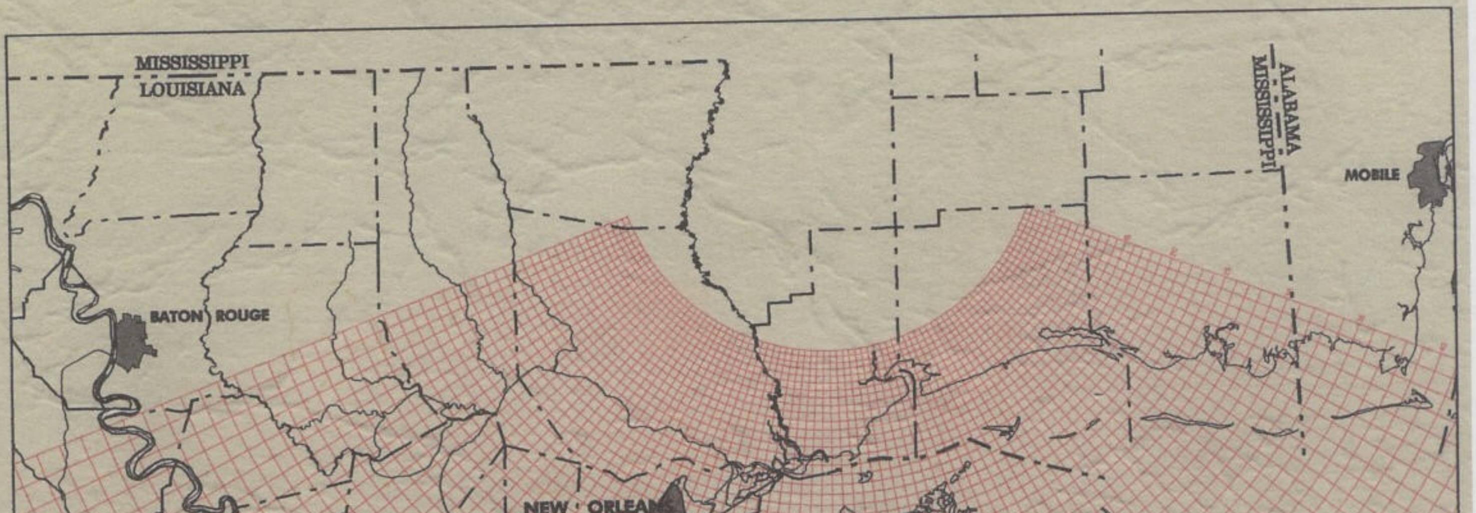
SOUTHEAST LOUISIANA HURRICANE PREPAREDNESS STUDY 1994



TECHNICAL DATA REPORT

Federal Emergency Management Agency, Region VI
U. S. Army Corps of Engineers, New Orleans District
National Weather Service

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TECHNICAL DATA REPORT

SOUTHEAST LOUISIANA HURRICANE PREPAREDNESS STUDY

Prepared for
Federal Emergency Management Agency
Region VI

by

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SOUTHEAST LOUISIANA
HURRICANE PREPAREDNESS STUDY

FOREWORD

Most extreme events in nature (i.e., tornadoes, earthquakes, volcanoes, hurricanes) cannot be controlled, yet the human consequences may be affected dramatically by actions taken prior to the event. One challenge is to investigate the natural processes at work and attempt to predict where these extremes will occur. Earthquake zones, stream flood plains, storm surge zones, and other areas at risk should be identified.

Another major challenge is to plan and implement measures that will mitigate human suffering. Warning systems can alert people to impending danger. Evacuation plans can guide them to safety. These measures call for careful scientific and engineering research and for skillful application by public officials. We will never be able to completely eliminate the hazards of extreme events, but where life is at stake we should not be satisfied until serious steps have been taken to greatly reduce the risks.

TECHNICAL DATA REPORT
SOUTHEAST LOUISIANA HURRICANE PREPAREDNESS STUDY

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CHAPTER ONE

INTRODUCTION

I. PURPOSE.

Southeast Louisiana is undergoing rapid change. As is typical of most coastal locations throughout the United States and particularly in the Sun Belt states, tremendous development and population increases have occurred over the past 20 to 25 years. Much of the population growth and development has taken place in coastal communities and along the lakes and bayous of southeast Louisiana. With little relief provided by the surrounding topography, these communities are at risk to inundation from hurricane surge. The rate of growth and development has slowed in recent years as a result of the recession, but expectations are for population growth to increase as the local economy continues to improve.

The tremendous population growth and development has presented emergency management officials with the difficult task of developing hurricane evacuation plans which can reasonably assure safe and effective evacuations for the vulnerable population. The critical data necessary for the development of these plans often requires comprehensive and specialized analyses. The fiscal and staffing limitations of most state and local emergency management agencies preclude the development of this type of data. In an effort to assist state and local governments develop the needed technical information, the Federal Emergency Management Agency, the National Oceanic and Atmospheric Administration (National Weather Service), and the U.S. Army Corps of Engineers have joined state and local emergency management agencies in Louisiana in conducting the Southeast Louisiana Hurricane Preparedness Study.

The purpose of the Southeast Louisiana Hurricane Preparedness Study is to provide state and local emergency management agencies with realistic, quantitative data pertaining to the major factors affecting decision-making under hurricane threats. The report also provides guidance on how this information, along with advisories issued by the National Weather Service, can be used to assist in the decision-making process. The technical data presented in this report is not intended to replace the detailed plans developed by the state and parishes within the study area. Rather, this data will provide a framework within which the state and each parish can update and revise existing hurricane evacuation plans and from which operational procedures and decision guides for future hurricane threats can be developed. The data developed for this report is based on existing conditions and conditions that are expected to occur in the immediate-future. No attempt was made to project future conditions.

II. AUTHORITY.

The Southeast Louisiana Hurricane Preparedness Study was funded by the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the National Weather Service. The study authority for the Federal Emergency Management Agency is the Disaster Relief Act of 1974 (Public Law 93-288), and the study authority for the Corps of Engineers is Section 206 of the Flood Control Act of 1960 (Public Law 86-645). These laws authorize the allocation of resources for planning activities related to hurricane preparedness.

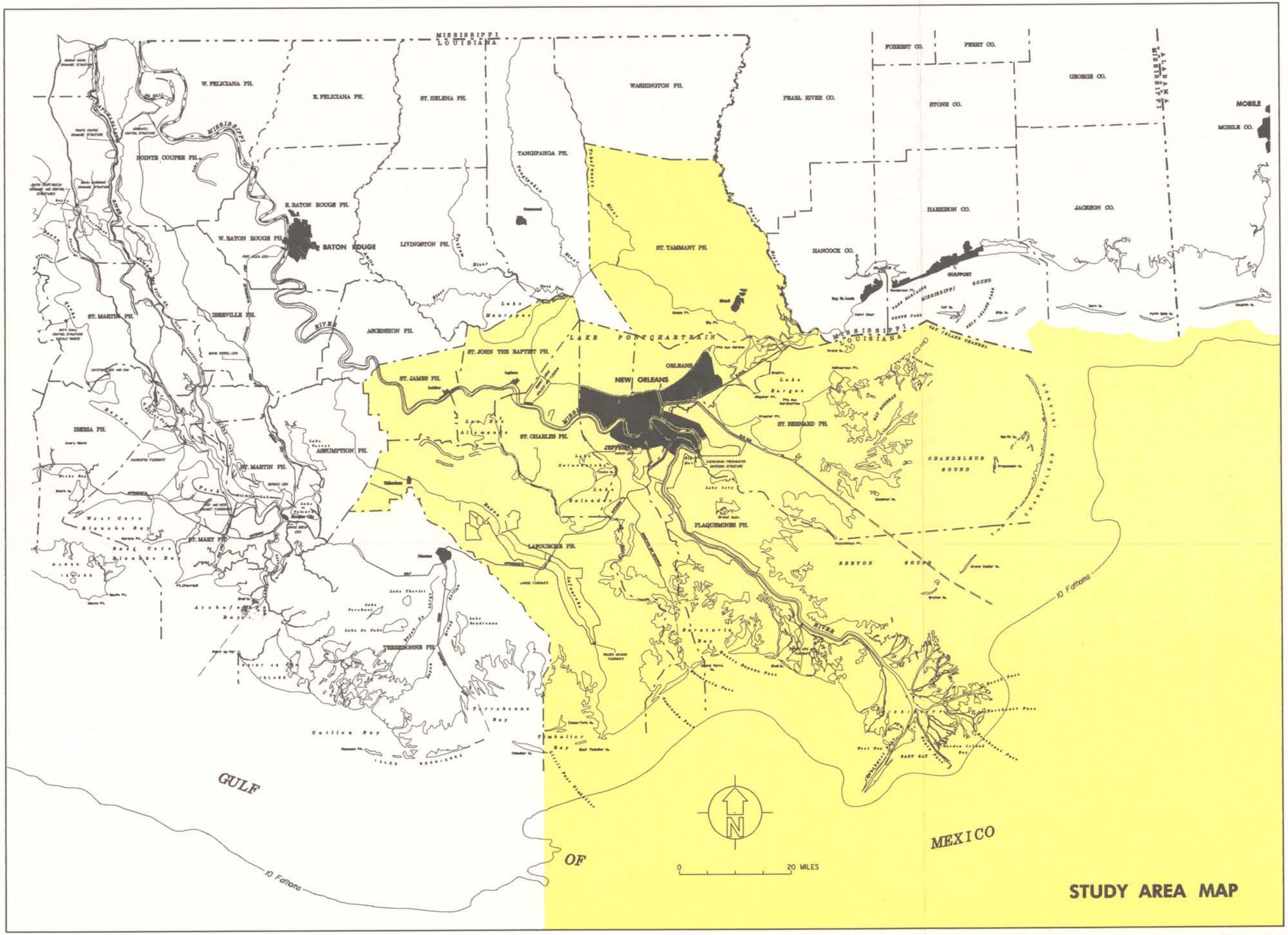
This study was conducted by the New Orleans District, U.S. Army Corps of Engineers, which provided the project management and technical assistance in accordance with U.S. Army Corps of Engineers publication, *Technical Guidelines for Hurricane Evacuation Studies*, November 1984, and Federal Emergency Management Agency publication *CPG 2-16, A Guide to Hurricane Preparedness Planning for State and Local Officials*, December 1984.

III. DESCRIPTION OF STUDY AREA.

A. Geography. The Southeast Louisiana Hurricane Preparedness Study area encompasses nine parishes in southeast Louisiana. These parishes include Jefferson, Lafourche, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St. John the Baptist, and St. Tammany. Significant geographic features within the study area include: approximately 150 miles of open coastline; a number of large shallow lakes including Lake Pontchartrain, Lake Borgne, and Lake Maurepas; the Mississippi River and its abandoned courses and distributaries; and numerous bayous, swamps, and marshes. The study area is shown in Figure 1-1.

B. Topography. The study area is very low in elevation, comprised primarily of sea-level marsh, swamp, and open water, with relief provided by the alluvial ridges of the present and abandoned courses and distributaries of the Mississippi River. The elevation of topographic features within the study area were referenced to National Geodetic Vertical Datum (NGVD), formerly known as the mean sea level of 1929. Elevations within the study area, excluding the northern reaches of St. Tammany Parish, vary from as low as -10 feet NGVD in developed areas which have been leveed off and drained by pumps to about +25 feet NGVD along the ridges of the Mississippi River. Northern St. Tammany Parish, located on the north shore of Lake Pontchartrain, has ground elevations of up to +200 feet NGVD.

The topography of the study area is characteristic of the region's formation as a deltaic plain. An extensive system of Federal and local levees have been constructed in southern Louisiana to protect against hurricane surge and flooding from the Mississippi River. The levees constructed along the Mississippi River have eliminated the seasonal sediment-laden overbank flow that once nourished adjacent wetland areas. A lack of nourishment



MISSISSIPPI
LOUISIANA
W. FELICIANA PH.
E. FELICIANA PH.
ST. HELENA PH.
WASHINGTON PH.
PEARL RIVER CO.
FORREST CO.
PERRY CO.
STONE CO.
GEORGE CO.
ALABAMA
MISSISSIPPI
MOBILE
MOBILE CO.
POINTE COUPEE PH.
TANGIPAHOA PH.
E. BATON ROUGE PH.
W. BATON ROUGE PH.
BATON ROUGE
LIVINGSTON PH.
ST. TAMMANY PH.
HARRISON CO.
JACKSON CO.
HANCOCK CO.
ST. MARTIN PH.
IBERVILLE PH.
ASCENSION PH.
LAKE PONTCHARTRAIN
ST. JOHN THE BAPTIST PH.
ST. JAMES PH.
ORLEANS
NEW ORLEANS
ST. CHARLES PH.
ST. BERNARD PH.
IBERIA PH.
ASSUMPTION PH.
ST. MARTIN PH.
CHANDELEUR SOUND
ST. MARY PH.
LAFOURCHE PH.
PLAQUEMINES PH.
BRETON SOUND
TERREBONNE PH.
MISSISSIPPI SOUND
GULF
OF
MEXICO
10 Fathoms
0
20 MILES
N
STUDY AREA MAP

Figure 1-1

along with erosion, subsidence, compaction, sea-level rise, and saltwater intrusion have resulted in widespread coastal land loss. Current land loss rates in southern Louisiana are estimated at 25 square miles per year. As the loss of wetlands in Louisiana continues, the urbanized areas become even more vulnerable to hurricane surge.

C. Bathymetry. The bathymetry near the coastline is very important in determining the magnitude of storm surge. Shallow coastal bathymetry will tend to increase the magnitude of hurricane induced storm surge. If the topography of the shoreline is also gradual and sloping, hurricane surge is able to penetrate further inland, inundating vast areas. As the slope of the coastline increases, hurricane induced storm surge will tend to decrease but the magnitude of the waves will increase. The bathymetry along the southeast Louisiana coastline varies considerably. The 10-fathom (-60 feet NGVD) contour lies about 25 to 30 miles offshore around Caillou Bay and Terrebonne Bay, then tapers to within 10 to 15 miles offshore around Timbalier Bay. It parallels the coastline 10 to 12 miles offshore along Barataria Bay and east to West Bay, then gradually converges coming within 5 miles of the coastline at the mouth of the Mississippi River (Head of Passes). North of the Head of Passes, the 10-fathom contour quickly moves offshore to a distance of 35 to 40 miles in Breton Sound and Chandeleur Sound. The 10-fathom contour is shown in Figure 1-1.

The 100-fathom (-600 feet NGVD) contour lies about 65 miles offshore at Terrebonne Bay and gradually decreases to 50 miles offshore at Barataria Bay. From Barataria Bay to the Head of Passes the 100-fathom contour converges to within 8 miles of the coast. North of the Head of Passes, it quickly moves offshore to more than 80 miles in Breton Sound. The close proximity of the 10- and 100- fathom contour lines at the Head of Passes is a result of the continuing growth of the deltaic plain formed by the Mississippi River.

The study area also includes a number of large shallow lakes, the most significant of which are Lake Maurepas, Lake Borgne, and Lake Pontchartrain. Lake Maurepas, with a length of 9 miles and a width of 15 miles, has a maximum depth of approximately 12 feet. Lake Borgne has a length of 16 miles, a width of 13 miles, and a maximum depth of approximately 10 feet. Lake Pontchartrain, the largest of the three lakes, has a length of about 30 miles and a width of over 20 miles. Maximum depths in the Lake Pontchartrain range from 12 to 15 feet. The reaction of these lakes to a hurricane poses a significant threat to the study area.

D. Population. The permanent resident population of southeast Louisiana has increased by 13% over the past 20 years compared with an increase of 16% for the state over the same period. The two most heavily populated parishes within the state, both located within the study area, are Jefferson and Orleans Parishes. These parishes, with a total population in excess of 945,000 based on the 1990 census, comprise approximately 32% of the population of the state and nearly 70% of the population of the study area. The city of New Orleans, located within the boundaries of Orleans Parish, has slowly declined in total population over the past 20 years. The majority of the population decline is a result of residents moving away from the city to the less populated surrounding parishes. This net out-migration has resulted in substantial increases in the population of the surrounding parishes. The population of St. Tammany Parish has increased by 127% over the past 20 years, St. John the Baptist Parish increased by 68%, St. Charles Parish increased by 43%, and St. Bernard Parish increased by 30% over the same period. Table 1-1 lists the total population for each of the nine parishes within the study area for the years 1970, 1980, and 1990. Percentages of increase or decrease between these periods are also indicated.

TABLE 1-1

POPULATION OF NINE PARISH STUDY AREA

PARISH	1970	1980[1]	1990[2]
Jefferson	338,229	454,592 (+34%)	448,306 (- 1%)
Lafourche	68,941	82,483 (+20%)	85,860 (+ 4%)
Orleans	593,471	557,927 (- 6%)	496,938 (-11%)
Plaquemines	25,225	26,049 (+ 3%)	25,575 (- 2%)
St. Bernard	51,185	64,097 (+25%)	66,631 (+ 4%)
St. Charles	29,550	37,259 (+26%)	42,437 (+14%)
St. James	19,733	21,495 (+ 8%)	20,879 (- 3%)
St. John the Baptist	23,813	31,924 (+34%)	39,996 (+25%)
St. Tammany	63,585	110,869 (+74%)	144,508 (+30%)
Totals	1,213,732	1,386,695 (+14%)	1,371,130 (- 1%)

Source: Census of Population and Housing.

[1] Percent population change between 1970 and 1980 is shown within ( ).
[2] Percent population change between 1980 and 1990 is shown within ( ).

IV. HISTORIC HURRICANE ACTIVITY.

A. General. Hurricanes are a classification of tropical cyclones which are defined by the National Weather Service as nonfrontal, low pressure synoptic scale (large scale) systems that develop over tropical or subtropical waters and have a definite organized circulation. Tropical cyclones are categorized based on the speed of the sustained (one-minute average) surface winds near the center of the storm. The categories are: Tropical Depression (winds $\leq$ 33 knots), Tropical Storm (winds 34 to 63 knots inclusive), and Hurricanes (winds $\geq$ 64 knots).

