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U. S. ARMY CORPS OF ENGINEERS

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART I - CHALMETTE

Prepared in the Office of the District Engineer
New Orleans District, Corps of Engineers
New Orleans, Louisiana

August 1966

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no. 1
pt. 1
1966

LMVED-TD (NOD 18 Aug 66) 3d Ind
SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part I - Chalmette

DA, Lower Miss. Valley Div, CE, Vicksburg, Miss. 39180 1 Nov 66

TO: District Engineer, New Orleans District, ATTN: LMNED-PP

Referred to note approval, subject to comments of 1st and 2d Indorsements.

FOR THE ACTING DIVISION ENGINEER:

George B. Davis
for A. J. DAVIS
Chief, Engineering Division

ENGCW-EZ (18 Aug 66) 2nd Ind
SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part I - Chalmette

DA, CofEngrs, Washington, D. C., 20315, 27 October 1966

TO: Division Engineer, Lower Mississippi Valley Division

Approved, subject to the comments of the Division Engineer and the following:

a. Paragraph 8d(5), page 22. The standard project hurricane surge elevation of 13.0 feet appears reasonable and is approved subject to the future studies of the effects of the Mississippi River - Gulf Outlet on the surge elevations presently under investigation, as indicated in paragraph 8d(7) of the subject design memorandum.

b. Table 13, Page 24. The results of the wave runup determinations should indicate the type and the slope of structure on the water side of the protection. The design memorandum should also include a clear explanation of procedures and criteria used in estimating wave characteristics and runup on embankment slopes.

FOR THE CHIEF OF ENGINEERS:

wd Incls

WENDELL E. JOHNSON
Chief, Engineering Division
Civil Works

LMVED-TD (NOD 18 Aug 66) 1st Ind
SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part I - Chalmette

DA, Lower Miss. Valley Div, CE, Vicksburg, Miss. 39180 1 Sep 66

TO: Chief of Engineers, ATTN: ENGCW-V/ENGCW-E

1. Design Memorandum No. 1, Part I, is forwarded for review and approval pursuant to paras 16a and 17a, ER 1110-2-1150, 1 Jul 66. Approval is recommended.

2. It will be noted on plate 2 that the alignment of the levee paralleling Bayou Dupre along the southeast boundary of the Chalmette area includes the bayou, whereas the alignment for the same levee on plate 3 of the project document (HD 231/89/1) excludes it. This and other departures from the project document plan will be covered in the general design memorandum as required by para 7g, ER 1110-2-1150. This modification in levee alignment does not adversely affect the subject memorandum.

FOR THE DIVISION ENGINEER:

1 Incl (7cy)
wd 5 cy

A. J. DAVIS
Chief, Engineering Division

Copy furnished:
New Orleans District
ATTN: LMNED-PP

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

IN REPLY REFER TO
LMNED-PP

11 August 1966

SUBJECT: Lake Pontchartrain, Louisiana and Vicinity, Design Memorandum No. 1, Hydrology and Hydraulic Analysis, Part I - Chalmette

TO: Division Engineer, Lower Mississippi Valley
ATTN: LMVED-TD

1. Forwarded herewith for review and approval, in accordance with the provisions of EM 1110-2-1150, is the subject design memorandum.

2. Approval of this memorandum is recommended.

1 Incl (12 cys)
D.M. No. 1

THOMAS J. BOWEN
Colonel, CE
District Engineer

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART I - CHALMETTE

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GLOSSARY

ASTRONOMICAL TIDE - See PREDICTED NORMAL TIDE.

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

BUILDUP - The increase, in feet, over that from other causes, of water surface elevation in a body of water resulting from:

1. Convergence in depth or width
2. Construction of a barrier
3. Ponding

CENTRAL PRESSURE - The minimum atmospheric pressure within the hurricane at any specific time.

FETCH - The continuous area of water over which the wind blows in essentially a constant direction. Often used with FETCH LENGTH.

FETCH LENGTH - The horizontal distance over which the wind from a fixed direction may have unobstructed contact with the water surface.

HURRICANE - A cyclonic storm, usually of tropical origin, containing winds of 75 miles per hour or more.

a. DESIGN HURRICANE - That hurricane selected by the reporting office as a basis for design of the proposed plan of improvement.

b. STANDARD PROJECT HURRICANE - A hurricane that may be expected from the most severe combination of meteorological conditions that are considered characteristic of the region involved.

c. PROBABLE MAXIMUM HURRICANE - The hurricane that may be expected from the most severe combination of meteorological conditions that are reasonably possible in the region.

d. MODERATE HURRICANE - A hurricane that may be expected from a combination of meteorological conditions that are frequently experienced in the region.

e. TRANSPOSED HURRICANE - A storm transferred from actually observed location to another location for the purpose of study, with appropriate changes in storm characteristics.

HURRICANE TRACK - The line connecting successive locations of central pressure of the hurricane.

HURRICANE SPEED - The rate of forward movement.

HURRICANE SURGE - The mass of water causing an increase in elevation of the water surface at the time of a hurricane.

HURRICANE SURGE HEIGHT - The elevation of the stillwater level at a given point resulting from hurricane surge action. It may be the result of one or more of the following components:

1. Predicted normal tide
2. Pressure setup
3. Setup due to winds over the continental shelf
4. Buildup

In inland lakes, hurricane surge height is the average lake level and does not include local wind setup.

HURRICANE TIDE - The elevation of the stillwater level at a given point during a hurricane. In inland lakes it is the sum of hurricane surge height and additional local wind setup.

ISOVEL - Line drawn through locations having the same velocity at a given time.

KNOT - A velocity equal to one nautical mile (6,080 feet) per hour, or about 1.15 statute miles per hour.

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

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

PONDING - The storage behind a water-retaining structure of water from interior runoff or from overtopping of a structure.

PREDICTED NORMAL TIDE - The periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting upon the rotating earth.

PRESSURE SETUP - The conversion of atmospheric pressure anomaly to equivalent height of water and adjusted for its dynamic effects as a part of the total hurricane surge.

RANGE - A narrow fetch over which the hurricane surge height is computed.

RUNUP - The vertical elevation above stillwater level to which water rises on the face of a structure as a result of wave action.

SETDOWN - The decrease in water surface elevation behind a water-retaining barrier or at a windward shore due to wind action.

SETUP - The vertical rise in the stillwater level, above that which would occur without wind action, caused by wind stresses on the surface of the water.

SIGNIFICANT WAVE - A statistical term denoting waves having the average height and period of the highest one-third waves of a given wave train.

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

STORM SURGE - Same as HURRICANE SURGE, except that it may be caused by storms not of hurricane characteristics as well as by hurricanes.

WAVE HEIGHT - The vertical distance between the crest and the preceding trough. (Referenced to significant waves in this report.)

WAVE SETUP - The superelevation of the water surface above the hurricane tide height due to wave action alone.

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

WIND SETUP - Same as SETUP.

WIND TIDE LEVEL - Same as STILLWATER LEVEL.

LAKE PONTCHARTRAIN, LOUISIANA AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART I - CHALMETTE

SECTION I - ANALYSES

1. Project authorization. The project is authorized under Public Law 298, 89th Congress, 1st Session, approved 27 October 1965. General information and basic data on the entire project are available in House Document No. 231, 89th Congress, 1st Session.

2. Purpose and scope. The Hydrology and Hydraulic Analysis Design Memorandum for the Lake Pontchartrain, Louisiana and Vicinity, project will be presented in three separate reports--parts I, II, and III, entitled Chalmette, Barrier, and South Shore, respectively. This is part I, and the hydrology of the entire project area and development of design elevations for the Chalmette, Inner Harbor Navigation Canal, Citrus Back, and New Orleans East back protective works are covered herein. Detailed description and analyses of the tidal hydraulic methods and procedures used in the tidal hydraulic design of the above features are presented. Included in the description and analyses are the essential data, assumptions, and criteria used, and the results of studies which provide the bases for determining surges, routing, wind tides, runup, overtopping, and frequencies.

3. Description.

a. The project area, as shown on plate 1, is located in southeastern Louisiana in the vicinity of New Orleans. The dominant topographic feature is Lake Pontchartrain, a shallow tidal basin approximately 640 square miles in area and averaging 12 feet in depth. Lake Pontchartrain is connected to the Gulf of Mexico through the Rigolets and Chef Menteur Pass, Lake Borgne, and Mississippi and Chandeleur Sounds, and is connected with lesser Lake Maurepas to the west. The Rigolets and Chef Menteur Pass have developed naturally deep and wide channels having adequate capacity for normal tidal and ebb flows and discharge of tributary flow.

b. The area along the south shore of Lake Pontchartrain is essentially uniform in topography. The land slopes gently downward from an average elevation 12 feet above m.s.l.* along the natural

*mean sea level, the datum to which all elevations in this memorandum are referenced, unless otherwise indicated.

banks of the Mississippi River to approximately sea level near the lakeshores. All of this area is protected from the river overflow by the main line Mississippi River levee system. Most of the area is afforded partial protection from tidal overflow. Runoff within the protected areas is pumped into the lake and the pumping operations have caused subsidence of natural ground elevations to as much as 7 feet below mean sea level.

4. Problem.

a. The area surrounding Lake Pontchartrain is susceptible to flooding from wind-driven hurricane tides from the lake. This condition is aggravated by increases in lake level resulting from the influx of tidal surges from Lake Borgne and the Gulf of Mexico that accompany hurricanes from the southeast, south, and southwest. The occurrence of a standard project hurricane critical to the south shore of Lake Pontchartrain would result in an 11-foot surge in Lake Borgne. This surge would enter Lake Pontchartrain through the Rigolets and Chef Menteur passes, and the Inner Harbor Navigation Canal, raising the average lake elevation by as much as 6 feet.

b. As the hurricane winds blow over the surge-elevated lake, wind tides and waves would be generated against the south shore causing overtopping of all existing protective works and massive ponding in the developed areas. Much of the developed area in the New Orleans area is below mean sea level, some land being as low as 7 feet and a considerable portion more than 2 feet below mean sea level. Because of these low elevations, flooding as deep as 16 feet would result from severe overtopping.

c. On several occasions, the marsh area between Lake Borgne and Lake Pontchartrain has been flooded up to elevations of 11 feet. These stages have caused overtopping of the existing Chalmette back levee, the Inner Harbor Navigation Canal levees, and the Citrus and New Orleans East back levees.

5. Plan of protection. The plan of protection is described in the following subparagraphs and shown on plate 2.

a. A barrier will be constructed along the east shore of Lake Pontchartrain extending from the New Orleans levee system to high ground in St. Tammany Parish to control hurricane-generated stages in the lake. Included as parts of the barrier will be navigation and control structures in the Rigolets and Chef Menteur Pass. Existing protective works along the south shore of the lake will be raised, strengthened, and extended. A lock will be constructed at the lakeward end of the Inner Harbor Navigation Canal to alleviate high velocities in the canal, control salt water intrusion into Lake Pontchartrain, and control the entry of hurricane tides into the lake. Protective systems facing Lake Borgne, including the levees along the Inner Harbor Navigation Canal, the Gulf Intracoastal Waterway, and the Mississippi River-Gulf Outlet will be raised and strengthened to provide adequate protection. The existing seawall at Mandeville on the north shore will be strengthened.

b. A new levee to protect the Chalmette area will be constructed along the south bank of the Mississippi River-Gulf Outlet from the Inner Harbor Navigation Canal to Bayou Lawler, thence returning to the Mississippi River at Violet, La.

6. Climatology.

a. Climate. The project area is located in a subtropical latitude having mild winters and hot, humid summers. During the summer, prevailing southerly winds produce conditions favorable for convective thundershowers. In the colder seasons, the area experiences frontal passages which produce squalls and sudden temperature drops. River fogs are prevalent in the winter and spring when the temperature of the Mississippi River is somewhat colder than the air temperature. Climatological data for the area are contained in monthly and annual publications by the U. S. Department of Commerce, Weather Bureau, titled "Climatological Data for Louisiana," and "Local Climatological Data, New Orleans, La."

b. Temperature. The first-order weather station in New Orleans has temperature records extending back to 1871. The mean annual temperature is 70° F. and the recorded extremes are 7° and 102°. The average temperature in summer and winter is 82.3° and 56.1°, respectively. Detailed temperature records and station locations are shown in table 1 and on plate 3, respectively.

