State of Louisiana, Department of Public Works, as an emergency measure. Actual costs for the jetty and sand fill were less than the Government estimate (see tables C-1 through C-4).

(3) Easement costs. The unit cost for the easement for plan A was assigned only a nominal value since the plan would protect beachfront property from erosion and has no undesirable features. However, unit costs for the perpetual easements required in connection with plans B, C, or D are estimated to represent a significant portion of the total land value since construction of the dune and berm would deprive property owners of their beachfront rights by creating state-owned property gulfward of the existing shoreline.

c. Estimates of annual costs.

(1) Five-year periodic replenishment. The estimated requirements for periodic replenishment are the same for each of the three plans considered. The annual requirement of 40,000 cubic yards of sandfill per year would be accomplished by placement of 200,000 cubic yards at 5-year intervals to reduce unit costs (see paragraph 8b of appendix B). Fill for this replenishment would be dredged from the borrow areas located offshore of each end of the island. Computation of annual cost for the 5-year periodic maintenance is given in table C-1.

(2) Post-hurricane nourishment. The estimated sand fill requirements for post-hurricane nourishment are 500,000 cubic yards for the beach erosion protection plan and 1 million cu.yds. for the combined beach erosion and hurricane protection plans (see paragraph 8b of appendix B). Borrow areas for the sand fill required for this nourishment are the same as those used for initial construction. These estimated volumes are based on volume of sand removed by Hurricane Betsy in 1965 and the assumption that a hurricane with characteristics producing wind, stages, and wave action similar to those produced by Hurricane Betsy will strike during the 50-year life of the project. Computations of annual costs for post-hurricane nourishment as given in tables C-1 and C-2 were based on the nourishment being accomplished 25 years after the completion of the project.

(3) Dune maintenance. Annual maintenance to dunes, such as fertilization of dune vegetation and occasional placement of sand fill and shaping of the dune will be required. A lump sum estimate for this maintenance is included in the cost estimates for the combined beach erosion and hurricane protection plans given in tables C-2, C-3, and C-4.

TABLE C-1
COST ESTIMATE

PLAN A - Beach erosion protection plan

FIRST COST

Item	Quantity	Unit	Unit cost	Cost
Preauthorization Construction by Non-Federal Interests:				
Jetty				
Riprap	30,700	ton	$11.50	$353,000
Shell	7,100	cu.yd.	7.00	50,000
Filter cloth	197,300	sq.ft.	.19	37,000
Sandfill	640,000	cu.yd.	.93	595,000
Subtotal				$1,035,000
Contingencies				259,000
Subtotal				$1,294,000
Engineering and design				86,000
Supervision and administration				110,000
Subtotal - preauthorization construction				$1,490,000[1]
Post-authorization Construction:				
Sandfill	607,000	cu.yd.	1.70	$1,032,000
Contingencies				258,000
Subtotal				$1,290,000
Engineering and design				80,000
Supervision and administration				110,000
Subtotal - post-authorization construction				$1,480,000
Total first cost				$2,970,000[2]

ANNUAL COSTS

INTEREST AND AMORTIZATION:				
First cost				$2,970,000
Amortization factor				.05906[3]
Interest and amortization				$ 175,000
PERIODIC BEACH NOURISHMENT (5-year intervals):				
Sandfill	200,000	cu.yd.	1.85	$ 370,000
Contingencies				92,500
Subtotal				$ 462,500
Engineering and design				37,000
Supervision and administration				32,500
Cost of one periodic nourishment				$ 532,000

TABLE C-1 (contd)

Present worths of periodic nourishment
$532,000

brought back 5 years =	$532,000	(.76513)		
brought back 10 years =	$532,000	(.58543)		
brought back 15 years =	$532,000	(.44793)		
brought back 20 years =	$532,000	(.34273)		
brought back 25 years =	$532,000	(.26233)		
brought back 30 years =	$532,000	(.20064)		
brought back 35 years =	$532,000	(.15352)		
brought back 40 years =	$532,000	(.11746)		
brought back 45 years =	$532,000	(.08988)		
Total of present worths	$532,000	(2.96495)	=	$1,577,000
Amortization factor				.05906[3]
Annual cost of periodic nourishment				$ 93,000

POST-HURRICANE REPLENISHMENT:

Item	Quantity	Unit	Unit cost	Cost
Sandfill	500,000	cu.yd.	$ 1.70	$ 850,000
Contingencies				212,500
Subtotal				$1,062,500
Engineering and design				85,000
Supervision and administration				74,500
Total cost of post-hurricane replenishment				$1,222,000
Present worth factor (25 years hence)				.26223
Present worth				$ 320,000
Amortization factor				.05906[3]
Annual cost of post-hurricane replenishment				$ 19,000

SUMMARY OF ANNUAL COSTS:

Interest and amortization	$ 175,000
Periodic nourishment (5-year intervals)	93,000
Post-hurricane replenishment (25th year)	19,000
Jetty maintenance	2,000
Total annual cost	$ 289,000

[1]Does not include cost of aids to navigation; actual cost of preauthorization construction was $1 million excluding engineering and design.

[2]Does not include $105,000 preauthorization study costs or $97,000 for easement costs.

[3]Amortization over 50-year period at 5 1/2 percent.

TABLE C-2
COST ESTIMATE FOR RECOMMENDED PLAN

Plan B - Combined beach erosion and hurricane protection plan
(dune elevation @ 11.5 feet)

FIRST COST

Item	Quantity	Unit	Unit cost	Cost
Preauthorization Construction by Non-Federal Interests:				
Jetty				
Riprap	30,700	ton	$11.50	$ 353,000
Shell	7,100	cu.yd.	7.00	50,000
Filter cloth	197,300	sq.ft.	.19	37,000
Sandfill	640,000	cu.yd.	.93	595,000
Subtotal				$1,035,000
Contingencies				259,000
Subtotal				$1,294,000
Engineering and design				86,000
Supervision and administration				110,000
Subtotal - preauthorization construction				$1,490,000[1]
Post-authorization Construction:				
Dune and berm				
Sandfill	1,900,000	cu.yd.	1.65	$3,135,000
Dune vegetation	54	acre	350.00	19,000
Subtotal				$3,154,000
Contingencies				789,000
Subtotal				$3,943,000
Engineering and design				192,000
Supervision and administration				335,000
Subtotal				$4,470,000
Easement cost				3,140,000[2]
Subtotal - post-authorization construction				$7,610,000
Total first cost				$9,100,000[3]

ANNUAL COSTS	
INTEREST AND AMORTIZATION:	
First cost	$9,100,000
Amortization factor	.05906[4]
Interest and amortization	$ 537,000
ANNUAL COST OF PERIODIC MAINTENANCE (5-year intervals)	$ 93,000[5]

TABLE C-2 (contd)

POST-HURRICANE REPLENISHMENT (25th year):

Item	Quantity	Unit	Unit cost	Cost
Sandfill	1,000,000	cu.yd.	$ 1.70	$1,700,000
Contingencies				425,000
Subtotal				$2,125,000
Engineering and design				170,000
Supervision and administration				149,000
Total cost of post-hurricane replenishment				$2,444,000
Present worth factor (25 years hence)				.26223
Present worth				$ 641,000
Amortization factor				.05906[4]
Annual cost of post-hurricane replenishment				$ 38,000

SUMMARY OF ANNUAL COSTS:

Interest and amortization	$537,000
Periodic nourishment (5-year intervals)	93,000
Post-hurricane replenishment (25th year)	38,000
Dune and jetty maintenance	10,000
Total annual cost	$678,000

[1]Does not include cost of aids to navigation; actual cost of preauthorization construction was $1 million excluding engineering and design.

[2]Consists of 113 acres at $22,500/acre, acquisition costs of $85,000 and contingencies.

[3]Does not include $105,000 preauthorization study costs.

[4]Amortization over 50-year period at 5 1/2 percent.

[5]Five-year periodic nourishment is the same as in Plan A. Computation of annual cost is given in table C-1.

TABLE C-3
COST ESTIMATE

PLAN C - Combined beach erosion and hurricane protection plan
(dune elevation @ 13 feet)

FIRST COST				
Item	Quantity	Unit	Unit cost	Cost
Preauthorization Construction by Non-Federal Interests:				
Jetty				
Riprap	30,700	ton	$11.50	$ 353,000
Shell	7,100	cu.yd.	7.00	50,000
Filter cloth	197,300	sq.ft.	.19	37,000
Sandfill	640,000	cu.yd.	.93	595,000
Subtotal				$1,035,000
Contingencies				259,000
Subtotal				$1,294,000
Engineering and design				86,000
Supervision and administration				110,000
Subtotal - preauthorization construction				$1,490,000[1]
Post-authorization Construction:				
Dune and berm				
Sandfill	2,406,000	cu.yd.	1.60	$3,850,000
Dune vegetation	60	acre	350.00	21,000
Subtotal				$3,871,000
Contingencies				971,000
Subtotal				$4,842,000
Engineering and design				316,000
Supervision and administration				412,000
Subtotal				$5,570,000
Easement cost				3,140,000[2]
Subtotal - post-authorization construction				$8,710,000
Total first cost				$10,200,000[3]

ANNUAL COSTS	
INTEREST AND AMORTIZATION:	
First cost	$10,200,000
Amortization factor	.05906[4]
Interest and amortization	$ 602,000
ANNUAL COST OF PERIODIC NOURISHMENT (5-year intervals)	$ 93,000[5]

TABLE C-3 (contd)

ANNUAL COST OF POST-HURRICANE REPLENISHMENT	$ 38,000[6]

SUMMARY OF ANNUAL COSTS:

Interest and amortization	$602,000
Periodic nourishment (5-year intervals)	93,000
Post-hurricane replenishment (25th year)	38,000
Dune and jetty maintenance	10,000
Total annual cost	$743,000

[1]Does not include cost of aids to navigation; actual cost of preauthorization construction was $1 million, excluding engineering and design.

[2]Includes contingencies and acquisition costs.

[3]Does not include $105,000 preauthorization study costs.

[4]Amortization over 50-year period at 5 1/2 percent.

[5]Five-year periodic nourishment is the same as in Plan A. Computation of annual cost is given in table C-1.

[6]Post-hurricane replenishment is the same as in Plan B. Computation of annual cost is given in table C-2.

TABLE C-4
COST ESTIMATE

PLAN D - Combined beach erosion and hurricane protection plan
(dune elevation @ 15 feet)

FIRST COST				
Item	Quantity	Unit	Unit cost	Cost
Preauthorization Construction by Non-Federal Interests:				
Jetty				
Riprap	30,700	ton	$11.50	$ 353,000
Shell	7,100	cu.yd.	7.00	50,000
Filter cloth	197,300	sq.ft.	.19	37,000
Sandfill	640,000	cu.yd.	.93	595,000
Subtotal				$1,035,000
Contingencies				259,000
Subtotal				$1,294,000
Engineering and design				86,000
Supervision and administration				110,000
Subtotal - preauthorization construction				$1,490,000[1]
Post-Authorization Construction:				
Dune and berm				
Sand fill	2,700,000	cu.yd.	1.60	$4,320,000
Dune vegetation	80	acre	350.00	28,000
Subtotal				$4,348,000
Contingencies				1,087,000
Subtotal				$5,435,000
Engineering and design				353,000
Supervision and administration				462,000
Subtotal				$6,250,000
Easement cost				3,140,000[2]
Subtotal - post-authorization construction				$9,390,000
Total first cost				$10,880,000[3]

ANNUAL COSTS	
INTEREST AND AMORTIZATION:	
First cost	$10,880,000
Amortization factor	.05906[4]
Interest and amortization	$ 643,000
ANNUAL COST OF PERIODIC MAINTENANCE (5-year intervals)	$ 93,000[5]

TABLE C-4 (contd)

ANNUAL COST OF POST-HURRICANE REPLENISHMENT	\$ 38,000[6]

SUMMARY OF ANNUAL COSTS:

Interest and amortization	\$643,000
Periodic nourishment (5-year intervals)	93,000
Post-hurricane replenishment (25th year)	38,000
Dune and jetty maintenance	10,000
Total annual cost	\$784,000

[1]Does not include cost of aids to navigation; actual cost of preauthorization construction was \$1 million, excluding engineering and design.

[2]Includes contingencies and acquisition costs.

[3]Does not include \$105,000 preauthorization study costs.

[4]Amortization over 50-year period at 5 1/2 percent.

[5]Five-year periodic nourishment is the same as in Plan A. Computation of annual cost is given in table C-1.

[6]Post-hurricane replenishment is the same as in Plan B. Computation of annual cost is given in table C-2.

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX D
BENEFIT ANALYSIS

REVIEW REPORT
GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX D
BENEFIT ANALYSIS

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REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX D
BENEFIT ANALYSIS

1. DESCRIPTION OF PROJECT AREA

Grand Isle is located along the Gulf of Mexico in Jefferson Parish, Louisiana, approximately 50 miles due south of the city of New Orleans. It is one of the many low, irregular islands separated by bays, lagoons, and bayous which form a part of the shoreline of Louisiana. Extending some 7.5 miles in a generally northeast to southwest direction, Grand Isle is only about 0.75 mile in width at the center. The entire island is low, having a maximum elevation of about 8 feet above m.s.l. (mean sea level)[1] along the existing dune and a natural ground elevation varying from 5 feet to slightly above sea level. The only land access from the mainland is by means of Louisiana Highway 1 which crosses Caminada Pass at the western end of the island.

2. ECONOMIC DEVELOPMENT IN THE PROJECT AREA

Grand Isle is a base of operations for large offshore petroleum and sulphur industries and is a commercial fishing and sportfishing center. It is also an important recreational area for residents of Louisiana and nearby states. Of the 2,340 acres on the island, there are 640 acres in residential development, 210 in industrial development, and 213 in commercial, Government, and public establishments. This latter acreage includes 126 acres of state-owned beach designated as a state park. The remainder of the island is as yet undeveloped, with part of it being low and swampy. The following table shows the estimated improvement values on the island by categories as obtained in a 1970 field survey.

TABLE D-1
VALUE OF IMPROVEMENTS (1970)

Item	No.	Buildings	Contents	Total
Residential--1 story	713	$7,686,000	$3,843,000	$11,529,000
" 2 story	101	1,521,000	746,000	2,267,000
Mobile homes	307	1,280,000	640,000	1,920,000
Public		241,000	48,000	289,000
Commercial		1,581,000	790,000	2,371,000
Industrial				19,838,000
Coast Guard				3,500,000
Other				225,000
				$41,939,000

[1]Unless otherwise specified, all elevations herein are in feet referred to mean sea level datum.

3. DESCRIPTION OF WATER RESOURCES PROBLEMS IN THE PROJECT AREA

Damage and destruction are occurring on Grand Isle due to beach erosion and hurricane tidal overflows. An elaboration on these two types of damages follows:

a. Hurricanes.

(1) Grand Isle is subject to severe damage from hurricanes since it lies fully exposed fronting on the Gulf of Mexico. Advancing tropical storms push gulf water inland and, in so doing, inundate the improvements on the island. Large waves driven by the hurricane winds strike flooded improvements wreaking widespread devastation. The force of these waves is the most significant cause of damage on the island.

(2) All storms passing within an effective distance of Grand Isle drive massive volumes of gulf water over and around the island into the bay areas to the north. These hurricane-generated tidal movements are accompanied by gulf wave action. Since the wind direction in which hurricanes turn in the northern hemisphere is a counterclockwise one, storms which move inland to the east of the island create, during part of their passage, high tides and wave action in the bays. In these cases, floodwaters with accompanying bay wave action are driven back over the island into the gulf. Conversely, storms which pass to the west of the island have the effect of causing high tides and wave action to approach the island from the Gulf of Mexico side only. There is no historical evidence to suggest that hurricanes will travel more frequently to either the east or west side of the island; therefore, it can be reasonably assumed that an equal number will pass in either direction. Because of the shallower depths and the existence of numerous small islands to break up their force, waves striking the island from the bay side are of much smaller magnitude and energy level than gulf waves resulting from hurricanes of corresponding intensities. Consequently, the bay waves are, by comparison, considerably less destructive.

(3) The passage of Hurricane Flossy (September 1956) was to the south and east of Grand Isle causing its complete inundation. The floodwaters were driven from the interior bays in a southerly direction over the top of the island and into the Gulf of Mexico. Maximum stages experienced during this storm were about 8 feet. Flood damages were sustained by nearly 400 homes, camps, businesses, schools, and churches; total flood losses were estimated to be $1,750,000.

(4) In September 1965 the eye of Hurricane Betsy passed slightly to the west of Grand Isle placing the island directly in the path of very severe winds and tidal overflow originating from the gulf. Stages of approximately 9 feet covered the area causing flood damages estimated at $11,500,000. The combined effects of

wind and tide destroyed approximately 85 percent of the improvements on the island excluding industrial development.

b. Erosion.

(1) Erosion of the gulf shoreline, which is a serious problem on Grand Isle, is constantly in process and is most severe on the western end of the island. The sand beach is particularly attractive to recreationists since it offers an open view of the gulf in addition to other esthetic considerations. The most developed portion of the island lies adjacent to the beach area.

(2) Historical data on erosion rates, by range, are shown for the island of Grand Isle in appendix B, table B-9. These rates were used as a basis for determination of the area to be eroded during the project life.

(3) In addition to the loss of the valuable and scenic beachfront, many homes, business establishments, Louisiana Highway 1, and other public improvements are subject to damage resulting from erosion of the island. If these lands are allowed to erode, there will also exist a requirement for the moving, at considerable expense, of affected improvements or the abandonment of same.

(4) Construction of a rock jetty on the eastern end of the island has halted erosion in that area. The jetty traps materials that are suspended in the eastward littoral current, and considerable accretion of land, rather than decrement, takes place as a result.