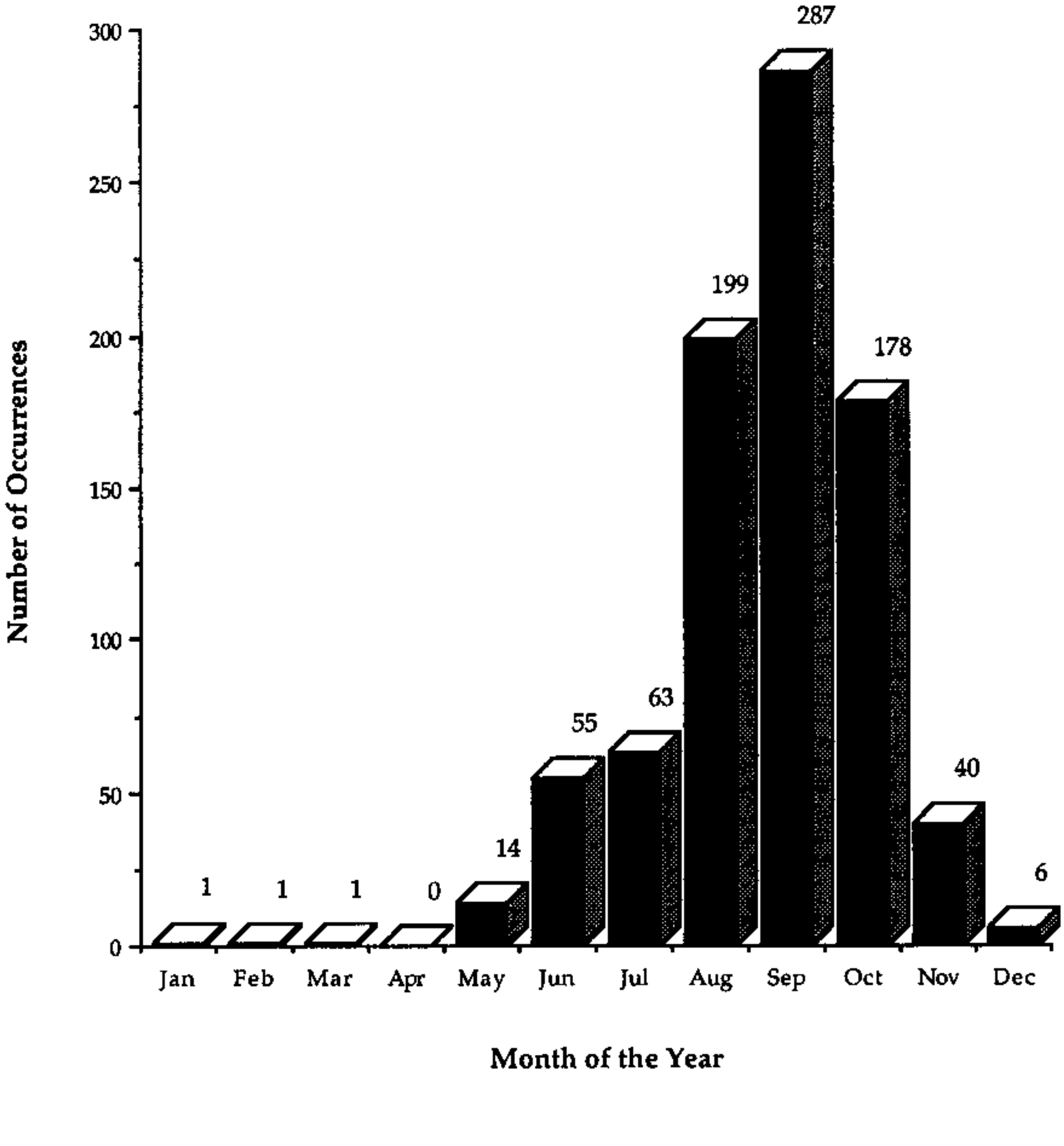
The geographical areas affected by tropical cyclones are referred to as tropical cyclone basins. The Atlantic tropical cyclone basin is one of six in the world and includes much of the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The Atlantic hurricane season officially begins on June 1 and extends through November 30 of each year; however, occasional tropical cyclones occur outside of this period.

B. Atlantic Tropical Cyclone Basin. In the Atlantic basin, tropical cyclones occurring early in the hurricane season are almost exclusively confined to the western Caribbean and the Gulf of Mexico. However, by the end of June or early July, the area of formation gradually shifts eastward, with a slight decline in the overall frequency of storms. By late July, the frequency gradually increases, and the area of formation shifts still farther eastward. By late August, tropical cyclones form over a broad area which extends eastward to near the Cape Verde Islands off the coast of Africa. The period from about August 20 through about September 15 encompasses the maximum of the Cape Verde type storms, many of which travel across the entire Atlantic Ocean. Hurricane Andrew, which struck southern Florida and south-central Louisiana in late August 1992, was a Cape Verde hurricane. After mid-September, the frequency begins to decline and the formative area retreats westward. By early October, the area is generally confined to longitudes west of 60 degrees West, and the area of maximum occurrence returns to the western Caribbean. In November, the frequency of tropical cyclone occurrence further declines. Figure 1-2 illustrates the monthly occurrence of tropical cyclones within the Atlantic basin for the period 1886 through 1986.

Through the research efforts of the National Climate Center in cooperation with the National Hurricane Center, records of tropical cyclone occurrences within the Atlantic tropical cyclone basin have been compiled dating back to 1871. Although other researchers have compiled fragmentary data concerning tropical cyclones within the Atlantic tropical cyclone basin back to the late fifteenth century, the years from 1871 to the present represent the complete period of the development of meteorology and organized weather services in the United States. For the 122-year period 1871 through 1992, a total of nearly 1,000 tropical cyclones have occurred within the Atlantic tropical cyclone basin; however, for the years 1871 through 1885, existing data does not allow accurate determinations of the intensities of tropical cyclones occurring during those years. The National Hurricane Center maintains detailed computer files of Atlantic tropical cyclone tracks back to 1886. Of the 845 known Atlantic tropical cyclones of at least tropical storm intensity which occurred for the period 1886 through 1986, 496 are known to have reached

FIGURE 1-2

MONTHLY OCCURRENCE OF TROPICAL CYCLONES IN THE ATLANTIC BASIN BETWEEN 1886 AND 1986



hurricane intensity. The average number of tropical cyclones reaching at least tropical storm intensity and the number of hurricanes occurring in a given year during the same period of record is 8.4 and 4.9, respectively.

C. Central Gulf of Mexico. The central Gulf of Mexico is one of the more hurricane vulnerable locations along the coastline of the United States. Records of tropical cyclone occurrences have been compiled dating back to 1872. For the years 1872 through 1885, insufficient historical data exists to determine between storms of hurricane or tropical storm intensity. Between 1886 and 1992, 35 tropical cyclones of hurricane intensity have passed within 125 statute miles of New Orleans, Louisiana. A listing of these hurricanes is provided in Table 1-2. The corresponding storm tracks are shown in Figure 1-3. The tracks represent "best estimates" and are based on a variety of data sources. Historically, storm strength, location, and motion were only inferred, from analyses of wind, pressure, and cloud observations made at ships and land stations being influenced by the storm. In 1943, aircraft reconnaissance of hurricanes began. Not until 1959 were there land-based weather radars, as now at Lake Charles and Slidell, Louisiana, and Pensacola, Florida, which could be used to observe and record structure, development, and motion of precipitation fields and help infer center location and radius of maximum winds. Further improvements occurred in the 1960's with the added ability to observe tropical storm behavior through satellite photography. A distribution of the intensity of hurricanes passing within 125 miles of New Orleans between 1900 and 1992 is shown in Figure 1-4.

TABLE 1-2

HURRICANES PASSING WITHIN 125 STATUTE MILES OF NEW ORLEANS (1886 - 1992)

YEAR	MONTH	NAME (1)	CATEGORY (2)	FORWARD SPEED
1887	October	Unnamed	-	7
1888	August	Unnamed	-	7
1889	September	Unnamed	-	15
1893	September	Unnamed	-	12
1893	October	Unnamed	-	12
1897	September	Unnamed	-	16
1901	August	Unnamed	2	7
1906	September	Unnamed	3	10
1909	September	Unnamed	4	17
1912	September	Unnamed	1	15
1915	September	Unnamed	4	13
1916	July	Unnamed	3	10

TABLE 1-2 (Continued)

YEAR	MONTH	NAME [1]	CATEGORY [2]	FORWARD SPEED
1917	September	Unnamed	3	11
1920	September	Unnamed	2	19
1923	October	Unnamed	1	25
1926	August	Unnamed	2	7
1926	September	Unnamed	3	9
1932	September	Unnamed	1	10
1934	June	Unnamed	1	13
1947	September	Unnamed	3	14
1948	September	Unnamed	1	14
1956	September	Flossy	2	13
1960	September	Ethel	1	9
1964	October	Hilda	2	13
1965	September	Betsy	3	19
1969	August	Camille	5	16
1971	September	Edith	2	23
1974	September	Carmen	4	9
1977	September	Babe	1	7
1979	July	Bob	1	22
1979	September	Frederic	3	14
1985	September	Elena	3	18
1985	October	Juan	1	12
1988	September	Florence	1	13
1992	August	Andrew	3	16

(1) Storms were not formally named before 1950.

(2) Classification is based on the category of the hurricane while it was within 125 miles of New Orleans. For the years 1886-1898, the categories of hurricanes occurring during this period cannot be determined from existing historical data.

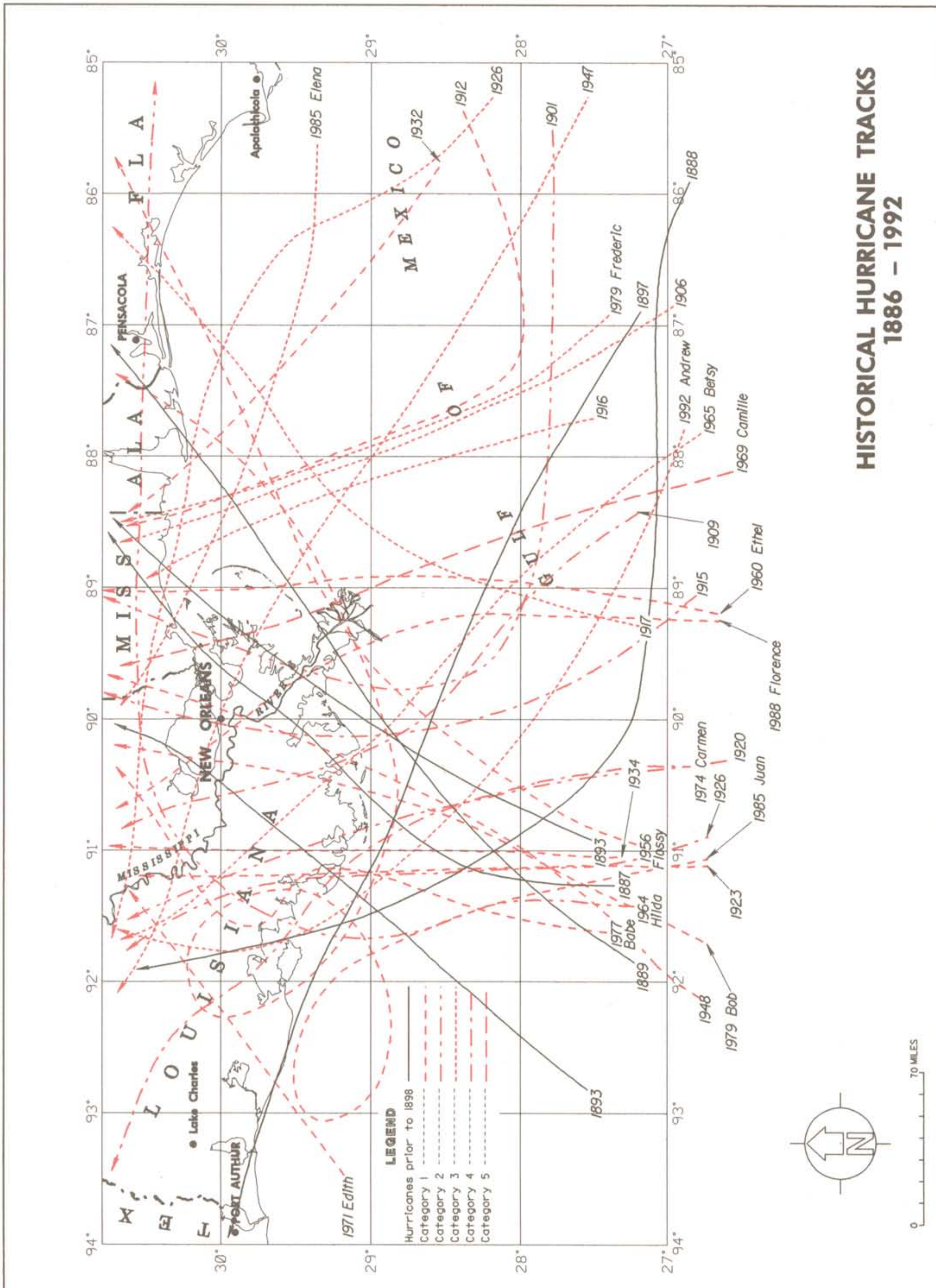
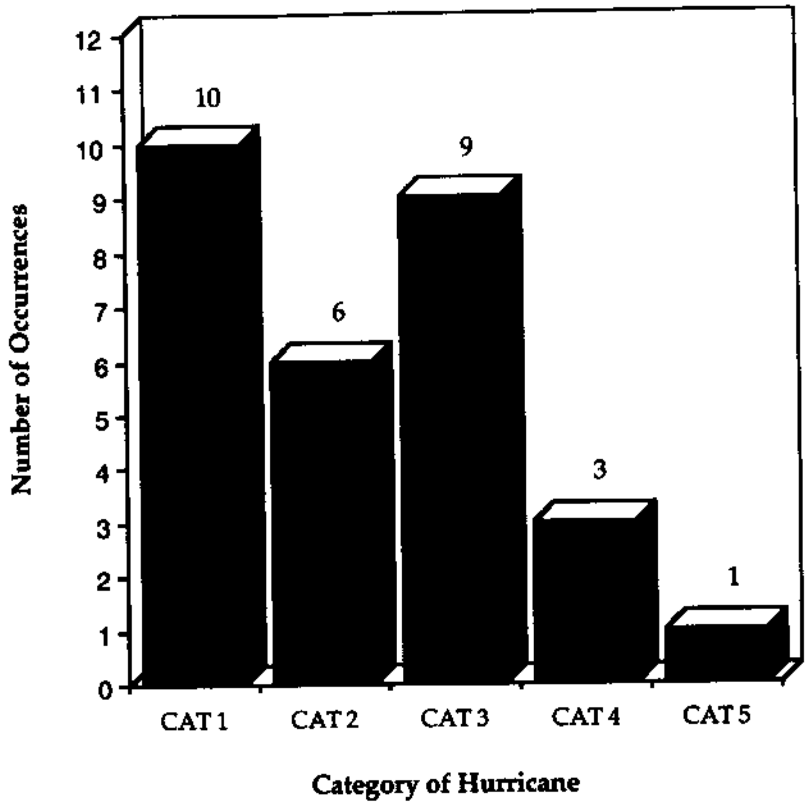

HISTORICAL HURRICANE TRACKS
1886 – 1992
LEGEND
Hurricanes prior to 1898
Category 1
Category 2
Category 3
Category 4
Category 5
PENSACOLA
Apalachicola
NEW ORLEANS
Lake Charles
PORT AUTHUR
MISSISSIPPI RIVER
GULF OF MEXICO
LOUISIANA
MISS.
ALA.
FLA.
TEX.
1985 Elena
1932
1912
1926
1901
1947
1888
1979 Frederic
1897
1906
1992 Andrew
1965 Betsy
1969 Camille
1916
1909
1960 Ethel
1915
1917
1988 Florence
1974 Carmen
1920
1926
1985 Juan
1934
1893
1956 Flossy
1887
1923
1964 Hilda
1977 Babe
1889
1948
1979 Bob
1893
1971 Edith
70 MILES
0
N

Figure 1–3

FIGURE 1-4

DISTRIBUTION OF HURRICANE INTENSITY

(Within 125 miles of New Orleans, 1900 - 1992)



V. STUDY ANALYSES.

The Southeast Louisiana Hurricane Preparedness Study consists of several related analyses that develop technical data concerning hurricane hazards, vulnerability, public response, timing of evacuations, and sheltering needs and availability for various hurricane threat situations. Brief descriptions of the major analyses conducted as part of the Southeast Louisiana Hurricane Preparedness Study are provided below.

A. Hazards Analysis. The purpose of the hazards analysis is to determine the extent of storm surge flooding and the wind speeds that can be expected from various categories, tracks, and forward speeds of hurricanes having a probability of impacting the study area. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) numerical model was used to develop the data. The effects of rainfall are not treated by the SLOSH model. Freshwater flooding was generally addressed by identifying areas within each parish which had a history of flooding from rainfall.

B. Vulnerability Analysis. Utilizing the results of the hazards analysis, the vulnerability analysis identifies those areas, populations, and facilities that are potentially vulnerable to specific hazards under a variety of hurricane threats. Evacuation zones were developed for each of the parishes within the study area, delineated by major natural or man-made geographic features. Hurricane evacuation scenarios were also developed for each parish in which groups of zones were identified as potentially vulnerable to storm surge flooding under combinations of hurricane intensities. The 1990 census population data were utilized to determine the vulnerable population within each parish for a range of hurricane threats.

C. Behavioral Analysis. This analysis determines the expected response of the threatened population to differing hurricane threats in terms of the percentage of the population expected to evacuate, probable destinations of the evacuees, use of public shelter, and utilization of available vehicles. The methodology utilized in the Southeast Louisiana Hurricane Preparedness Study to develop the behavioral data consisted of telephone sample surveys within the study area, data from other hurricane evacuation studies, and data from post-hurricane evacuation assessments.

D. Shelter Analysis. The shelter analysis presents an inventory of existing public shelter facilities; capacities of the shelters; vulnerability of shelters to storm surge flooding; and identifies the range of potential shelter demand for each parish. Vulnerability to the high winds associated with a hurricane were not addressed in the shelter analysis. Inventories of existing shelters and shelter capacities were furnished by the American Red Cross and parish emergency management officials. First floor elevations were obtained by actual survey, through review of construction drawings, and by comparison to existing contour information. These elevations provided a basis for determining shelter vulnerability. A shelter demand/capacity analysis was also conducted to determine the adequacy of existing shelter space under a variety of hurricane threats.

E. Transportation Analysis. The results of all previous analyses were utilized in the transportation analysis. The purpose of this analysis is to determine the time required to evacuate the threatened population under a variety of hurricane evacuation scenarios. Transportation modeling techniques developed to simulate hurricane evacuation traffic patterns were used to conduct this analysis.

F. Decision Arcs. The decision arc method is a hurricane evacuation decision-making tool that uses clearance times determined by the transportation analysis, in conjunction with the National Weather Service advisories, to calculate when evacuations must begin in order for them to be completed prior to the onset of hurricane hazards.

VI. COORDINATION.

A comprehensive coordination program was established for the Southeast Louisiana

Hurricane Preparedness Study and includes state and local emergency management agencies plus other organizations and agencies having a direct responsibility in hurricane emergencies. A coordinative mechanism was implemented to assure proper and thorough data gathering and coordination of the study and to provide maximum flexibility in the effort. A description of the coordinative structure of the Southeast Louisiana Hurricane Preparedness Study is as follows:

A. Interagency. With the advent of the Southeast Louisiana Hurricane Task Force in October 1988, a channel of communication and coordination was established. The Corps of Engineers and the Federal Emergency Management Agency used this established system to coordinate the study effort with officials from the Louisiana Office of Emergency Preparedness and other task force members. The Southeast Louisiana Hurricane Task Force includes representatives from the Louisiana Office of Emergency Preparedness, the National Weather Service, the American Red Cross, the National Guard, State Police, parish emergency management, local law enforcement, and other state and local agencies involved in hurricane preparedness and response. All disaster preparedness committee meetings and reviews of study products were arranged through the task force. The New Orleans District, Corps of Engineers, provided quarterly status reports to the Lower Mississippi Valley Division, Corps of Engineers; to the Federal Emergency Management Agency, Region VI; and to the Louisiana Office of Emergency Preparedness.

B. Disaster Preparedness Committees. The Disaster Preparedness Committees were composed of the agencies and organizations described for the Southeast Louisiana Hurricane Task Force. The primary purpose of the Disaster Preparedness Committees was to provide important data for the study and to review appropriate study products. Since the committee members will be the "users" of the information generated by the study, committee meetings provided the forum needed to explain the methodologies and products of the various study analyses and to receive comments. Meetings were held at major milestones in the study to present the results of analyses accomplished to date; to describe the relationships of the major analyses; and to review the progress of the study.