TABLE 1

MONTHLY TEMPERATURES (1871-1964)
New Orleans

Month	Degrees Fahrenheit			Month	Degrees Fahrenheit		
	Mean	Maximum	Minimum		Mean	Maximum	Minimum
Jan	54.8	67.2	43.0	Jul	82.7	85.9	79.1
Feb	57.5	67.2	45.0	Aug	82.8	87.1	79.3
Mar	62.9	71.4	55.0	Sep	79.6	84.0	75.6
Apr	69.2	74.4	65.1	Oct	71.5	79.5	66.0
May	75.8	79.8	72.2	Nov	61.9	68.6	56.2
Jun	81.3	84.8	77.4	Dec	56.0	64.7	48.1
				Annual	69.7		

Extreme minimum 7° F., 13 February 1899
Extreme maximum 102° F., 30 June 1954 (also other dates).

c. Rainfall. Precipitation is generally heavy in two fairly definite rainy periods. Summer showers occur from about mid-June to mid-September, and heavy winter rains generally occur from mid-December to mid-March. The drainage area tributary to Lake Pontchartrain is served by 29 precipitation stations of the U. S. Weather Bureau, with periods of record ranging from 3 to 94 years. Based on the records from U. S. Weather Bureau station in New Orleans, the average annual precipitation is 61 inches, with variations of plus or minus 50 percent. Extreme monthly rainfalls exceeding 12 inches are not uncommon, and as much as 25 inches have been recorded in a single month. Average monthly rainfalls range from 6.9 inches in July to 3.3 inches in October. Several stations have experienced calendar months in which no rainfall was recorded. Snow occurs infrequently in the area. An 8.2-inch fall occurred in New Orleans on 14-15 February 1895. The last measurable snowfall occurred on 31 December 1963 when 4.5 inches fell in New Orleans. Detailed precipitation records and station locations are shown in table 2 and on plate 3, respectively.

TABLE 2

MONTHLY RAINFALL (1870-1964)
New Orleans

	Inches				Inches		
Month	Mean	Maximum	Minimum	Month	Mean	Maximum	Minimum
Jan	4.61	11.15	0.61	Jul	6.91	18.16	2.02
Feb	4.53	13.85	0.04	Aug	5.99	22.74	0.87
Mar	5.37	21.09	0.04	Sep	5.46	16.57	0.25
Apr	5.29	14.94	0.04	Oct	3.31	25.11 (1)	0.00 (2)
May	4.78	18.68	0.02	Nov	3.75	14.41	0.10
Jun	5.86	16.01	0.59	Dec	4.72	14.43	0.67
				Annual	60.58	85.73 (3)	31.07 (4)

LEGEND
(1) Oct 1937; (2) Oct 1963; (3) 1875; (4) 1899

d. Wind. Wind records are available adjacent to and over Lake Pontchartrain for various periods. Periods of record for anemometers are shown in table 3.

TABLE 3

METEOROLOGIC STATIONS

Map index No. (plate 3)	Station	Length of record in years (thru 1965)		Collecting agency
	COMPLETE METEOROLOGICAL STATIONS			
1	New Orleans	94		WB
2	New Orleans International Airport, Moisant Field	19		WB
	RECORDING BAROGRAPH STATIONS			
3	Lake Pontchartrain at Frenier	8		NOD
4	Lake Pontchartrain near Madisonville	9		NOD
5	Lake Pontchartrain at West End (New Orleans)	9		NOD
	RECORDING RAINFALL STATIONS			
6	New Orleans - Algiers	66		S&WB
7	New Orleans - Dublin Street	72		S&WB
8	New Orleans - Jefferson Avenue	72		S&WB
9	New Orleans - Jourdan Avenue	32		S&WB
10	New Orleans - London Avenue	72		S&WB
	NON-RECORDING RAINFALL STATIONS			
11	Metairie	17		WB
12	New Orleans - Citrus	11		WB
13	Nott Fire Tower near Mandeville (Disc. May 1955)	3		WB
14	Pearl River (Disc. January 1963)	56		WB
15	Pearl River, Lock 1	17		WB
16	Violet	10		WB
	RAINFALL (NON-RECORDING) AND TEMPERATURE STATIONS			
		Rainfall	Temp.	
17	New Orleans Airport (Disc. July 1954)	15	17	WB
18	New Orleans - Audubon Park	76	76	WB
19	Greater New Orleans Expressway Bridge	9	9	WB
20	Reserve	64	64	WB
21	Slidell	9	9	WB

TABLE 3 (cont'd)

Map index No. (plate 3)	Station	Length of record in years (thru 1965)	Collecting agency
	RECORDING ANEMOMETER STATIONS		
22	GIWW at Paris Road Bridge (near New Orleans)	6	NOD
3	Lake Pontchartrain at Frenier	8	NOD
19	Greater New Orleans Expressway Bridge near Mandeville	9	WB
23	Greater New Orleans Expressway Bridge near Metairie	9	WB
24	Lake Pontchartrain near north end of U.S. Hwy. 11 bridge	7	NOD
5	Lake Pontchartrain at West End (New Orleans)	9	NOD
25	Mississippi River at H. P. Long Bridge (U.S.Hwy. No. 90)	28	NOPBRR
4	Mouth of Tchefuncta River, Madisonville	9	NOD

LEGEND
WB = U. S. Weather Bureau
NOD = U. S. Army Engineer District, New Orleans
S&WB = New Orleans Sewerage and Water Board
NOPBRR = New Orleans Public Belt Railroad

(1) Two overwater recording anemometers were installed in 1957 on the Greater New Orleans Expressway Bridge across Lake Pontchartrain, approximately 8 miles from the north and south termini. Recording anemometers were installed around the perimeter of the lake at West End (New Orleans), Madisonville, Frenier, and Slidell in 1957-59. The installations on the bridge furnish the only dependable overwater records of winds. At other locations wind speeds are influenced by friction as the winds traverse land masses.

(2) The U. S. Weather Bureau anemometer coverage at the New Orleans International Airport, Moisant Field, installed in 1949 provides the longest record available adjacent to the lake. A 16-year summary of winds at Moisant Field is shown in table 4. The average wind velocity is 8.6 m.p.h., but winds over 100 m.p.h. are experienced occasionally in hurricanes. The predominant wind directions are south to south-southeast from January through July, and northeast to east-northeast from September through November. In applying Moisant Field wind summaries to Lake Pontchartrain, the factors for comparing overland to overwater conditions, as

described in the U. S. Weather Bureau Hydrometeorological Report No. 32(1)*, are considered applicable. It is a matter of record that important changes in lake level reflect changes in the wind patterns.

7. Hydrologic regimen.

a. General. The water level in Lake Pontchartrain is subject to variations from direct rainfall, tributary inflow, wind-driven water movements, and flow through the Rigolets and Chef Menteur passes and the Inner Harbor Navigation Canal caused by tidal variations originating in the Gulf of Mexico. Infrequently, lake level is influenced by diversion of Mississippi River floodflow through Bonnet Carre' Spillway. Combinations of these factors determine the salinity regimen in the lake. Locations and periods of record of hydrologic stations are shown in tables 5 and 6.

*Numbers in parentheses indicate references in Section II, Bibliography.

TABLE 4

WIND SUMMARIES, NEW ORLEANS INTERNATIONAL AIRPORT, MOISANT FIELD
(1949-1964)

Wind direction (or velocity)	Percent of time												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
N	7.36	7.04	5.99	4.77	4.62	4.02	3.57	5.21	5.83	7.64	9.19	7.48	6.05
NNE	7.07	7.12	5.81	4.61	4.23	3.39	3.01	4.53	7.26	8.64	8.82	8.74	6.09
NE	8.13	8.93	7.78	5.33	5.52	5.00	4.90	7.07	13.30	12.39	9.94	10.11	8.19
ENE	8.30	7.64	7.15	5.64	5.04	5.14	4.47	6.49	15.95	12.53	10.12	9.48	8.16
E	5.67	6.11	5.08	4.70	4.61	4.40	4.60	5.66	8.30	7.61	6.12	7.03	5.82
ESE	3.55	3.72	4.66	5.13	4.84	3.72	3.07	3.07	4.18	4.50	3.75	4.24	4.04
SE	4.75	5.00	6.33	8.23	7.12	5.42	4.65	3.60	4.84	4.39	5.22	4.44	5.33
SSE	10.32	8.15	9.53	13.32	11.38	8.91	5.64	4.94	4.45	4.15	6.93	6.80	7.87
S	10.17	9.05	11.36	13.92	13.22	11.62	9.40	6.19	4.48	3.15	6.08	7.40	8.83
SSW	5.54	7.38	7.35	6.95	7.92	11.10	8.93	6.89	2.64	1.74	3.68	4.72	6.23
SW	2.81	5.07	4.14	4.51	6.19	7.22	8.59	7.18	2.02	1.44	1.93	2.43	4.46
WSW	2.09	2.74	2.66	2.48	3.13	4.17	5.71	4.70	1.44	1.38	1.54	1.71	2.82
W	2.58	3.11	2.60	2.41	3.13	3.98	6.01	5.48	1.86	2.00	2.70	2.58	3.21
WNW	3.06	3.36	3.25	3.04	2.21	3.12	4.93	3.91	1.88	2.52	3.12	2.87	3.11
NW	4.13	3.71	4.08	3.04	2.71	3.26	3.77	4.07	2.18	3.27	4.12	4.30	3.56
NNW	7.46	6.19	5.76	4.45	3.96	3.66	3.99	4.60	3.75	6.04	7.02	7.35	5.35
Calm	7.01	5.68	6.46	7.46	10.16	11.87	14.76	16.41	15.64	16.62	9.73	8.30	10.88
0-3 m.p.h.	12.33	10.14	10.95	12.38	16.00	19.58	23.53	25.82	22.73	23.54	15.89	14.31	17.32
4-7	24.67	23.29	21.19	23.49	29.63	36.42	39.54	38.03	29.16	27.60	26.55	24.86	28.74
13-18	22.29	25.85	27.09	24.77	17.32	10.39	7.45	7.38	15.78	16.12	20.54	21.83	18.01
19-24	6.01	6.74	6.69	4.60	2.42	0.63	0.64	0.56	2.51	3.34	5.39	5.02	3.69
25-31	1.16	1.12	1.40	1.04	0.33	0.10	0.09	0.09	0.39	0.58	1.33	0.99	0.72
32-38	0.11	0.03	0.13	0.06	0.02	0.02	0.02	0	0.11	0.06	0.10	0.05	0.06
39-46	0.03	0.02	0	0.02	0.01	0	0.02	0.01	0.05	0.01	0	0	0.01
47 and over	0	0	0	0	0	0	0	0	0.01	0	0	0	0

TABLE 5

HYDROLOGIC STATIONS ON TRIBUTARY STREAMS

Map index No. (plate 3)	Station	Period of record: Type of water level gage	Period of record: Records available thru 1965	Collecting agency
26	Amite River at Port Vincent	Recorder.	Gage heights, Dec. 1954 to date. High water discharge, 7 observations in 1950, 1 in 1953, 2 in 1955, 1 in 1956, 1 in 1959, and 1 in 1961.	NOD
27	Amite River at French Settlement	Recorder.	Gage heights, intermittent 1947-1951 and daily. Dec 1954 to date. High water discharge, 5 observations in 1950, 1 in 1956, 3 in 1961, 1 in 1962, 1 in 1963, and 2 in 1964.	NOD
28	Petite Amite River near St. Paul	Recorder. Crest indicator.	Gage heights, intermittent Mar 1950 to May 1951 and daily Oct 1951 to date.	NOD
29	Bayou Pierre near St. Paul	Recorder. Crest indicator.	Gage heights, intermittent May 1949 to Jan 1950 and daily Jan 1950 to Sep 1959. Discharge observations, 1 in 1955, 2 in 1956, 3 in 1961, 1 in 1962, 1 in 1963, and 3 in 1964.	NOD
30	Tickfaw River near Springfield	Recorder.	Gage heights, May 1947 to date.	NOD

LEGEND

NOD = U. S. Army Engineer District, New Orleans

TABLE 6

HYDROLOGIC STATIONS, LAKES MAUREPAS, PONTCHARTRAIN, AND BORGNE

Map index No. (plate 3)	Station	Period of record		Collecting agency
		Type of water level gage	Records available thru 1965	
31	Pass Manchac near Ponchatoula	Staff gage. Crest indicator.	Gage heights, July 1955 to date. Salinity, Mar 1951 to date.	NOD
3	Lake Pontchartrain at Frenier	Staff gage prior to Feb 1950. Recording gage from Feb 1950 to date. Crest indicator.	Gage heights, Sep 1931 to date. Wave data, Mar 1958 to date. Salinity, June 1947 to Dec 1950.	NOD
32	Greater New Orleans (Lake Pontchartrain) Expressway Bridge near Metairie	Recording wave gage.	Wave data, Aug 1957 to date. Salinity, Aug 1957 to date.	NOD
33	Greater New Orleans (Lake Pontchartrain) Expressway Bridge near midlake	Recorder.	Gage heights, Aug 1957 to date.	NOD
34	Greater New Orleans (Lake Pontchartrain) Expressway Bridge at north shore (Mandeville)	Staff, Sep 1931 to Oct 1947. Recorder, Oct 1947 to date. Crest indicator.	Gage heights, Sep 1931 to date. Wave data, 1957 to date. Salinity, Aug 1957 to date	NOD
5	Lake Pontchartrain at West End (New Orleans)	Staff, Sep 1931 to Jan 1947. Recorder, Jan 1947 to date. Crest indicator.	Gage heights, Sep 1931 to Nov 1946 and Mar 1949 to date. Salinity, Oct 1945 to Dec 1946.	NOD