4. PROJECTED GROWTH RATES

Numerous factors bear on the projected economic growth for the island. These factors are enumerated below and are largely based on information gained through numerous field interviews with businessmen, local officials, and residents at the project location.

a. The population of Grand Isle increased from 1,190 in 1950, to 2,074 in 1960, and to 2,236 in 1970. Experienced growth rates were thus 5.7 percent annually for the period 1950 to 1960, and 0.75 percent annually during the last decade. The reduction in the overall growth rate for the second 10-year period was due to the widespread damage wrought by Hurricane Betsy in 1965, at which time some 85 percent of the total developments other than industrial on the island was destroyed. Immediately following Betsy, it is estimated that the population was reduced to about 500 people.

b. Redevelopment of the island has been rapid following Hurricane Betsy. Just prior to that storm the total value of all improvements on Grand Isle was approximately $33 million. Immediately after Betsy this figure was reduced to about $21 million. The estimated value of such improvements in 1970, as developed by the surveys for this report, was nearly $42 million as is shown in table D-1. This phenomenal recovery in the development of the area following a disaster is indicative of its tremendous growth potential.

c. The size of the oil company installations will remain essentially constant in the future. Technology is forthcoming which will facilitate exploration and mining of fields located in very deep water off the Louisiana coast. Large stores of crude oil are available which are as yet untapped, and a higher rate of recovery of known stores of these valuable minerals will ensue with the advanced technology. However, representatives of the companies involved indicate that significant future increases in physical facilities are not anticipated.

d. Grand Isle offers one of the few viable beaches located in the State of Louisiana. It provides opportunities for excellent fishing and boating. New, improved facilities have been constructed on the island in the wake of Hurricane Betsy which offer a much better environment for summer visitors. In the face of continuing demand for such facilities, the recreation-oriented economic activity on the island is expected to continue at a rapid growth.

e. The increase of recreationists on the island will attract, as it has in the past, permanent residents who will supply the facilities, goods, and services which the visitors require. Thus, a direct relationship will exist between the increase in population and the amount of investment required in physical plant for these purposes.

f. The very rapid growth in population accompanying the recovery from Betsy will level off within the next few years. It is conservatively estimated that the overall growth rate for the period 1970 to 1980 will approximate that for the period 1950 to 1960. This rate will yield a population of about 3,900 persons in 1980. Subsequently, growth rates will further decline as the base for growth expands and as the area available for growth is used up. By 2010, it is estimated that the population growth rate for Grand Isle will approximate that projected by OBE for Water Resources Subarea 0809 (WRSA 0809). The anticipated population growth for Grand Isle is shown in table D-2.

TABLE D-2
POPULATION PROJECTIONS DATA

Years	Annual Growth Rate	Growth Factor	Projected Population
1970			2,236[1]
1980	5 3/4	1.75	3,900
1990	4 1/2	1.55	6,100
2000	3 3/8	1.39	8,400
2010	2 3/16	1.24	10,500
2020	1	1.10	11,500
2030	1	1.10	12,600

[1]1970 Census data

5. EXTENT AND SCOPE OF PROPOSED PROJECT

The proposed project (Plan B) consisting of a widened beach and dune along the gulf side of the island, as is shown on plates 2 and 3, will largely eliminate the damages resulting from beach erosion and will greatly lessen the damages attendant to hurricanes. Flooding will still occur from rising water accompanying hurricanes, but the damage from wave action originating on the gulf side of the island will be greatly mitigated. The town of Grand Isle now has an ordinance requiring residential-type structures to be built on pilings with the floor levels at least 8 feet above ground level, thus further reducing future prospective flood damages from hurricanes both with and without the proposed project in place. Three plans of improvement were analyzed during the detailed study. They are Plan A - Beach Erosion Protection, Plan B - Combined beach erosion and hurricane protection (dune elevation--11.5), Plan C - Combined beach erosion and hurricane protection (dune elevation--13.0), and Plan D - Combined beach erosion and hurricane protection (dune elevation--15.0). Plan A provides protection from erosion while Plans B, C, and D provide erosion protection plus protection from gulf-wave damage caused by hurricanes having frequencies of approximately once in 50 years, once in 100 years, and once in 200 years, respectively.

6. BENEFITS

a. General. The base year for this economic evaluation is 1980. Since the project life has been determined to be 50 years, benefits were evaluated for the period 1980-2030 using the current 5 1/2 percent interest rate. Benefits are discussed in the following paragraphs and are categorized by type (erosion prevention, flood damages prevented, intensified land use, recreational, area redevelopment, indirect, and social well-being). There are two accounts to which these benefits are creditable; namely, the national account and the regional account.

(1) The national account consists of those benefits which will accrue to the nation as a whole. Such benefits are any net increases in the value of the nation's production achieved by means of more efficient use of national resources.

(2) The regional account comprises those benefits which will accrue only to the project region. For the Grand Isle project, the region is defined as that portion of southeastern Louisiana generally lying east of the Atchafalaya River and south of the latitude of Baton Rouge. Regional benefits are a measure of total economic, social, and environmental enhancements accruing to the region as a result of project construction.

(3) A summary of benefits is given in paragraph i below, table D-11. The only benefits which are used in the computation of the B/C ratio are those national account benefits listed in table D-11 which are footnoted.

b. Beach erosion prevention benefits.

(1) Damages which will occur without project as a result of beach erosion were classified generally as residential, commercial, public, highways, utilities, and land.

(2) Based on the erosion rates shown in table B-9, appendix B, projections of advancing erosion were made for the period of project life (1980-2030) and the area to be eroded was determined. The existing improvements in the area to be eroded were determined by detailed field surveys made in the year 1970 and are shown in table D-3 below. Portions of the area are substantially developed and property investment is growing rapidly. In addition to the camps, there are many trailer homes as well as a few commercial establishments. Main line utilities which service the island are also located in the erosion area. Louisiana Highway 1 runs the full length of the island from the bridge over Caminada Pass on the western end to the Coast Guard station on the eastern end. Trunk line utilities for electricity, water, gas, and telephone service are located in the highway rights-of-way. All services, excepting the electric service, are located below ground level.

(3) By contacting the public officials, local builders, other businessmen, and residents, it was determined that the majority of the buildings and residences would be moved rather than abandoned, as they became endangered by erosion. Accordingly, the losses on the first eight categories on table D-3 were the cost of moving the buildings and improvements plus the loss of piling, septic tanks, etc., which would not be salvaged. Data concerning these dollar losses

were obtained through interviews with representatives of companies which move buildings on Grand Isle. Data concerning the location of utilities in the affected area were obtained by interview with the personnel of the Louisiana Power and Light Company, the Lafourche Telephone Company, and officials of the town of Grand Isle who administer the water and gas services. The future growth that will take place in the erosion area during the life of the project, allowing for the erosion anticipated to occur, was determined by projecting all existing development other than highways and utilities in accordance with the population growth rates shown in table D-3 below. The growth for utilities and the highways within the area to be eroded was projected at rates equaling half of the growth rates shown.

TABLE D-3
1970 DEVELOPMENT SUBJECT TO EROSION DAMAGE BY YEAR 2030

Category	Quantity	Unit
Camps	194	each
Trailers	81	"
Motels	9	"
Library	1	"
Restaurants	2	"
Post Office	1	"
Parking lot	1	"
Grocery store	1	"
Road	4.1	miles
Main and lateral gas lines	8.7	"
Main and lateral water lines	8.7	"
Powerlines and poles	8.4	"
Telephone lines	6.3	"
Land	338	acres

(4) Inasmuch as the future development will be taking place in an area that is shrinking in size, it is quite obvious that the length of the period in which growth will take place in any specific area depends on its location within the erosion area. Furthermore, it follows that those specific areas located closer to the beachfront will have less time in which future development will take place. For this reason, the analysis of erosion damages was facilitated by dividing the overall erosion area into 50 subareas or strips. A period of time was assigned during which each of the subareas would be subject to future development and that growth was restricted accordingly. Similarly, it was also necessary that each subarea be assigned a time frame in which it would be eroded. Damages were then determined for each of the subareas by bringing back to present value the total development in the subarea when erosion took place and amortizing this value for the life of the project.

(5) To arrive at the average annual damage without the project, the total costs over the life of the proposed project incurred as a result of erosion were determined and reduced to an average annual value. This was done by computing the costs associated with the development summarized in table D-3, and adding to this total the costs associated with future development projected in accordance with the growth rates previously presented. In the case of utilities and highway losses, the growth rates used for projection were one-half the population growth rates indicated. Future growths of these facilities will generally be only in the form of feeder and lateral lines to the new buildings expected to be constructed in the area. Although the new main lines to supply increased capacity will be necessary in the future, these are being planned for the north side of the island and thus beyond the area subject to erosion during the project life.

(6) Cost associated with the relocation of a typical camp and of a small commercial establishment are shown in the following tabulations:

Erosion Damage Caused to Camp

Cost of moving and setting on new piling		$ 4,200
Loss of old piling		300
Loss of septic tank and drain field		500
Loss of walkways		200
Loss of gravel driveways		30
		$ 5,230
	Rounded	$ 5,200

Erosion Damage to Restaurants and Grocery Stores

Cost of moving building and put on new piling	$ 9,600
Cost to move and set up equipment	2,000
Loss of old piling	400
Loss of septic tank and drain field	600
Loss of walkways	50
Loss of parking lot	300
	$12,950

(7) The costs associated with the prevention of loss or relocation of the residential, commercial, and public structures situated in the erosion area (table D-3) are tabulated below:

Category	Quantity	Relocation Costs (1970)
Camps	194	$1,008,800
Trailers	81	81,000
Motels	9	149,000
Library	1	16,200
Restaurants	2	26,000
Post Office	1	11,000
Parking Lot	1	3,000
Grocery Store	1	13,000
Total		$1,308,000

(a) Projecting the relocation costs of $1,308,000 for 1970 conditions was accomplished by use of the growth factor shown in table D-2. Relocation costs (1980 conditions) = $1,308,000 x 1.75 = $2,289,000. Assuming equal distribution of this development throughout the 50 strips comprising the total erosion area (see paragraph 6b(4) above), the average cost per strip, with conditions of 1980 development existing, equals $2,289,000 ÷ 50 = $45,780.

(b) Computation of the average annual erosion losses to residential, commercial, and public structures, over the project life period of 1980 to 2030, are shown in table D-4.

(8) The costs associated with the two major relocations of the Louisiana State Highway 1 and the utilities adjacent thereto (table D-3) are shown in the following tabulations:

Category	1995 Relocation		2010 Relocation	
	Quantity (miles)	Cost	Quantity (miles)	Cost
Road	1.7	$144,500	2.4	$204,000
Main & lateral gas lines	3.4	38,500	5.3	61,000
Main & lateral water lines	3.4	93,100	5.3	242,100
Powerlines & poles	3.5	35,300	4.9	49,200
Telephone lines	2.3	79,200	4.0	141,300
Totals		$390,600		$697,600

(a) Projecting the relocation costs (1970 conditions) to reflect anticipated growth to the years in which the major relocations would occur was accomplished by the use of growth factors based on one-half of the annual growth rates shown in table D-2.

TABLE D-4
COMPUTATION OF AVERAGE ANNUAL EROSION DAMAGES TO RESIDENTIAL, COMMERCIAL, AND PUBLIC STRUCTURES
1980-2030

End of year when eroded	Strip No.	Value of strip as of 1980	Growth rate	Years of growth	Growth factor	Value of strip when eroded	Present value factor	Present values
1980	1	$45,780	4.5%	0	1.0000	$ 45,780	1.0000	$ 45,780
		⋮	⋮	⋮	⋮	⋮	⋮	⋮
1989	10	45,780	4.5%	9	1.4861	68,034	.6176	42,017
1990	11	45,780	3.375%	10	1.5363	70,332	.5843	41,171
		⋮	⋮	⋮	⋮	⋮	⋮	⋮
1999	20	45,780	3.375%	19	2.0712	94,820	.3616	34,299
2000	21	45,780	2.1875%	20	2.1166	96,898	.3427	33,217
		⋮	⋮	⋮	⋮	⋮	⋮	⋮
2009	30	45,780	2.1875%	29	2.5716	117,728	.2117	24,931
2010	31	45,780	1.0%	30	2.5973	118,904	.2006	23,860
		⋮	⋮	⋮	⋮	⋮	⋮	⋮
2019	40	45,780	1.0%	39	2.8406	130,043	.1239	16,115
2020	41	45,780	1.0%	40	2.8691	131,347	.1175	15,435
		⋮	⋮	⋮	⋮	⋮	⋮	⋮
2029	50	45,780	1.0%	49	3.1379	143,653	.0726	10,428

Sum =	1,429,659
(Amortization factor)	.05906
Total average annual cost for relocation of structures	$ 84,400
Average annual cost for relocating existing structures (1980)	-45,800
Average annual cost for relocating future structures	$ 38,600

Item	Growth Factors				Costs	
	1970-80	1980-90	1990-95	1970-95	1970	1995
1995 setback	1.3277	1.2492	1.0873	1.8034	$390,600	$ 704,000
				1970-2010	1970	2010
2010 setback		(not shown)		2.1860	$697,600	$1,525,000

(b) Computations of the average annual damages, based on the present worth values of the relocation costs in the base year 1980, are as follows:

1995 setback	$704,000 x .44793 =	$315,342
2010 setback	$1,525,000 x .20064 =	305,976
Total present worth value		$621,318
Amortization factor		x .05906
Total average annual costs--highway and utilities relocations		$36,695
	(rounded)	$36,700

(c) The average annual costs for relocating the existing roads and utilities are computed below:

Setback	1970 costs	Growth factor	(Base year) 1980 costs	Year eroded	Present value factor (5 1/2%)	Amortization factor	Average annual costs existing development
	$		$				$
First	390,600	1.3277	518,600	1995	.44793(15 yrs)	.05906	13,719
Second	697,600	1.3277	926,200	2010	.20064(30 yrs)	.05906	10,975
							24,694
						(rounded)	24,700

(d) The annual costs for relocating future road and utility improvements are $36,700 less $24,700, or $12,000.

(9) The computation of average annual damages resulting from the loss of land is shown below:

(a) Total value of land to be eroded:

Area to be eroded	Unit value	Total
233 acres	$25,000 per acre	$5,825,000
105 acres	15,000 per acre	1,575,000
338 acres		$7,400,000

(b) Average area of individual strips to be eroded: 338 acres ÷ 50 strips = 6.76 acres per strip.

(c) Assignment of dollar values to each of the 50 strips to be eroded and computation of present value of future erosion:

Strip numbers	Value per strip	Sum of present value factors (5 1/2%)	Total present value
1 through 23	$25,000 x 6.76=$169,000	13.5831	$2,295,544
24 and 25	$15,000 x 6.76=$101,400	.5685	57,646
26 through 50	$19,587 x 6.76=$132,408	3.7111	491,379
			$2,844,569

(d) Computation of average annual land loss:

$2,844,569 x .05906 = $168,000

(10) Construction of any of the three plans would eliminate losses resulting from erosion shown above. Erosion losses prevented are summarized in table D-5 below:

TABLE D-5
AVERAGE ANNUAL EROSION LOSSES PREVENTED

Item	Existing development	Future development	Total
	$	$	$
Residential, commercial, & public structures	45,800	38,600	84,400
Roads & utilities	24,700	12,000	36,700
Land	168,000	-	168,000
Total	238,500	50,600	289,100

(11) The breakdown of private and public benefits is shown in the computations which follow:

PUBLIC

Item	Average annual benefits
Loss of land (68 acres)	$33,600[1]
Relocation of library and post office	1,700[2]
Relocation of highway (4.1 miles)	12,200[3]
Relocation of main & lateral water lines (8.7 mi.)	10,700[4]
Total avg. annual public benefits	$58,200

[1]West End Park = 12 acres
Highway (4.1 mi. with 60-foot right-of-way) = 30 "
Other roads (53 x 50 ft. x 400 ft.) = 24 "
Other = 2 "
68 acres

Percent of total area eroded that is public = 68 acres ÷ 338 acres = 20%

Loss of land = 20% x $168,000 = $33,600

[2]Cost for moving library and post office = $ 27,200 / 1,308,000 = 2%

Average annual loss = 2% x $84,400 = 1,700

[3](1995) $144,500 x 1.8034 x .44793 x .05906 = 6,894
(2010) $204,000 x 2.1860 x .20064 x .05906 = 5,284
12,178
(rounded) 12,200

[4](1995) $ 93,100 x 1.8034 x .44793 x .05906 = 4,442
(2010) $242,100 x 2.1860 x .20064 x .05906 = 6,271
10,713
(rounded) 10,700

PRIVATE

Private benefits consist of the following items which constitute 80 percent of the total erosion prevention benefits:

194 camps
81 trailers
9 motels
2 restaurants
1 grocery store & 1 parking lot
8.7 miles main & lateral gas lines
8.4 miles powerlines & poles
6.3 miles telephone lines
270 acres

Total shore protection benefits	$289,100
Less public benefits	-58,200
Total average annual private benefits	$230,900

(a) A disaggregation of the erosion losses in the private and public sectors that will be prevented by the project is shown in the following table:

TABLE D-6
AVERAGE ANNUAL EROSION LOSSES PREVENTED
IN PRIVATE AND PUBLIC SECTORS

Item	Existing Development	Future Development	Total
Public	$ 46,100	$12,100	$58,200
Private	192,400	38,500	230,900
Total	$238,500[1]	$50,600[1]	$289,100

[1]These benefits are creditable to both the national account and the regional account as shown in table D-11.

c. Flood damages prevented.

(1) Stage-frequency data. The stage-frequency relationship for Grand Isle is shown on plate D-1. The same curve is applicable for both "with" and "without" project conditions since the project will not materially alter the flood stages (rising water) occurring on the island.