CHAPTER TWO

HAZARDS ANALYSIS

I. PURPOSE.

The purpose of the hazards analysis is to quantify the still-water surge heights, waves, and wind speeds for various intensities, tracks, and forward speeds of hurricanes considered to have a reasonable meteorological probability of occurrence within a particular coastal basin. Potential freshwater flooding from rainfall accompanying hurricanes is also addressed in this study; however, due to the wide variation in amounts and times of occurrence from one storm event to another, rainfall is only addressed in general terms.

The primary objective of the hazards analysis is to determine the probable worst-case effects from various intensity hurricanes which have the potential to impact the study area. For the purposes of this study, the term worst-case is used to describe the peak surges, wind speeds, wave effects, and potential rainfall from hurricanes for all locations within the project area regardless of where landfall occurs. Worst-case effects for each category of storm were obtained by varying three parameters: point of landfall, direction of approach, and forward speed and do not represent a single hurricane, but rather a composite of hurricane events. Uncertainties inherent in hurricane forecasting justify the use of worst-case effects for the purposes of hurricane preparedness.

The majority of effort expended in the hazards analysis is related to the accurate estimation of potential surge heights. This focus on surge heights does not, however, reflect a discounting of the danger of high winds associated with hurricanes. The magnitude, extent, timing, and duration of winds of a threatening hurricane are the direct subject of the National Weather Service/National Hurricane Center observations and forecasts. Greater emphasis in this report was placed on the realistic estimation of potential surge heights due to their complex nature. Surge heights are not only dependent on wind speed and direction of the storm, but also on the shoreline configuration, direction of approach, and forward speed.

II. FORECASTING INACCURACIES

An analysis of hurricane forecasts made by the National Hurricane Center indicates the magnitude of error that can be expected in forecasting the track of approaching hurricanes. The average error in the official hurricane track forecast between 1970 and 1979 was 51 miles for the 12-hour forecast, 109 miles for the 24-hour forecast, 247 miles for the 48-hour forecast, and 377 miles for the 72-hour forecast. Thus, if a storm were forecast to make landfall due south of New Orleans in 24 hours, and if, in fact, it made landfall anywhere between Dauphin Island, Alabama and Marsh Island, Louisiana, the error in forecast landfall position would be no worse than average. There has been a small, but statistically significant, long-term downward trend in the forecast errors in the Atlantic basin over the period 1970-1991. The downward trend is found not only in the 24-hour forecast, but also in the 48- and 72-hour forecasts. During the period 1970-1991, errors in the official forecast track have decreased by 0.8 miles per year for the 24-hour forecast, 2.6 miles per year for the 48-hour forecast, and 5.0 miles per year for the 72-hour forecast. Using these downward trends, the probable errors in the forecast track during the 1993 hurricane season would average 95 miles for the 24-hour forecast, 200 miles for the 48-hour forecast, and 290 miles for the 72-hour forecast.

Errors also occur in forecasting the maximum sustained windspeed of an approaching hurricane. During the period 1970-1979, the average error in the official 24-hour wind speed forecast was 15 miles per hour (mph), and the average error in the 12-hour forecast was 10 mph. Hurricane evacuation decision makers should note that an increase in wind speed of 10 to 15 mph can easily raise the intensity category of the approaching hurricane one category on the Saffir/Simpson Hurricane Scale. To account for inaccuracies in forecasting the behavior of approaching hurricanes, the National Hurricane Center and the Louisiana Office of Emergency Preparedness recommend that public officials faced with an eminent evacuation prepare for the evacuation as if the approaching hurricane will intensify one category above the strength forecast for landfall.

III. STORM SURGE.

A. General. A hurricane moving over the continental shelf produces a buildup of water at the coastline which is commonly referred to as storm surge. Storm surge is the increase in height of the surface of the sea due to the forces of an approaching hurricane. Storm surge normally occurs over a coastline for distances of 100 miles or more. The winds associated with a hurricane are the largest single component responsible for the buildup of storm surge within a basin. The wind blowing over the surface of the water exerts a horizontal force which induces a surface current in the general direction of the wind. The surface current, in turn, induces currents in subsurface water. This process of current creation continues to a depth which is determined by the depth of the water and by the intensity and forward motion of the hurricane. For example, a fast moving hurricane of moderate intensity may only induce currents to a depth of a hundred feet, whereas a slow moving hurricane of moderate intensity might induce currents to several hundred feet. These horizontal currents are impeded by a sloping continental shelf as the hurricane approaches the coastline, thereby causing the water level to rise. A wide gently sloping continental shelf is particularly conducive to the formation of large storm surges. The amount of rise increases shoreward to a maximum level at, or some distance inland from the shoreline.

Waves and swells breaking at or near the coast also transport water shoreward. During storms when there is an increase in wave height and wave steepness, water cannot flow back to the sea as rapidly as it is brought shoreward. This results in a phenomenon known as "wave setup" and causes a further increase of water level along the coastline. Waves are directly affected by water depth and will break and dissipate their energy in shallow water. A steep continental shelf will allow large ocean waves to approach the coastline before breaking thus increasing wave setup. This phenomenon is primarily a concern near the coastline because large waves are generally not transmitted inland.

The elevation of the storm surge within a coastal basin depends upon the meteorological parameters of the hurricane as well as the physical characteristics existing within the basin. The meteorological parameters affecting the amount of storm surge generated include the intensity of the hurricane measured by the central barometric pressure and maximum surface winds at the center of the storm, path or forward track of the storm, forward speed, and radius of maximum winds (storm size). The radius of maximum winds is measured from the center of the hurricane to the location of the highest wind speeds within the storm. This distance can vary from as little as 4 miles to as much as 50 miles. Due to the counter-clockwise rotation of the wind field, the highest recorded surge levels are generally located to the right of the forward track of the hurricane. This is particularly important when the storm makes landfall because the maximum storm surge may vary significantly within a relatively short distance depending on whether a location is to the right or left of the path of the hurricane.

The physical characteristics of a basin also influence potential surge heights. These factors include the basin bathymetry, roughness of the continental shelf, configuration of the coastline, and the existence of significant natural or man-made barriers. Another factor which affects the storm surge heights is the initial water level existing within the basin at the time of arrival of a hurricane and includes the astronomical tide plus any anomalous sea surface height.

B. Background. Numerous methods and models have been utilized to quantify the potential storm surge generated by hurricanes. One of the earlier guides developed for that purpose is the Saffir/Simpson Hurricane Scale. The Saffir/Simpson Hurricane Scale, shown in Table 2-1, is a descriptive scale which categorizes hurricanes based upon intensity and relates hurricane intensity to damage potential. The Saffir/Simpson Hurricane Scale also provides a range of wind speeds and nominal surge heights associated with each of the five categories of hurricanes.

TABLE 2-1

SAFFIR/SIMPSON HURRICANE SCALE

CATEGORY 1. Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real damage to other structures. Some damage to poorly constructed signs. Storm surge 4 to 5 feet above normal. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.

CATEGORY 2. Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings. Storm surge 6 to 8 feet above normal. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying inland areas required.

CATEGORY 3. Winds of 111 to 130 miles per hour. Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed. Storm surge 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives.

CATEGORY 4. Winds of 131 to 155 miles per hour. Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows, and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. Storm surge 13 to 18 feet above normal. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches.

CATEGORY 5. Winds greater than 155 miles per hour. Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes. Storm surge possibly greater than 18 feet above normal. Major damage to lower floors of all structures less than 15 feet above sea level. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives.

The National Hurricane Center has added a range of central barometric pressures associated with each category of hurricane described by the Saffir/Simpson Hurricane Scale. A condensed version of the Saffir/Simpson Hurricane Scale with the barometric pressure ranges by category is shown in Table 2-2.

TABLE 2-2

SAFFIR/SIMPSON HURRICANE SCALE
WITH
CENTRAL BAROMETRIC PRESSURE RANGES

	CENTRAL PRESSURE		WINDS	SURGE	
CATEGORY	MILLIBARS	INCHES	(MPH)	(FT)	DAMAGE
1	>980	>28.94	74 - 95	4 - 5	Minimal
2	965-979	28.50 - 28.91	96 - 110	6 - 8	Moderate
3	945-964	27.91 - 28.47	111 - 130	9 - 12	Extensive
4	920-944	27.17 - 27.88	131 - 155	13 - 18	Extreme
5	<920	<27.17	>155	>18	Catastrophic

The Saffir/Simpson Hurricane Scale was intended as a general guide for use by public safety officials during hurricane emergencies. It does not reflect the effects of varying localized bathymetry, coastline configuration, barriers, or other factors which can greatly influence the surge heights that occur at differing locations during a single hurricane event.

The National Weather Service later developed computer models for specific coastal basins that account for the varying bathymetry and other factors affecting surge heights. The most notable of these mathematical models is the Special Program to List the Amplitude of Surges from Hurricanes (SPLASH) model. Two versions of this model, SPLASH I and SPLASH II, were developed for selected basins along the Gulf and Atlantic coasts. Although the SPLASH model provides reliable still-water storm surge heights, the limiting aspect of this model is that the surge heights are calculated only for open coastlines. The latest mathematical model; the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model; represents an extension of the SPLASH model and has the expanded capabilities for calculating storm surge heights throughout selected coastal basins. The SLOSH model was used to simulate the effects of hypothetical hurricanes which could occur in the future, and to simulate actual hurricanes which have occurred in the past.

C. The SLOSH Model.

1. General. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is the latest and most sophisticated mathematical model yet developed by the National Weather Service to calculate potential surge heights from hurricanes. The SLOSH model is a two dimensional model that was developed for real-time forecasting of surges from actual hurricanes within selected Gulf and Atlantic coastal basins. In addition to furnishing surge heights for the open coast, the SLOSH model has the added capability to compute the routing of storm surge into bays, estuaries, or coastal river basins as well as calculating surge heights for overland locations. Significant natural and man-made barriers are represented in the model and their effects simulated in the calculations of surge heights within a basin.

The SLOSH model is designed for use in an operational mode; that is, for forecast/hindcast runs without controlled, local calibration, or observed winds. The rationale for this design is to avoid having the forecaster predict unavailable input data. The SLOSH model contains a storm model into which simple, time-dependent meteorological data are input and from which the driving forces of a simulated storm are calculated. These data are as follows:

a. Latitude and Longitude of storm positions at six-hour intervals for a 72-hour track.

b. The lowest atmospheric sea level pressure in the eye of the hurricane at six-hour intervals.

c. The storm size measured from the center to the region of maximum winds; commonly referred to as the "radius of maximum winds". Wind speed is not an input parameter since the model calculates a windfield for the modeled storm by balancing forces according to meteorological input parameters.

Input data to the SLOSH model also includes the initial height of the water surface well before the storm directly affects the area of interest. This initial height is the observed still water level occurring about two days before storm arrival and includes any existing anomalous rise in the water surface. Water surface elevations are referenced to the vertical datum used to specify land elevations and water depths within the model. All water surface elevations, land elevations, and water depths were referenced to NGVD. Tidal fluctuations immediately prior to landfall have not been accounted for because a small error in predicting the phasing of storm track and astronomical tide would likely invalidate the model results. The possible effects of landfall occurring at a particular phase of the tide, such as at the time of high or low tide, are evaluated as an increment to the surge values predicted by the SLOSH model.

The values or functions for the coefficients within the SLOSH model are generalized to serve for modeling all storms within all basins and are set empirically through comparisons of computed and observed meteorological and surge height data from numerous historical hurricanes. It is probable that the coefficients are a function of differing storm parameters and basin characteristics; therefore, calibration of the model based on a single storm event within a basin is avoided since there is no guarantee that the same coefficient values will serve as well for alternate storms.

2. SLOSH Grid Configuration. The SLOSH model utilizes a telescoping polar coordinate (fan-shaped) grid system within which a particular coastal basin is represented. The grid configuration of the "Lake Pontchartrain Basin" SLOSH model is illustrated in Figure 2-1. The grid consists of 74 arcs (the curved lines) and 93 radials (the straight lines). The resolution of the model for inland locations near the focus is approximately 1/2 square miles per grid square and increases to approximately 50 square miles at the outer fringe of the grid. As shown in Figure 2-1, the grid "squares" constantly expand in size and become progressively larger out from the coastline. The larger grid cells in the offshore region permits the inclusion of a large geographic area in the model so that model boundary effects on the dynamics of the storm are diminished. The advantage of this grid system is that it offers good resolution in areas of primary interest while conserving computer resources by minimizing the number of calculations required to model a storm.

The characteristics of a particular basin are constructed as input data within the model. These characteristics include the topography of inland areas; river basins and waterways; bathymetry of nearshore areas, bays and large inland water bodies; significant natural and man-made barriers such as barrier islands, dunes, roadbeds, floodwalls, levees, etc.; and a segment of the continental shelf. The SLOSH model simulates inland flooding from storm surge and permits the overtopping of barriers and flow through barrier gaps.

3. Verification of the Model. After a SLOSH model has been constructed for a coastal basin, verification experiments are conducted. The verification experiments are performed in a "hindcast" mode, using the real-time operational model code and meteorological input from historical storms. These input data consist solely of observed storm parameters and an initial observed sea surface height occurring approximately 48 hours before the storm landfalls or affects the basin. Ideally there would be a large number of actual storm events with well documented meteorology and storm surge histories which could be compared to the storm surge histories hindcast by the SLOSH model for the same storms. In reality, hurricanes are a rare meteorological event for any given region, and it is even rarer to find adequate, reliable measurements of storm surge elevations over a representative number of sites within a region due to the difficulty in making such measurements during hurricane conditions.

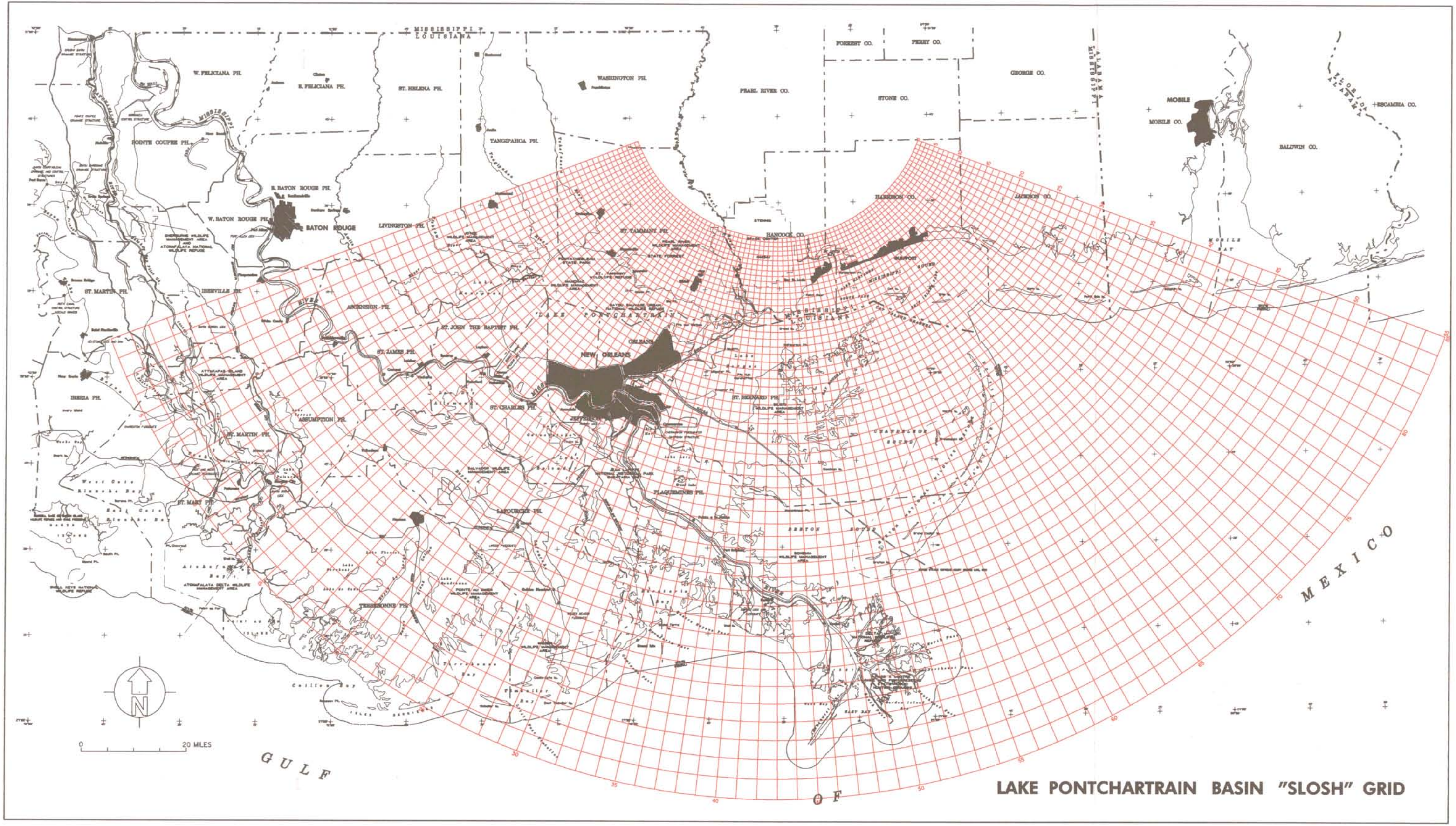
The computed surge heights are compared with those measured from historic storms and, if necessary, adjustments are made to the input or basin data. These adjustments are not made to force agreements between computed and measured surge heights from historical storms but to more accurately represent the basin characteristics or historic storm parameters. In those instances where the model gave realistic results in one area of a basin but not in another, closer examination of the basin often revealed inaccuracies in the representation of barrier heights or missing values in bathymetric or topographic charts. In the case of historic storms, most of the data was coarse; with parameters prescribed invariant with time and with an unrealistically smoothed storm track. When necessary, further analysis and subjective decisions are employed to amend the track or other parameters of the historic storms used in the verification process.

4. Model Output. The SLOSH model output for a modeled storm consists of a tabulated storm history containing hourly values of storm position, speed, direction of motion, pressure drop and radius of maximum winds; a surface envelope of highest surges; and, for preselected grid points, time-history tabulations of values for surge heights, wind speeds, and wind directions. If desired, the model can also furnish two-dimensional snapshot displays of surges at specified times during a simulation.

The highest water level reached at each location along the coastline during the passage of a hurricane is called the maximum surge. Maximum surges along the coastline do not necessarily occur at the same time. The time of the maximum surge for one location may differ by several hours from the maximum surge that occurs at another location. A plot of the maximum water surface elevation attained at each grid cell over the duration of the simulated storm does not represent a "snapshot" of the storm surge at a given instant of time. Instead, it represents the highest water level at each grid cell during a hurricane irrespective of the actual time of occurrence.

The printed envelope of highest surges from the SLOSH model shows the computed surge heights in feet NGVD in the center of each grid square. Other information depicted includes symbols for natural and man-made geographic features, latitude and longitude lines, and the storm path through the basin. In order to output computed surges on a line printer, the polar grid for a basin is transformed onto an image plane of equal spacing. Cells near the origin of the polar grid are thus expanded relative to their original size and cells near the outer portion of the polar grid are contracted relative to their original size. The result is that the model grid is represented by equally spaced parallel lines while Latitude and Longitude lines and all other geographic features within the basin are distorted.