TABLE 6 (cont'd)

Map index No. (plate 3)	Station	Period of record: Type of water level gage	Period of record: Records available thru 1965	Collecting agency
35	Lake Pontchartrain at Little Woods	Staff gage. Crest indicator.	Gage heights, Sep 1931 to date. Salinity, Mar 1946 to date.	NOD
36	Lake Pontchartrain (Irish Bayou) near south shore	Recorder.	Gage heights, May 1949 to date.	NOD
24	Lake Pontchartrain near north end of U. S. Hwy.11 Bridge	Crest indicator installed 1956.	Salinity, July 1957 to date.	NOD
37	Rigolets at U.S.Hwy. 90 Bridge	Staff prior to June 1949. Recorder June 1949 to date. Crest indicator.	Gage heights, Sep 1931 to date. Salinity, Jul 1957 to date.	NOD
38	Chef Menteur U.S. Hwy.90 Bridge	-	Salinity, Mar 1957 to date.	NOD
39	Lake Borgne at Rigolets	Recorder.	Gage heights, Dec 1957 to date.	NOD
40	Lake Borgne at Chef Menteur Pass	Recorder.	Gage heights, Apr-Jun 1945, Feb & Mar 1950, Jul 1957 to date	NOD
41	Lake Borgne at Shell Beach	Recorder. Crest indicator.	Gage heights, Jul 1948 to Jun 1961. Salinity, Aug 1948 to date.	NOD
41	Miss.River-Gulf Outlet at Shell Beach	Recorder. Crest indicator.	Gage heights, Jun 1961 to date.	NOD

TABLE 6 (cont'd)

Map index No. (plate 3)	Station	Period of record: Type of water level gage	Period of record: Records available thru 1965	Collecting agency
42	Lake Borgne at Doulluts Canal west of Shell Beach		Salinity, Feb 1957 to date	NOD
22	Gulf Intracoastal Waterway at Paris Road	Staff gage, Apr 1948--Feb 1964. Recorder, Jun-Oct 1944, Jun-Aug 1945, and May 1959 to date. Crest indicator.	Gage heights, Apr 1948 to date. Salinity, Aug 1948 to date	NOD

LEGEND

NOD = U. S. Army Engineer District, New Orleans

CREST INDICATORS*

Map index No. (plate 3)	Location	Year installed
$\frac{56}{1}$ (AR)	Amite River at Clio	1956
$\frac{59}{19}$ (LP)	Lake Pontchartrain near Madisonville	1959
$\frac{57}{17}$ (LP)	Lake Pontchartrain at Pass Manchac	1957
$\frac{59}{18}$ (LP)	Lake Pontchartrain at Ruddock	1959
$\frac{56}{10}$ (LP)	Lake Pontchartrain at Jefferson Parish Pumping Station No. 4	1956
$\frac{56}{14}$ (LP)	Lake Pontchartrain at North Shore	1956
$\frac{57}{15}$ (LP)	Lake Pontchartrain at mouth of of Bayou Lacombe	1957

*This list includes only those indicators not associated with other types surface gages.

b. Runoff and streamflow. Runoff from the 4,700 square miles north and west of Lakes Pontchartrain and Maurepas, estimated to average five million acre-feet annually, drains into the lakes via the Amite, Tickfaw, Natalbany, Tangipahoa, and Tchefuncta Rivers, and Bayous Lacombe, Bonfouca, and Liberty. Streamflow records are available at five locations on these streams and two locations on Pearl River for the periods of record listed in table 7. New Orleans and adjacent parishes are drained by outfall canals that discharge directly into Lake Pontchartrain. Yearly fresh water inflow records show considerable variation, as shown in table 7.

TABLE 7

PERTINENT STREAMFLOW DATA (1938-1964)

Inflow point	Total drainage area	Gage location*	Gaged area	Period of record	Avg.	Discharge: Maximum Rate	Discharge: Maximum Date	Discharge: Minimum Rate	Discharge: Minimum Date
	sq.mi.		sq.mi.		c.f.s.	c.f.s.		c.f.s.	
Amite River	2,373	Amite River near Denham Springs	1,334	9/38 to date	1,887	67,000	5/20/53	271	10/17/56 10/18/56
Tickfaw River	735	Tickfaw River at Holden	242	10/40 to date	361	14,500	4/29/62	74	11/19/63
		Natalbany River at Baptist	80	8/43 to date	115	9,550	5/3/53	2	10/22/52
Tangipahoa River	885	Tangipahoa River at Robert	646	10/38 to date	1,105	50,500	5/3/53	264	Several days in 10/39
Tchefuncta River	459	Tchefuncta River near Folsom	96	1/44 to date	166	29,200	5/3/53	33	8/29/57
Bayous Lacombe and Liberty	211								
Pearl River	8,689	Pearl River at Bogalusa	6,630	10/38 to date	8,896	88,200	12/23/61	1,020	10/29/63 thru 11/1/63
		Bogue Chitto near Bush	1,210	10/37 to date	1,875	57,000	2/23/61	424	10/26/55 thru 10/28/55
Vicinity of New Orleans	213								

*U.S. Geological Survey gage stations

c. Stages, salinities, waves, and tides.

(1) Lake stages.

(a) The Bonnet Carre' Spillway is operated as required during major high water seasons on the Mississippi River to divert flows through Lake Pontchartrain in order to insure that a stage of 20 feet on the Carrollton gage is not exceeded at New Orleans. Studies indicate that the operations of the spillway produced maximum increases in lake level of about 0.8 foot in 1937, 1.5 feet in 1945, and 1.0 foot in 1950. These variations are small when compared to stage increases produced by hurricanes.

(b) The maximum recorded stage in Lake Pontchartrain of 13.0 feet occurred at Frenier on 29 September 1915. The minimum of minus 2.2 feet occurred at New Orleans (West End) on 26-27 January 1938. The mean lake stage for the period from 1949 through 1965 was 1.0 foot.

(c) Maximum stages occur in Lake Pontchartrain during hurricane activity in the vicinity. A list of recorded high stages is presented in table 8.

TABLE 8

MAXIMUM STAGES - LAKE PONTCHARTRAIN

Location	Date	Stage-ft.m.s.l.	
Mandeville	20 Sep 1909	8.0	
West End	20 Sep 1909	6.2	
Frenier	20 Sep 1915	13.0	
West End	29 Sep 1915	6.0	
West End	19 Sep 1947	5.4	
Mandeville	19 Sep 1947	6.8	
New Orleans	4 Sep 1948	4.9	
Frenier	24 Sep 1956	6.8)	"Flossy"
Little Woods	24 Sep 1956	7.0)	
West End	24 Sep 1956	5.3)	
Mandeville	27 Jun 1957	4.1*	"Audrey"
Frenier	9 Aug 1957	3.3	"Bertha"
Frenier	18 Sep 1957	4.5	"Esther"
Mandeville	10 Sep 1961	5.5	"Carla"
Frenier	17 Sep 1963	4.0	"Cindy"
Mandeville	4 Oct 1964	6.4	"Hilda"
Frenier	10 Sep 1965	12.1	"Betsy"

*Possibly higher, gage failed during storm.

(2) Salinities. Diluted saline gulf water enters Lake Pontchartrain from Lake Borgne via the Rigolets and Chef Menteur Pass and the Mississippi River-Gulf Outlet and Inner Harbor Navigation Canal in large quantities and mixes with the fresh water inflow. The salinity in Lake Pontchartrain averages about 1,500 parts per million of chloride ion, ranging seasonally from a low of about 450 in the spring to a high of 5,300 in the late fall. Salinity is subject to considerable variation with respect to location, seasonal trends, and short-term fluctuations. More extensive data on salinities, tides, and currents in Lake Pontchartrain and vicinity are shown in the U. S. Army Engineer Waterways Experiment Station (WES) Technical Report No. 2-636, dated November 1963, and entitled "Effects on Lake Pontchartrain, La., of Hurricane Surge Control Structures and Mississippi River-Gulf Outlet Channel."

(3) Waves. In August 1957, two wave gages were installed on the east side of the Greater New Orleans Expressway Bridge, station "10" at the north end and station "4" on the south end. Both are approximately one-quarter mile from shore. In 1958, station "9" was established at Frenier, with the gage on a tower approximately 1,200 feet from shore. Locations are shown on plate 3. Pertinent observed data are listed in table 9.

TABLE 9

WAVE DATA

Station	Significant waves Range ft.	Maximum waves Wind m.p.h.	Maximum waves Height ft.	Maximum waves Date
4	0.1 to 4.9	38	8.8*	9 Sep 65
9	0.1 to 4.9	29	7.8	9 Oct 58
10	0.1 to 5.3	40	9.0	10 May 59

*Possibly higher, gage failed during storm.

(4) Tides and currents. The normal tide is diurnal in nature and has general ranges of one-half foot in Lake Pontchartrain and one foot in Lake Borgne. However, wind effects usually mask the daily ebb and flood variations. Because of the annual volume of fresh water inflow, tides, and storm surges, enormous volumes of water pass in both directions through the Rigolets and Chef Menteur passes, Lake Borgne, Mississippi Sound, Inner Harbor Navigation Canal, and Mississippi River-Gulf Outlet. With so many variables operating on the several elements of the system, the current patterns are continually changing.

8. <u>Description and verification of procedures.</u>

a. Hurricane memorandums. The Hydrometeorological Branch (HMB), U. S. Weather Bureau, cooperated in the development of hurricane criteria for experienced and potential hurricanes in the project 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. Hurricane memorandums pertinent to the project area are listed in Section II, Bibliography.

b. Historical storms used for verification. Two observed storms, with known parameters and effects, were used to establish and verify procedures and relationships for determining surge heights, wind tide levels (WTL's), and overtopping flows. These two storms occurred in September of 1915 and 1947. Isovel patterns for the hurricanes of September 1915(2) and September 1947(3) are shown on plates 4 and 5, respectively.

(1) The hurricane of 29 September 1915 had a central pressure index (CPI) of 27.87 inches, an average forward speed of 10 knots, and a maximum windspeed* of 99 m.p.h. at a radius of 29 nautical miles. This hurricane approached the mainland from the south. At the Lake Borgne entrance to the Rigolets, a high water elevation of about 10 feet was experienced and the average elevation in Lake Pontchartrain rose to 6 feet.

(2) The 19 September 1947 hurricane had a CPI of 28.57 inches, an average forward speed of 16 knots, and a maximum windspeed of 100 m.p.h. at a radius of 33 nautical miles. The direction of approach of this hurricane was approximately from the southeast. In Lake Borgne, at the entrance of the Rigolets, the maximum water surface elevation was 10 feet and in Lake Pontchartrain, the maximum elevation was 6.8 feet at Mandeville on the north shore.

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 U. S. Weather Bureau. The standard project hurricane (SPH) was used for all locations in the project area changing track and forward speed as appropriate.

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*Windspeeds represent a 5-minute average 30 feet above ground level unless otherwise indicated.

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 Lake Pontchartrain, Louisiana and Vicinity, Interim Survey Report, was derived by the U. S. Weather Bureau from a study of 42 hurricanes that occurred in the region over a period of 57 years. Based on subsequent studies of recent hurricanes, the U. S. Weather Bureau revised the SPH wind field patterns(4)(5)(6). However, the other characteristics of the SPH were not changed. The SPH track critical to the Chalmette area and isovel patterns at the critical hour are shown on plate 6. The SPH track critical to the Inner Harbor Navigation Canal, Citrus back, and New Orleans East back areas and isovel patterns at the critical hour are shown on plate 7.

(a) The SPH has a frequency of once in 100 years for the Louisiana coastal region. The CPI that corresponds to this frequency is 27.6 inches. CPI probabilities are based on the following relationship(7):

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

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 an index of hurricane size. The average radius of 12 hurricanes occurring in the New Orleans area is 36 nautical miles. From relationships of CPI and radius of maximum winds of gulf coast hurricanes(7), a radius of 30 nautical miles is considered representative for an SPH having a CPI of 27.6 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 used for the SPH along the west shore of Lake Borgne.

(d) Maximum theoretical gradient wind(7) 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)[8] in the 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, a 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 U. S. Weather Bureau[9][10]. A hurricane with this CPI actually occurred at 33° 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 8. 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[7]. Characteristics of synthetic storms and some historic storms are listed in table 10.

TABLE 10

HURRICANE CHARACTERISTICS

Hurricane*	CPI inches	Radius of max. winds nautical miles	Forward speed knots	V_x m.p.h.
Sep 1915	27.87	29	10	99
Sep 1947	28.57	33	16	100
Sep 1956	28.76	30	10	80
Sep 1965	27.79	32	20	122
Track F PMH	26.9	30	11	114
Track F SPH	27.6	30	11	100
Track F Mod H	28.3	30	11	83

*Tracks are shown on plate 9.

d. Surges.