(2) Stage-damage data. Stage-damage curves were developed, based on existing and future development, for various years within the project life (1980-2030). These curves (plates D-2 through D-5) are shown for four conditions; namely, (1) rising water only, (2) rising water and bay waves only, (3) rising water and all waves--without project, and (4) rising water and all waves--with Plan B in place. Computations for all of these conditions were necessary so that the effects of bay waves (those originating from the bay areas on the backside of the island) and gulf waves (those formed on the front or gulf side) could be identified and evaluated separately. The intensity and damaging effects of gulf waves exceed by a substantial margin those caused by waves originating on the bay side. Thus, for storm occurrences in which damaging waves are generated from each direction, damages inflicted by the gulf waves are considered to be the limiting factor for establishing the overall losses due to both causes. The beneficial effects of the project insofar as preventing flood damages consist solely in the prevention of damages incident to high-intensity waves which originate on the gulf side of Grand Isle. Outlined in the following paragraphs are the bases for determining damages for each of the four flood conditions.

(a) Stage-damage curves for the condition of rising water only (plate D-2) were derived by use of depth-damage curves which were developed for use in several flood insurance studies that were prepared by the New Orleans District. These depth-damage curves indicate the percent-damages that would occur to buildings and contents as related to flood depths over floors. Basic considerations included that the flooding would be by salt water and that attending low-flow velocities would create no serious scour conditions. Information on the depth-damage curves was combined with field survey data relating to numbers, types, values, and floor elevations of improvements to determine residential and commercial losses. Industrial damages, loss of business profits and salaries, damages to utilities, governmental and other facilities, costs of cleanup, and other miscellaneous costs were determined from field interviews, on-site appraisals, and various historical flood damage data on file in the District.

(b) Stage-damage curves depicting the condition of rising water and bay waves only (plate D-3) were derived mainly from flood damages that occurred on Grand Isle during Hurricane Flossy (1956) as related to the then-existing developments. Supplementary flood damage data for losses that occurred during Hurricane Camille (1969) in the areas surrounding Lake Pontchartrain were used in these determinations.

(c) Stage-damage relationships representing the condition of rising water and all waves--without project (plate D-4) were based primarily on flood damages that occurred on Grand Isle during Hurricane Betsy (1965), as related to the then-existing developments. Supplementary flood damage data acquired following Hurricanes Flossy (1956), Audrey (1957), Carla (1961), Hilda (1964), and Camille (1969) along the Louisiana coast were used where judgment aspects were involved.

(d) Construction of the proposed dune along the front side of the island will materially reduce the damaging effects of tidal waves originating from that direction. Stage-damage relationships for the condition of rising water and all waves--with plan B in place (plate D-5) were developed from information contained in the curves discussed in paragraphs (a), (b), and (c) immediately above. By subtracting damages occurring for specific flood elevations for rising water only from damages caused by rising water and all waves--without project, losses resulting from gulf waves only--without project were determined. Hydraulic studies were made to determine the modified wave energy levels that would attend hurricanes of various intensities for with-project conditions (see plate D-6). The result of this investigation indicates that the reduction in wave damages will range from a high of 100 percent at a stage of about 8.5 feet (frequency of about 50 years) to 0 percent at a stage of 14.0 feet. Thus, at the latter stage and higher ones, the project will become ineffective for the reduction of flood damages. Stage-damage curves for with-project conditions were then constructed by:

1. Computing bay waves only damage. This was accomplished by subtracting rising water only damages from rising water and bay waves only damages for appropriate flood elevations.

2. Adding 50 percent of the bay waves only damages determined in 1 above to rising water only damages because bay waves occur with only one-half of the hurricane occurrences. This would represent the condition that would exist if all gulf wave damages were prevented.

3. Determining gulf waves only damages for without-project conditions by subtracting rising water only damages from those damages occurring with rising water and all waves--without project. As is discussed in paragraph 6c(2) above, gulf waves are considered to be the limiting factor for establishing overall wave losses.

4. Computing residual gulf waves only damages for with-project conditions (applying residual damage factors discussed in (d) above to gulf waves only damages determined in 3 above).

5. Adding residual gulf waves only damages (those in excess of the bay waves only damages) to the losses computed in 2 above. This represents the condition of all residual losses with the project in place.

(3) Damage-frequency data. Integration of the stage-damage relationships for the four conditions (plates D-2 through D-5) with the stage-frequency curve (plate D-1) provided the basis for constructing the damage-probability curves (plates D-7 through D-10). The areas inclosed under these curves represent the average annual damages for each of the conditions based on different periods during the project life.

(4) Annual flood damages. From the determination in paragraph (3) above, the average annual damages for each of the four conditions were computed over the period 1980-2030. A sample calculation for damages attributable to rising water and all waves--without-project condition follows. Computations for losses for the remaining conditions--rising water only, rising water and bay waves, and rising water and all waves--with project--were made in the same manner.

COMPUTATION OF AVERAGE ANNUAL DAMAGES
RISING WATER AND ALL WAVES--WITHOUT PROJECT
(5 1/2%)

(1)	Constant	$1,006,000
(2)	$\frac{\$1{,}314{,}000-\$1{,}006{,}000}{10 \text{ yrs.}}$ x 38.14344 x .05906 =	69,384
(3)	($1,314,000-$1,006,000) x 16.04612 x .58543 x .05906 =	170,879
(4)	$\frac{\$1{,}664{,}000-\$1{,}314{,}000}{10 \text{ yrs.}}$ x 38.14344 x .58543 x .05906 =	46,158
(5)	($1,664,000-$1,314,000) x 14.53375 x .24273 x .05906 =	102,965
(6)	$\frac{\$1{,}968{,}000-\$1{,}664{,}000}{10 \text{ yrs.}}$ x 38.14344 x .34273 x .05906 =	23,471
(7)	($1,968,000-$1,664,000) x 11.95038 x .20064 x .05906 =	43,059
(8)	$\frac{\$2{,}196{,}000-\$1{,}968{,}000}{10 \text{ yrs.}}$ x 38.14344 x .20064 x .05906 =	10,305
(9)	($2,196,000-$1,968,000) x 7.53763 x .11746 x .05906 =	11,922
(10)	$2,430,000-$2,196,000 x 38.14344 x .11746 x .05906 =	6,191
		$1,490,692
	(rounded)	$1,490,000

(5) Flood-damage summation. A tabulation of the average annual flood damages estimated to occur over the project life for with- and without-project conditions is shown in table D-7. As is explained in paragraph 6c(2) on page D-14, the only flood damages that will be prevented by the project are those resulting from high intensity, gulf side waves.

TABLE D-7
AVERAGE ANNUAL FLOOD DAMAGES SUMMATION

Condition	Damages: Present development	Damages: Future development	Total
	$	$	$
Without Project:			
Rising water only	497,000	293,000	790,000
Rising water & bay waves	714,000	404,000	1,118,000
Rising water & all waves	1,006,000	484,000	1,490,000
With Project:			
Rising water & all waves	626,000	322,000	948,000

(6) Computation of flood damages prevented - plan B. Flood damages to be prevented by the project (plan B) consist solely of those resulting from the elimination of hurricane-driven waves that are generated on the gulf side of the island. The procedures used in making this determination are shown below:

Average annual damage, rising water and all waves--without project		$1,491,000
Less average annual damage, rising water and all waves--with project		-949,000
Average annual benefits due to prevention of gulf wave damage		$ 542,000
Less damage due to bay waves:		
Average annual damage, rising water & bay waves	$1,118,000	
Less average annual damage, rising water only	-790,000	
Average annual damage due to bay waves (100% occurrence)[1]	$ 328,000	
Less average annual damage due to bay waves (50% actual expected occurrence)[1]		$ -164,000
Net average annual flood damage prevented on existing and future development		$ 378,000
Net average annual flood damage prevented on existing development		$ 271,000[2]
Net average annual flood damage prevented on future development		$ 107,000[2]

[1]Only those hurricanes with tracks south and east of Grand Isle cause damage from bay waves. Such hurricanes constitute 50% of the expected total occurrences.

[2]These benefits are creditable to both the national account and the regional account as shown in table D-11.

(7) Computation of flood damages prevented - plans C and D. Flood damages that would be prevented if plans C or D were constructed were determined using the same rationale as that used in the above (plan B). With plan C in place residual flood damages would be $970,000 annually and hurricane-wave damages prevented would amount to $520,000 annually. With plan D in place, residual flood damages would be $954,000 annually and hurricane-wave damages prevented would amount to $536,000 annually.

d. Intensified land use.

(1) For approximately 1.5 million residents of southeast Louisiana and for other thousands of recreationists who enjoy surf bathing, surf fishing, and gulf-side sand beaches with an unrestricted view of the open waters of the Gulf of Mexico, only the Grand Isle beach front affords access to these recreational activities. Louisiana, with more than 360 miles of gulf shoreline, has almost no beach front on the Gulf of Mexico. Louisiana residents must travel out of state to find surf-side recreational opportunities comparable to those available on Grand Isle. Sports fishermen flock to Grand Isle for incomparable salt-water fishing at the many oil rigs off the Louisiana coastline. Commercial fishermen, shrimpers, and oystermen use Grand Isle as a base of operations.

(2) The market value of land reflects the net income opportunities of the land, capitalized at an appropriate interest rate consistent with investment conditions. The repeated occurrences of damages from hurricane-driven waves generated from the Gulf of Mexico are reflected in the market price of land on Grand Isle. Relief from such damages with the project in place will encourage higher use of the land not feasible without the project. This will be reflected in the increased market value of land as attributable to project construction.

(3) Because there is no alternative, representative, flood-free land for comparison purposes, values assigned to land for pre-project and post-project conditions were based on analyses of land values solely within the project area.

(4) The increased value created by the project installation is real and tangible and constitutes a definite and measurable gain. Higher market value, reflecting potential intensified land use, is realized upon project completion and can be equated, in monetary form, to return on the increase in market value without discounting.

(5) Computations for intensified land-use are shown below and are based on a 6 percent annual return on the increase in land values that will result from construction of either plan B, plan C, or plan D. These benefits are totally attributed to the hurricane protection features of the project since no appreciable flood control can be realized with plan A which is a single purpose, beach erosion protection plan.

TABLE D-8
INTENSIFIED LAND USE COMPUTATIONS

Acres	Unit value pre-project	Unit value post-project	Total value pre-project	Total value post-project	Increase in value
			$	$	$
154	25,000	32,000	3,850,000	4,928,000	1,078,000
12	15,000	19,000	180,000	228,000	48,000
79	25,000	28,500	1,975,000	2,251,500	276,500
93	15,000	17,000	1,395,000	1,581,000	186,000
493	40,000	42,000	19,720,000	20,706,000	986,000
50	15,000	16,000	750,000	800,000	50,000
755	12,000	12,600	9,060,000	9,513,000	453,000
206	10,000	10,500	2,060,000	2,163,000	103,000
471	5,000	5,250	2,355,000	2,472,750	117,750
2,313			41,345,000	44,643,250	3,298,250
	Annual rate of return				x 6%
	Annual return on increased value				197,895
	(Rounded)				198,000[1]

[1]These benefits are creditable to both the national account and the regional account as shown in table D-11.

(6) The annual benefits resulting from intensified land use represent only 16.5 percent of the total average annual benefits which are summarized in table D-11.

e. Recreation benefits. Grand Isle is a significant recreation and sport fishing area and is the major beach area on the Gulf of Mexico in Louisiana. The state park (126 acres in two tracts) on the island is one of only two state-maintained public beach on the gulf within the state. The island has suffered in the past as a recreation resource because of inadequate facilities, trash pickup, maintenance and sanitary facilities. The gulf side beach is approximately 7 miles in length and varies from 25 to 400 feet in width (1968 survey). The existing beach is of adequate size if developed, protected, and maintained to offer a quality resource to the expected visitor load. Using the design criteria of 75 square feet of beach per visitor and no turnover rate, the existing beach has a one-time capacity for about 73,000 visitors. This visitor level is far greater than existing or projected land access, parking, or service facilities could handle.

(1) Recreation demand. Grand Isle is within the limits of Region 1 of the Louisiana State Comprehensive Outdoor Recreation Plan. The following is a tabulation of projected visitor-day demand for the "high quarter" summer season covering camping (trailer and tent), beach swimming, and picnicking:

TABLE D-9
SUMMER VISITATION DEMAND

Activity	1975	1980	1985
Camping			
Tent	695,700	844,000	1,035,700
Trailer	696,000	1,175,600	1,442,600
Swimming (beach)	3,515,900	4,265,300	5,234,200
Picnicking	2,223,900	2,697,900	3,310,700

Demand for fishing was not included because the state recreation plan does not separate salt-water from fresh-water fishing.

(2) Present use. The State of Louisiana operates a state park on each end of the island; the east end park (103 acres, 1968 survey) and the west end park (23 acres, 1968 survey). At the present time, eight portable toilets (five at the east end and three at the west end) are the only facilities available at either park. Despite these limited facilities, the state estimates that 13,000 people utilized the park areas in June 1970. Their estimate is based on visitor fees for overnight campers and random sampling of day-use. The state had only one ranger to collect fees; however, they feel that collections were received from about 75 percent of the camping visitors during June. Based on this assumption, the state estimated that 6,400 to 6,500 campers used the park during June. The random sampling of day-use indicated that day use was equal to camping use. Although similar use data are not available for July and August, as the ranger only worked part time, it is estimated that use equaled or exceeded the June level. Taking 13,000 as average monthly use for June, July, and August, the state park received about 39,000 total recreation days use for the summer season. The state estimates that use for the remaining 9 months is about one-half of the summer season or 19,500 visitors making the total annual use with very minimal facilities, 58,500 visitors, rounded to 60,000. The State Parks and Recreation Commission lost almost 100 percent of the 1970 use of the west end park in 1971 due to the land loss by erosion. Their estimate of use at the west end park in 1970 was 10,000 visitors. The use of the state beaches was estimated to be 50,000 in 1971.

(3) Interim development.

(a) The Louisiana State Parks and Recreation Commission has an interim development plan for the state park which is contingent upon implementation of a plan to prevent erosion and maintain a suitable beach for recreational use. The interim development on the west end

TABLE D-10
RECREATION BENEFITS
GRAND ISLE STATE PARK[1]

	Average annual visitation	Value per visitor-day $	Value $
WITHOUT PROJECT (1971)	50,000	0.50	25,000
PLAN A - BEACH EROSION PROTECTION (with State Park Interim Development Plan)			
Total with Plan A	150,000	0.50	75,000
Less value without project			25,000
Total attributable to Plan A			50,000[2]
PLAN B, C, or D - COMBINED BEACH EROSION AND HURRICANE PROTECTION (with State Park Optimum Development Plan)			
Total with Plan B, C, or D	342,000	1.00	342,000
Less value without project			25,000
Total attributable to Plans B, C, or D			317,000[1]

[1]Increased use of the private sector of beach by the public was not included in this analysis due to the inability to predict future private capital investment upon which this use is predicated.

[2]These benefits are creditable to both the national account and the regional account as shown in table D-11.

f. Area redevelopment benefits.

(1) Area redevelopment benefits are not included in either the national account or in the benefit-cost analysis because the project area is not classified by the Economic Development Administration as being economically depressed.

(2) Redevelopment benefits accruing to the regional account are those resulting from all new wages earned in the construction and operation and maintenance of the project and spent within the region. The methodology followed herein for computing regional benefits is that developed in the study of the Whiteoak Dam and Reservoir water resources project in Appalachia.[2] Total labor costs are estimated to be 20 percent of construction costs; an estimated 60 percent of project labor costs represent new wages which will be spent within the area, ($5,960,000 x .20 x .60 = $715,200). This amount was amortized at an interest rate of 5 1/2 percent for 50 years, and represents an average annual regional benefit from construction expenditures of $42,200. Operation and maintenance labor costs comprise 20 percent of the total annual operation and maintenance costs. Operation and maintenance benefits credited to the regional account were estimated to be 80 percent of annual operation and maintenance costs ($141,000 x .20 x .80 = $22,600). A total regional redevelopment benefit of $64,800 annually results.

g. Indirect benefits.

(1) The benefits in the national account will be increased to the extent that project construction utilizes otherwise underemployed, potentially productive labor resources. It is estimated that 20 percent of total construction costs will be expended for labor, and that one-third of total labor costs will be expended upon underemployed labor. This added income (rounded to 7 percent of construction costs) will be subject to the multiplier effect producing additional income through the respending process. The accelerator principle of induced investment will be activated by additional consumer expenditures out of this injection of new income. The Council of Economic Advisers estimated that the combined multiplier-accelerator effect upon GNP of a tax cut was in the range of 3 to 4.[3] An indirect benefit to the national account was obtained by applying a multiplier-accelerator factor of 3 to the construction expenditures on under-utilized labor resources and amortizing at an interest rate of 5 1/2 percent for 50 years.

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[2] Development of Water Resources in Appalachia, Main Report Part III, Project Analyses Chapters 4 through 16, Office of Appalachian Studies, Corps of Engineers, Department of the Army, 1969 pp. III-14-149.

[3] In testimony before the Joint Committee of the 88th Congress of the United States in favor of the Kennedy tax cut.

Construction costs	Expenditure subject to multiplier-accelerator effect	Annual indirect benefit to national account (rounded)
$5,960,000	$417,200	$73,900

(2) The regional account is credited with all indirect benefits which measure total economic, social, and environmental enhancements accruing to the region as a result of project construction. Quantified herein are those economic benefits associated with project construction expenditures which will generate new wage income that will be spent within the area. In paragraph f(2) this figure is shown as $42,200. It is anticipated that there will be, within the region of economic influence of the project, a total benefit in excess of this amount through the application of the multiplier principle. Community multipliers, where they have been measures, range between 1.6 and 3.0.[4] A factor of 2 was applied to this new income which will be spent within the region; therefore, an incremental indirect regional benefit of $42,200 results.