The time-history data of surge heights, wind speeds, and wind directions are tabulated for each pre-selected grid point in the model. These data are listed for each grid point at ten-minute intervals for a 72-hour segment of a simulated storm track, starting 48 hours prior to landfall and continuing for 24 hours after landfall or closest approach. The surge heights are in feet NGVD; the wind speeds in miles per hour; and the wind directions in degrees azimuth from which the wind is blowing. Water depths are not computed because terrain height varies within a grid square. The depth of flooding is deduced by



LAKE PONTCHARTRAIN BASIN "SLOSH" GRID

Figure 2–1

subtracting the actual terrain height from the model-generated surge height.

D. Southeast Louisiana SLOSH Modeling Process.

1. General. The Lake Pontchartrain basin SLOSH model was the primary model used for the Southeast Louisiana Hurricane Preparedness Study. The Lake Pontchartrain SLOSH basin covers the Louisiana and Mississippi coastline from Vermilion Bay to the Mississippi Sound, and extends inland to cover Lake Pontchartrain, Figure 2-1.

2. Topographic and Bathymetric Input. The accuracy of the SLOSH model depends heavily on the ability to accurately model the topographic and bathymetric features of the basin. Inaccuracies in modeling these features will contribute directly to errors in the modeling of storm surge. This is of particular importance for the Lake Pontchartrain basin which is comprised primarily of sea-level marsh, swamp and open water. The major barriers to storm surge in southeast Louisiana are generally man-made features such as, levees, floodwalls, highways, and railroad embankments. The bathymetry of the coastline and the areas lakes, rivers, canals, and bayous are also of importance in accurately modeling hurricane surge. Data was collected to establish the heights of both Federal and non-Federal levees and floodwalls, and to establish the existence of any gaps or other information that might affect the integrity of a barrier to hurricane surge. Levee and floodwall heights used in the model were projected through 1991, the approximate date for completion of the study. Although completion of the study has been delayed, the projected barrier heights remain reasonably accurate. Other barrier heights were obtained from existing profiles or actual surveys of features critical to the limits of inundation. The bathymetry of the coastline and other bodies of water within the study area was obtained using hydrographic surveys, bathymetric maps, and U.S.G.S. quadrangle maps. Input to the model also included average ground elevations for each grid square within the basin.

3. Verification. The historical hurricanes used in the verification process for the Lake Pontchartrain basin SLOSH model were Hurricane Betsy of 1965 and Hurricane Camille of 1969.

4. Simulated Hurricanes. As part of the Southeast Louisiana Hurricane Preparedness Study, a total of 1,640 simulated hurricanes were modeled using the Lake Pontchartrain basin SLOSH model. The characteristics of the simulated hurricanes were determined from an analysis of historical hurricanes which have occurred within the study area. The parameters selected for the modeled storms were the intensities, forward speeds, directions of motion, and radius of maximum winds. These parameters were defined based on a meteorological probability of occurrence within the Lake Pontchartrain basin. A breakdown of the hypothetical hurricanes for the Lake Pontchartrain basin is presented in Table 2-3.

TABLE 2-3

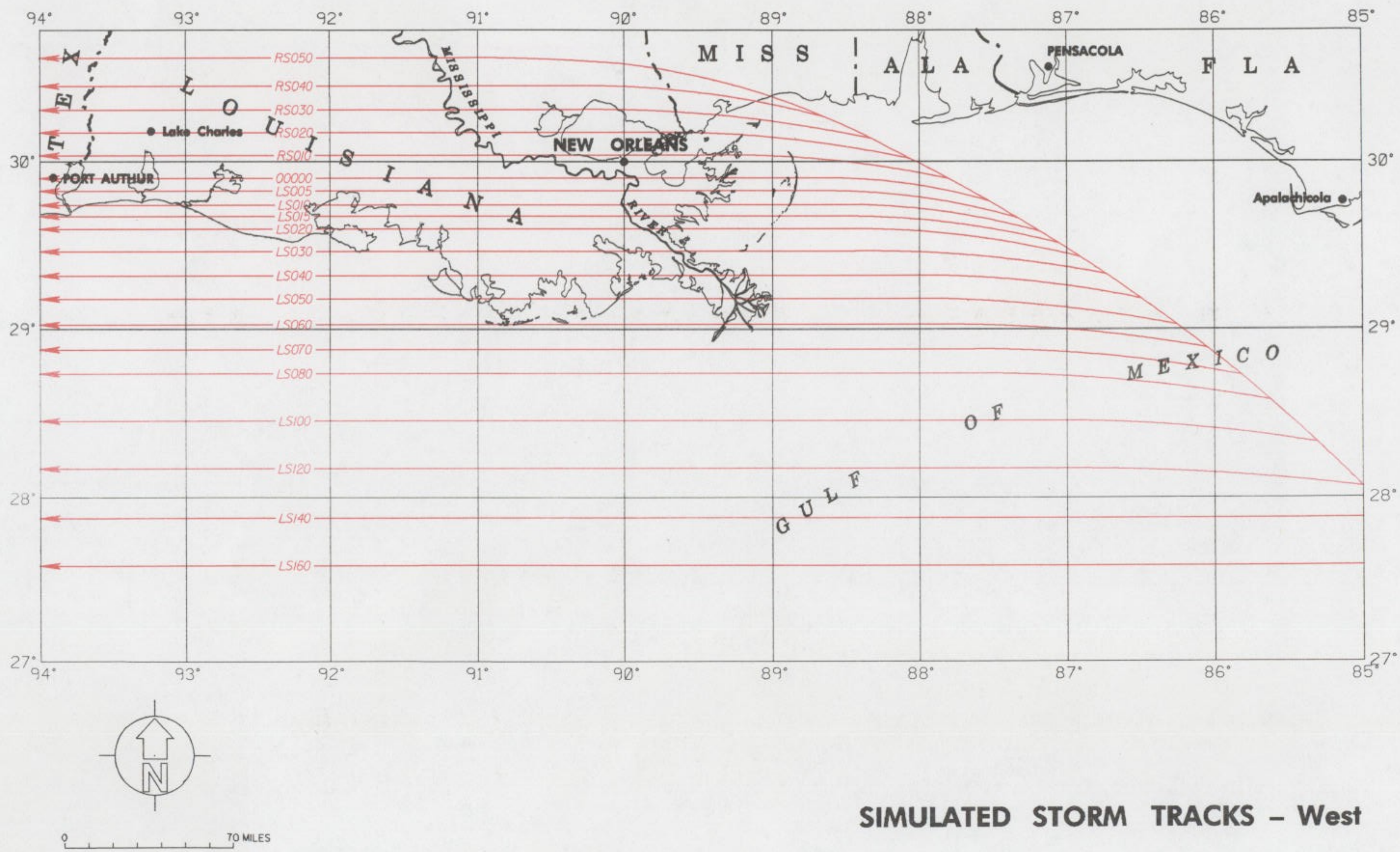
STORM PARAMETERS FOR THE LAKE PONTCHARTRAIN BASIN

Direction	Speed (mph)	Intensities	Tracks	Runs
W	5 and 15	1 through 5	20	200
WNW	5 and 15	1 through 5	19	190
NW	5 and 15	1 through 5	19	190
NNW	5 and 15	1 through 5	19	190
N	5 and 15	1 through 5	19	190
NNE	5 and 15	1 through 5	19	190
NE	5 and 15	1 through 5	17	170
ENE	5 and 15	1 through 5	17	170
E	5 and 15	1 through 5	15	150
			Total	1,640

A total of 164 storm tracks were modeled for the Southeast Louisiana Hurricane Preparedness Study. These tracks are shown in Figures 2-2 through 2-10. The simulated hurricanes moving along these tracks had combinations of parameters representing five categories of hurricane intensity, as described by the Saffir/Simpson Hurricane Scale; nine approach directions for landfalling and paralleling hurricanes (west, west-northwest, northwest, north-northwest, north, north-northeast, northeast, east-northeast, and east); two forward speeds of 5 and 15 miles per hour; and numerous landfall or closest approach locations separated by 20 miles or less along the coastline. The radius of maximum winds specified for all of the simulated hurricanes was 25 miles at landfall.

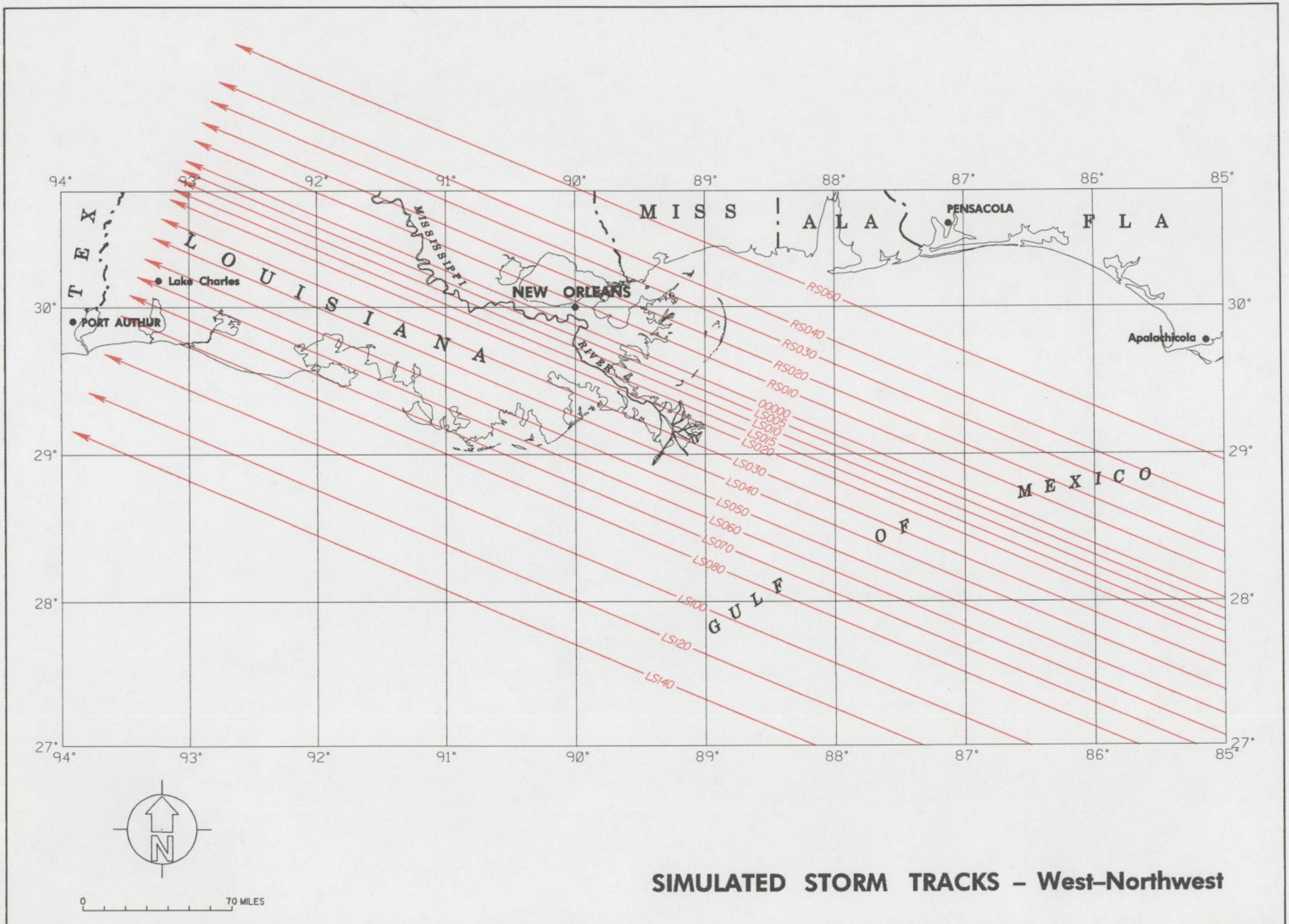
Most hurricanes weaken after making landfall because the central pressure increases (the storm fills) and the radius of maximum winds tends to increase. The terrain of southern Louisiana is very low, flat, and marshy and the transition to "land" from "water" is not abrupt. When Gulf waters are at above-normal heights, for example, during the approach of a hurricane, the "coastline" is somewhere north of that usually drawn by cartographers. A "virtual coastline," shown in Figure 2-11, was used for SLOSH model calculations. Modeled storms were assumed to have "over water" characteristics until they traversed the virtual coastline, where landfall was defined to occur.

The primary factor which determines the intensity or category of a hurricane is the difference between the central barometric pressure of the center of the storm and the ambient barometric pressure surrounding the system. The term for the difference in