(1) Maximum hurricane surge heights along the western shores of Lake Borgne were obtained from computations made for ranges extending from the shores out to the continental shelf by use of a general wind tide formula that is based on the steady state conception of water superelevation[11][12][13]. 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:

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

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 incremental summation of wind setup above the water elevation at the gulf end of the range. The low strip of marshland between Lake Borgne and the gulf was considered already submerged prior to the time of maximum elevation at shore. Initial elevation at the beginning of each range was determined from the predicted normal tide and the setup due to atmospheric pressure anomaly. Typical tidal cycles for the project area are shown on plate 10. 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 height 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 11.

TABLE 11

HURRICANE SURGE HEIGHTS

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

*Average of several high water marks.

(3) The incremental step computation was used to check experienced maximum hurricane surge heights at several locations within the project area. Verification of these surge heights and the surge adjustment factors used in the computations are shown in table 12.

TABLE 12

VERIFICATION OF HURRICANE SURGE HEIGHTS

Location	Surge adjustment factor (Z)	Sep 1915		Sep 1947		Sep 1956	
		Observed	Computed	Observed	Computed	Observed	Computed
		feet m.s.l.		feet m.s.l.		feet m.s.l.	
Shell Beach	0.30	8.3	8.4	11.2	10.5	10.9	10.7
Violet	0.30	-	-	7.3	7.9	6.5	7.7
Michoud	0.30	11.0	11.4	-	-	-	-
Long Point	0.21	9.8	9.6	10.0	10.1	-	-

(4) Computed surge heights for hurricane "Betsy," September 1965, at the location listed in table 11 and using the same Z factors averaged about 2.2 feet higher than the observed surge heights. 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 (11)(12)(13). 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, and the resulting design elevations are conservative (high).

(5) An example of the setup computation for one increment ($\triangle F$) along a range radiating from the vicinity of Chalmette for an SPH along Track F at one hour before landfall of the hurricane is as follows:

(a) Initial elevation:

Normal pressure	=	30.14 inches of mercury
Pressure at beginning of range, 57 miles from center	=	<u>29.05</u> inches of mercury
Deviation from normal pressure	=	1.09 inches of mercury
Pressure setup 1.09 x 1.14 feet	=	1.24 feet of water
Normal predicted tide	=	1.60 feet above mean low water (m.l.w.)
Initial elevation	=	2.84 feet m.l.w.

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

Sta.	$\triangle F$		Cos θ	V^2Cos θ	Avg. V^2Cos θ	Depth	D= ΣS+ Av.D+2.84 + $\triangle S/2$	$\triangle S$	ΣS
mile	miles	m.p.h.				feet m.l.w.		feet	feet
4.0		90	0.766	6200		0			9.86
	4.0				5090		12.98	0.55	
0.0		75	0.707	3980		0			10.41

$$S = 1.165 \times 10^{-3} \times \frac{5{,}090 \times 4.0}{12.98} \times 1 \times 0.31 = 0.55'$$

(c) Setup for pressure differential:

Normal pressure = 30.14 inches of mercury
Pressure at end of range, 34 miles from center = 28.69 inches of mercury
Deviation from normal = 1.45 inches of mercury
(1.45x1.14 feet) = 1.65 feet of water
Deviation at beginning = 1.24 feet of water
Differential setup = 0.41 foot

(b) Final surge height:

Pressure setup at beginning of range = 1.24 feet
Normal predicted tide = 1.60 feet m.l.w.
Correction m.l.w. to m.s.l. = -0.60 foot
S (wind setup) = 10.41 feet
Pressure differential setup = 0.41 foot
Surge height at shore = 13.06 feet m.s.l.

(6) The storms under consideration are accompanied by strong winds. The average windspeed and average depth were determined from isovel and hydrographic charts for each surge computation. The storm isovel patterns were furnished by the U. S. Weather Bureau[14][15][16].

(7) A study is presently being made by a consultant to evaluate effects of the Mississippi River-Gulf Outlet on hurricane surge elevations at key locations in the Lake Borgne area. The procedures presented in this report were based on the assumption that the Gulf Outlet had no effect on the hurricane surge elevation. If it is found that the Gulf Outlet does contribute to the surge elevation, revisions will be necessary.

e. Wave runup.

(1) Wave runup on a protective structure depends on the physical characteristics of the structure (i.e., configuration and surface 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 slope of a protective structure. This condition occurs when the WTL is at a maximum, and is calculated by the interpolation of model study data developed by Saville[17][18][19] which relates relative runup (R/H_o'), wave steepness (H_o'/T^2), relative depth (d/H_o'), and structure slopes as shown on plate 11.

(2) Protective structures exposed to wave runup will be constructed to an elevation that is sufficient to prevent all overflow from the significant wave and waves smaller than the significant wave accompanying the SPH. Waves larger than the significant wave will be allowed to overtop the protective structures; however, such overtopping will not endanger the security of the structures or cause material interior flooding. In cases of levees with berms, runup is computed for waves breaking on each berm to determine the required levee elevation. The elevation of protective structures not exposed to wave runup is approximately one foot higher than the maximum WTL for the SPH. Wave data, runup elevations, and required elevations of protective structures are shown in table 13. Runup elevations are based on preliminary levee cross sections and since runup depends on the section configuration, runup elevations will require adjustments if the final section is materially different from the preliminary section. The proposed elevations for the structures along the Inner Harbor Navigation Canal are based on Seabrook Lock and rock dikes being constructed with a controlling elevation of 7.2 feet. A report supporting this elevation is now in preparation.

TABLE 13

WAVE RUNUP AND PROPOSED ELEVATIONS OF PROTECTIVE STRUCTURES
STANDARD PROJECT HURRICANE

Location	Av. Depth	Hs	T	WTL elevation	Runup elevation	Proposed elev. of protective structures
	ft.	ft.	sec	ft.m.s.l.	ft.m.s.l.	ft.m.s.l.
Inner Harbor Navigation Canal						
Lake Pontchartrain to L&N RR Br.	-	-	-	11.4-12.9	-	13.0-14.0
L&N RR Br. to Miss. River	-	-	-	12.9-13.0	-	14.0
Chalmette						
West of Paris Road	-	-	-	13.0	-	14.0
East of Paris Road						
Paris Road to Bayou Lawler	16.3	7.0	6.4	13.0-12.5	4.7	17.5
Bayou Lawler to Violet	9.7	4.6	5.2	12.5-13.0	4.3	17.5
Citrus, back						
West of Paris Road	-	-	-	13.0	-	14.0
East of Paris Road	13.1	4.7	5.4	13.0	4.5	17.5
New Orleans East, back	13.1	4.7	5.4	13.0	4.5	17.5

f. Residual flooding. Protective structures were designed to prevent wave overtopping from the significant or any lower wave that would be experienced during an occurrence of the SPH. However, 14 percent of the waves in a spectrum are higher than the significant wave and the maximum wave height to be expected is about 1.87 times the significant wave height. Thus, a structure designed to prevent all overtopping by a significant or any lower wave would be overtopped by that portion of the spectrum that is higher than the significant wave. A determination of the residual overtopping was made and it was concluded that no material flooding would result if design grades allowed overtopping by waves higher than the significant wave.

9. Frequency estimates.

a. Procedure.

(1) The area along the south shore of Lake Pontchartrain was used in developing a procedure for making frequency estimates since more historical hurricane data were available for this area than for any other location. The maximum WTL or stage for a specific area is a measure of the character of storm that produces it. In order to use data from early hurricanes which caused high wind tides along the south shore of Lake Pontchartrain, it was necessary to analyze meteorologic factors and to adjust the observed data to represent stages that would have occurred had presently existing protective works then been in place. It was found that adjustments were required for the 1893 and 1901 hurricanes. Along the south shore of Lake Pontchartrain, determinations of maximum WTL's from the adjusted historical data form the locus of points through which a representative WTL-frequency curve would pass in the low-stage, high-frequency region. Probabilities for historical data on the curve shown on plate 12 were calculated by means of the formula:

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

The WTL for the PMH, which has an infinite return period, establishes another limit for the frequency curve in the high-stage, low-frequency region. However, because of the lack of historical data for the region of the curve between these two extremes, synthetic WTL-frequency relationships were established to develop the shape of the curve in this region. In the process of formulating such relationships, it was necessary to correlate the following hurricane parameters: central pressure indexes, tracks of approach, wind velocities, radii to maximum winds, and speeds of translation.

(2) 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. Oakey, 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. The data indicate that there is no locality along the Louisiana coast which is more prone to hurricane attack than other localities.

(3) The first requirement in the development of synthetic frequency relationships for localities within the project area was to select representative critical hurricane tracks for the particular locale in question. Tracks A and F were selected as critical tracks for the south shore of Lake Pontchartrain and the Lake Borgne area, respectively. These tracks are shown on plate 9.

(4) Surge heights were then developed for at least three storms of different CPI values for each track. Each hurricane selected for the representative tracks was assumed to have the same radius of maximum winds, the same 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 and WTL's is covered in paragraph 8.c.(2). Wind tide elevations for storms with other CPI values were obtained graphically by plotting the above data and reading from the resulting curves.

(5) Hurricane characteristics of area-representative storms were developed in cooperation with the U. S. Weather Bureau. This agency 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 presented the results in a memorandum(7). Frequencies for hurricane central pressure indexes that were presented in the report, as shown on plate 8, reflect the probability of hurricane recurrence from any direction in the midgulf 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 hurricane track is oblique to the shoreline as shown in table 2 of the HMB memorandum(7). The average projection along the coast of this 50-mile swath for the azimuths of 42 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 midgulf Zone B. Thus, 20 percent of the Zone B frequencies shown on plate 8 was 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, 24 tracks were from the south, 14 from the east, 3 from the west, and 1 from the north. Hurricanes with tracks having major components from south or east are more critical relative to WTL's within the project area than hurricanes from the other directions. Approximately two-thirds of all experienced hurricanes have come from a southerly direction, whereas about

one-third have come from the east. The average azimuth of tracks from the south is 180°. Tracks from the east had an average azimuth of 115°. Azimuths approximating these values were used in computing WTL's. Further adjustment of the probability of occurrence for the south shore of Lake Pontchartrain was made by using two-thirds the probability of WTL's computed for hurricanes approaching from the south and one-third the probability for WTL's computed for hurricanes approaching from the east. The probabilities of equal stages for both groups of tracks were then added arithmetically to develop a curve representing a synthetic probability of recurrence of maximum WTL's for hurricanes from all directions. Table 14 presents these computations and those of the previous paragraph for the south shore of Lake Pontchartrain.

TABLE 14

STAGE-FREQUENCY
SOUTH SHORE - LAKE PONTCHARTRAIN

CPI in.	Zone B occ/100 yrs.	South Shore 80-mi. subzone occ/100 yrs.	TRACK A WTL ft. m.s.l.	TRACK A Freq.* (67% col. 3) occ/100 yrs.	TRACK F WTL ft.m.s.l.	TRACK F Freq.* (33% col. 3) occ/100 yrs.
1	2	3	4	5	6	7
27.6	1	0.2	11.5	0.13	8.0	0.07
27.8	2	0.4	10.9	0.27	7.0	0.13
28.1	5	1.0	9.8	0.67	6.1	0.33
28.3	10	2.0	9.1	1.34	5.6	0.66
28.6	20	4.0	8.0	2.68	4.9	1.32
29.0	40	8.0	6.5	5.36	4.1	2.64

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

(7) Using the shape of the synthetic stage-frequency curve as a guide, it was possible to complete a final curve for the south shore of Lake Pontchartrain between the predetermined limits mentioned in paragraph 9.a.(1).

(8) Lack of historical data prevented the similar development of WTL-frequency relationships for other localities within the project area. For the remaining areas, wind tide levels were calculated for Zone B hurricanes of different frequencies and using different combinations of critical tracks and distribution of azimuths of incidence. It followed that a Zone B hurricane of a particular frequency would have the same recurrence period for any locale in the project area since all are within the same subzone. Therefore, the

final stage-frequency curves for the remaining areas were developed by plotting the computed stages for several different Zone B hurricanes at the corresponding frequencies indicated for the south shore of Lake Pontchartrain. Only two-thirds of the hurricanes from the south or east are most critical relative to WTL's along the south shore of Lake Pontchartrain, while all of the hurricanes from the south or east are equally critical to the area affected by Lake Borgne. Therefore, the most critical WTL along the south shore of Lake Pontchartrain for a Zone B hurricane of given frequency occurs only two-thirds as often as the most critical WTL along the shores of Lake Borgne for the same hurricane.

b. Relationships. Based on the above-described procedures, stage-frequency relationships were established for the area affected by Lake Borgne. Stage-frequency curves are shown on plate 13.

10. Design hurricane.

a. Selection of the design hurricane. The standard project hurricane was selected as the design hurricane (Des H) due to the urban nature of the project area. A design hurricane of lesser intensity which would indicate a lower levee grade and an increased frequency would expose the protected areas to hazards to life and property that would be disastrous in event of the occurrence of a hurricane of the intensity and destructive capability of the standard project hurricane.

b. Characteristics. The characteristics of the Des H's for the proposed plan of protection are identical to the standard project hurricane described in paragraph 8.c. However, due to transposition of the regional SPH to the smaller project area the design hurricane would have a probability of recurrence of only once in about 200 years in the project area. The tracks of the Des H's were located successively to produce maximum hurricane tides along the entire length of the proposed structures. The Des H's are theoretical hurricanes but hurricanes of similar intensity have been experienced in the area. Table 15 is a summary of the Des H characteristics.