(3) Indirect benefits common to both accounts and included in the figures cited previously are computed as follows:

Construction cost		$5,960,000
Common factors:		
Labor cost 20% of total		
Unemployed labor 33.3%		x.07
		$ 417,200
Interest and amortization		x .05906
	(rounded)	$ 24,600

h. Social well-being benefits. The social well-being of the residents of Grand Isle and of the many recreationists who contribute to the local economy will be benefited through project construction. The propitious climate encourages year-round recreational use of the island. As the fear of flooding from hurricane-driven gulf waves abates with project construction, more intensive land use is expected. Extensive and better facilities will be constructed. Recreation-oriented service activities will employ greater numbers of local residents. Added incomes mean higher standards of living for residents of the project area. As the recreationists are encouraged by good facilities to vacation year-round on Grand Isle, greater economic stability for the residents will follow. An economic and social atmosphere conducive to orderly development of the island will ensue. Properties will be maintained in good repair as fewer resources will

[4]Edgar Z. Palmer, Editor, The Community Economic Base and Multiplier the University of Nebraska, 1958, p.101. Floyd K. Harmston and Richard E. Lund, Application of an Input-Output Framework to a Community Economic System, University of Missouri Press, 1967 pp. 16 and 17.

be required to continually replace property damaged by severe waves generated from the Gulf of Mexico. The expanded tax base will allow for more and better community services to be provided to the residents and to the visitors. The island can be expected to develop to its full potential as a resort area unmatched along the Louisiana gulf coast.

i. Summary of benefits. Average annual benefits are tabulated in table D-11. Those benefits credited to the national account which are included in the benefit-cost ratio are footnoted.

TABLE D-11
AVERAGE ANNUAL BENEFITS, PLAN B

Category of benefits	National account $	Regional account $	Common to both accounts $
Erosion prevention:			
on existing development	238,500[1]	238,500	238,500
on future development	50,600[1]	50,600	50,600
Flood damages prevented:			
on existing development	271,000[1]	271,000	271,000
on future development	107,000[1]	107,000	107,000
Intensified land use	198,000[1]	198,000	198,000
Recreational	317,000[1]	317,000	317,000
Area redevelopment:			
on construction labor	0	42,200	0
on operation & maintenance labor	0	22,600	0
Indirect	73,900	42,200	24,600
Social well-being		Not quantified	
Subtotal of national account benefits included in benefit-cost ratio	1,182,100		
Totals	1,256,000	1,289,100	1,206,700

[1]Benefits included in the benefit-cost ratio.

j. Maximization of net benefits.

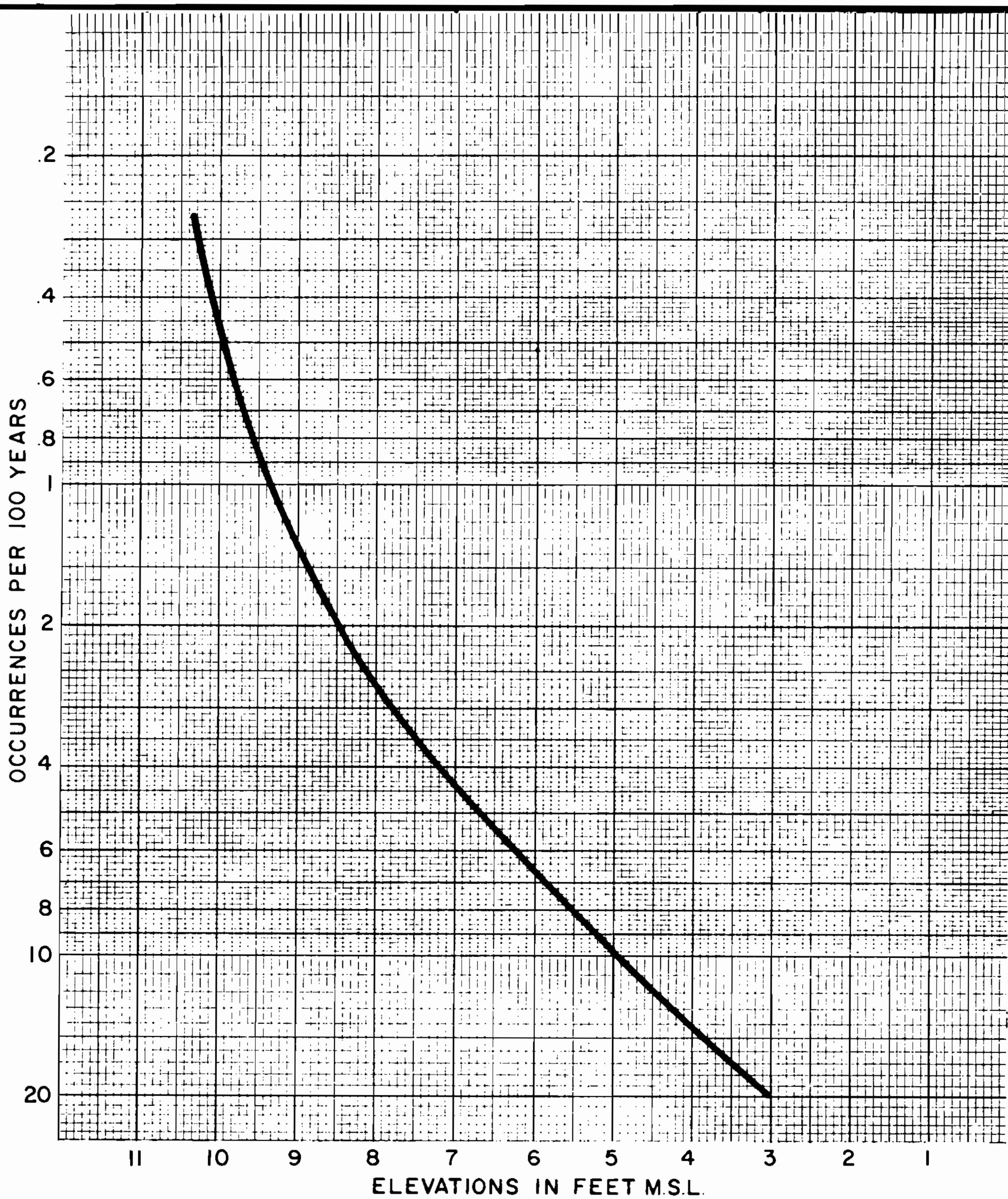
(1) Studies conducted during the preliminary evaluation indicated that alternative solutions such as a groin system with beach-fill, a ring levee system with bulkheads, or an offshore breakwater are impracticable either because of the high costs associated with construction and maintenance or the small amount of benefits attributed to the plan, or both.

(2) Various plans for beach erosion protection alone (prevention of erosion) were not analyzed because plan A provides the minimum design section required to restore and stabilize the beach. It also provides sufficient area for present and future recreational demand.

(3) Based on preliminary and detailed designs for the study, cost estimates and benefits as shown in table D-12 below were determined for three plans providing combined beach erosion and hurricane protection differing only in scale. These data were plotted to determine the point at which net benefits are at a maximum, see plate D-11. This graphical representation shows that all three of the plans are close to the point of maximum excess benefits.

TABLE D-12
SUMMARY OF AVERAGE ANNUAL BENEFITS AND CHARGES
PLANS B, C, AND D

Plan	Annual charges	Annual benefits
	$	$
B	678,000	1,182,000
C	743,000	1,323,000
D	784,000	1,340,000

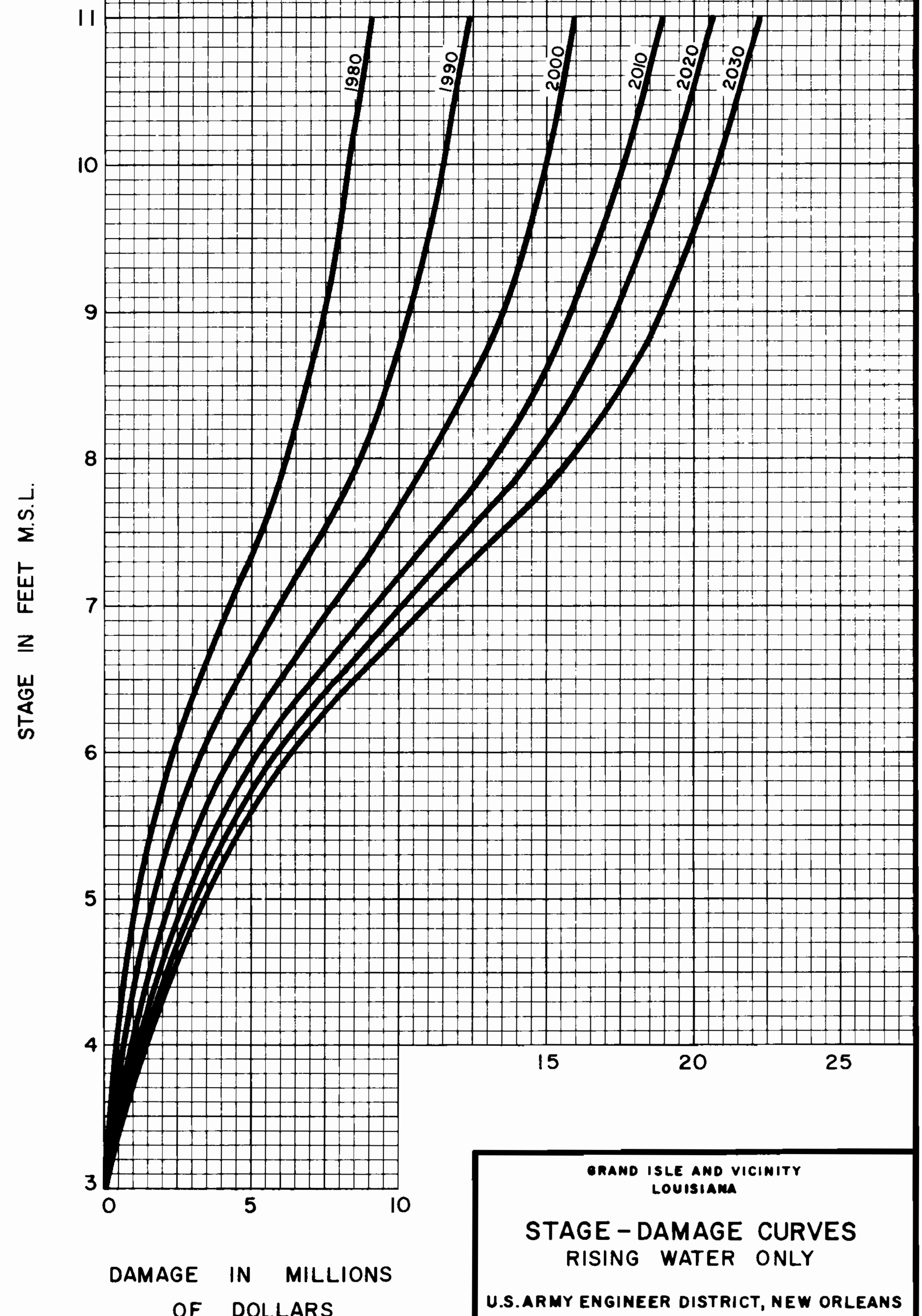


GRAND ISLE AND VICINITY
LOUISIANA

STAGE – FREQUENCY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629



GRAND ISLE AND VICINITY
LOUISIANA

STAGE - DAMAGE CURVES
RISING WATER ONLY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

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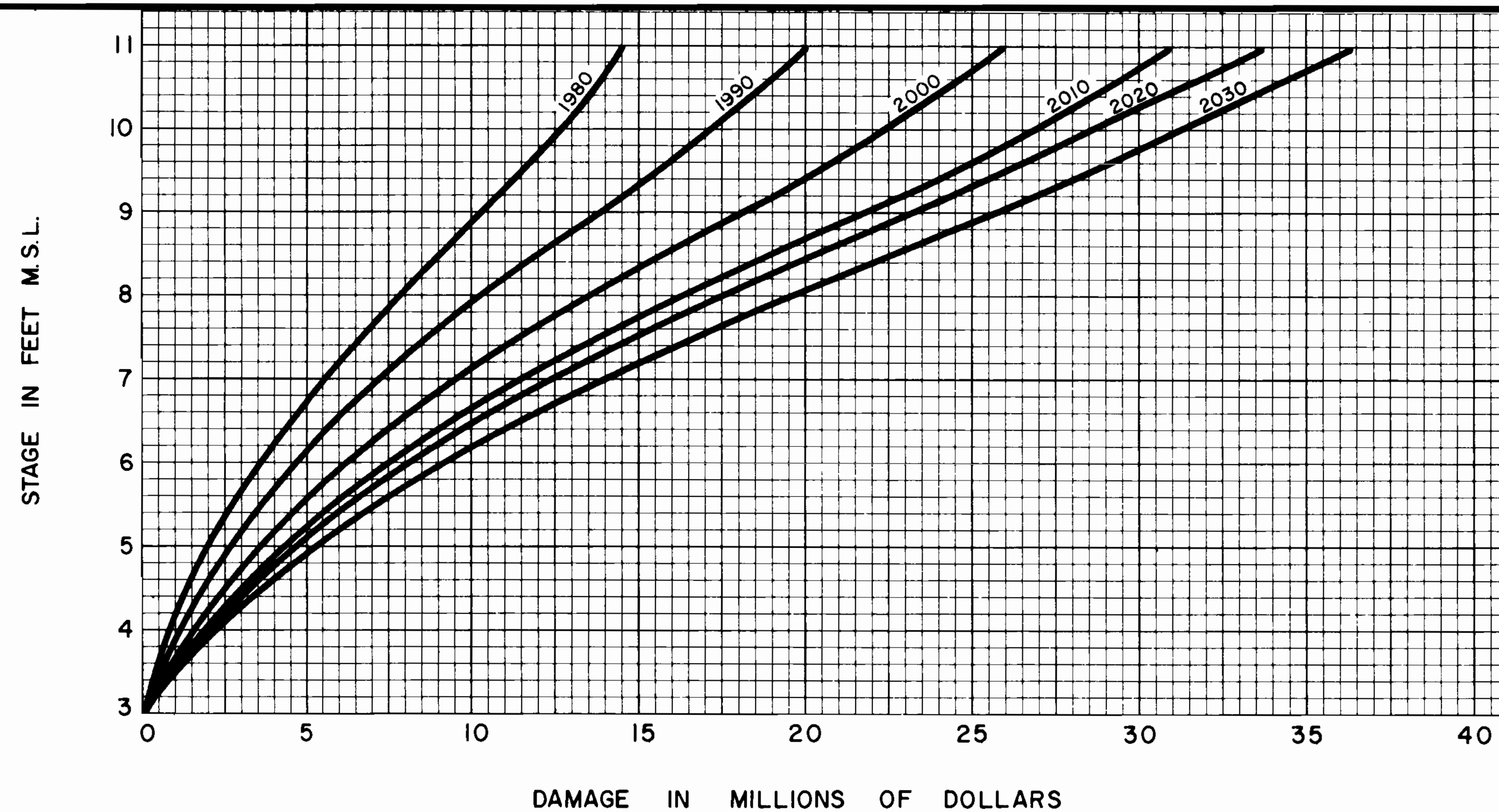