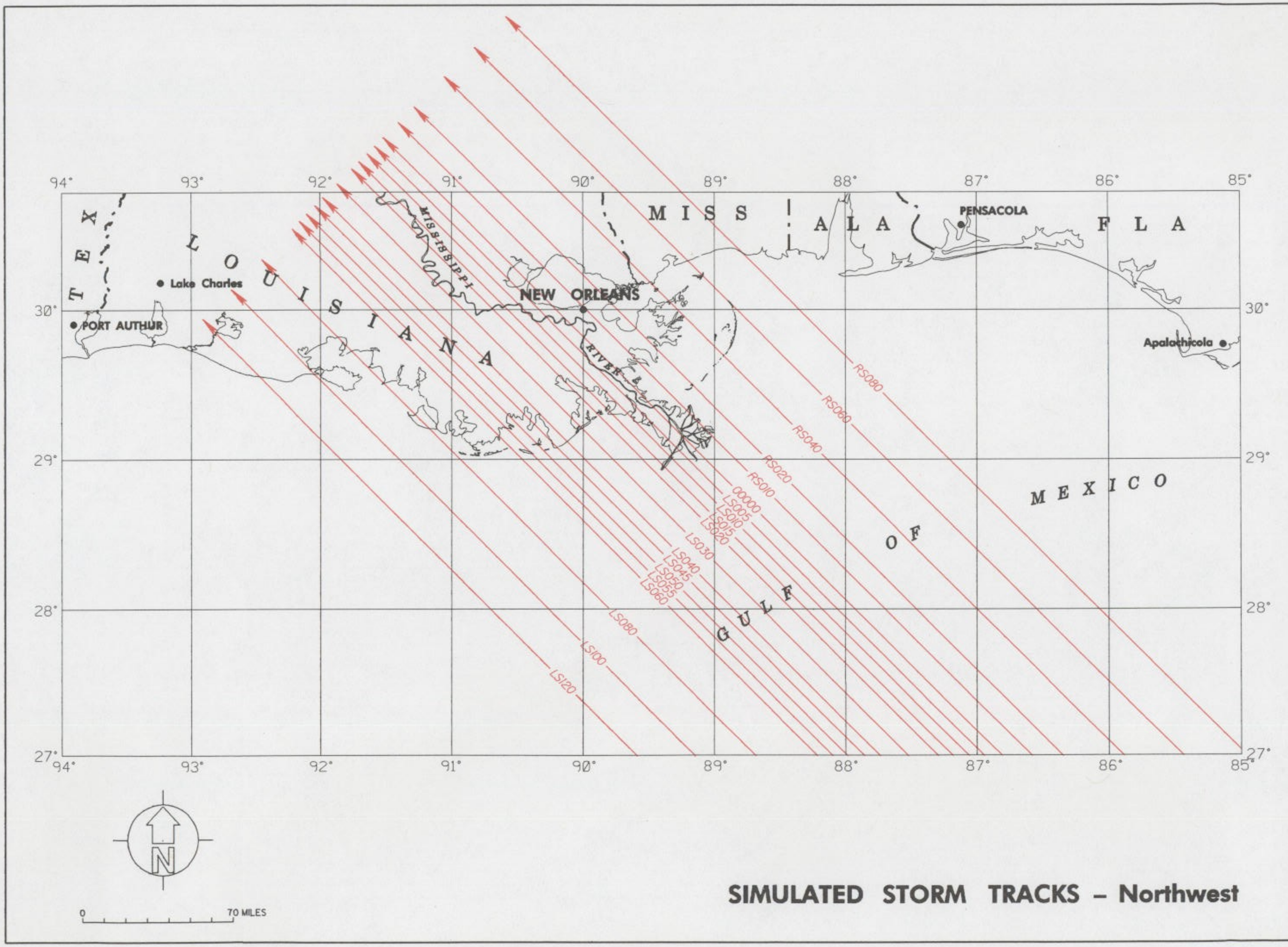
SIMULATED STORM TRACKS – West

Figure 2-2



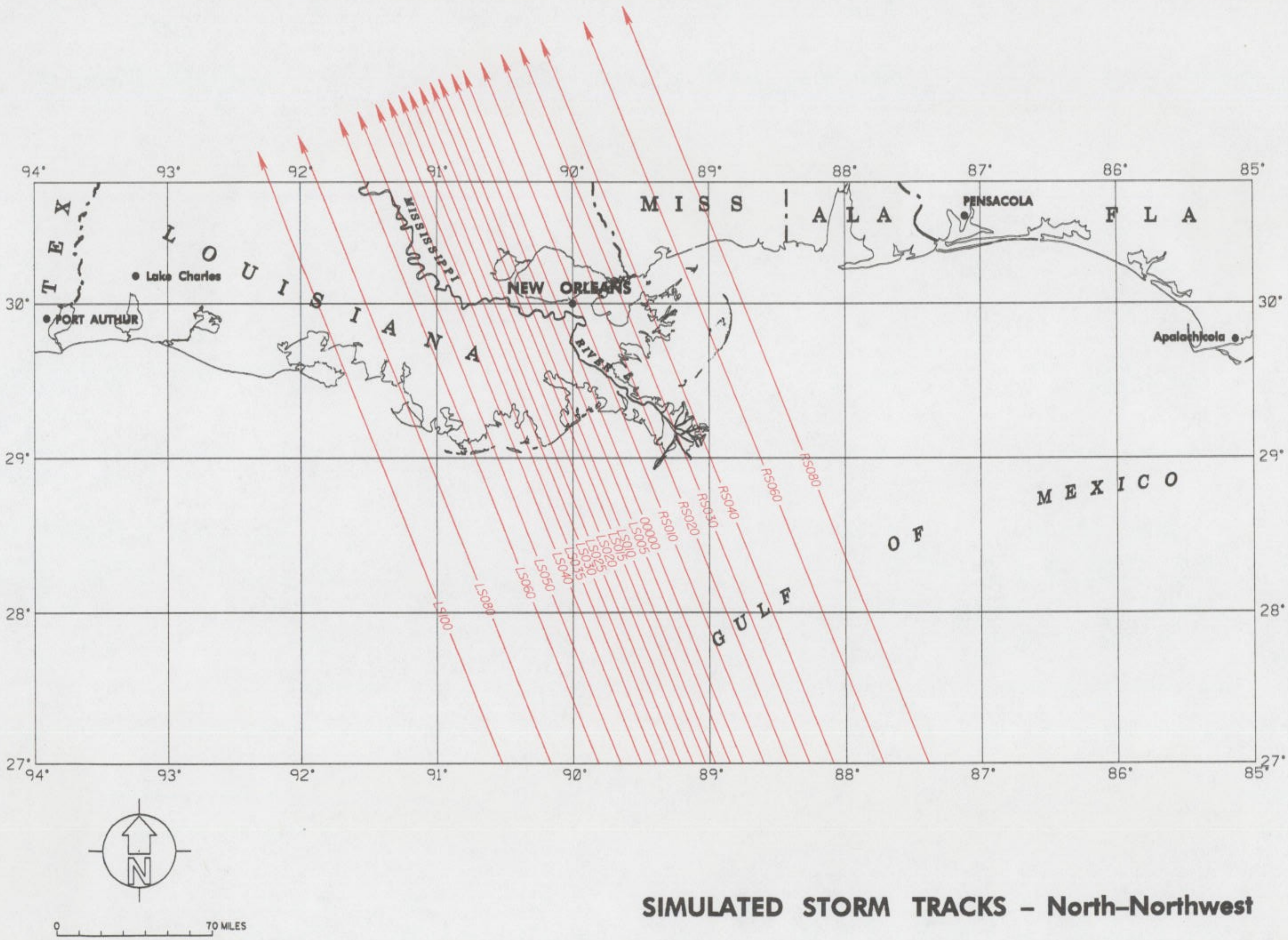
SIMULATED STORM TRACKS – West–Northwest

Figure 2–3



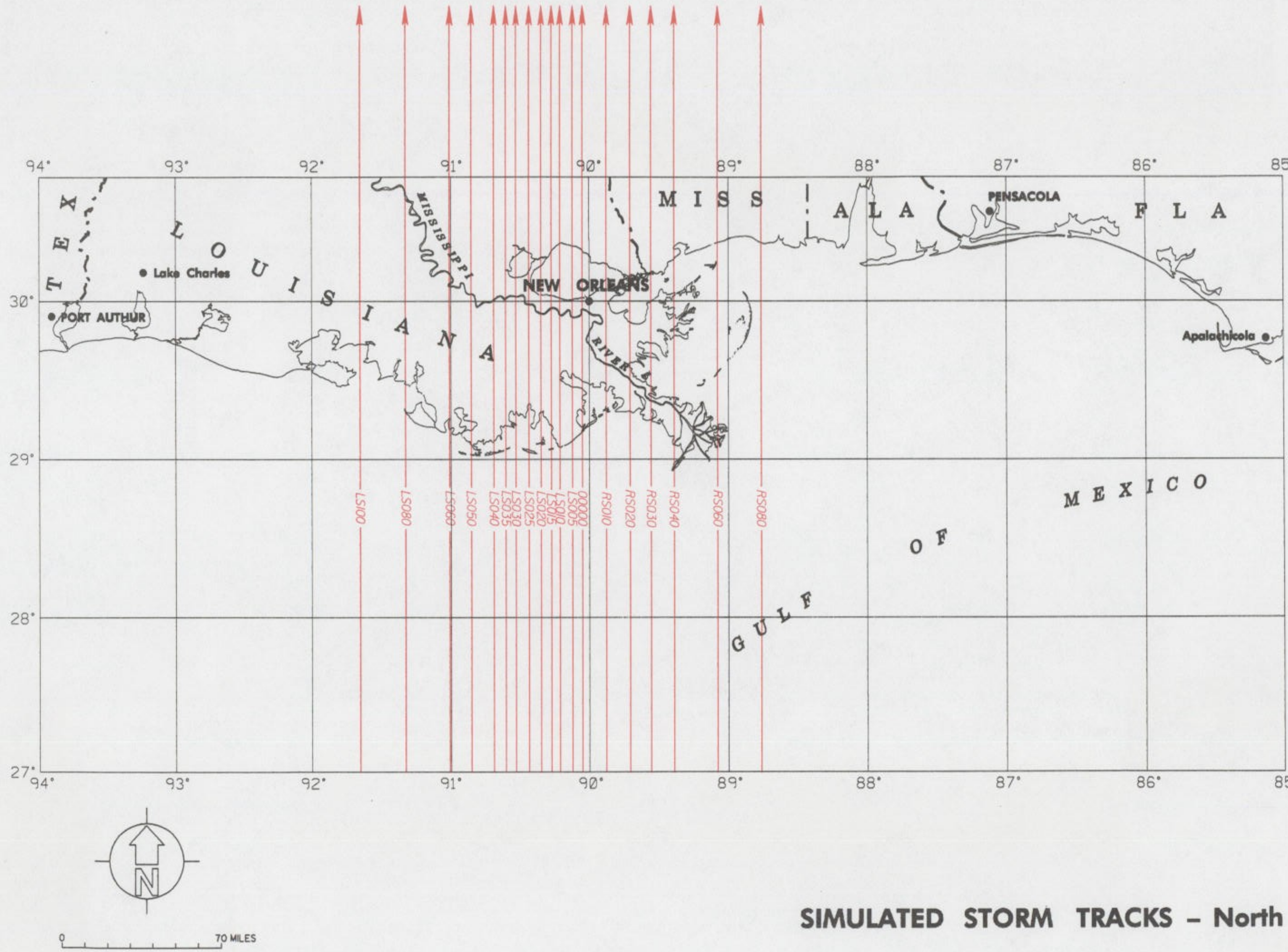
SIMULATED STORM TRACKS – Northwest

Figure 2–4



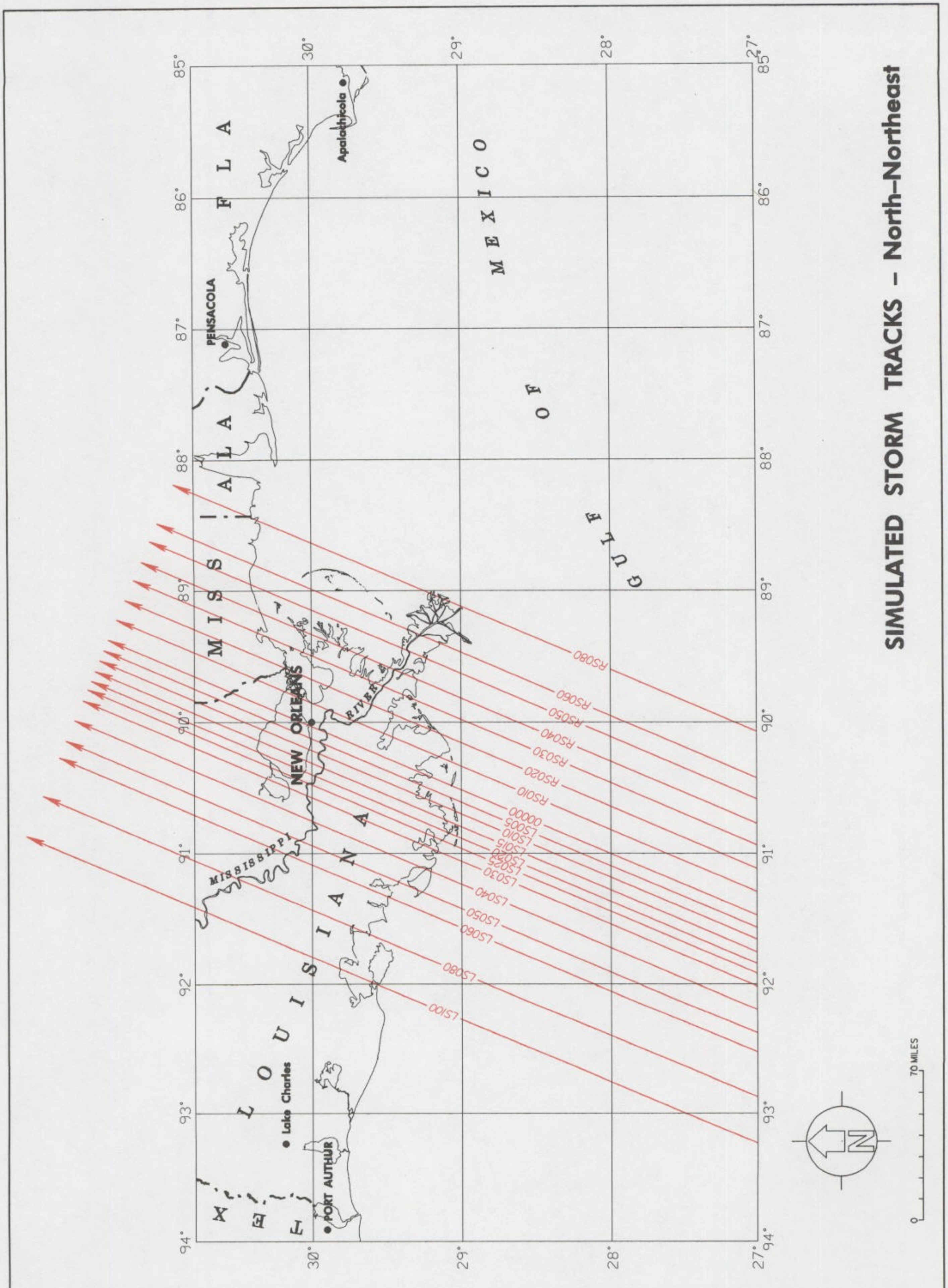
SIMULATED STORM TRACKS – North–Northwest

Figure 2–5



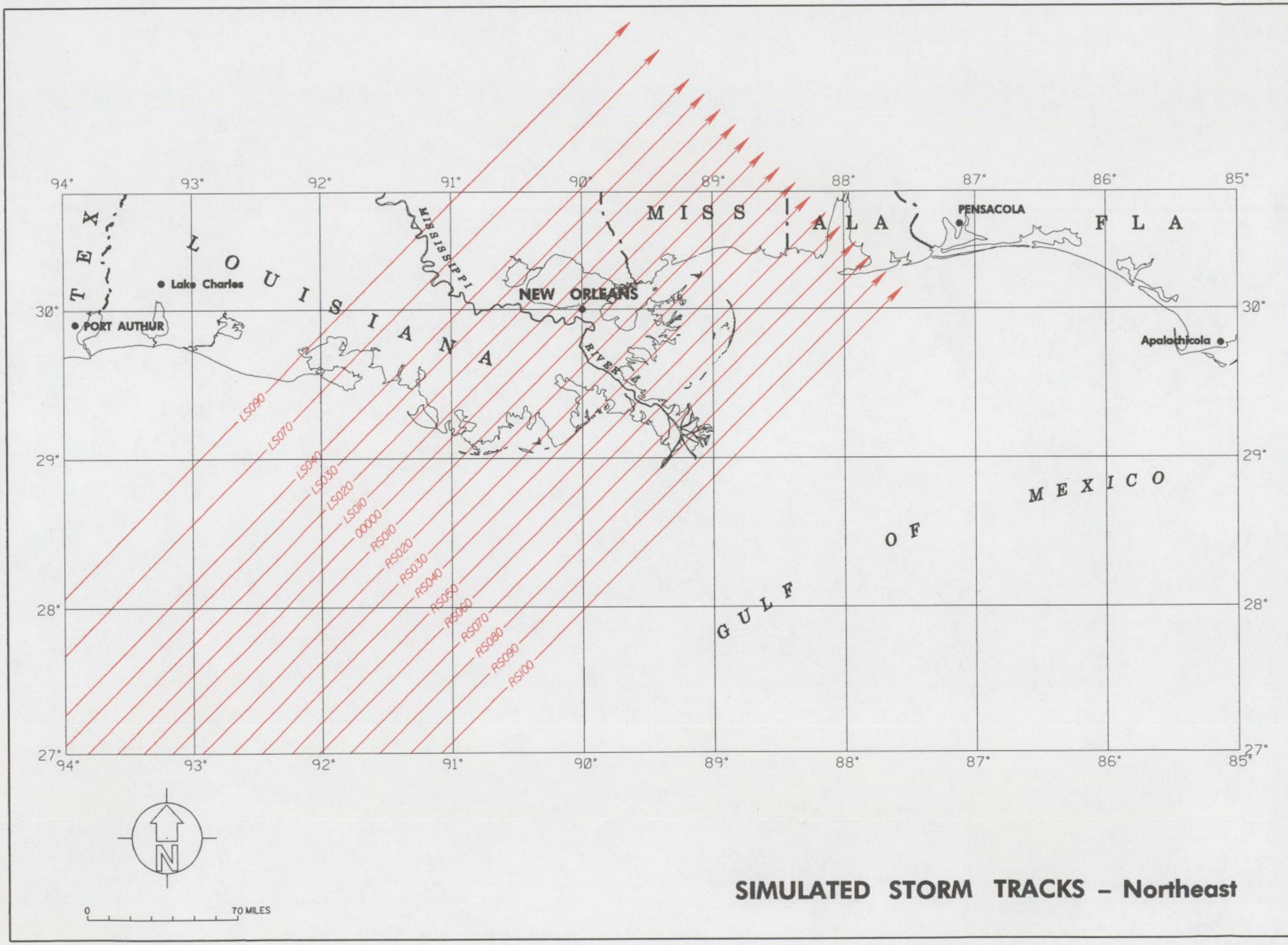
SIMULATED STORM TRACKS - North

Figure 2-6



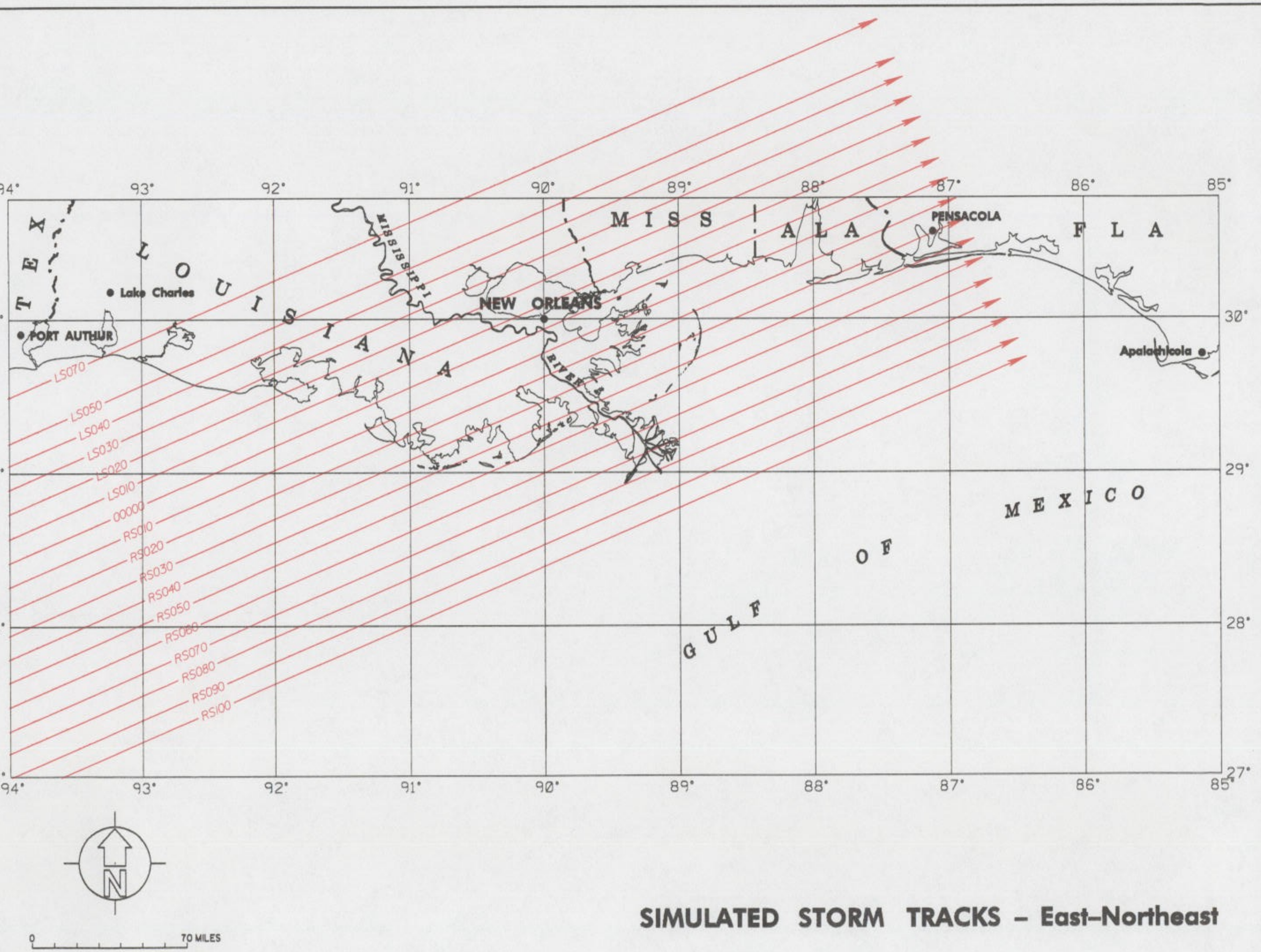
SIMULATED STORM TRACKS – North-Northeast