TABLE 15

DESIGN HURRICANE CHARACTERISTICS

Location	CPI inches	Max. winds m.p.h.	Radius of max.winds miles	Forward speed knots	Direction of approach	Track (plate 9)
Lake Borgne area						
New Orleans East	27.6	100	30	11	East	F
Citrus	27.6	100	30	11	East	F
Chalmette	27.6	100	30	11	East	F

c. Normal predicted tides. The average tidal ranges in Lakes Borgne, Pontchartrain, and Maurepas are 1.0 foot, 0.5 foot, and 0.3 foot, respectively. The average elevation of the three lakes differs very little. Lake Borgne has an average elevation of 0.9 foot; Lakes Pontchartrain and Maurepas are 1.0 foot and 1.1 feet, respectively. In determining the elevation of design surges and wind tide levels, the mean normal predicted tide was assumed to occur at the critical period.

d. Design tide. The hurricane tide is the maximum still-water surface elevation experienced at a given location during the passage of a hurricane. It reflects the combined effects of the hurricane surge, and, where applicable, the overland flow of the surge and wind tide. Design hurricane tides were computed for conditions reflecting authorized protective works or improvements. The resultant elevations, which are identical to those for an SPH, are the same for existing or project conditions in the Lake Borgne area.

11. Hydraulic design interior drainage. The hydraulic design for the interior drainage of the Chalmette area will be covered in Design Memorandum No. 3, General Design, Chalmette Area Plan.

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(18) Saville, Thorndike, Jr., "Laboratory Data on Wave Run-Up and Overtopping on Shore Structures," Beach Erosion Board, Technical Memorandum No. 64, October 1955.

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PROJECT AREA
LIVINGSTON PARISH
ASCENSION PARISH
TANGIPAHOA PARISH
ST TAMMANY PARISH
ST JOHN THE BAPTIST PARISH
ST JAMES PARISH
ST CHARLES PARISH
JEFFERSON PARISH
ORLEANS PARISH
ST BERNARD PARISH
LOUISIANA
MISSISSIPPI
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
LAKE ST CATHERINE
MISSISSIPPI SOUND
MISSISSIPPI RIVER
MISSISSIPPI RIVER GULF OUTLET
NEW RIVER CANAL
PASS MANCHAC
BONNET CARRE SPILLWAY
INNER HARBOR NAVIGATION CANAL
INTRACOASTAL WATERWAY
LITTLE WOODS CANAL
DWYER CANAL
CHEF MENTEUR PASS
RIGOLETS
PEARL RIVER
METAIRIE RELIEF OUTFALL CANAL
New Orleans International Airport (Moisant Field)
NEW ORLEANS
Sorrento
Manchac
Ruddock
Frenier
La Place
Kenner
Metairie
West End
Madisonville
Mandeville
Slidell
North Shore
South Point
Long Point
Little Woods
Citrus
Michoud
Chalmette
Algiers
Gretna
Violet
GRAND ISLAND
LEGEND
Existing levee
Existing seawall
Railroad embankment
Spoil
SCALE OF MILES
VICINITY MAP
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE
GENERAL MAP
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
AUGUST 1966
FILE NO. H-2-23893

PLATE 1

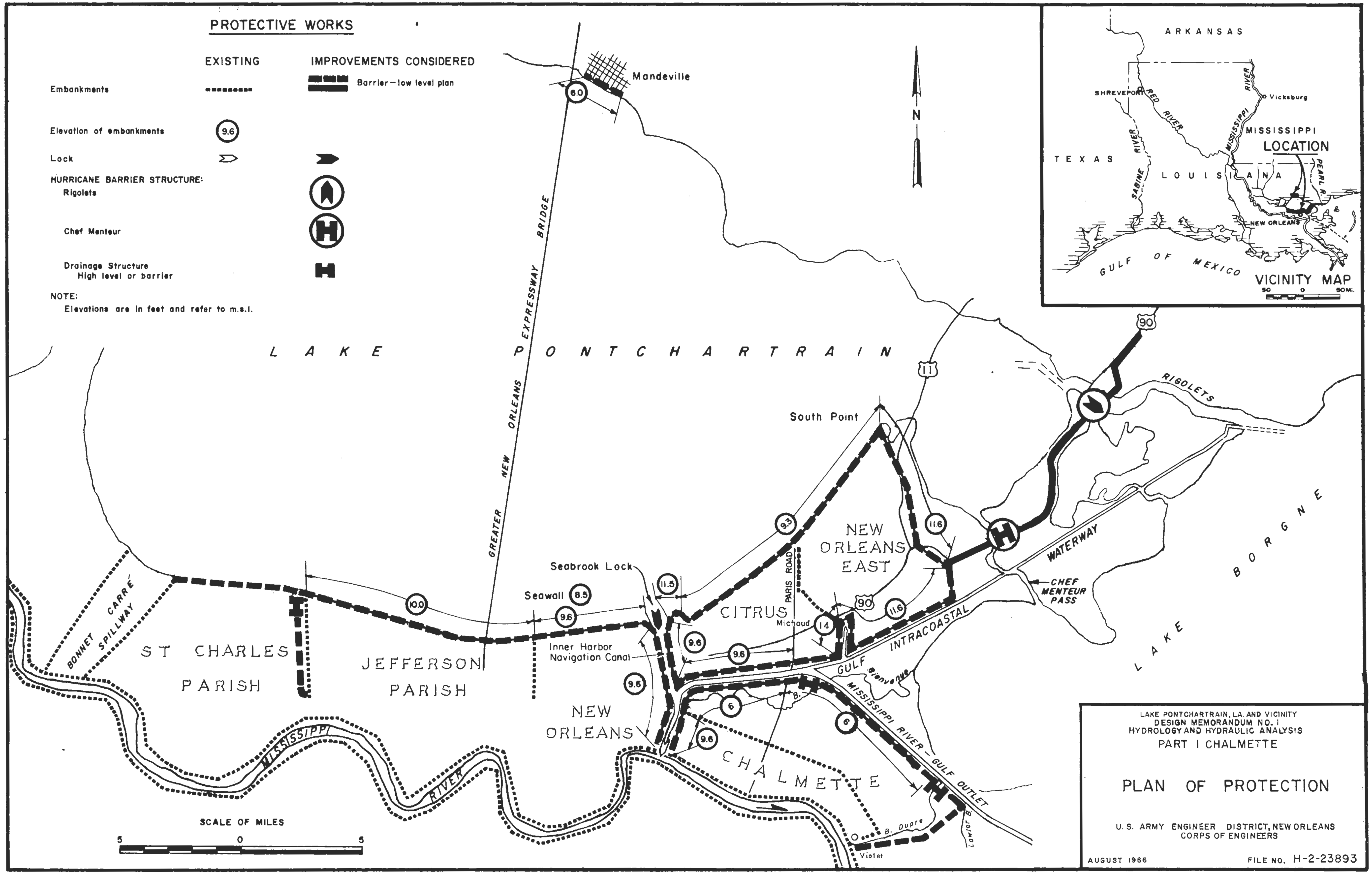
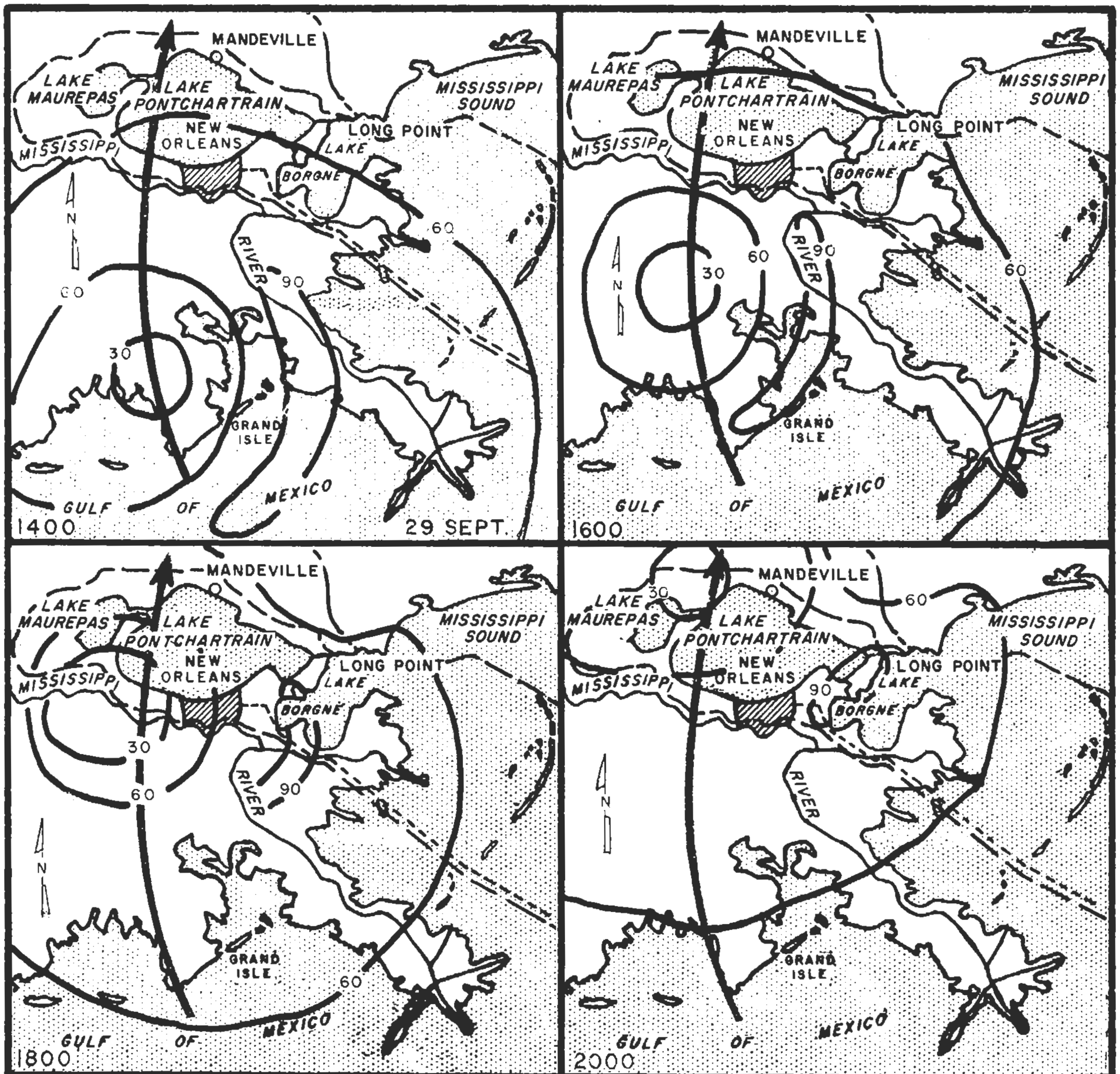
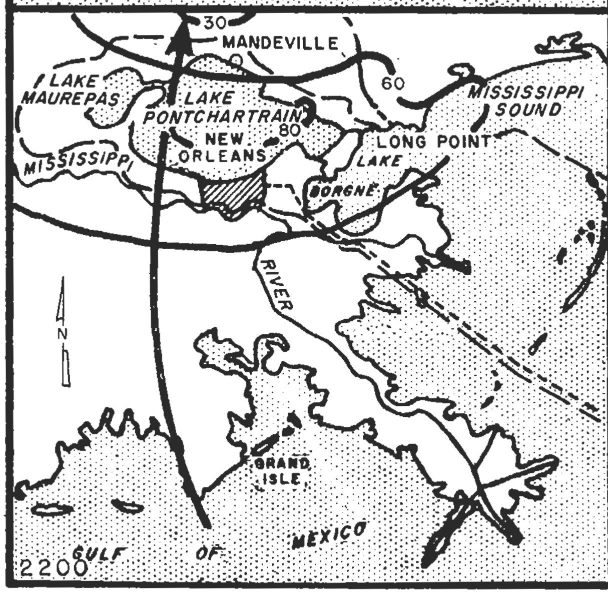

PROTECTIVE WORKS
EXISTING
IMPROVEMENTS CONSIDERED
Embankments
Barrier – low level plan
Elevation of embankments
Lock
HURRICANE BARRIER STRUCTURE:
Rigolets
Chef Menteur
Drainage Structure
High level or barrier
NOTE:
Elevations are in feet and refer to m.s.l.
Mandeville
N
L A K E P O N T C H A R T R A I N
GREATER NEW ORLEANS EXPRESSWAY BRIDGE
South Point
RIGOLETS
NEW ORLEANS EAST
CITRUS
PARIS ROAD
Michoud
Seabrook Lock
Seawall
Inner Harbor Navigation Canal
GULF INTRACOASTAL WATERWAY
CHEF MENTEUR PASS
L A K E B O R G N E
BONNET CARRE SPILLWAY
ST CHARLES PARISH
JEFFERSON PARISH
NEW ORLEANS
CHALMETTE
MISSISSIPPI RIVER
MISSISSIPPI RIVER – GULF OUTLET
Bienvenue
B. Dupre
Violet
SCALE OF MILES
ARKANSAS
SHREVEPORT
RED RIVER
Vicksburg
MISSISSIPPI
LOCATION
TEXAS
SABINE RIVER
LOUISIANA
PEARL R.
NEW ORLEANS
GULF OF MEXICO
VICINITY MAP
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE
PLAN OF PROTECTION
U. S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
AUGUST 1966
FILE NO. H-2-23893