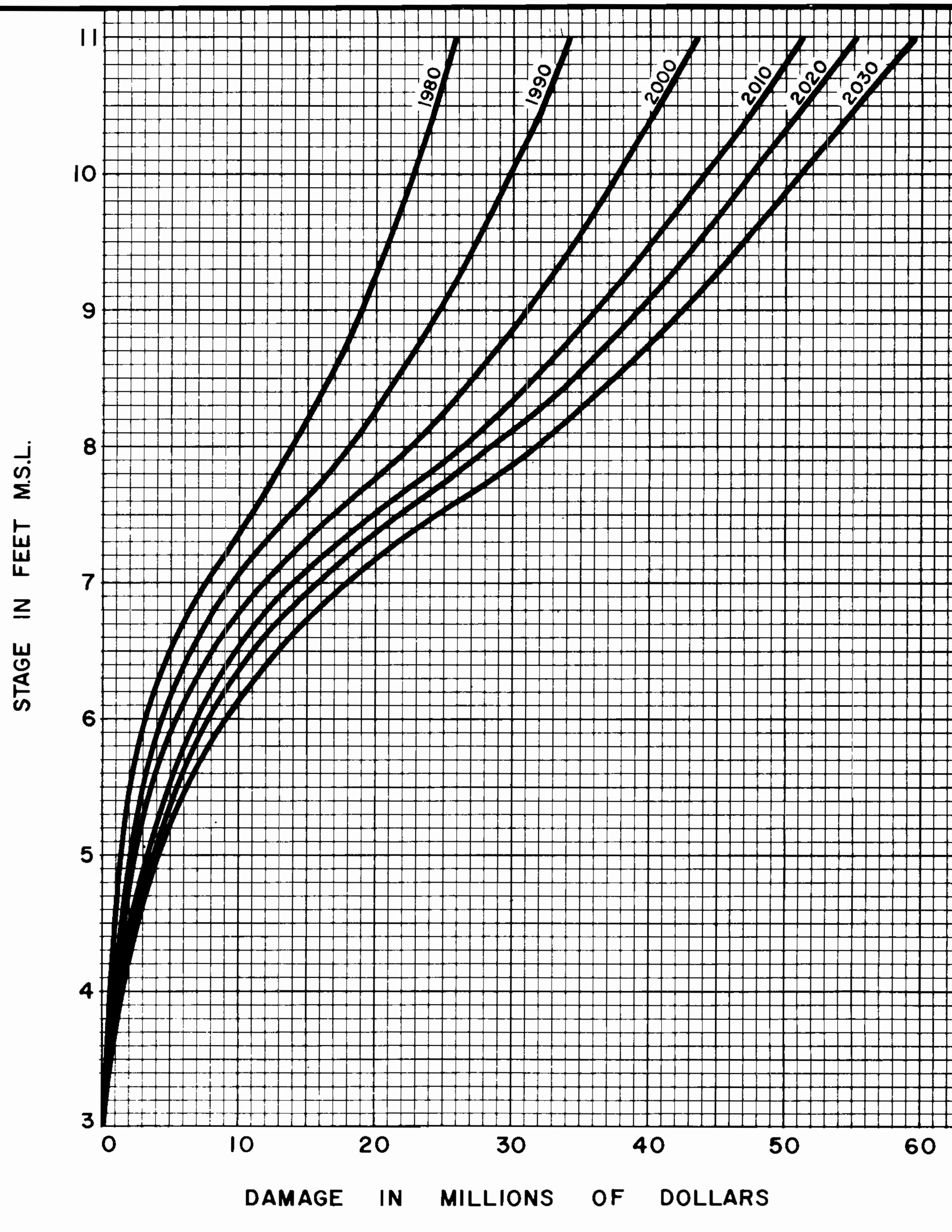
GRAND ISLE AND VICINITY
LOUISIANA

STAGE - DAMAGE CURVES
RISING WATER AND BAY WAVES ONLY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

PLATE D-3



GRAND ISLE AND VICINITY
LOUISIANA

STAGE - DAMAGE CURVES
RISING WATER AND ALL WAVES-
WITHOUT PROJECT

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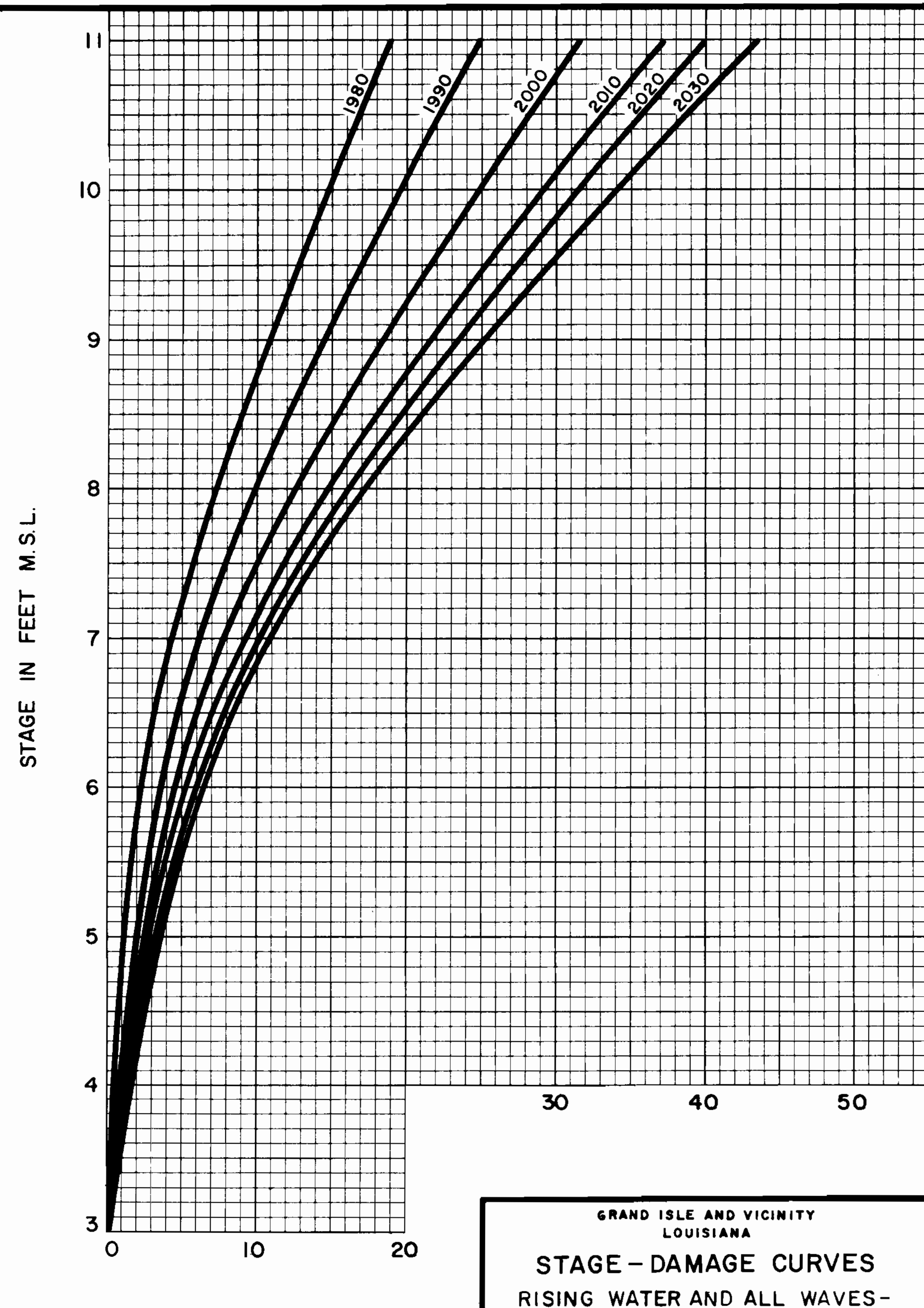

GRAND ISLE AND VICINITY
LOUISIANA

STAGE – DAMAGE CURVES

RISING WATER AND ALL WAVES – WITH PLAN B IN PLACE

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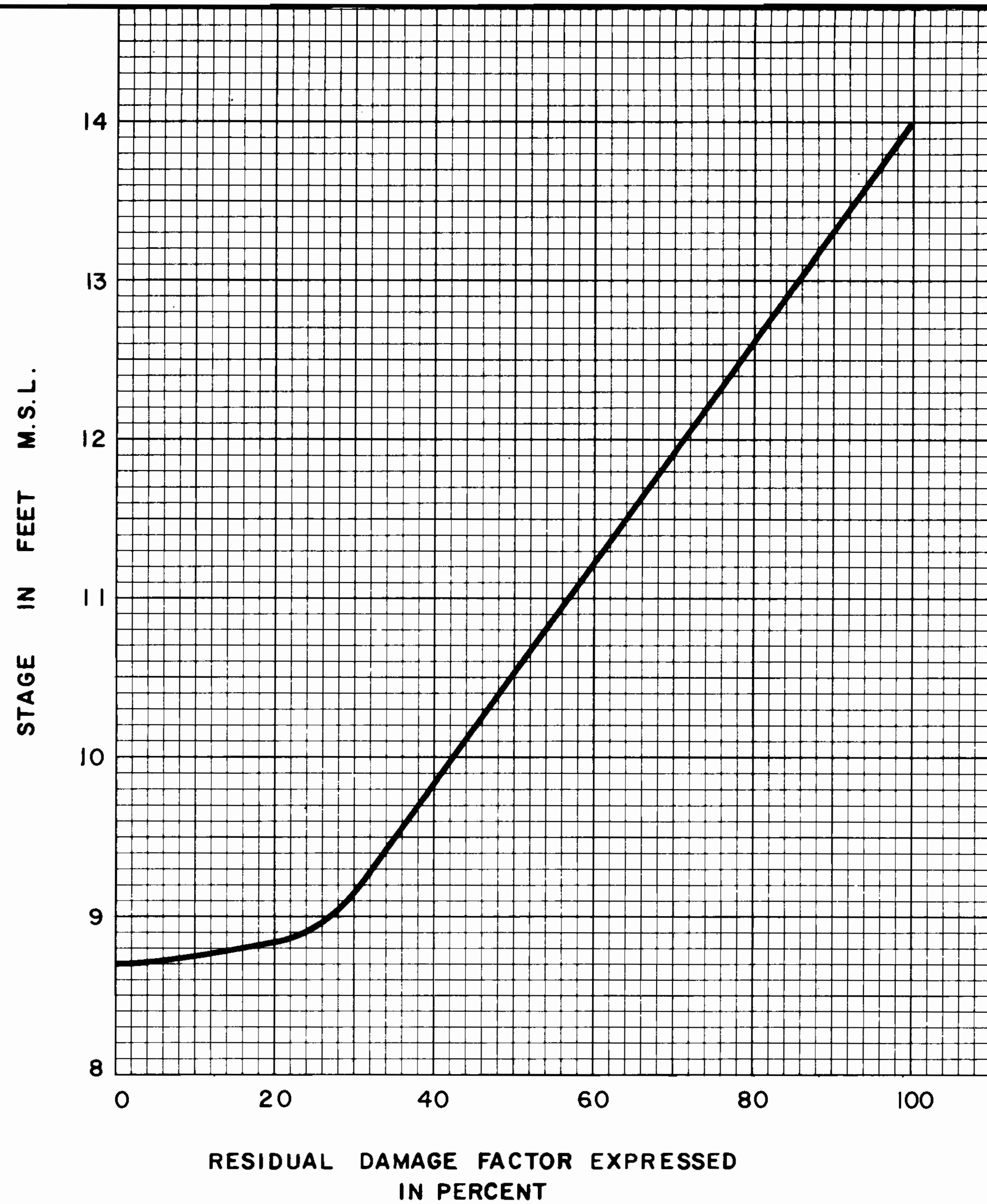
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H–2–25629



GRAND ISLE AND VICINITY
LOUISIANA

GULF WAVE DAMAGE FACTORS WITH PLAN B IN PLACE

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
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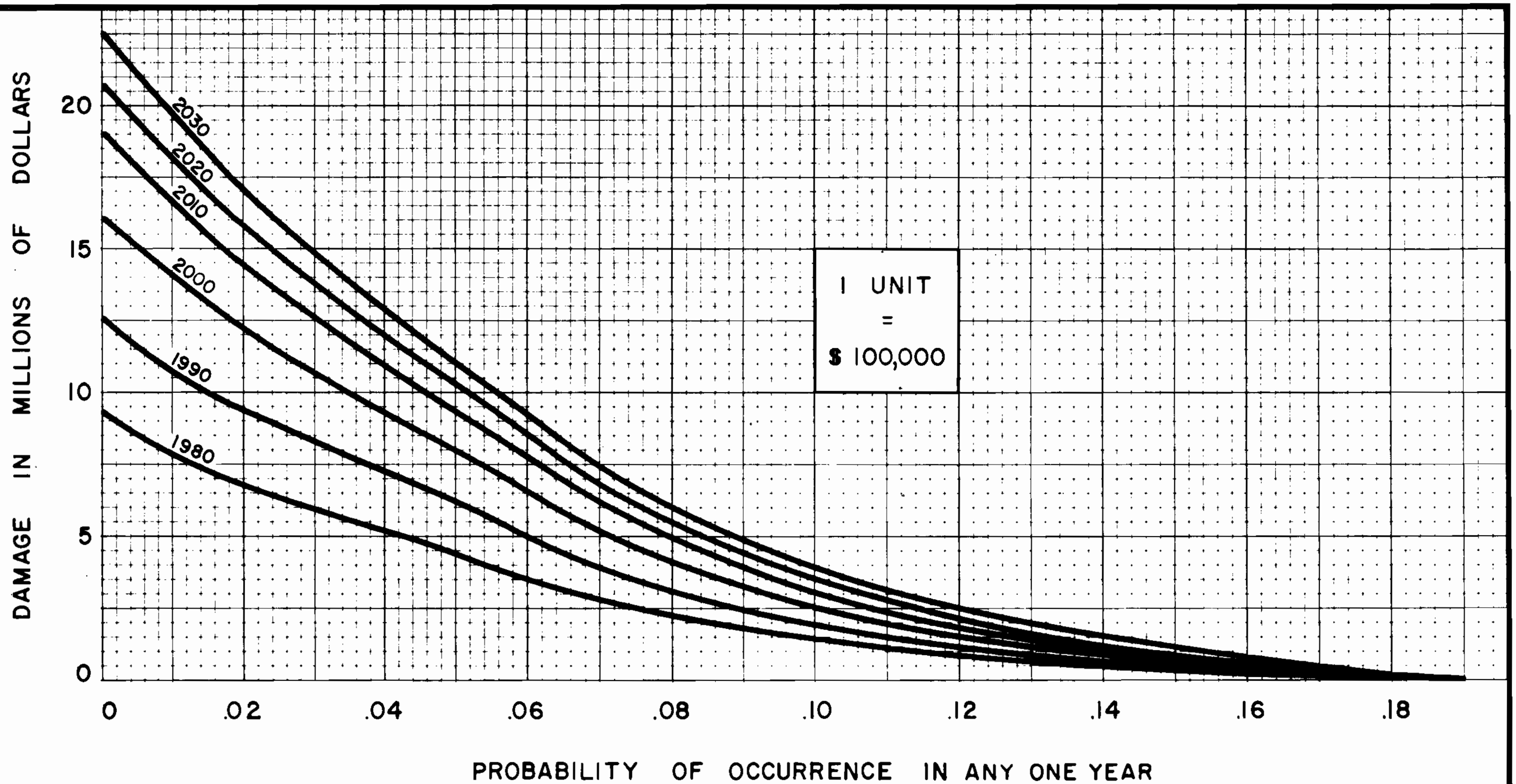


AVERAGE ANNUAL DAMAGES

1980	4.97 □	X	$ 100,000	=	$497,000
1990	6.94 □	X	$ 100,000	=	$694,000
2000	9.02 □	X	$ 100,000	=	$902,000
2010	10.71 □	X	$ 100,000	=	$1,071,000
2020	11.80 □	X	$ 100,000	=	$1,180,000
2030	12.96 □	X	$ 100,000	=	$1,296,000

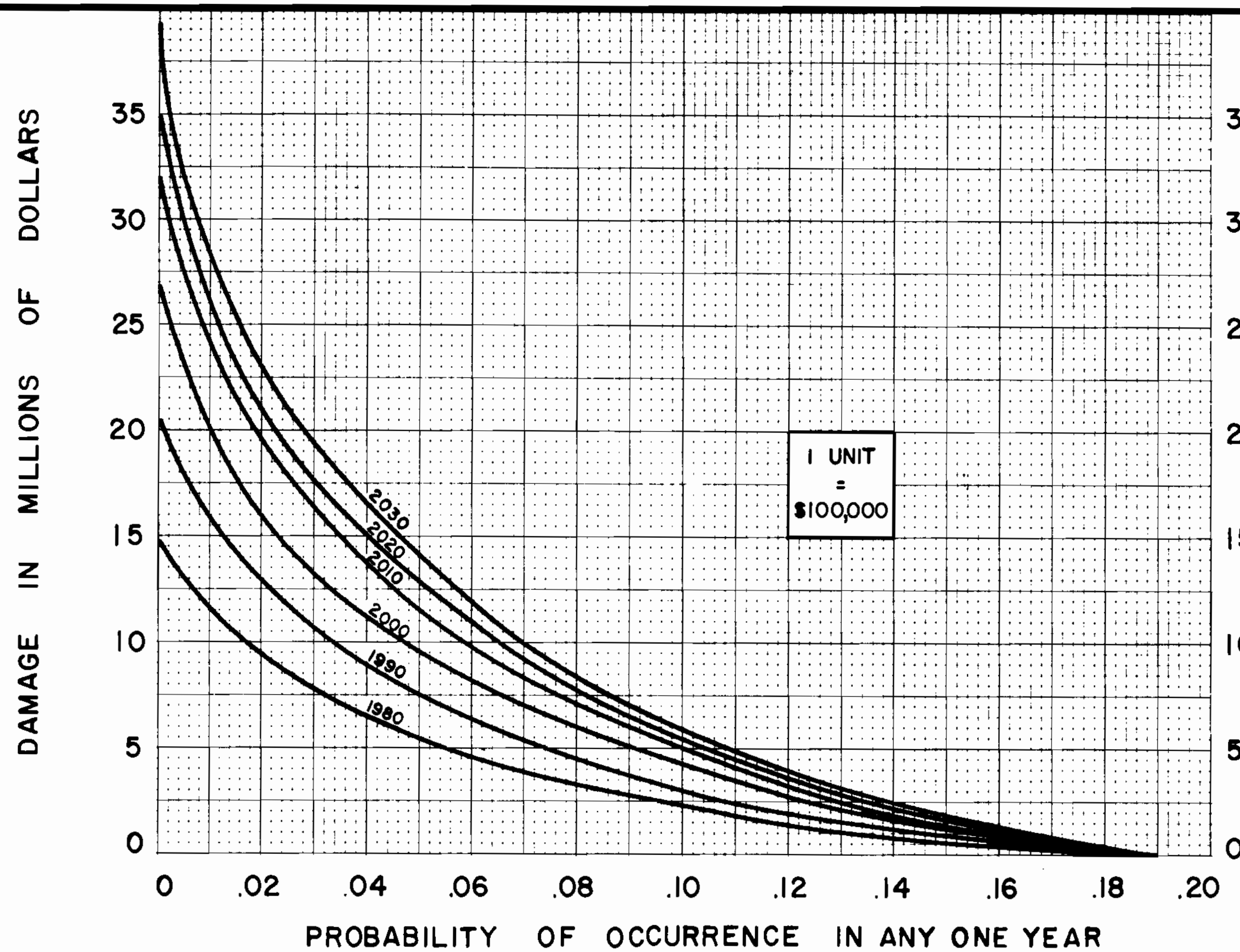
GRAND ISLE AND VICINITY
LOUISIANA

DAMAGE–PROBABILITY CURVES
RISING WATER ONLY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

PLATE D-7



AVERAGE ANNUAL DAMAGES

1980	7.14 □	X	$ 100,000	=	$714,000
1990	9.83 □	X	$ 100,000	=	$983,000
2000	12.81 □	X	$ 100,000	=	$1,281,000
2010	14.83 □	X	$ 100,000	=	$1,483,000
2020	16.69 □	X	$ 100,000	=	$1,669,000
2030	18.41 □	X	$ 100,000	=	$1,841,000