Figure 2–7



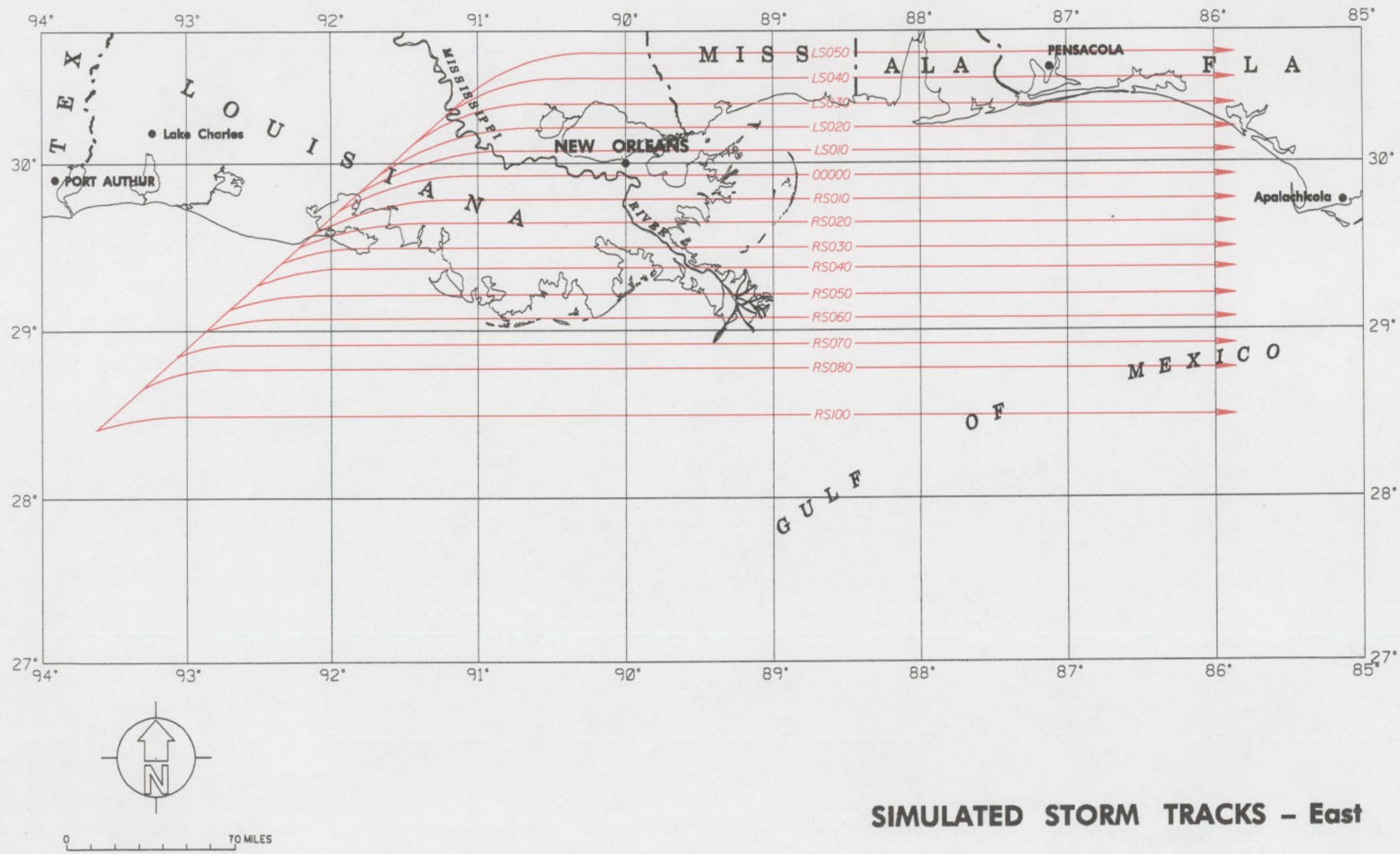
SIMULATED STORM TRACKS – Northeast

Figure 2–8



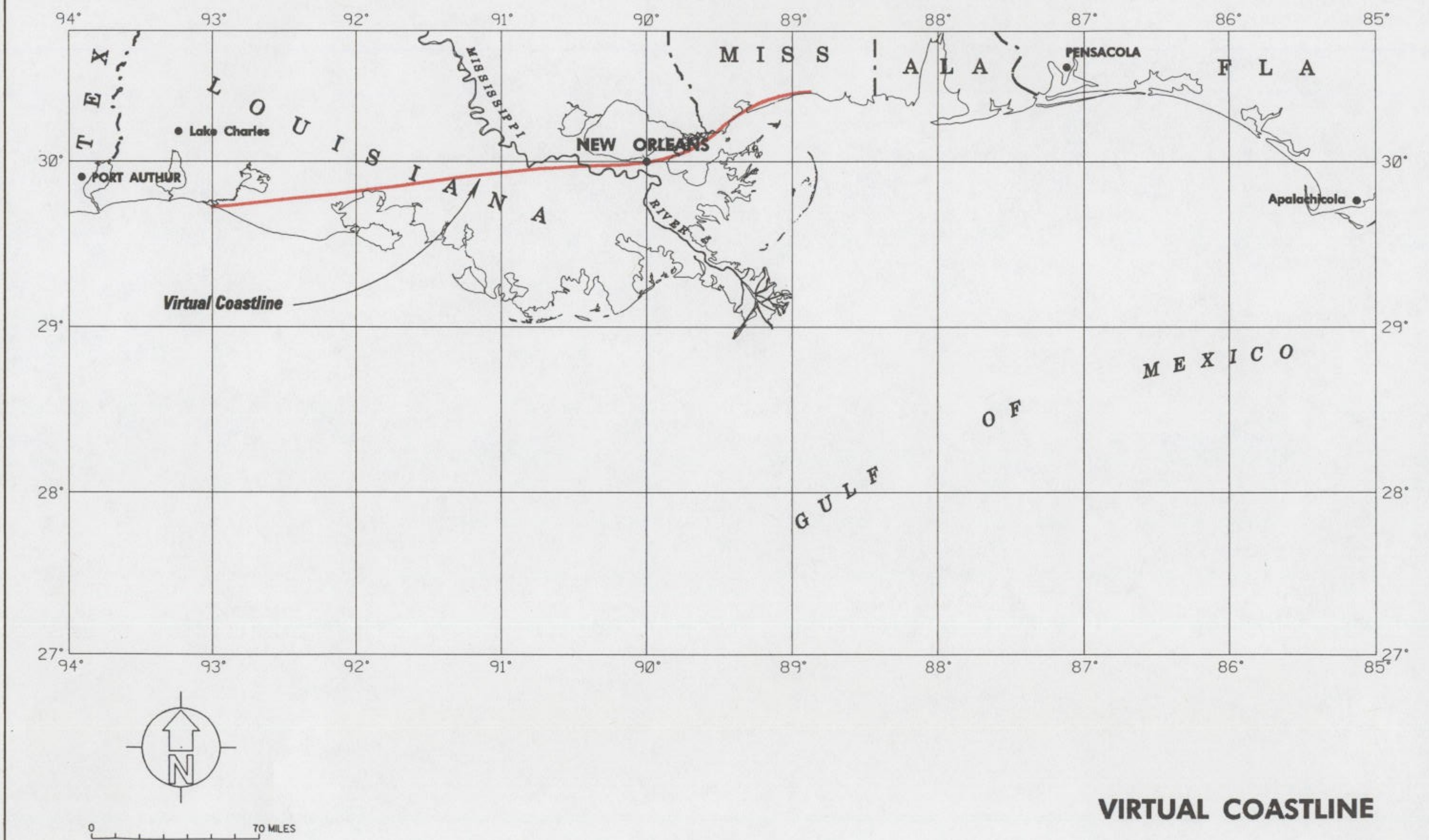
SIMULATED STORM TRACKS – East–Northeast

Figure 2-9



SIMULATED STORM TRACKS – East

Figure 2–10



VIRTUAL COASTLINE

Figure 2–11

internal and external pressures of a tropical cyclone is delta-p (Δp). Table 2-4 lists the categories of hurricanes modeled for the Southeast Louisiana Hurricane Preparedness Study, the ranges of pressures constituting each category, the central barometric pressures for the simulated storms, and the resulting pressure difference, assuming an ambient standard barometric pressure of 1010 millibars.

TABLE 2-4

CENTRAL BAROMETRIC PRESSURES AND PRESSURE DIFFERENCE
FOR SIMULATED HURRICANES, LAKE PONTCHARTRAIN BASIN MODEL

CATEGORY	CENTRAL BAROMETRIC PRESSURES		PRESSURE DIFFERENCE
	Actual Hurricane	Modeled Hurricane	
Category 1	1000mb - 980mb	990mb	Δp = 20mb
Category 2	979mb - 965mb	970mb	Δp = 40mb
Category 3	964mb - 945mb	950mb	Δp = 60mb
Category 4	944mb - 920mb	930mb	Δp = 80mb
Category 5	<920mb	910mb	Δp = 100mb

The initial water surface elevations used in the SLOSH model for the Lake Pontchartrain basin were +1.0 feet NGVD in the Gulf of Mexico and +2.0 feet NGVD for lakes within the basin. These initial heights, known as the tide anomaly, represent the heights of the water surface above mean sea level existing several days in advance of approaching hurricanes. The values for the tide anomaly used in the SLOSH model represent the average sea surface heights recorded at tide gauges for historical hurricanes several days prior to landfall.

5. Maximum Envelopes of Water. One of the outputs from the SLOSH model is a plot of the maximum water surface elevation at each grid cell within the basin affected by the storm, irrespective of when that water level was obtained. The imaginary surface defined by the maximum water level in each grid cell is termed the "envelope" of maximum water surface elevations. The largest individual water surface elevation within the entire basin for a particular storm is termed the "peak" surge. The location of the peak surge depends on where the eye of a hurricane crosses the coastline, its intensity, the bathymetry and topography of the basin, configuration of the coastline, the approach direction, and the size or radius of maximum winds of the hurricane. In most instances, the peak surge from a hurricane occurs to the right of the storm path near the radius of maximum winds. This is largely due to the counter-clockwise rotation of the windfield

surrounding the eye of the hurricane. To the right of the point of landfall, winds blow toward the shoreline; to the left of the point of landfall, winds blow away from the shoreline. It should be noted that during an actual hurricane, the point of landfall is highly unpredictable.

Due to the inability to precisely forecast the ultimate landfall location, forward speed, direction of movement, or other characteristics of a threatening hurricane, the objective of the hazards analysis is to determine the potential peak surges for all locations within the study area. For that purpose, a "maximum envelope of water" (MEOW) is utilized. A maximum envelope of water is developed from an array of peak surges calculated for the individual hurricanes modeled within the Lake Pontchartrain basin. Maximum envelopes of water can be created for any specified storm parameter or sets of parameters desired. A total of 90 MEOW's were developed for the Lake Pontchartrain basin. Each MEOW represented a different combination of hurricane intensity, direction of approach, and forward speed. The maximum envelope of water shows the peak surge heights for each grid cell within the basin, independent of where the hurricane actually crosses the coastline.

The results of the 90 original MEOW's were analyzed to determine which changes in storm parameters--i.e., intensity, forward speed, and direction of approach--resulted in the greatest differences in the values of the peak surges for all locations and which parameters could reasonably be combined to facilitate evacuation decision making. The extensive system of levees and floodwalls located throughout southeast Louisiana has created a unique sensitivity to storm surge and care must be taken when combining various hurricane parameters. Relatively small increases in peak surge can place entire communities at risk to inundation.

In most instances a change in storm category accounted for the greatest change in the peak surge heights calculated for grid cells along the open coast. Changes in the forward speed of the simulated hurricanes resulted in the greatest peak surge height differences for lakes and overland locations within the study area. Generally, the faster moving (15 miles per hour) storms produced higher surge levels at the open coast while the slower (5 miles per hour) storms resulted in higher surge levels within most lakes and overland locations within the basin. In many instances the differences in surge heights resulting from changes in forward speed were as much or more than those resulting from a one-category change in storm intensity. A review of the limits of inundation for category 1 (very limited flooding) storms revealed that the vulnerable population is not sensitive to the forward speed of the storm. This proved to be the case for category 5 (catastrophic flooding) storms as well. For the remaining categories of storms (categories 2, 3 & 4), the limits of inundation were determined and surge inundation maps were prepared for forward speeds of both 5 and 15 miles per hour.

The direction of approach also had a significant effect on the potential surge heights in the study area. However, the inherent difficulties in predicting the direction of approach for a hurricane in excess of 24 hours prior to landfall made the grouping of hurricanes by approach direction impracticable. Including the direction of approach in the decision-making process could lead to problems given the lengthy clearance times for southeast Louisiana. The approach directions were, therefore, combined for each category and forward speed of hurricane modeled.

The MEOW's were then further grouped according to overall similarities in the predicted envelopes of maximum water level throughout the entire basin. Additional sets of maximum envelopes of water (MEOW's of the MEOW's or MOM's) were developed combining all hurricane approach directions. The forward speeds were also combined for all category 1 and all category 5 storms. This final grouping was performed in order to provide for the development of hurricane scenarios to be used in the evacuation planning process. It is from these maximum envelopes of water that the surge inundation maps shown in Appendix B to this report were developed. The surge maps depict the limits of inundation from peak storm surge heights potentially generated by the five categories of storm intensity. These maps do not predict the limits of inundation from a single storm, but rather delineate the areas that are threatened by storm surge.

E. Adjustments to SLOSH Model Values. The surge height values contained in the maximum envelopes of water represent the water surface elevations produced by the driving forces of the modeled hurricanes in combination with astronomical mean tide. Tide anomaly values were set at +1.0 feet NGVD in the Gulf of Mexico and +2.0 feet NGVD in lakes within the basin. Gage observations made prior to the arrival of past hurricanes show that tide anomalies of this magnitude are common. The occurrence of peak surge at times of higher (or lower) tides would result in a corresponding larger (or smaller) surge elevation than that shown on the inundation maps.

1. Statistical Analysis. Hurricane evacuation decision-makers should keep in mind that the SLOSH model is a mathematical model and does not give perfect results. To determine the accuracy of the SLOSH model, runs were conducted by the National Weather Service for 10 historical landfalling hurricanes. A total of 523 observations of storm surge heights from tide gages and measured high water marks were made and compared to the SLOSH model values for the same locations (i.e., SLOSH model height minus observed height). A negative difference meant the SLOSH model underestimated the storm surge and a positive difference meant the model overestimated surge. Tide gage readings accounted for 14 percent of the observations, while the remainder were high water mark readings. Although the error range was from -7.1 feet to +8.8 feet, the standard deviation was only 2.0 feet. The arithmetic mean for these observations was -0.3 feet, which indicates a slight negative bias. This does not mean that the same negative bias will appear in future hurricane events.

Based on the results of the statistical analysis conducted by the National Weather Service, a +20 percent adjustment to the SLOSH values would eliminate most of the potential negative errors occurring from the model. However, such an adjustment would also add additional surge height to those values that already contain positive errors, possibly endangering the credibility of the SLOSH model results. With this in mind, southeast Louisiana emergency management officials elected not to make a general adjustment to the computed surge heights. Evacuation planners should remain cognizant of the potential for the SLOSH model to underestimate some of the surge values.

2. Variations in Hurricane Parameters. As mentioned earlier, the parameters of the 1,640 hurricanes modeled for the Lake Pontchartrain basin were: five categories of storm intensity, nine approach directions (west, west-northwest, northwest, north-northwest, north, north-northeast, northeast, east-northeast, and east), two forward speeds (5 and 15 miles per hour), radius of maximum winds of 25 miles and storm tracks separated by 20 miles or less. The parameters of future hurricanes having the greatest potential for variation from those modeled for the study are radius of maximum winds, forward speed, and central barometric pressure.

a. Radius of Maximum Winds. The radius of maximum winds for hurricanes modeled for the Lake Pontchartrain basin represent those that are expected to occur most frequently in future hurricanes along the central Gulf Coast. It is possible that the radius of maximum winds associated with future hurricanes could be different from those of the modeled storms. Increases in the radius of maximum winds, however, will not result in a significant increase in the peak surge height associated with those hurricanes but will most probably result in the peak surge occurring over a larger area of the coastline than from those of a smaller radius.

b. Forward Speed. SLOSH model calculations were performed for the Lake Pontchartrain basin for hypothetical hurricanes with forward speeds of 5 (slow) and 15 (fast) miles per hour. These forward speeds were selected as being representative of storm behavior in the Gulf of Mexico. An analysis of the SLOSH model results revealed that the faster storms create greater surge heights along the coastline. These storms have a greater potential for damage to the coastal areas which are not protected by levees. The faster a storm moves inland the quicker the surge will dissipate. The unique topography of southeast Louisiana allows slower storms to push greater quantities of water into the areas marshes, lakes, and bayous causing surge heights to be maintained. The heavily populated metropolitan areas located well inland and protected by extensive levee systems are more vulnerable to surge inundation from slower storms. The average forward speed for historical hurricanes within the Lake Pontchartrain basin is 11 miles per hour.

c. Central Barometric Pressure. Table 2-4 lists the central barometric pressures for the five categories of simulated hurricanes modeled for the study and the resulting pressure difference assuming a standard external pressure of 1010 millibars. It is possible to increase or decrease the central pressure by 5 to 10 millibars and technically remain within the same category of hurricane. For each 5 millibar change in pressure difference, surge heights within the Lake Pontchartrain basin could potentially increase or decrease 0.5 to 2.0 feet. As the central barometric pressure decreases, the pressure difference increases resulting in greater surge heights.

3. Surge Heights Within Protected Areas. In addition to providing surge heights along the open coast, the SLOSH model simulates the routing of storm surge into bays, estuaries, and coastal river basins and calculates surge heights for overland locations. The surge heights for overland locations are based on average ground elevations assigned to individual grid cells. Of greatest concern are the surge heights within the heavily developed areas, many of which are protected by hurricane surge barriers. The potential for flow through gaps in the protection and for limited overtopping increases the difficulty in modeling these areas. Given the difficulty in modeling the protected areas within the basin, existing stage-storage curves were utilized to determine interior stages. This required converting maximum water surface elevations into volumes of water. The depth of water within a particular grid cell was determined by subtracting the average ground elevation assigned to that cell. This depth was then converted to a volume of water by multiplying by the area of the cell. The volume of water within a protected area was determined by adding the volumes within all of the individual grid cells together. Once the total volume of water had been computed, a site specific stage-storage curve was utilized to obtain the corresponding stage. These stages are shown on the surge inundation maps shown in Appendix B.

4. Levee Performance. Residents of southeast Louisiana are heavily reliant on the levees and floodwalls (both Federal and non-Federal) which have been constructed as barriers to hurricane surge. The extent of flooding during a hurricane depends greatly on the ability of these barriers to function as intended. The performance of a levee or floodwall depends on many factors (design criteria, construction techniques, maintenance, severity of storm, etc.) and these factors cannot be accounted for by the SLOSH model. The SLOSH model runs performed for the Lake Pontchartrain basin assumed that the levees and floodwalls remained intact, even if overtopped. In past storms, such as Hurricane Betsy and Hurricane Juan, portions of levees have failed. The failure of a levee or floodwall could significantly increase the extent and degree of flooding. Emergency management officials should be aware of the potential for a failure in the protection and the corresponding impacts.

III. TIME-HISTORY DATA.

A total of 110 grid points within the Lake Pontchartrain basin were selected for the tabulation of surge height, wind speed, and wind direction. The grid points were selected in consultation with parish emergency management officials at the outset of the study. The selected grid points coincided with critical areas identified within each of the study area parishes and represented the locations of critical roads and bridges of low elevation, potentially vulnerable population centers, and areas adjacent to significant natural or man-made barriers. The time-history information furnished by the SLOSH model for the 110 critical points, lists values for still-water surge heights, wind speeds, and wind direction at ten-minute intervals for 72 hours.

The purpose of the time-history data is to determine the pre-landfall hazards time for each of the parishes within the study area. Pre-landfall hazards time is the amount of time, in advance of eye landfall or closest approach by a threatening hurricane, that weather conditions deteriorate to the point that an evacuation could become hazardous. Stated another way, it is the amount of time in advance of an approaching hurricane that an evacuation would ideally be completed to avoid exposing evacuees to hazardous weather conditions. These assumed thresholds for the Southeast Louisiana Hurricane Preparedness Study are the arrival of sustained gale-force winds (40 m.p.h. sustained wind speeds, one-minute average) or the time that storm surge begins to inundate low-lying roads, bridges, or other critical areas. Sustained gale-force winds are a selected threshold because high-profile vehicles or vehicles pulling campers or boats, especially over high-rise bridges, could be overturned by the wind gusts associated with these sustained wind speeds. Such an accident would most certainly cripple or stop traffic flow on that evacuation route. The time of arrival of sustained gale-force winds is also the time at which, under the majority of hurricane threats, the heaviest rainfall begins. Generally, one-half of the total amount of rainfall received from a hurricane occurs from the time of arrival of gale-force winds until the eye reaches the coastline.

The other limiting condition to an evacuation is the onset of storm surge inundation. Storm surge is an increase in the height of the water surface due to the forces of the approaching hurricane. For most locations within the Lake Pontchartrain basin, the arrival of sustained gale-force winds are expected to occur prior to the onset of storm surge inundation. It was therefore determined that for the purposes of this study, the pre-landfall hazards time would be determined by the arrival of sustained gale-force winds. It should be noted that barrier islands and unprotected coastal communities could be subjected to tidal flooding prior to receiving gale-force winds. Strong southerly winds associated with a weather system which is unrelated to a hurricane have periodically produced flooding of low-lying evacuation routes and emergency management officials should be aware of the local weather conditions well in advance of an approaching hurricane.

Since the limiting factor for hurricane evacuation in the study area is the arrival of sustained gale-force winds, the pre-landfall hazards distance for any parish can be defined as the distance to the eye of the approaching hurricane upon the arrival of sustained gale-force winds, or, more simply stated, the radius of sustained gale-force winds of the threatening hurricane. Thus, for the Southeast Louisiana Hurricane Preparedness Study area, the pre-landfall hazards distance and the radius of sustained gale-force winds are synonymous.

Although the wind fields of actual hurricanes can vary significantly from one storm to another as well as within the same storm over time, the SLOSH model calculates a quasi-symmetrical wind field. This means that the wind speeds are distributed almost evenly around the modeled storm. After analyzing data extracted from the time-history information produced by the Lake Pontchartrain basin.SLOSH model, the National Weather Service has concluded that the radius of gale-force winds calculated by the model are essentially independent of hurricane forward speed and approach direction, but dependent upon hurricane strength. Thus, there is a radius of gale-force winds associated with each of the five hurricane categories that is independent of forward speed and approach direction, and is valid for any location within the study area. This radius from storm center represents the distance in nautical miles that sustained gale-force winds extend from the centers of the hurricanes simulated for this study.