PLATE 2


PROJECT AREA
LIVINGSTON PARISH
ASCENSION PARISH
TANGIPAHOA PARISH
ST TAMMANY PARISH
ST JOHN THE BAPTIST PARISH
ST JAMES PARISH
ST CHARLES PARISH
JEFFERSON PARISH
ORLEANS PARISH
ST BERNARD PARISH
LOUISIANA
MISSISSIPPI
LAKE MAUREPAS
LAKE PONTCHARTRAIN
LAKE BORGNE
LAKE ST CATHERINE
MISSISSIPPI SOUND
NEW ORLEANS
MISSISSIPPI RIVER
NEW RIVER CANAL
PASS MANCHAC
BONNET CARRE SPILLWAY
METAIRIE RELIEF OUTFALL CANAL
New Orleans International Airport (Moisant Field)
INNER HARBOR NAVIGATION CANAL
LITTLE WOODS CANAL
DWYER CANAL
Madisonville
Mandeville
Slidell
Manchac
Sorrento
La Place
Kenner
Metairie
West End
Algiers
Gretna
Chalmette
Violet
Shell Beach
Long Point
South Point
North Shore
LEGEND
Seawall
Spoil
Levee
METEOROLOGIC STATIONS
Complete meteorologic station
Barograph
Recording precipitation
Non-recording precipitation
Non-recording precipitation and temperature
Recording anemometer
HYDROLOGIC STATIONS
Recording gage
Staff gage
Wire weight
Recording wave gage
Salinity
Crest indicator
NOTE:
Figures adjacent to symbols refer to stations listed in tables 3, 5 and 6.
VICINITY MAP
SCALE OF MILES
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE
METEOROLOGIC AND HYDROLOGIC STATIONS
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS
AUGUST 1966
FILE NO. H-2-23893

PLATE 3





LEGEND

Project area

Average wind velocity (30)

Hurricane path

LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART 1 CHALMETTE

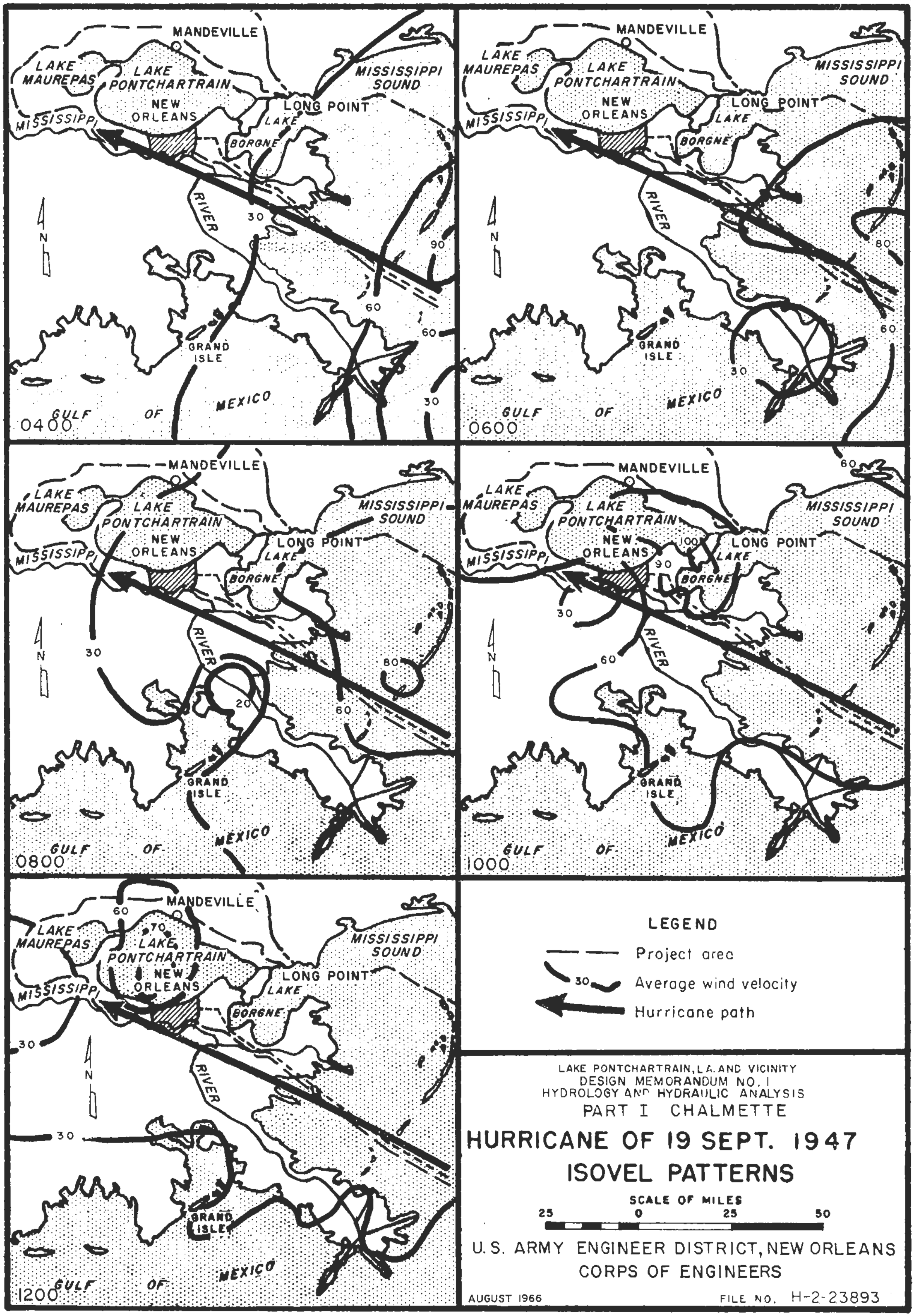
HURRICANE OF 28 SEPT. TO 1 OCT. 1915 ISOVEL PATTERNS

SCALE OF MILES
25 0 25 50

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

AUGUST 1966

FILE NO. H-2-23893



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DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

HURRICANE OF 19 SEPT. 1947 ISOVEL PATTERNS

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CORPS OF ENGINEERS

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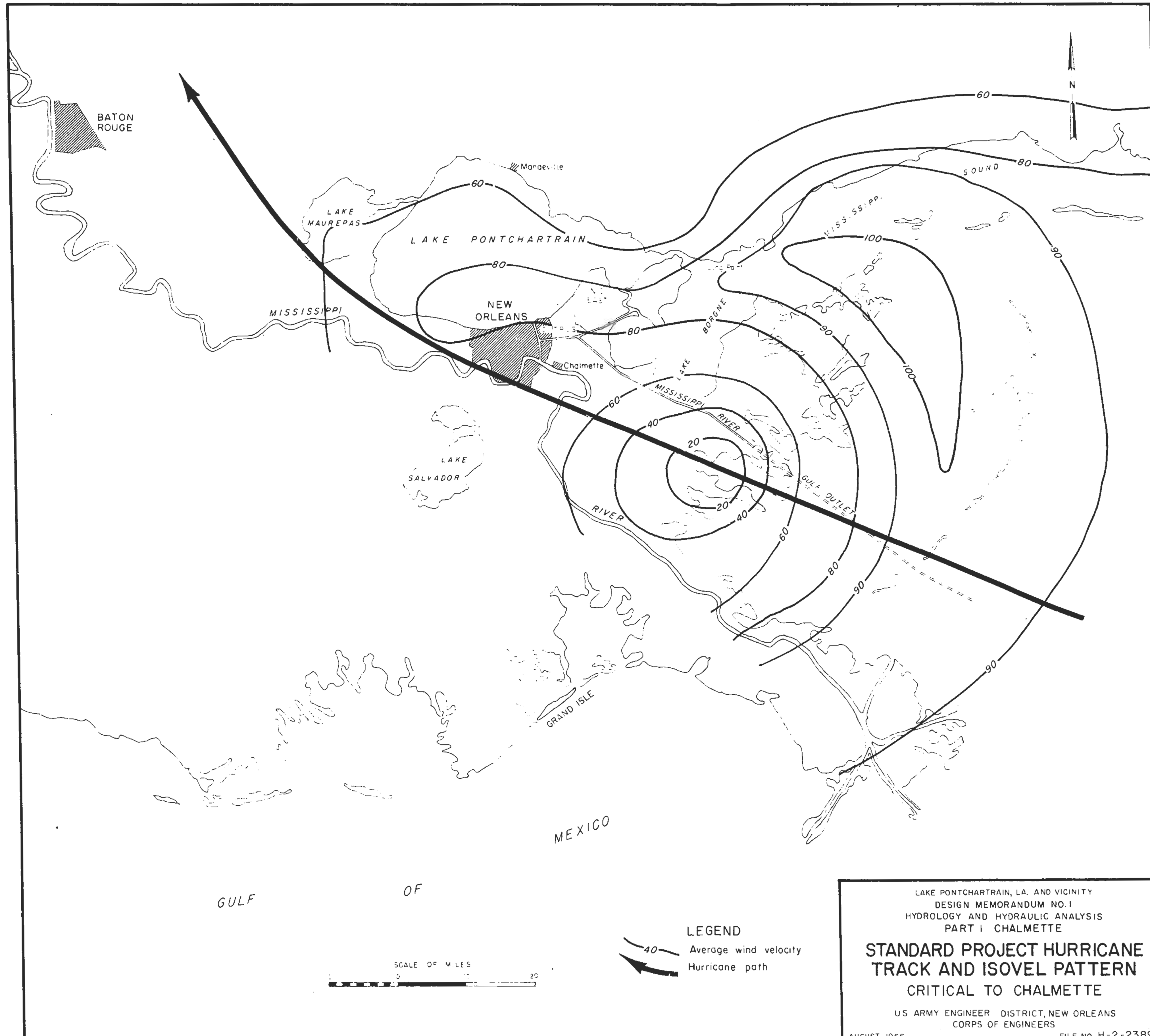
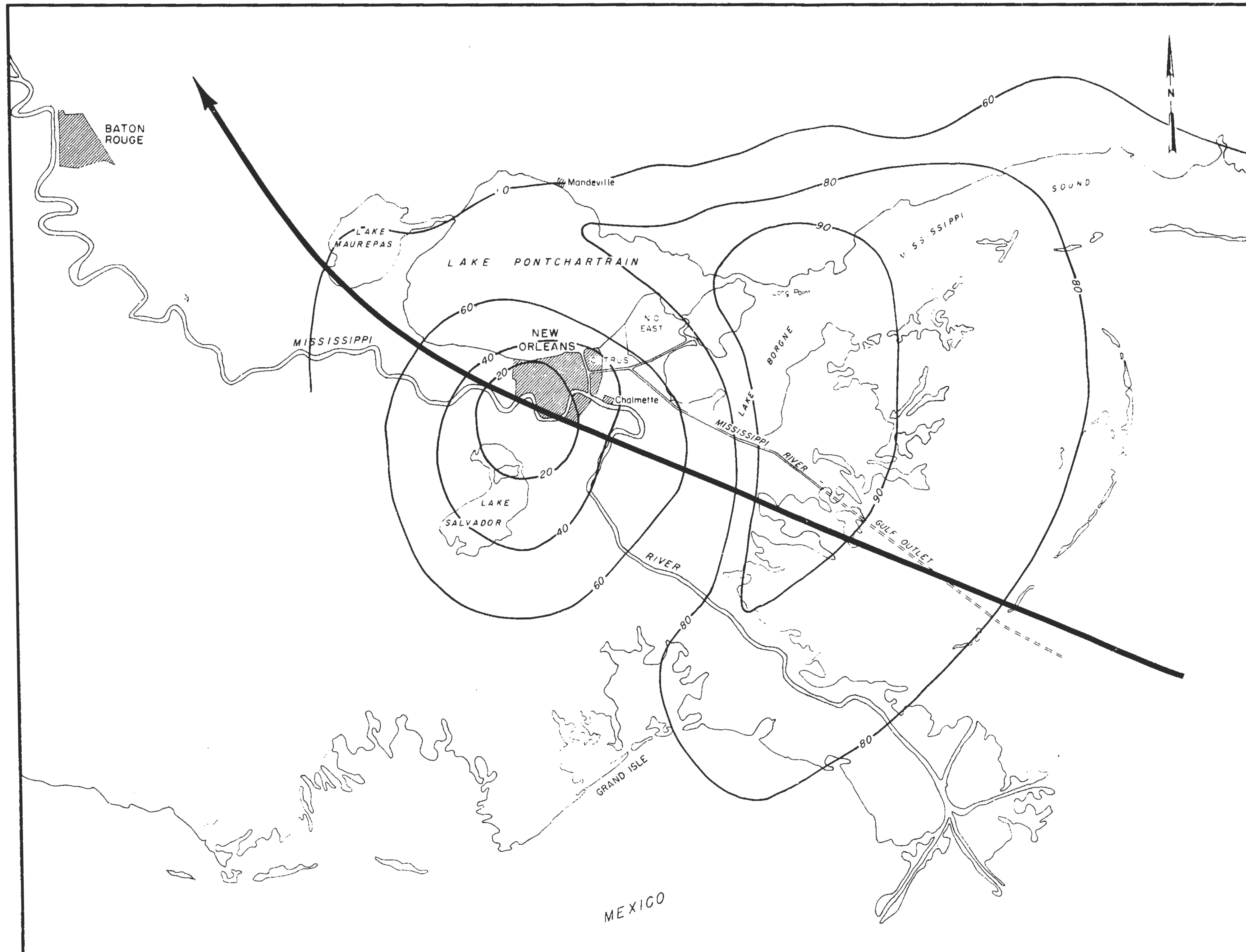


LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

STANDARD PROJECT HURRICANE
TRACK AND ISOVEL PATTERN
CRITICAL TO CHALMETTE

US ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

AUGUST 1966 FILE NO. H-2-23893



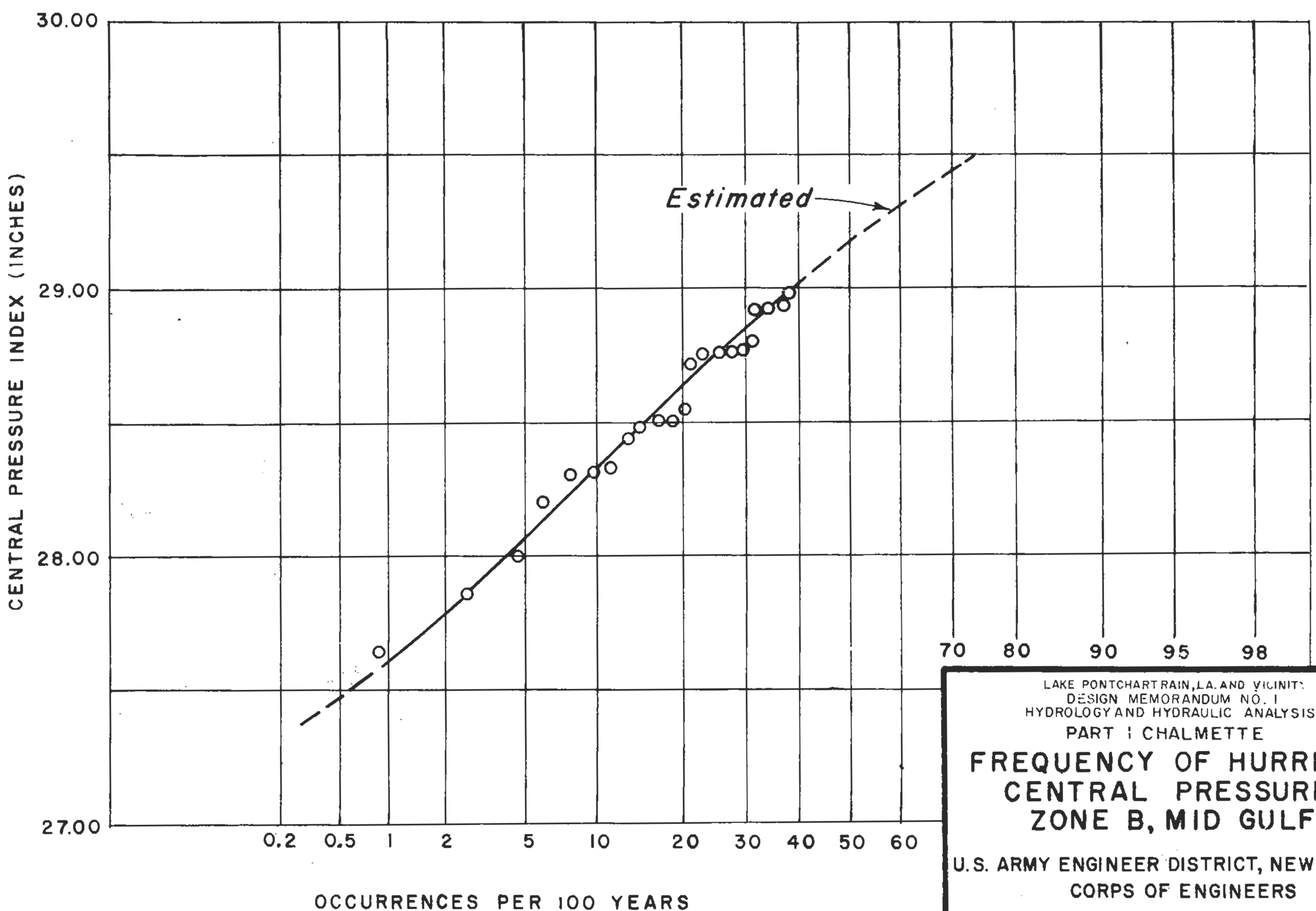
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

STANDARD PROJECT HURRICANE TRACK AND ISOVEL PATTERN CRITICAL TO CITRUS AND NEW ORLEANS EAST (BACK)

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

AUGUST 1966 FILE NO. H-2-23893

PLATE 7



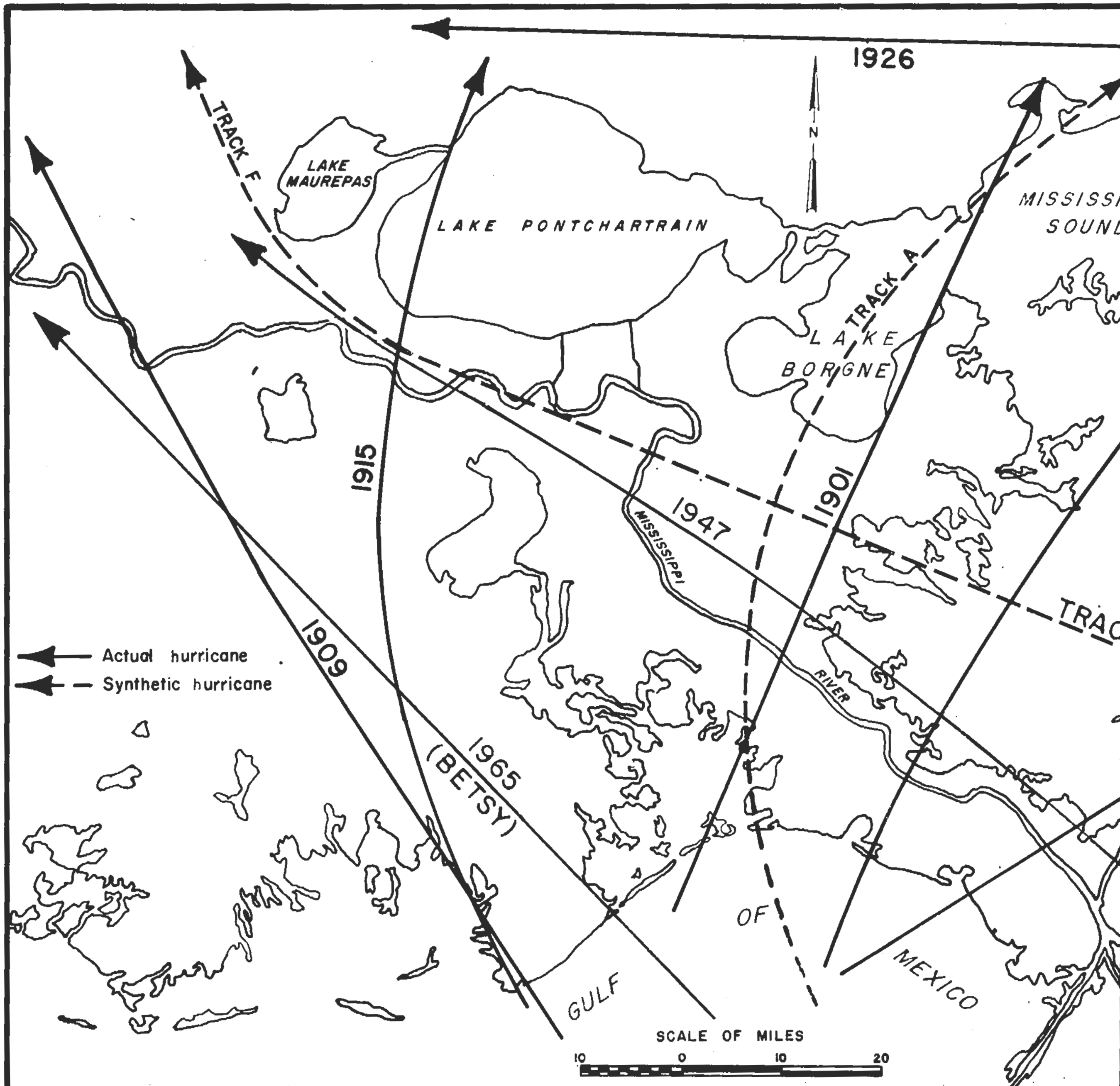
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

FREQUENCY OF HURRICANE CENTRAL PRESSURES ZONE B, MID GULF

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

AUGUST 1966 FILE NO. H-2-23893

PLATE 8



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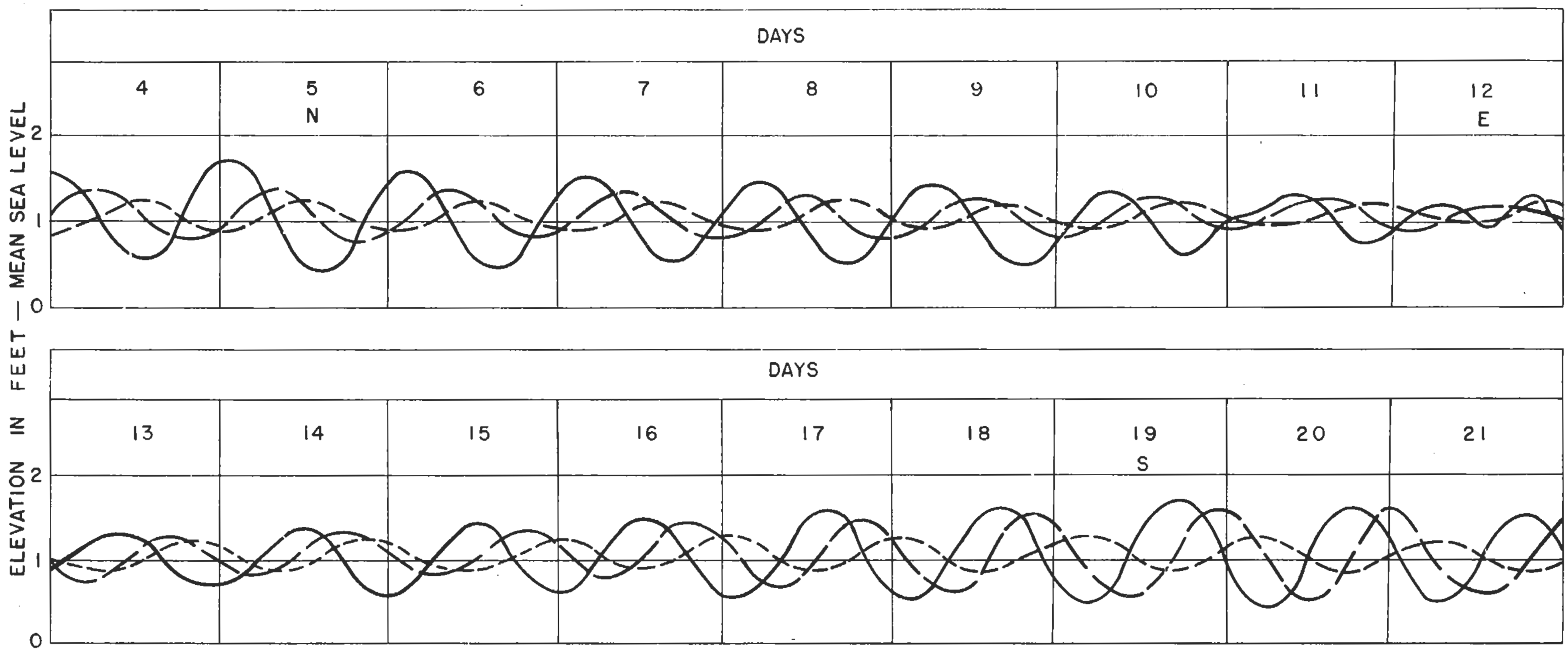
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