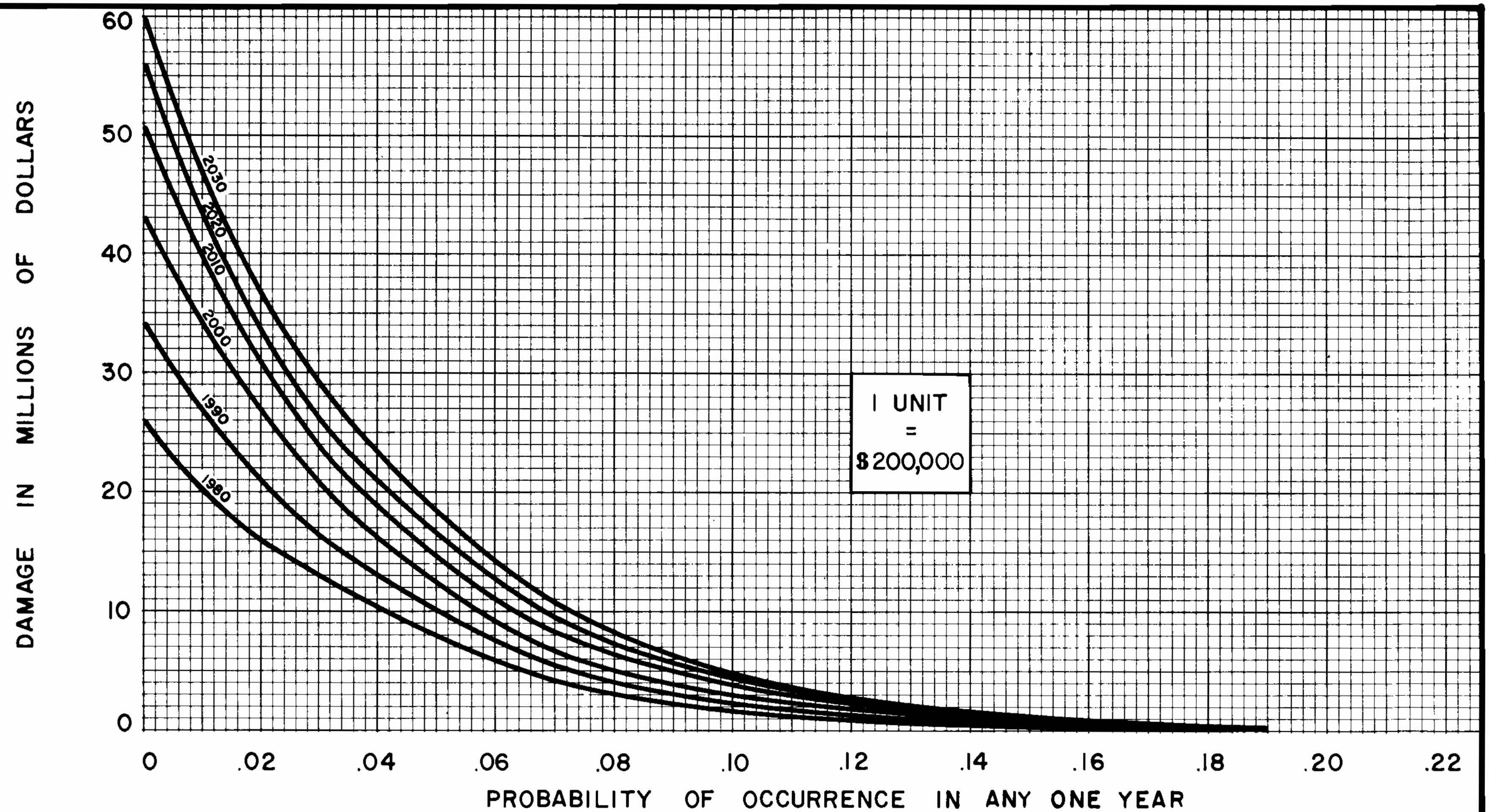
GRAND ISLE AND VICINITY
LOUISIANA

DAMAGE-PROBABILITY CURVES
RISING WATER AND BAY WAVES ONLY

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

PLATE D-8



AVERAGE ANNUAL DAMAGES

1980	5.03 □	X	$200,000	=	$1,006,000
1990	6.57 □	X	$200,000	=	$1,314,000
2000	8.32 □	X	$200,000	=	$1,664,000
2010	9.84 □	X	$200,000	=	$1,968,000
2020	10.98 □	X	$200,000	=	$2,196,000
2030	12.15 □	X	$200,000	=	$2,430,000

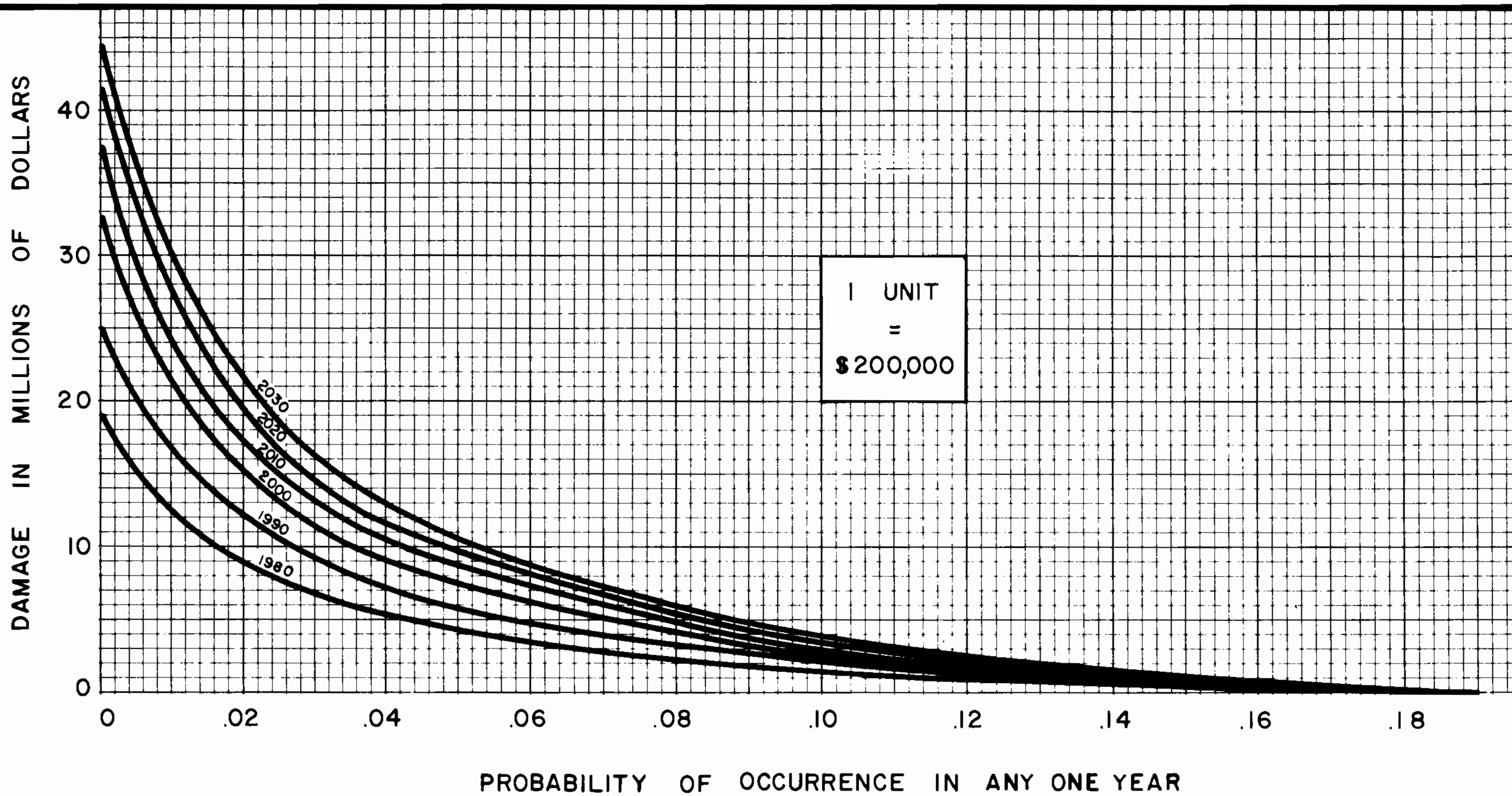
GRAND ISLE AND VICINITY
LOUISIANA

DAMAGE-PROBABILITY CURVES
RISING WATER AND ALL WAVES-
WITHOUT PROJECT

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

PLATE D-9



AVERAGE ANNUAL DAMAGES

1980	3.13 □	X	$200,000	=	$626,000
1990	4.21 □	X	$200,000	=	$842,000
2000	5.31 □	X	$200,000	=	$1,062,000
2010	6.25 □	X	$200,000	=	$1,250,000
2020	7.02 □	X	$200,000	=	$1,404,000
2030	7.77 □	X	$200,000	=	$1,554,000

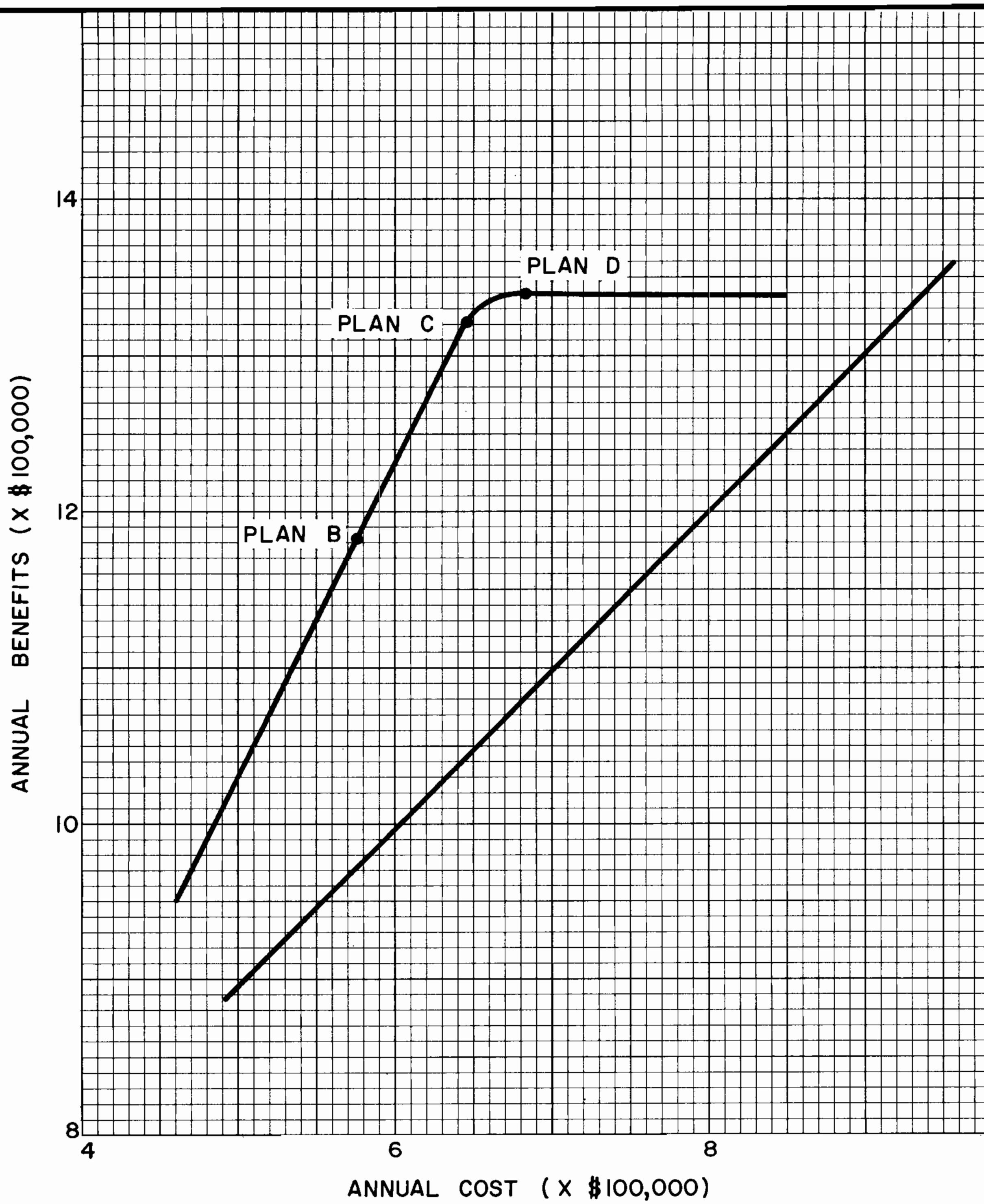
GRAND ISLE AND VICINITY
LOUISIANA

DAMAGE-PROBABILITY CURVES
RISING WATER AND ALL WAVES
WITH PLAN B IN PLACE

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1972 FILE NO. H-2-25629

PLATE D-10



GRAND ISLE AND VICINITY
LOUISIANA

MAXIMIZATION OF NET BENEFITS

U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

SEPTEMBER 1972 FILE NO. H-2-25629

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX E
ALLOCATION AND APPORTIONMENT OF COSTS

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX E
ALLOCATION AND APPORTIONMENT OF COSTS

TABLE OF CONTENTS

REVIEW OF REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX E

ALLOCATION AND APPORTIONMENT OF COSTS

1. COST ALLOCATION

a. Plan A provides beach erosion protection for Grand Isle's gulf shore and all costs for this plan are allocated to that function.

b. Plans B, C, and D provide both beach erosion and hurricane-wave protection. Costs of the various plans are allocated below to thier beach erosion control and hurricane protection functions by the separable costs-remaining benefits method, which is outlined in appendix I to ER 1165-2-19, dated 20 August 1969.

(1) Cost Allocation of Recommended Plan B

Line	Item	Shore Protection	Hurricane protection	Combined project
1.	Average annual benefits	339,000	843,000	1,182,000
	Combined project costs			
2.	Interest and amortization			537,000
3.	Periodic nourishment			93,000
4.	Other maintenance			48,000
5.	Totals			678,000
	Alternative project costs			
6.	Interest and amortization	175,000	537,000	
7.	Periodic nourishment	93,000	93,000	
8.	Other maintenance	21,000	48,000	
9.	Totals	289,000	678,000	
	Separable costs of each			
10.	Interest and amortization	0	362,000	
11.	Periodic nourishment	0	0	
12.	Other maintenance	0	27,000	
13.	Totals	0	389,000	
14.	Remaining benefits	339,000	454,000	
15.	Limit on remaining benefits	289,000	289,000	
16.	Ratios	50%	50%	

(1) Cost Allocation of Recommended Plan B (Cont'd)

Line	Item	Shore Protection	Hurricane protection	Combined project
	Allocated joint costs			
17.	Interest and amortization	87,500	87,500	175,000
18.	Periodic nourishment	46,500	46,500	93,000
19.	Other maintenance	10,500	10,500	21,000
20.	Totals	144,500	144,500	289,000
	Allocated combined costs			
2.	Interest and amortization	87,500	449,500	537,000
3.	Periodic nourishment	46,500	46,500	93,000
4.	Other maintenance	10,500	37,500	48,000
5.	Totals	144,500	533,500	678,000
17.	First costs	1,480,000	7,620,000	

(2) Cost Allocation of Plan C

Line	Item	Shore Protection	Hurricane protection	Combined project
1.	Average annual benefits	339,000	984,000	1,323,000
	Combined project costs			
2.	Interest and amortization			602,000
3.	Periodic nourishment			93,000
4.	Other maintenance			48,000
5.	Totals			743,000
	Alternative project costs			
6.	Interest and amortization	175,000	602,000	
7.	Periodic nourishment	93,000	93,000	
8.	Other maintenance	21,000	48,000	
9.	Totals	289,000	743,000	
	Separable costs of each			
10.	Interest and amortization	0	427,000	
11.	Periodic nourishment	0	0	
12.	Other maintenance	0	27,000	
13.	Totals	0	454,000	
14.	Remaining benefits	339,000	530,000	
15.	Limit on remaining benefits	289,000	289,000	
16.	Ratios	50%	50%	
	Allocated joint costs			
17.	Interest and amortization	87,500	87,500	175,000
18.	Periodic nourishment	46,500	46,500	93,000
19.	Other maintenance	10,500	10,500	21,000
20.	Totals	144,500	144,500	289,000

(2) Cost Allocation of Plan C (Cont'd)

Line	Item	Shore Protection	Hurricane protection	Combined project
	Allocated combined costs			
2.	Interest and amortization	87,500	514,500	602,000
3.	Periodic nourishment	46,500	46,500	93,000
4.	Other maintenance	10,500	37,500	48,000
5.	Totals	144,500	598,500	743,000
21.	First costs	1,480,000	8,720,000	

(3) Cost Allocation of Plan D

Line	Item	Shore Protection	Hurricane protection	Combined project
1.	Average annual benefits	339,000	1,001,000	1,340,000
	Combined project costs			
2.	Interest and amortization			643,000
3.	Periodic nourishment			93,000
4.	Other maintenance			48,000
5.	Totals			784,000
	Alternative project costs			
6.	Interest and amortization	175,000	643,000	
7.	Periodic nourishment	93,000	93,000	
8.	Other Maintenance	21,000	48,000	
9.	Totals	289,000	784,000	
	Separable costs of each			
10.	Interest and amortization	0	468,000	
11.	Periodic nourishment	0	0	
12.	Other maintenance	0	27,000	
13.	Totals	0	495,000	
14.	Remaining benefits	339,000	506,000	
15.	Limit on remaining benefits	289,000	289,000	
16.	Ratios	50%	50%	
	Allocated joint costs			
17.	Interest and amortization	87,500	87,500	175,000
18.	Periodic nourishment	46,500	46,500	93,000
19.	Other maintenance	10,500	10,500	21,000
20.	Totals	144,500	144,500	289,000
	Allocated combined costs			
2.	Interest and amortization	87,500	555,500	643,000
3.	Periodic nourishment	46,500	46,500	93,000
4.	Other maintenance	10,500	37,500	48,000
5.	Totals	144,500	639,500	784,000
21.	First costs	1,480,000	9,400,000	

2. COST APPORTIONMENT.

a. Beach erosion. Costs allocated to shore and beach protection are apportioned between Federal and non-Federal interests in accordance with provisions of Public Law 826, 84th Congress, as amended. The costs to be shared in beach erosion control projects exclude both the costs of preauthorization surveys, which are entirely Federal, and the costs of lands, easements, and rights-of-way which are entirely local.