Table 2-5 lists the radius of sustained gale-force winds by category of hurricane for the Lake Pontchartrain basin. These are hypothetical values extracted from the SLOSH model and represent typical distances to the hurricane eye upon the arrival of sustained gale-force winds at the boundary of each parish. These distances should be used as an approximation for planning purposes or when no actual observations are available. Marine advisories, produced by the National Weather Service every 6 hours, give the measured distance in nautical miles of the 34-knot (approximately 40 miles per hour), 1-minute sustained wind speed from the eye of an approaching hurricane. These distances are given for the four quadrants of a hurricane (i.e., northwest, northeast, southeast, and southwest). Forecasts of these distances for 12, 24, 48, and 72 hours into the future are also given. When actual measured distances of the radius of 34-knot winds are available, the largest radius should be used for evacuation decision-making.

TABLE 2-5

RADIUS OF GALE-FORCE WINDS

Saffir/Simpson Hurricane Category	Radius of Gale-Force (34-knot) Winds (Nautical Miles)
1	60
2	80
3	105
4	125
5	140

Further discussion of the application of the radius of gale-force winds to hurricane evacuation decision-making is contained in Chapter 7, Decision Arc Method.

IV. WAVE EFFECTS.

The SLOSH model does not provide data concerning the additional heights of waves generated on top of the still-water storm surge. Generally, waves do not add significantly to the areal coverage of the storm surge in a basin and can usually be ignored except for locations immediately along the open coastline or the shorelines of very large bays where significant fetch lengths and water depths are possible. Since near-shore wave phenomena under hurricane conditions are not well understood, it is assumed that for the open coast, maximum theoretical wave heights based upon relationships to water depth occur near the time of landfall. The coastal bathymetry of southeast Louisiana tends to increase surge heights and decrease waves. Shallow offshore depths cause waves to break and dissipate energy before reaching the coastline. The smaller waves reaching the coastline will not have the destructive power of the larger offshore waves.

The results of the SLOSH model depend, to a large degree, on the ability to accurately model the basin. The size of the Lake Pontchartrain basin restricted the level of detail that could be included in the SLOSH model. The size of the grid squares precluded modeling the Algiers Canal, Harvey Canal, Gulf Intracoastal Waterway (GIWW), or the Inner Harbor Navigation Canal (IHNC). As a result, the model was not able to account for the occurrence of flow in these channels. Barriers to hurricane surge are represented in the model by cell boundaries and water is only allowed to flow across cell boundaries in one direction at a time. As the surge builds up against these barriers, some return flow will occur along the bottom. The model does not compute this flow. These factors contribute to a conservative estimation of potential surge heights for portions of the Lake Pontchartrain basin. Wave run-up and overtopping were, therefore, neglected in an effort to more accurately represent actual levels of flooding.

It is perhaps more important for evacuation planning purposes to calculate potential wave effects for less than sustained gale-force wind speeds. The rationale here is to determine when critical areas may be flooded by wave action accompanying the still-water storm surge and whether such inundation adds to the pre-landfall hazards distance calculated for specific locations.

Before making calculations of wave height and runup at critical locations within the study area, surge heights at the time of arrival of gale-force winds should be considered. A review of SLOSH time histories show that the maximum surge at critical points within the study area at the time of arrival of gale-force winds are on the order of 2 to 3 feet NGVD. Tides of this magnitude are experienced fairly routinely during periods of sustained southerly winds and do not usually cause major traffic problems. Most locations which might be vulnerable to surge heights prior to the arrival of gale-force winds are along the coast. Residents living in these communities must travel significant distances prior to reaching safety and will generally leave well in advance of rising tides or gale-force winds. Calculations of wave height and runup were therefore not made. Evacuation planners should be aware that low-lying coastal highways could be subject to minor wave action prior to the arrival of sustained gale-force winds.

V. FRESHWATER FLOODING.

Amounts and arrival times of rainfall associated with hurricanes are highly unpredictable. For most hurricanes, the heaviest rainfall begins near the time of arrival of sustained gale-force winds; however, heavy rains in amounts exceeding 20 inches can precede an approaching hurricane by as much as 24 hours. Unrelated weather systems can also contribute significant rainfall amounts within a basin in advance of a hurricane. Although drainage systems are in place to handle rainfall runoff within protected areas, the disruption of normal drainage systems and loss of power to operate pumps during storms may render drainage systems inoperative. The higher outside stages created by rising tides and surge would also drastically reduce pumping efficiency. The pumping stations will significantly reduce rainfall flooding during the early stages of a hurricane but will become less effective as outside stages increase and weather conditions deteriorate.

Due to the unpredictability of rainfall from hurricanes, no attempt was made to employ sophisticated modeling or analysis in quantifying the effects of rainfall for the Southeast Louisiana Hurricane Preparedness Study area. Areas and facilities which have historically flooded during periods of heavy rainfall were identified throughout the study area and assumed to be vulnerable to freshwater flooding under hurricane threats. The additive effects of rainfall can be expected to compound flooding within leveed areas.

CHAPTER THREE

VULNERABILITY ANALYSIS

I. PURPOSE.

The primary purpose of the vulnerability analysis is to identify the areas, populations, and facilities which are potentially vulnerable to flooding associated with hurricanes. The storm surge data from the hazards analysis were used to develop inundation maps (see Appendix B); to determine evacuation zones and evacuation scenarios for each of the study area parishes; to quantify the population at risk under a range of hurricane intensities; and to identify major medical/institutional and other facilities that are potentially vulnerable to storm surge.

Mobile homes were the only type of structures that this study addressed in terms of vulnerability to hurricane force winds. Historical evidence suggests that mobile homes are not able to withstand the high winds associated with a hurricane. Sudden and catastrophic failures of mobile homes are common occurrences during hurricanes. Given the high degree of vulnerability to hurricane force winds, residents of mobile homes were assumed to evacuate even if located outside of the area at risk to hurricane surge inundation. No attempt was made to identify other types of structures particularly vulnerable to wind damage.

II. HURRICANE EVACUATION ZONES.

Evacuation zones have been developed for each of the nine parishes within the Southeast Louisiana Hurricane Preparedness Study area. Each of the evacuation zones were delineated as much as possible using major natural or man-made geographic features and conform to existing political or demographic boundaries (i.e., census tracts) within each parish. The purpose for this delineation is to aid in the development of population and other socioeconomic data to be used in traffic modeling; to determine sheltering requirements; and to facilitate future updating. Evacuation zones for each parish are delineated on the evacuation zone maps in Chapter 6 (Plates 6-1 through 6-9). The number of evacuation zones within each parish are provided below:

Jefferson Parish. A total of 28 evacuation zones have been established for Jefferson Parish. The evacuation zone delineations are shown on Plate 6-1.

Lafourche Parish. A total of 6 evacuation zones have been established for Lafourche Parish. The evacuation zone delineations are shown on Plate 6-2.

Orleans Parish. A total of 35 evacuation zones have been established for Orleans Parish. The evacuation zone delineations are shown on Plate 6-3.

Plaquemines Parish. A total of 6 evacuation zones have been established for Plaquemines Parish. The evacuation zone delineations are shown on Plate 6-4.

St. Bernard Parish. A total of 5 evacuation zones have been established for St. Bernard Parish. The evacuation zone delineations are shown on Plate 6-5.

St. Charles Parish. A total of 15 evacuation zones have been established for St. Charles Parish. The evacuation zone delineations are shown on Plate 6-6.

St. James Parish. A total of 12 evacuation zones have been established for St. James Parish. The evacuation zone delineations are shown on Plate 6-7.

St. John the Baptist Parish. A total of 12 evacuation zones have been established for St. John the Baptist Parish. The evacuation zone delineations are shown on Plate 6-8.

St. Tammany Parish. A total of 23 evacuation zones have been established for St. Tammany Parish. The evacuation zone delineations are shown on Plate 6-9.

III. HURRICANE EVACUATION SCENARIOS.

A. General. Hurricane evacuation scenarios have been developed for each parish within the Southeast Louisiana Hurricane Preparedness Study area. The evacuation scenarios are groups of evacuation zones that will potentially require evacuation under specific hurricane intensities due to the threat of storm surge. In many instances, the evacuation zones threatened by storm surge are the same for more than one intensity of hurricane. In those cases, the zones requiring evacuation have been combined into evacuation scenarios based on combinations of hurricane intensities.

B. Evacuation Scenarios. Table 3-1 provides a breakdown by parish of the hurricane categories comprising each evacuation scenario. Maps illustrating these evacuation scenarios are contained in Chapter 6 (Plates 6-1 through 6-9).

IV. VULNERABLE POPULATION.

A. General. The vulnerable population in each of the nine parishes within the study area is comprised of those persons residing within the evacuation zones subject to inundation from storm surge, as well as the residents of mobile homes located in non-vulnerable zones. All mobile home residents are assumed to evacuate as a result of increased vulnerability to hurricane force winds. The potential tourist population within

TABLE 3-1

EVACUATION ZONES AND VULNERABLE POPULATION BY STORM SCENARIO

Parish	Number of Zones	Scenario	Saffir-Simpson Category	Vulnerable Population
Jefferson	28	A	Category 1/Fast Category 2	33,635
		B	Fast Category 3	149,795
		C	Slow Category 2	259,130
		D	Fast Category 4	315,640
		E	Slow Category 3-4/Category 5	371,435
Lafourche	6	A	Category 1/Fast Category 2	28,640
		B	Fast Category 3	47,840
		C	Slow Category 2	50,340
		D	Slow Category 3/Category 4-5	72,395
Orleans	35	A	Category 1/Fast Category 2	19,300
		B	Slow Category 2/Fast Category 3	64,065
		C	Fast Category 4	361,085
		D	Slow Category 3-4/Category 5	441,400
Plaquemines	6	A	Category 1/Fast Category 2	16,410
		B	Slow Category 2/Category 3-5	24,135
St. Bernard	5	A	Category 1-2/Fast Category 3	10,275
		B	Slow Category 3/Category 4-5	60,355
St. Charles	15	A	Category 1/Fast Category 2	6,415
		B	Fast Category 3	21,915
		C	Slow Category 2	26,260
		D	Slow Category 3/Category 4-5	37,410
St. James	12	-	Category 1/Fast Category 2	----
		A	Fast Category 3	3,560
		B	Slow Category 2/Fast Category 4	7,020
		C	Slow Category 3	12,170
		D	Slow Category 4/Category 5	17,920
St. John the Baptist	12	A	Category 1/Fast Category 2	4,910
		B	Fast Category 3	10,032
		C	Slow Category 2/Fast Category 4	15,235
		D	Slow Category 3-4/Category 5	31,325
St. Tammany	23	A	Category 1/Fast Category 2	4,050
		B	Slow Category 2/Fast Category 3	59,370
		C	Slow Category 3/Fast Category 4	80,735
		D	Slow Category 4/Category 5	98,325

the surge vulnerable zones has also been included based on the number of existing tourist units and assumed occupancy rates. Evacuation rates among tourists in response to a hurricane threat will depend heavily upon recommendations by hotel management, as well as upon explicit instructions from public officials.

B. Vulnerable Population. The vulnerable population within each parish is presented in Table 3-1 for each of the previously developed evacuation scenarios. The 1990 census data was used to determine vulnerable population totals.

V. INSTITUTIONAL/MEDICAL FACILITIES.

A. General. The inventory of institutional/medical facilities was developed through utilization of various phone directories and through coordination with emergency management officials within each parish. The purpose of this analysis is to identify, locate, and determine the vulnerability of all institutional/medical facilities which would require special care during an evacuation. Establishing the first floor elevation for each institutional/medical facility was the first step in determining the potential vulnerability to storm surge inundation. Facility administrators were requested to provide first floor elevations, where available, from construction drawings or flood insurance policies. Windshield surveys were then conducted on those facilities where the elevation was unknown. Windshield surveys were performed using 1-foot contour maps and U.S. Geological Survey quadrangle maps. The vulnerability of each facility was determined by comparing the first floor elevation to the potential surge heights developed in the hazards analysis.

B. Institutional/Medical Facilities. The inventories, capacities, and potential vulnerability to storm surge inundation for the institutional/medical facilities within each parish of the Southeast Louisiana Hurricane Preparedness Study area are presented in Tables 3-2 through 3-10. When using the information contained in these tables to evaluate the safety of a facility, inaccuracies in hurricane forecasting should be taken into account. No attempt has been made to assess the vulnerability of any institutional/medical facility to the effects of hurricane force winds. The approximate locations of the facilities are shown on Plates 3-1 through 3-9. The facilities listed in Tables 3-2 through 3-10 are identified by a number which corresponds to the location of the facilities shown on Plates 3-1 through 3-9.

TABLE 3-2

INSTITUTIONAL/MEDICAL FACILITIES

JEFFERSON PARISH, LOUISIANA

				Potential Surge Heights for Each Scenario						
Key	Facility Name	Capacity	First Floor Elevation	1	2	3	4	5	6	7
01	Meadowcrest Hospital	125	1.0	Dry	Dry	7	8	14	15	23
02	Stonebridge Conv. Center	207	3.0	Dry	Dry	7	8	14	15	23
03	Meadowcrest Living Center	163	-1.5	Dry	Dry	7	8	14	15	23
04	River Oaks Psychiatric Hospital	60	4.5	Dry	Dry	Dry	Dry	15	4	23
05	City of Harahan Jail	1	11.1	Dry	Dry	Dry	Dry	15	4	23
06	Manhattan Manor ECF	122	2.0	Dry	Dry	8	8	14	15	23
07	Juvenile Detention Home	50	-0.4	Dry	Dry	8	8	14	15	23
08	Manhattan Guest House	100	5.0	Dry	Dry	8	8	14	15	23
09	Jefferson Healthcare Center	270	6.0	Dry	Dry	Dry	Dry	14	4	23
10	Magnolia School	110	7.5	Dry	Dry	Dry	Dry	15	4	23
11	Elmwood Medical Center	135	11.2	Dry	Dry	Dry	Dry	15	4	23
12	Waldon Healthcare	200	1.0	Dry	Dry	Dry	Dry	15	4	23
13	AMI St. Jude Med. Center	150	-2.3	Dry	Dry	Dry	Dry	15	4	24
14	Chateau Living Center	285	-3.3	Dry	Dry	Dry	Dry	15	4	23
15	West Jefferson Medical Center	325	4.6	Dry	Dry	8	Dry	14	15	23
16	Hope Haven Center	150	3.0	Dry	Dry	8	8	14	15	24
17	Heritage Manor Nursing Home	134	2.0	Dry	Dry	8	8	14	15	24
18	Metairie Healthcare Center	198	-3.0	Dry	Dry	Dry	Dry	14	15	23

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-2

INSTITUTIONAL/MEDICAL FACILITIES

JEFFERSON PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
19	St. John's House	12	4.1	Dry	Dry	Dry	Dry	15	4	23
20	Jefferson Parish Care Center	--	3.0	Dry	Dry	8	8	14	15	24
21	Lakeside Hospital	122	-3.5	Dry	Dry	Dry	Dry	15	4	23
22	Maison Marie	12	1.0	Dry	Dry	Dry	Dry	14	4	23
23	St. Anthony's Nursing Home	124	0.0	Dry	Dry	Dry	Dry	14	4	23
24	Colonial Oaks Living Center	110	2.9	Dry	Dry	Dry	Dry	14	4	23
25	Doctors Hospital of Jefferson	138	2.0	Dry	Dry	Dry	Dry	14	4	23
26	East Jefferson General Hospital	468	-0.2	Dry	Dry	Dry	Dry	14	4	23
27	Ochsner Foundation Hospital	400	7.2	Dry	Dry	Dry	Dry	14	4	23
28	The Atrium at LaFreniere	86	-2.3	Dry	Dry	Dry	Dry	15	4	23
29	Nouveau Marc Retirement Residence	111	-4.3	Dry	Dry	Dry	Dry	14	4	23
30	Flo's T.L.C. Services, Inc.	9	-1.8	Dry	Dry	Dry	Dry	14	4	23
31	Allied Health Care, Inc.	6	-2.3	Dry	Dry	Dry	Dry	15	4	23
32	Metairie Manor	287	-2.0	Dry	Dry	Dry	Dry	14	4	23
33	Flo's T.L.C. Servies, Inc.	4	-2.8	Dry	Dry	Dry	Dry	15	4	23
34	Flo's T.L.C. Servies, Inc.	6	-2.0	Dry	Dry	Dry	Dry	15	4	23
35	Flo's T.L.C. Servies, Inc.	6	-0.3	Dry	Dry	Dry	Dry	15	4	23
36	Jefferson Parish Correctional Center	700	8.0	Dry	Dry	8	8	14	15	24

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-3

INSTITUTIONAL/MEDICAL FACILITIES

LAFOURCHE PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
01	Lafourche Parish Jail	4	7.0	Dry	Dry	9	13	12	16	19
02	South Lafourche Nursing Center	123	4.0	Dry	Dry	9	13	12	16	19
03	Lady of the Sea General Hospital	45	7.0	Dry	Dry	9	13	12	16	19
04	Raceland Health Care	82	4.0	Dry	Dry	5	Dry	11	10	19
05	St. Anne General Hospital	32	13.0	Dry	Dry	5	Dry	11	10	19
06	Heritage Manor Nursing Home	58	11.9	Dry	Dry	Dry	Dry	12	13	19
07	Lafourche Parish Detention Center	120	6.4	Dry	Dry	Dry	Dry	12	13	19
08	South Louisiana Rehabilitation Center	12	2.0	Dry	Dry	Dry	Dry	12	13	19
09	Thibodaux Hospital and Health Center	70	17.0	Dry	Dry	Dry	Dry	12	13	19
10	Lafourche Home for the Aged	64	2.0	Dry	Dry	Dry	Dry	12	13	19
11	Audubon Guest House	155	14.5	Dry	Dry	Dry	Dry	12	13	19

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-4

INSTITUTIONAL/MEDICAL FACILITIES

ORLEANS PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
01	The New Orleanian	221	4.0	Dry	Dry	Dry	Dry	13	1	24
02	Tulane University Hospital	250	1.7	Dry	Dry	Dry	Dry	13	2	23
03	University Hospital	400	-0.4	Dry	Dry	Dry	Dry	13	2	23
04	F. Edward Hebert Hospital	194	6.0	Dry	Dry	8	8	14	15	23
05	Touro Shakespeare	--	3.5	Dry	Dry	8	8	14	15	23
06	The Landing at Behrman Place	120	3.5	Dry	Dry	7	7	14	15	23
07	New Orleans Tower	310	-2.7	Dry	Dry	7	7	14	15	23
08	Woldenberg Village Care Center	101	4.0	Dry	Dry	7	7	14	15	23
09	Mary Joseph	121	1.9	Dry	Dry	7	7	14	15	23
10	Jo Ellen Smith Psychiatric Health	30	-1.0	Dry	Dry	7	7	14	15	23
11	Educational Systems Training Inc.	7	-2.0	Dry	Dry	Dry	Dry	8	15	21
12	Touro Infirmary Sn. Facility	28	5.5	Dry	Dry	Dry	Dry	13	Dry	24
13	Touro Infirmary	382	5.5	Dry	Dry	Dry	Dry	13	Dry	24
14	Crescent City Health Care Facility	116	4.5	Dry	Dry	Dry	Dry	13	Dry	24
15	St. Charles Health Care	104	5.0	Dry	Dry	Dry	Dry	13	Dry	24
16	Eye, Ear, Nose & Throat Hospital	11	2.5	Dry	Dry	Dry	Dry	13	1	24
17	Southern Baptist Hospital	250	2.0	Dry	Dry	Dry	Dry	13	1	24
18	Southern Baptist Sn. Facility	32	2.0	Dry	Dry	Dry	Dry	13	1	24