HURRICANE TRACKS

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

AUGUST 1966 FILE NO. H-2-23893

PLATE 9



LEGEND

- Lake Borgne (solid line)
- Lake Pontchartrain (long dashes)
- Lake Maurepas (short dashes)
- E moon on the equator
- N,S moon farthest north or south of the equator

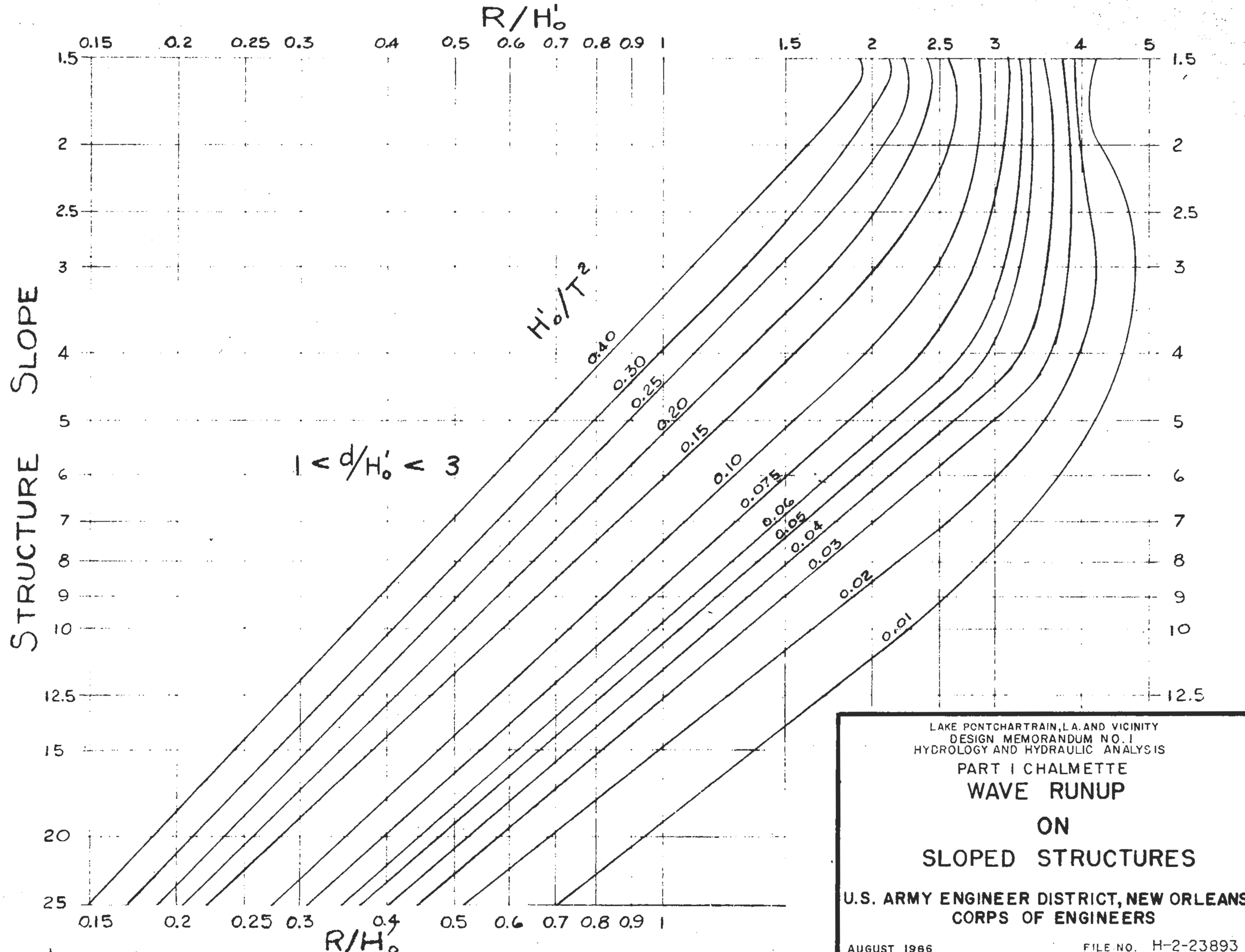
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

TYPICAL TIDAL CYCLES

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

AUGUST 1966 FILE NO. H-2-23893

PLATE 10



LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

WAVE RUNUP ON SLOPED STRUCTURES

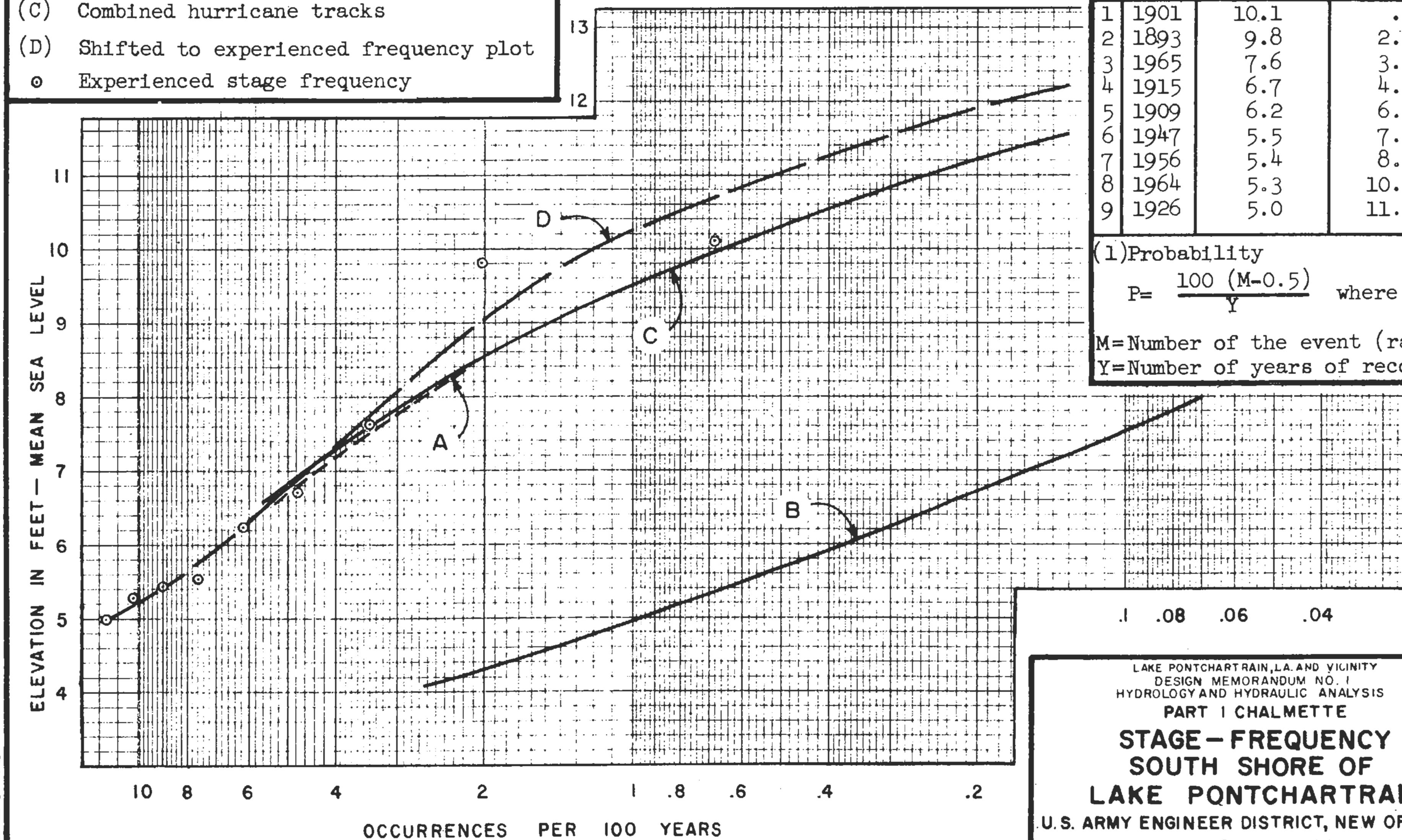
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

AUGUST 1966 FILE NO. H-2-23893

PLATE 11

LEGEND

(A) Hurricane tracks from the south
(B) Hurricane tracks from the east
(C) Combined hurricane tracks
(D) Shifted to experienced frequency plot
⊙ Experienced stage frequency



FREQUENCY ANALYSIS

M	Years	Wind tide level (ft.)	(1) Probability
1	1901	10.1	.685
2	1893	9.8	2.05
3	1965	7.6	3.42
4	1915	6.7	4.79
5	1909	6.2	6.16
6	1947	5.5	7.53
7	1956	5.4	8.90
8	1964	5.3	10.27
9	1926	5.0	11.64

(1) Probability

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

M = Number of the event (rank)
Y = Number of years of record (73)

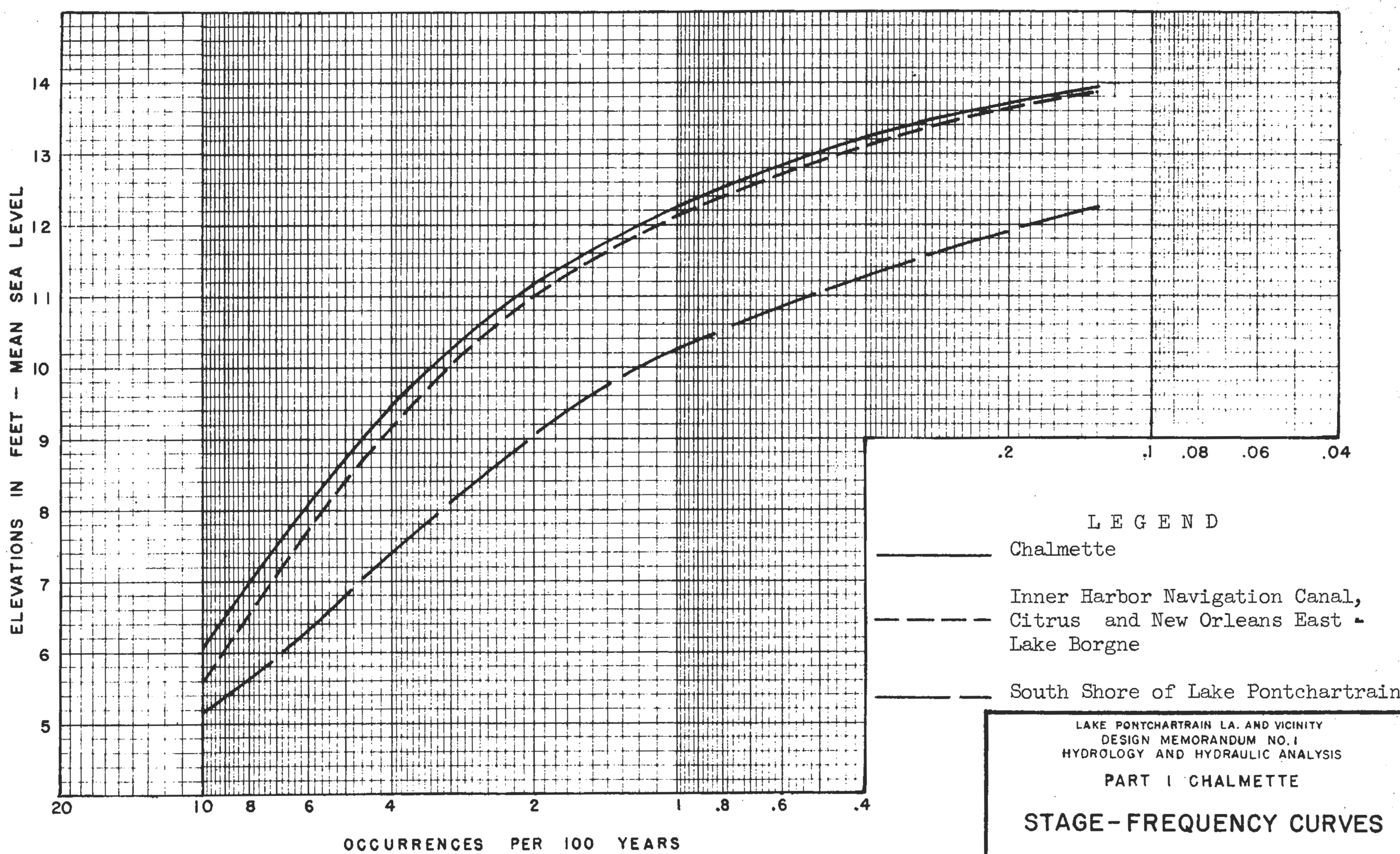
LAKE PONTCHARTRAIN, LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS
PART I CHALMETTE

STAGE — FREQUENCY
SOUTH SHORE OF
LAKE PONTCHARTRAIN

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

AUGUST 1966 FILE NO. H-2-23893

PLATE 12



LAKE PONTCHARTRAIN LA. AND VICINITY
DESIGN MEMORANDUM NO. 1
HYDROLOGY AND HYDRAULIC ANALYSIS

PART I CHALMETTE

STAGE-FREQUENCY CURVES

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

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PLATE 13