(1) The following is a breakdown of shore by category based on ownership and use:

	Shore category	Linear feet of frontage
I	Federally owned	-
II	Publicly owned, non-Federal park	8,000
III	Publicly owned, non-Federal	2,500
IV	Privately owned, with public benefits	28,500
V	Privately owned, no public benefits	-
	Total	39,000

(2) Category IV - Benefits. In order to determine the Federal share of costs for category IV frontage, it is necessary to determine the ratio of public benefits along category IV shore to total benefits along category IV shore. The following is a breakdown of annual public benefits applicable to the private sector of shore frontage. (See appendix D for details.)

(a) Public benefits (annual).

Relocation of approximately 4.1 miles of La. Hwy. 1	$12,200
Relocation of approximately 8.7 miles of water lines (mains and laterals)	10,700
Relocation of library and post office	1,700
*Loss of land (56 acres)	27,700
Total public benefits (category IV)	$52,300

(b) Private benefits (annual). The following items were considered in the benefit determination for the private Sector:

Camps	194
House trailers	81
Motels	9
Restuarants	2
Grocery store and parking lot	1
Gas lines (mains and laterals)	8.7
Powerlines and poles	8.4
Telephone lines	6.3
Land (acres)	270
Total shore protection benefits (excluding recreation)	$289,100
Less public benefits private sector	58,200
Total private benefits (category IV)	$230,900

(3) Computation of cost apportionment of first cost and annual maintenance.

(a) The Federal share of the first cost of construction and periodic nourishment for the first 10 years for the shore protection plan and the shore protection function of the combined plan is computed below in accordance with ER 1120-2-110. This computation is based on the assumption that the cost per unit length of benefited shore is reasonably uniform.

Federal share of total construction cost, in percent =

$$\left\{ \left[\frac{\text{Category I frontage}}{\text{Total frontage}}\right] + \left[\frac{\text{Category II frontage}}{\text{Total frontage}} \times 0.7\right] + \left[\left(\frac{\text{Category III frontage}}{\text{Total frontage}}\right) + \left(\frac{\text{Category IV frontage}}{\text{Total frontage}} \times \frac{\text{*Public benefits along Category IV frontage}}{\text{**Total benefits along Category IV frontage}}\right)\right] \times 0.5 \right\} \times 100$$

$$= \left\{ \left[0\right] + \left[\frac{8,000}{39,000} \times 0.7\right] + \left[\left(\frac{2,500}{39,000}\right) + \left(\frac{28,500}{39,000} \times \frac{52,300}{283,200}\right)\right] \times 0.5 \right\} \times 100$$

= 24.3%

Use 24%

(b) Hurricane protection. Costs allocated to hurricane protection are apportioned between Federal and non-Federal interests in accordance with the cost-sharing formula adopted in the Flood Control Act of 1958 for the Narragansett Bay, R.I. and Mass.; New Bedford, Mass.; and Texas City, Texas, projects. First costs, including costs of construction and the costs of lands, easements, rights-of-way, and relocations, but excluding the costs of preauthorization surveys, shall be apportioned at least 30 percent to non-Federal interests and not to exceed 70 percent to the Federal Government. Lands, easements, rights-of-way, and relocations, if any, are to be provided by non-Federal interests without costs to the United States and will be credited to the local contribution. Maintenance, operation, and replenishment costs are a responsibility of non-Federal interests. The Federal share of the first cost of the hurricane protection function of the combined project is the total cost of the hurricane protection function less the cost of lands, easements, and rights-of-way since the lands, etc., exceed 30 percent of the first cost.

(c) Apportionment of first costs of the plans as shown in table E-1 is computed below:

Plan A

Federal cost = .24 (first cost) = .24 (2,970,000) = $710,000
Non-Federal cost = .76 (first cost) = .76 (2,970,000) = $2,260,000

Combined Shore and Hurricane Protection

Plans (Plan B, C, and D)

Federal cost = .24 (shore protection portion) + .70 (hurricane protection portion)

Non-Federal cost = .76 (shore protection portion) + .30 (hurricane protection portion)

Plan B

Federal cost = .24 (1,480,000) + 4,480,000 1/ = $4,840,000

Non-Federal cost = .76 (1,480,000) + 3,140,000 1/ = $4,260,000

1/ Estimated real estate costs are in excess of 30 percent.

Plan C

Federal cost = .24 (1,480,000) + 5,580,000 1/ = $5,940,000

Non-Federal cost = .76 (1,480,000) + 3,140,000 1/ = $4,260,000

1/ Estimated real estate costs are in excess of 30 percent.

Plan D

Federal cost = .24 (1,480,000) + 6,260,000 1/ = $6,620,000

Non-Federal cost = .76 (1,480,000) + 3,140,000 1/ $4,260,000

1/ Estimated real estate costs are in excess of 30 percent.

(d) Annual costs for the periodic beach nourishment of the beach erosion protection plan and the portion of periodic beach nourishment allocated to the beach erosion protection function of the combined plans are apportioned between Federal and non-Federal interests for the first 10 years of the project at the same ratio as the first costs of the beach erosion protection plan. Periodic beach nourishment would be accomplished twice during the first 10 years of the project (years 5 and 10) at a total cost of $532,000 each time. For the combined plans, one-half of this cost ($266,000) would be allocated to the beach erosion protection function and one-half to the hurricane protection function. The computation of the apportionment of annual costs for periodic beach nourishment is given below.

Plan A

Federal cost = (.24) (Cost of one periodic nourishment) (Sum of present worth factors for 5 and 10 years) (Interest and amortization factor) = .24 ($532,000) (.765134 + .585430) (.059061) = $10,000.

Non-Federal cost = (Cost of one periodic nourishment) (Interest and amortization factor) [.76 (Sum of present worth factors for years 5 and 10) + (sum of present worth factors for years 15, 20, 25, 30, 35, 40, and 45)] = ($532,000)(.059061) [.76 (1.350564) + 1.614386] = $83,000.

Plans B, C, and D

Federal costs = .24 (Portion of cost of one periodic beach nourishment allocated to shore protection function) (Sum of present worths of years 5 and 10) (Interest and amortization factor) = ($266,000) (1.350564) (.059061) = $5,000

Non-Federal cost = (Portion of cost of one periodic nourishment that is allocated to beach erosion protection) (Interest and amortization factor) [.76 (sum of present worth factors for 5 and 10 years) + (sum of present worth factors for 15, 20, 25, 30, 35, 40, and 45] + (Portion of cost of one periodic nourishment that is allocated to hurricane protection) (Interest and amortization factor) (Sum of present worth factors for 5, 10, 15, 20, 25, 30, 35, 40, and 45 years hence) = ($266,000) (.059061) [.76(1.350564) + (1.614386)] + ($266,000) (.059061) (2.96495) = $88,000

(e) The annual cost of dune and jetty maintenance and post-hurricane nourishment are totally non-Federal responsibilities for each of the plans.

TABLE E-1
SUMMARY OF COST APPORTIONMENT

	PLAN A Beach erosion protection	PLAN B Combined beach erosion and hurr. protection (dune elev. @ 11.5)	PLAN C Combined beach erosion and hurr. protection (dune elev. @ 13)	PLAN D Combined beach erosion and hurr. protection (dune elev. @ 15)
	$	$	$	$
First costs[1]				
Federal	710,000	4,840,000	5,940,000	6,620,000
Non-Federal	2,260,000	4,260,000	4,260,000	4,260,000
TOTAL	2,970,000	9,100,000	10,200,000	10,880,000
Annual costs				
Interest & amortization (5 1/2%)				
Federal	42,000	285,000	350,000	391,000
Non-Federal	133,000	252,000	252,000	252,000
TOTAL	175,000	537,000	602,000	643,000
Periodic beach nourishment (5-yr intervals)				
Federal	10,000	5,000	5,000	5,000
Non-Federal	83,000	88,000	88,000	88,000
TOTAL	93,000	93,000	93,000	93,000
Post-hurricane replenishment (25th yr)				
Federal	0	0	0	0
Non-Federal	19,000	38,000	38,000	38,000
TOTAL	19,000	38,000	38,000	38,000
Dune and jetty maintenance				
Federal	0	0	0	0
Non-Federal	2,000[2]	10,000	10,000	10,000
TOTAL	2,000	10,000	10,000	10,000
Total annual costs				
Federal	52,000	290,000	355,000	396,000
Non-Federal	237,000	388,000	388,000	388,000
TOTAL	289,000	678,000	743,000	784,000

[1] Does not include $105,000 preauthorization study costs.
[2] Jetty maintenance only

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX F
"BEFORE" AND "AFTER" HURRICANE BETSY
AERIAL PHOTOGRAPHS

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX F
"BEFORE" AND "AFTER" HURRICANE BETSY
AERIAL PHOTOGRAPHS

CONTENTS

Mosaics of aerial photographs of Grand Isle, Louisiana, flown on 7 October 1964 and 8 October 1965, before and after Hurricane Betsy which struck the Grand Isle area on 9 September 1965.

Photographs numbered F-1 through F-4

BEFORE HURRICANE "BETSY"
GRAND ISLE, LA.
7 October 1964

AFTER HURRICANE "BETSY"
GRAND ISLE, LA.
8 October 1965


BEFORE HURRICANE "BETSY"
GRAND ISLE, LA.
7 October 1964


AFTER HURRICANE "BETSY"
GRAND ISLE, LA.
October 1965


N
TIFF ISLAND
BAYOU RIGAUD
BARATARIA PASS
GRAND ISLE
1
GULF OF MEXICO
BEFORE HURRICANE "BETSY"
GRAND ISLE, LA
7 October 1964


N
BARATARIA PASS
TIFF ISLAND
BAYOU RIGAUD
GRAND ISLE
1
GULF OF MEXICO
AFTER HURRICANE "BETSY"
GRAND ISLE, LA
8 October 1965


CHENIERE CAMINADA
1
CAMINADA PASS
GRAND ISLE
1
GULF OF MEXICO
BEFORE HURRICANE "BETSY"
GRAND ISLE, LA.
7 October 1964


CHENIERE CAMINADA
1
CAMINADA PASS
GRAND ISLE
1
GULF OF MEXICO
AFTER HURRICANE "BETSY"
GRAND ISLE, LA.
8 October 1965

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX G
COORDINATION WITH OTHER AGENCIES

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX G
COORDINATION WITH OTHER AGENCIES

TABLE OF CONTENTS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
Intermountain Field Operation Center

Office of
Chief

BUILDING 20
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

December 29, 1971

Your reference:
LMNED-PR

Air Mail

Col. Richard L. Hunt
District Engineer, New Orleans District
U. S. Army Corps of Engineers
Box 60267
New Orleans, Louisiana 70160

Dear Colonel Hunt:

We have reviewed the draft report on Grand Isle and Vicinity, Louisiana, and in response to your November 11 letter offer these comments:

Minor references in the report (pages 11, 12, 32, D1, and D6) to "large offshore" mineral production and industry facilities based on Grand Isle need to be clearly defined; and in terms of specific impacts apt to incur from the recommended hurricane protection project, appropriate conclusions should be inserted (pages 60-d, 61-Table 6, and 73-paragraph 8). For example, the anticipated "increase in market value of the land," and the "public use of privately owned shores" might loom as adversities to these large mineral industries.

Benefits to the mineral industries from hurricane protection, however, should outweigh the adversities and, in any case, should appear in Table 6, page 61. Instead, the Syllabus, beginning the report, merely informs that "wind and tide destroyed approximately 85 percent of the improvements on the island excluding industrial development," and specifically defines damages as only the loss of about 35 acres, four houses stranded, and three housetrailers having to be moved.

Grand Isle and vicinity produces mostly from offshore a significant but undetermined annual share of Jefferson Parish's $300 million mineral production value of petroleum, sulfur, natural gas, salt, sand and gravel, and natural gas liquids.

A comprehensive map should be included to pinpoint mineral resources, production operations, processing and manufacturing industries, transportation routes, and other facilities showing these involvements with the recommended hurricane protection project for Grand Isle and Vicinity.

Our field-level comments are intended to be helpful, but they do not constitute a formal Bureau of Mines or Departmental review.

Sincerely yours,

L. F. Heising, Acting Chief
Intermountain Field Operation Center

ENVIRONMENTAL PROTECTION AGENCY
REGION VI
1600 PATTERSON, SUITE 1100
DALLAS, TEXAS 75201

November 30, 1971

Colonel Richard L. Hunt, District Engineer
U. S. Army Engineer District, New Orleans
P. O. Box 60267
New Orleans, Louisiana 70161

Dear Colonel Hunt:

Thank you for allowing us to review your draft report on Grand Isle and Vicinity, Louisiana.

We do not have any recommendations for changes at this time.

Sincerely,

Mac A. Weaver

Mac A. Weaver, P. E.
Air and Water Programs Division

United States Department of the Interior
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
PEACHTREE-SEVENTH BUILDING
ATLANTA, GEORGIA 30323

June 2, 1972

District Engineer
U.S. Army, Corps of Engineers
New Orleans, Louisiana

Dear Sir:

This is in response to your November 11, 1971, letter, LMNED-PR, to Mr. Richard E. Eichhorn of our Vicksburg, Mississippi, field office, requesting our review and comments on your October 1971 draft review report on emergency work for Grand Isle and Vicinity, Louisiana, project. Your studies were authorized by resolutions of the Committee on Public Works for the House of Representatives adopted September 26, 1963, and May 5, 1966. Our studies were made in cooperation with the Louisiana Wild Life and Fisheries Commission, and our comments are submitted in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The Bureau has investigated fish and wildlife aspects of plans for hurricane protection and beach improvement for Grand Isle on several occasions. Grand Isle is located on the southern shore of Hurricane Study Area III, which we commented on in a letter report dated September 15, 1960. On March 27, 1969, the Bureau issued a letter report that concerned plans for a ring levee to encompass an area of urban development on Grand Isle; construction of a rock and concrete breakwater structure parallel to this leveed area on the gulf side of the island; direct nourishment and widening of the beach on the gulf and east sides of the island; and extension and enlargement of the east jetty and construction of a revetment to protect the U.S. Coast Guard's Loran Installation from erosion damage. Our comments on the five parts of an environmental statement for these project features were prepared pursuant to Section 102(2)(C) of the National Environmental Policy Act of 1969, Public Law 91-190, and transmitted by letter dated August 7, 1970. The proposal for enlargement of the east jetty was deleted from your plans, and accordingly this Bureau transmitted a letter on February 8, 1971, which rescinded a recommendation regarding that feature.

Essentially, your draft review report discusses three plans to alleviate storm and erosion damages to the western end of Grand Isle and Vicinity, Louisiana, project. The three plans, referred to as plans A, B, and C, are similar to plans considered at a public hearing held on June 10, 1971, at Our Lady of the Isle Community Hall on Grand Isle. Alternatives of no action, and protection by groins, levees, bulkheads, and a breakwater structure are also discussed in the report.

Severe erosion has recently made the need for features to protect the western end of Grand Isle an emergency. During the period from March 1968 to May 1971, approximately 35 acres were eroded from the western tip of the island, leaving some houses stranded in gulf waters, and making further erosion an imminent threat to other houses. The 1971 Louisiana Legislature appropriated money for the emergency work, and the Louisiana Department of Public Works awarded a contract for construction of features described as plan B in the review report. It is anticipated that this work will be completed in the spring of 1972. The draft review report recommends that plan B be authorized as a Federal project. It also recommends that credit toward the non-Federal share of cost for the recommended plan be allowed for expenditures by the Louisiana Department of Public Works for emergency construction on the western end of Grand Isle.

Basically, plans A, B, and C each call for construction of a jetty approximately 2,600 feet long with crown elevation at 4 feet, top width of 6 feet, and side slopes of 1 on 2. Fill will be placed on the east side to stabilize the western end of the island at Caminada Pass. The three plans differ in regard to dimensions of beach berms and a dune east of the jetty, maintenance requirements, and degree of storm protection. Plan A is considered the minimum amount of work needed to restore and stabilize the beach for protection against erosion damage and to preserve it for recreational use. Plans B and C are shore and hurricane wave protection plans designed to provide protection from hurricanes having frequencies of approximately once in 50 years and once in every 100 years, respectively. The draft review report concludes that plan B is the most feasible of the three plans.

With plan B, the beach berm will have an elevation of 3 feet at a distance of 200 feet from the centerline of the dune, an elevation of 10 feet at the toe of the dune, and a crown elevation of 13 feet. The plan provides for initial construction, periodic nourishment (every 5 years), and posthurricane replenishments with sand fill. Project plans include establishment of 60 acres of dune vegetation to help stabilize the area. The mainland of Cheniere Caminada and the immediate offshore area at the western and eastern ends of the island are mentioned on page 19 as possible sources of sand fill for initial construction. On pages 41 and 50, littoral materials near the eastern and western ends of the island are cited as suitable sources for the fill. Page 4 of Appendix A states that the levee could be constructed from material obtained locally, and page 7 of Appendix C, item 7, mentions the possibility of securing fill from a borrow area on Cheniere Caminada.

Fish and wildlife and other recreational resources of Grand Isle, the surrounding gulf waters and bottoms, and Cheniere Caminada are of high value. There are approximately 22 acres of land on the western end and 104 acres on the eastern end of Grand Isle that are a part of the State park system and are the only lands on the gulf owned and maintained by Louisiana as a public beach. Grand Isle has the only gulf beach of significant size in southeastern Louisiana. (We note a discrepancy in information on the size of the State park given on page 11 and in Appendix D, page 32, of the draft report.) Recreational use of Grand Isle and vicinity is heavy, and sport- and commercial-fishing enterprises are highly remunerative. Cheniere Caminada traverses the 30,000-acre Wisner Wildlife Management Area near the western end and inshore from Grand Isle. This tract of land supports heavy concentrations of migratory waterfowl, rabbits, and fur-bearing animals, American alligators, and a few white-tailed deer. The State's marine fisheries research laboratory is located on Grand Terre Island, which lies to the east and is separated from Grand Isle by Barataria Pass. Shallow near-shore waters of the area serve as a nursery for finfish and shellfish species.

Project effects on fish and wildlife resources are discussed on page 54 of the review report. Initial construction and periodic maintenance are expected to cause local short-term damages. The draft review report states that remedial and protective measures are to be used to reduce adverse environmental impacts, and that no endangered species are expected to be affected. Since the review report does not specify any particular location on Cheniere Caminada from which spoil material may be secured, we cannot comment on that aspect of the plan at this time. Structural and artificial improvements will detract from scenic qualitites, although the project will assure better maintenance of Grand Isle for fishing and other recreational pursuits. Dimensions of the jetty and its location immediately adjacent to a public beach will make it well suited as a pier for sport fishermen. The presence of the jetty and resulting currents near its outside edge are expected to improve sport-fishing opportunities.

We conclude that the Grand Isle and Vicinity, Louisiana, project will help preserve resources but will encourage further development of the island. We are in general agreement with the need for this project. If care is exercised in construction and maintenance, damages to fish and wildlife resources will be minimal. Appropriate means should be employed to the hydraulic movement and spread of spoil material. To avoid damages to particularly valuable habitats, final selection of sites for borrowed spoil material should be made in cooperation with the Louisiana Wild Life and Fisheries Commission. We believe that a walkway from the jetty to the public beach area, with top elevation of 4 feet, would be necessary to assure safe crossing by fishermen who may otherwise attempt to wade to the structure.

The Bureau therefore recommends that:

1. Care be taken to minimize the hydraulic movement and spread of spoil material;
2. Final selection of areas for borrowing spoil materials be made in cooperation with the Louisiana Wild Life and Fisheries Commission; and
3. A safe walkway to the jetty at the west end of Grand Isle be provided.

This report has been reviewed and concurred in by the National Marine Fisheries Service and the Louisiana Wild Life and Fisheries Commission. Please see the comments made in Director Hoffpauer's letter which is attached.

We appreciate this opportunity to review and comment on the emergency measures for protection of the western part of Grand Isle. Please advise if we can be of further assistance.

Sincerely yours,

Jack E. Hemphill

~~Acting~~ Regional Director

Attachment

State of Louisiana
WILD LIFE AND FISHERIES COMMISSION
400 ROYAL STREET
NEW ORLEANS 70130

C.M.HOFFPAUER
DIRECTOR

April 13, 1972

Mr. Jerry L. Stegman, Regional Supervisor
Division of River Basin Studies
Bureau of Sport Fisheries and Wildlife
Fish and Wildlife Service
U. S. Department of the Interior
Peachtree-Seventh Building
Atlanta, Georgia 30323

Dear Mr. Stegman:

RE: Grand Isle and Vicinity, Louisiana

Reference is made to your request for this Commission to review the draft attached to your letter of March 24, 1972, as referenced above.

In general we concur with your comments on the Corps' project on the emergency work at Grand Isle; however, we would like to add one further recommendation to be included in this project which would request the Corps to do an evaluation study on the effects of this structure on the Grand Terre Island. In the past, whenever work was performed on Grand Isle it affected Grand Terre. Since the island is eroding as fast as Grand Isle, we would like to know that the work done on Grand Isle will not have any adverse effect on Grand Terre.

We appreciate the opportunity to comment on this project. If you should desire any further information, please let me know.

Sincerely yours,

Clark M. Hoffpauer
Director

CMH:HESJr/lm

STATE OF LOUISIANA
DEPARTMENT OF PUBLIC WORKS
BATON ROUGE, LA. 70804

C. H. DOWNS
DIRECTOR

January 3, 1972

Colonel Richard L. Hunt
District Engineer
New Orleans District Corps of Engineers
P. O. Box 60267
New Orleans, Louisiana 70160

Dear Colonel Hunt: Re: LMNED-PR, November 22, 1971

Your letter of November 22, 1971, forwarded to us a draft copy of the proposed report, entitled "Grand Isle & Vicinity, Louisiana", for our review and comment prior to finalizing the report.

We have reviewed the draft report in detail and suggest the following revisions be incorporated into the report. The following is a tabulation of our comments with reference to the particular page affected.

PAGE NO.	COMMENTS
Cover	The title of this report should be changed since this title conflicts with previous reports of the same name, particularly the project authorization in 1965.
ii	Second paragraph - the reference made that Plan B provides protection from a hurricane having a 50 year frequency is misleading. This should reflect reference to a hurricane tidal surge, since there is no complete levee system proposed and no protection from high water on the bay side.
Page 9 B-1	Low temperature - subsequent to 1949 - Our records indicate a low of 16°, January 11, 1962 on Grand Isle, and a low of 11°, January 24, 1963, at Golden Meadow.
Page 14 E-5	The U. S. Coast Guard installation property abutts Barataria Pass and Bayou Rigaud; our information reflects the Coast Guard property does not have Gulf of Mexico frontage.
Page 32	Paragraph d - The Humble groin, due to its location, has not been more effective than the groins to the west, but rather has had its effect drown out by the rock jetty on the east end of the island. It is presently totally covered due to acretion attributed to the rock jetty.

PAGE NO.	COMMENTS
Page 33	Paragraph F indicates the mattress width as being 66 feet. The width as constructed was variable depending upon the ground elevation and jetty height. The side slope of the jetty should read 1:1.5 in place of 1:15 as indicated. The photographs referred to were not included in the report.
Page 53	Paragraph B - The statement is made that the Department of Public Works awarded the west jetty contract on September 9, 1971, whereas, Page ii indicates we awarded the contract on September 3, 1971. The correct date for awarding the contract is September 3, 1971.
Page 54	Paragraph (26) - The environmental impact statement has a negative approach and underemphasizes the environmental improvements while dwelling on the alterations to the ecosystem. This section should be completely rewritten to reflect the major improvements to the environment for the entire area.
Page 56 C-7, C-9, C-11	The cost estimates indicated refer to Department of Public Works contract quantities, however, the unit prices indicated are not in accordance with the contract. The navigation light is not shown on these cost estimates. ($3,270.00)
Page 66 A-7	Paragraph (7) - This section is recommended by the Corps of Engineers as part of the local interest assurances. This item should not be included in the assurances, since there is no way of determining if an increased cost would result. In fact, on the basis of the existing trend of construction costs increasing each year, it is more practical to assume that a saving in overall cost to both local and federal interests will result from the work presently under contract by the Department of Public Works at Grand Isle, Louisiana.
Page 68	The photographs referred to Paragraph A - were not included in the report.
Page B-9 B-10	The information presented indicates the sand dune restoration was accomplished using a core of silty material with a two (2) feet cover of medium to fine sand. Our records do not indicate this type of construction was used during the restoration work. All material utilized

PAGE NO.	COMMENTS
	in the sand dune restoration came from the borrow area immediately west of the rock jetty located on the east end of the island. The material used was all of the same type and character.
Page C-1	Paragraph A uses the term "groin" in some instances, and the word "Jetty" in others for the same structure. The terminology should be consistant.

We appreciate the opportunity to review and comment on this draft copy of your proposed report. It is requested that you make the recommended revisions, particularly in the instance of Paragraph A-7, Page 66. Should you desire further information or conferences relative to the above, please contact us at your convenience.

Sincerely yours,

C. H. Downs

C. H. DOWNS
DIRECTOR

/dha

October 4,1972

Colonel Richard L. Hunt, C.E.
District Engineer
Department of the Army
N.O.District, Corps of Engineers
P.O.Box 60267
New Orleans, Louisiana 70160

SUBJECT: Combined Hurricane and Shore Protection Plan for Grand Isle and Vicinity, Louisiana

Dear Colonel Hunt:

The staff of the Regional Planning Commission for Jefferson, Orleans, St.Bernard and St.Tammany Parishes has reviewed the subject report as submitted by your office November,1971 and finds that the recommended project improvements are not in conflict with the regional comprehensive planning process in progress under the Regional Planning Commission program.

If the Regional Planning Commission can be of further assistance in moving this project forward please do not hesitate to contact this office.

Sincerely,

REGIONAL PLANNING COMMISSION

Charles F. O'Doniel, Jr.
CHARLES F. O'DONIEL,JR.
DIRECTOR

CFOjr/TWS/wsa

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Engr Dir

State of Louisiana

WILD LIFE AND FISHERIES COMMISSION
400 ROYAL STREET
NEW ORLEANS 70130

C.M. HOFFPAUER
DIRECTOR

January 13, 1972

Col. Richard L. Hunt, CE
New Orleans District Engineer
U. S. Army Corps of Engineers
P. O. Box 60267
New Orleans, Louisiana 70160

Dear Col. Hunt:

I agree with your Corps Report Serial No. 24, October 1971, which states that Grand Isle, due to its low elevation cannot be adequately protected from hurricane damage. Protection of life can be provided in the form of early warning of approaching hurricanes and perhaps a more suitable road for evacuation. Adequate protection of property in such a low-lying area on the coast is practically impossible. To prevent damage caused by breaking waves, winds and rising water, the entire island would have to be enclosed by a sea wall, and the structures on the island made to withstand high winds. Little, if any, protection could be provided against tornados which are quite numerous during hurricanes.

Damage from breaking waves and the storm surge could be reduced by offshore bars and/or a man-made berm or dune. Berms are eroded by major storms as evidenced by the loss of the berm on Grand Terre during Hurricane Betsy. A berm and dune on the gulf shore would not provide protection from rising waters from the north side of Grand Isle. Sand structures, however, would reduce damage to buildings by breaking waves, impede the inundation of the evacuation route, and prevent the erosion of some beach material.

The protection of Grand Isle depends, to a large extent, on the preservation of Grand Terre. If the Grand Terre barrier islands are allowed to erode at their present rate, the protection they afford Grand Island in the form of reducing wave forces and providing shelter from erosional agents from the east will cease. Grand Terre also provides protection from erosion of the marsh to the north of Grand Isle. The jetty located on the eastern end of Grand Isle has resulted in an increased erosion rate on Grand Terre. I request that this project include a study of its effects on Grand Terre so that the erosion problem can be solved and not shifted to another area.

The construction of sand barriers on Grand Isle would have no apparent long-term effects on the ecology of the area. However, the proposed jetty on the western end of Grand Isle may, in years to come, block Caminada Pass. The predominant sediment drift, as mentioned in your report, is from west to east. Much sediment, drifting from the west, would be blocked by this jetty and result in the shoaling of Caminada Pass. This Pass should remain open in order to protect the highly productive shrimp nursery area located in the marsh areas to the west of Caminada Bay.

During high Mississippi River discharge, there is evidence that the prevailing sediment drift is from east to west. The sediment size, when this direction of drift is predominant, is probably mostly fine silt and clay. Therefore, a jetty on the western end of Grand Isle would accumulate fine particles. It is desirous from an ecological point of view to have the sediment-laden waters of the Mississippi River dispersed naturally to the largest area.

Renourishment of such a large area as proposed in the Corps report will result in greatly increased turbidity in the nearby waters. Preventive measures, such as retaining dams, should be utilized in order to prevent the silting over of oyster beds in the adjacent bayous and Caminada Bay.

Some consideration should be given to fishing conveniences along the recommended jetty. A walkway along the top of the jetty with railings would provide access to fishing.

With best wishes and thanking you for allowing our Commission to comment on this matter, I am

Sincerely yours,

Clark M. Hoffpauer
Director

HES/CMH/lm

cc: Oysters, Water Bottoms
and Seafoods Division

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX H
STATEMENT OF LOCAL COOPERATION

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

APPENDIX H
STATEMENT OF LOCAL COOPERATION

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STATE OF LOUISIANA
DEPARTMENT OF PUBLIC WORKS
P. O. BOX 44155, CAPITOL STATION
BATON ROUGE, LA. 70804

Y AGUILLARD
DIRECTOR

September 6, 1973

Colonel Richard L. Hunt
District Engineer
New Orleans District
Corps of Engineers, U. S. Army
Post Office Box 60267
New Orleans, Louisiana 70160

Dear Colonel Hunt:

Reference is made to your letter of August 29, 1973 concerning the intention to provide the assurances as outlined for the "Grand Isle and Vicinity, Louisiana" project.

As the State agency designated to coordinate Corps of Engineer projects in the State of Louisiana, the Louisiana Department of Public Works gives the assurance to the Corps of Engineers, U. S. Army, that the requirements made of local interest will be provided if the project is authorized, and if at the time the formal assurances are required sufficient funds and the local ability to do so are available.

Sincerely yours,

Roy Aguillard

ROY AGUILLARD
DIRECTOR

DVC/mn

REVIEW REPORT

GRAND ISLE AND VICINITY, LOUISIANA

SUPPLEMENT

Information Called for by Senate Resolution 148, 85th Congress, Adopted 28 January 1958

REVIEW REPORT
GRAND ISLE AND VICINITY, LOUISIANA

SUPPLEMENT

Information Called for by Senate Resolution 148,
85th Congress, Adopted 28 January 1968

1. PROJECT DESCRIPTION AND ECONOMIC LIFE

The improvements recommended for Grand Isle, Louisiana, consist of a vegetated, sandfill dune with a 10-foot wide crown at an elevation of 11.5 feet, a 180-foot wide berm located gulfward of the dune, and a 2600-foot long stone jetty along the western end of the island at Caminada Pass. The dune and berm would extend along Grand Isle's gulf shore and provide protection from beach erosion and gulf waves driven by hurricanes having a frequency of recurrence once every 50 years. The jetty would stabilize the western end of Grand Isle. The economic analysis is based on a project life of 50 years.

2. PROJECT COST AND ANNUAL CHARGES

a. First costs. The first costs of the recommended dune, berm, and jetty, based on similar work adjusted to July 1972 price levels, is $9,100,000 of which $4,840,000 is Federal and $4,260,000 is non-Federal. Detailed estimates of the first costs are given in table 4 of the report in Appendix C.

b. Annual charges. Annual charges for the recommended improvements are based on an interest rate of 5 1/2 percent. Cost of periodic maintenance and post-hurricane replenishment are based on similar work adjusted to July 1972 price levels. The annual charges for 50- and 100-year project lives are given below. A summary of annual charges is given in table 5 of the report. A detailed breakdown of annual charges is given in Appendix C.

Project Life	Estimated Annual Charges		
	Federal	Non-Federal	Total
50 years	$290,000	$388,000	$678,000
100 years	273,000	373,000	646,000

3. BENEFIT-TO-COST RATIOS

The benefit-to-cost ratios for the recommended improvements, based on 50- and 100-year project lives are:

Project Life	Annual Benefits	Estimated Annual Charges	Benefit-to-Cost Ratios
50 years	$1,182,000	$678,000	1.7
100 years	$1,207,000	$646,000	1.9

4. INTANGIBLE PROJECT BENEFITS

Intangible benefits that would result from the construction of the recommended improvements are an increase in the social well-being of residents and recreationists on Grand Isle and protection of the valuable estuarine marshland located on Grand Isle's bayside from the eventual direct attack of gulf waves. The adverse intangible effects attributable to the recommended plan are the decrease in water quality and destruction and displacement of marine life resulting directly from construction. These adverse effects would be local in extent and temporary.

5. PHYSICAL FEASIBILITY AND COST OF PROVIDING FOR FUTURE NEEDS

The recommended improvements have been designed to protect Grand Isle and its existing and future improvements from damages caused by beach erosion and hurricane-driven gulf waves. Protection from gulf waves driven by hurricanes more severe that the design hurricane is economically feasible and could be provided by enlargement of the recommended dune and berm.

6. ALLOCATION OF COSTS

The recommended plan of improvement would provide both beach erosion and hurricane wave protection for Grand Isle. All costs for the plan have been allocated to these purposes by the separable costs-remaining benefits method as outlined in appendix E. For an economic project life of 50 years and 100 years this method results in $1,480,000 of the first cost being allocated to beach erosion protection and $7,610,000 being allocated to the hurricane protection.

7. EXTENT OF INTEREST IN PROJECT

Interest in beach erosion and hurricane protection for Grand Isle is very high. Local interests have constructed one feature of the recommended plan prior to authorization as an emergency measure. The Louisiana Department of Public Works, the Louisiana Parks and Recreation Commission, and the town officials of Grand Isle provided considerable information during various phases of the study.

8. EFFECT OF PROJECT ON STATE AND LOCAL GOVERNMENTS

The proposed project would have little effect on state and local governments