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles.
The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-4

INSTITUTIONAL/MEDICAL FACILITIES

ORLEANS PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
19	CPC Coliseum Medical Center	100	3.5	Dry	Dry	Dry	Dry	13	Dry	24
20	St. Charles General Hospital	75	3.3	Dry	Dry	Dry	Dry	13	Dry	24
21	Poydras Home	42	3.0	Dry	Dry	Dry	Dry	13	Dry	24
22	Covenant Home	84	1.0	Dry	Dry	Dry	Dry	13	Dry	24
23	Maison Hospitaliere	80	5.7	Dry	Dry	Dry	Dry	13	2	22
24	St. Martin Manor	145	5.0	Dry	Dry	Dry	Dry	13	2	22
25	Christopher Apts.	144	5.7	Dry	Dry	Dry	Dry	13	2	22
26	Annunciation Inn	110	3.7	Dry	Dry	Dry	Dry	13	2	22
27	United Medical Center	98	2.8	Dry	Dry	Dry	Dry	13	2	22
28	Villa St. Maurice	110	5.0	Dry	Dry	Dry	Dry	16	16	22
29	St. Margarets Daughter	112	5.0	Dry	Dry	Dry	Dry	16	16	22
30	DePaul Hospital	125	9.5	Dry	Dry	Dry	Dry	13	Dry	24
31	Childrens Hospital	160	13.0	Dry	Dry	Dry	Dry	13	Dry	24
32	New Orleans Adolescent Hospital	84	18.0	Dry	Dry	Dry	Dry	13	Dry	24
33	Waldo Burton Boys Home	35	6.1	Dry	Dry	Dry	Dry	13	1	24
34	Miller Manor	6	14.5	Dry	Dry	Dry	Dry	13	Dry	24
35	Joliet House	12	-1.8	Dry	Dry	Dry	Dry	13	1	22
36	New Orleans Home & Rehab. Center	180	9.0	Dry	Dry	Dry	Dry	13	Dry	24

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Scenario 1 = All Category 1 Storms
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Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-4

INSTITUTIONAL/MEDICAL FACILITIES

ORLEANS PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
37	Bethany	117	4.0	Dry	Dry	Dry	Dry	13	2	22
38	City of New Orleans Parish Prison	1,118	-3.0	Dry	Dry	Dry	Dry	13	2	24
39	Mercy Hospital	150	8.0	Dry	Dry	Dry	Dry	13	2	23
40	Montelepre Memorial Hospital	30	-0.8	Dry	Dry	Dry	Dry	13	2	23
41	The 1540 House	12	3.8	Dry	Dry	Dry	Dry	13	2	22
42	Villa St. Maurice II	75	6.0	Dry	Dry	Dry	Dry	16	16	22
43	Ronald McDonald House	30	5.5	Dry	Dry	Dry	Dry	13	2	23
44	Woldenberg Villas	60	3.5	Dry	Dry	7	8	14	15	23
45	St. John Berchmans Manor	150	3.2	Dry	Dry	Dry	Dry	13	2	22
46	Lafon (United Methodist Church)	95	4.0	Dry	Dry	Dry	Dry	13	2	22
47	Chateau De Notre Dame	180	1.5	Dry	Dry	Dry	Dry	13	2	24
48	St. Jude Community Services	--	-0.1	Dry	Dry	Dry	Dry	13	2	23
49	Prayer Tower	95	0.0	Dry	Dry	Dry	Dry	13	2	24
50	Lutheran Home	206	1.2	Dry	Dry	Dry	Dry	8	15	21
51	Lafon (The Holy Family)	169	4.3	Dry	Dry	Dry	Dry	8	15	21
52	Gordon Plaza	128	4.0	Dry	Dry	Dry	Dry	13	2	22
53	Lutheran Towers	200	-3.0	Dry	Dry	Dry	Dry	8	15	21
54	Forest Towers East	200	-3.8	Dry	Dry	Dry	Dry	8	15	21

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-4

INSTITUTIONAL/MEDICAL FACILITIES

ORLEANS PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
55	Bethelehem Childrens Centers	35	-6.1	Dry	Dry	Dry	Dry	8	15	21
56	Pendleton Memorial Methodist Hospital	169	-2.7	Dry	Dry	Dry	Dry	8	15	21
57	CPC Eastlake Hospital	55	-3.7	Dry	Dry	Dry	Dry	8	15	21
58	Nazareth Inn	164	2.6	Dry	Dry	Dry	Dry	8	15	21
59	Nazareth Inn II	126	2.6	Dry	Dry	Dry	Dry	8	15	21
60	Easthaven Care Center	243	-4.0	Dry	Dry	Dry	Dry	8	15	21
61	Ferncrest Manor Nursing Home	175	2.0	Dry	Dry	Dry	Dry	8	15	21
62	Fountain Manor, Inc.	217	3.5	Dry	Dry	Dry	Dry	8	15	21
63	Maison Orleans II	207	0.0	Dry	Dry	Dry	Dry	8	15	21
64	Tivolli Place	170	5.0	Dry	Dry	Dry	Dry	13	1	24
65	Hermitage Manor	6	-5.0	Dry	Dry	Dry	Dry	8	15	21
66	St. Anna Asylum	80	6.2	Dry	Dry	Dry	Dry	13	1	24
67	New Orleans General Hospital	87	12.4	Dry	Dry	Dry	Dry	13	1	24
68	Abode Board and Care, Inc.	18	-0.4	Dry	Dry	Dry	Dry	13	1	24
69	Jo Ellen Smith Medical Center	120	5.0	Dry	Dry	7	7	14	15	23
70	Jo Ellen Hosp. Conv. Home	165	5.4	Dry	Dry	7	7	14	15	23
71	Woodland Village	150	-2.3	Dry	Dry	7	7	14	15	23
72	Medical Center of LA-New Orleans	800	4.8	Dry	Dry	Dry	Dry	13	2	23

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-4

INSTITUTIONAL/MEDICAL FACILITIES

ORLEANS PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
73	Veterans Administration Hospital	450	5.0	Dry	Dry	Dry	Dry	13	2	23
74	Lakeland Medical Center	125	-3.7	Dry	Dry	Dry	Dry	8	2	21
75	Pratt Stanton Manor	90	4.6	Dry	Dry	Dry	Dry	13	1	24
76	Educational Systems Training, Inc.	6	-5.0	Dry	Dry	Dry	Dry	8	15	21
77	Special Dwelling	6	3.8	Dry	Dry	Dry	Dry	13	2	22

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-5

INSTITUTIONAL/MEDICAL FACILITIES

PLAQUEMINES PARISH, LOUISIANA

				Potential Surge Heights for Each Scenario						
Key	Facility Name	Capacity	First Floor Elevation	1	2	3	4	5	6	7
01	Plaquemine Parish Comprehensive Care	--	2.0	Dry	9	10	12	13	16	19
02	Port Sulphur Jail	--	2.0	Dry	9	10	12	13	16	19

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles.
The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-6

INSTITUTIONAL/MEDICAL FACILITIES

ST. BERNARD PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Maison Orleans	156	0.3	Dry	Dry	Dry	Dry	16	16	22
02	St. Ann's Convalescent Homes	58	3.0	Dry	Dry	Dry	Dry	16	16	22
03	Chalmette Rehabilitation Center	60	2.0	Dry	Dry	Dry	Dry	16	16	22
04	Chalmette Medical Centers	90	1.1	Dry	Dry	Dry	Dry	16	16	22
05	St. Rita's Nursing Home	75	5.1	Dry	Dry	Dry	Dry	17	20	24
06	Fernandez Nursing Homes Inc.	80	5.6	Dry	Dry	Dry	Dry	17	20	23
07	Simmons Nursing Home	48	5.0	Dry	Dry	Dry	Dry	17	19	25
08	Utopia Community Home	6	5.0	Dry	Dry	Dry	Dry	17	19	25
09	Poydras Manor	36	3.5	Dry	Dry	15	17	19	22	25

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-7

INSTITUTIONAL/MEDICAL FACILITIES

ST. CHARLES PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Evangeline of Ormond Inc.	148	1.0	Dry	Dry	7	Dry	15	11	25
02	St. Charles Sheriff	75	15.0	Dry	Dry	7	Dry	13	11	23
03	St. Charles Hospital	30	6.0	Dry	Dry	8	3	13	13	23
04	St. Charles Manor Nursing Home	103	6.0	Dry	Dry	8	3	13	13	23

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-8

INSTITUTIONAL/MEDICAL FACILITIES

ST. JAMES PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	St. James Parish Detention Center	80	21.7	Dry	Dry	Dry	Dry	Dry	Dry	30
02	Riverlands Health Care Center	110	0.0	Dry	Dry	9	Dry	17	9	30
03	St. James Parish Hospital	8	11.0	Dry	Dry	9	Dry	17	9	30
04	River Region Hospital	24	8.5	Dry	Dry	Dry	Dry	12	7	24

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-9

INSTITUTIONAL/MEDICAL FACILITIES

ST. JOHN THE BAPTIST PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Twin Oaks Nursing & Conv. Home	140	15.0	Dry	Dry	Dry	Dry	16	12	27
02	River Parishes Hospital	40	10.0	Dry	Dry	Dry	Dry	16	12	27
03	The Discovery Unit	12	10.0	Dry	Dry	Dry	Dry	16	12	27
04	Place DuBourg	116	12.0	Dry	7	9	8	16	12	27

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

TABLE 3-10

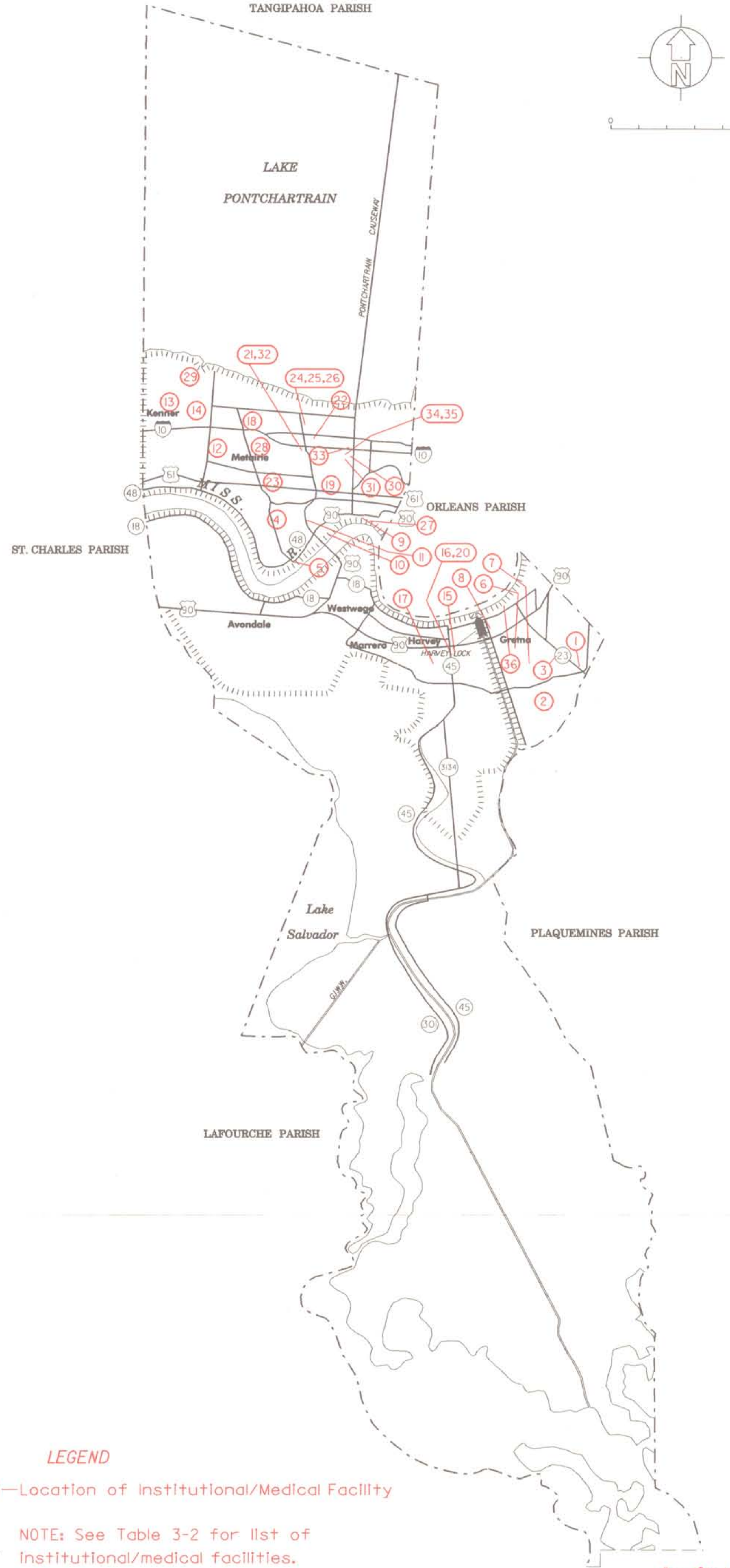
INSTITUTIONAL/MEDICAL FACILITIES

ST. TAMMANY PARISH, LOUISIANA

Key	Facility Name	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Forest Manor Nursing Home	192	15.0	Dry	Dry	Dry	Dry	Dry	Dry	21
02	Lacombe Nursing Center	98	15.0	Dry	Dry	Dry	Dry	Dry	Dry	20
03	Northshore Living Center	76	16.0	Dry	Dry	9	14	14	19	22
04	Riverview Boarding Lodge	6	5.0	Dry	7	9	12	14	16	21
05	Pontchartrain Guest House	160	10.0	Dry	Dry	Dry	Dry	14	Dry	20
06	Slidell Memorial Hospital	182	13.3	Dry	Dry	Dry	12	14	19	23
07	Guest House of Slidell	108	13.0	Dry	Dry	Dry	12	14	19	23
08	New Medico Neurologic Rehabilitation	100	14.0	Dry	9	9	16	15	20	25
09	Greenbriar Nursing & Convalescent Home	155	13.0	Dry	Dry	Dry	12	14	19	23
10	Towering Pines Center	32	4.0	Dry	9	9	16	15	20	25
11	Northshore Regional Med. Center	90	14.0	Dry	8	9	15	14	18	22
12	North Shore Psychiatric Hospital	30	17.4	Dry	Dry	9	14	14	19	22
13	St. Tammany Parish Hospital	199	20.0	Dry	Dry	Dry	Dry	Dry	Dry	21
14	Highland Park Medical Center	55	25.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
15	Three Rivers Hospital	64	29.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
16	Greenbrier Hospital	30	21.5	Dry	Dry	Dry	Dry	Dry	Dry	Dry
17	Rouquette Lodge	173	15.0	Dry	Dry	Dry	Dry	14	16	21

Elevations are referenced in feet NGVD, and were obtained from the facility owners, windshield surveys, or USGS Quadrangles. The source of these elevations are shown on individual facility data sheets and are available upon request.

Scenario 1 = All Category 1 Storms
Scenario 2 = Fast Category 2 Storms
Scenario 3 = Slow Category 2 Storms
Scenario 4 = Fast Category 3 Storms
Scenario 5 = Slow Category 3 Storms
Scenario 6 = Fast Category 4 Storms
Scenario 7 = Slow Category 4 Storms and all Category 5 Storms

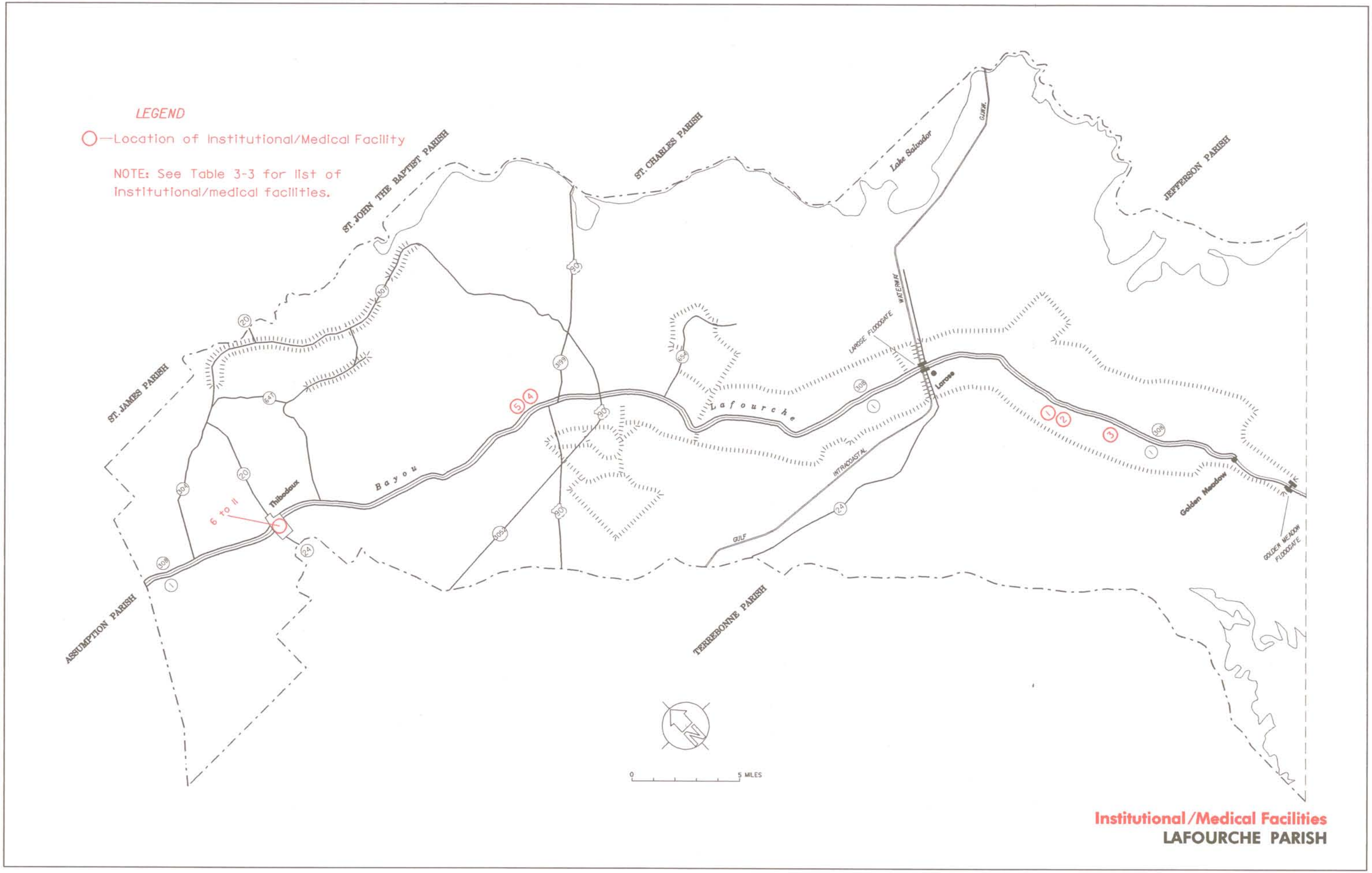


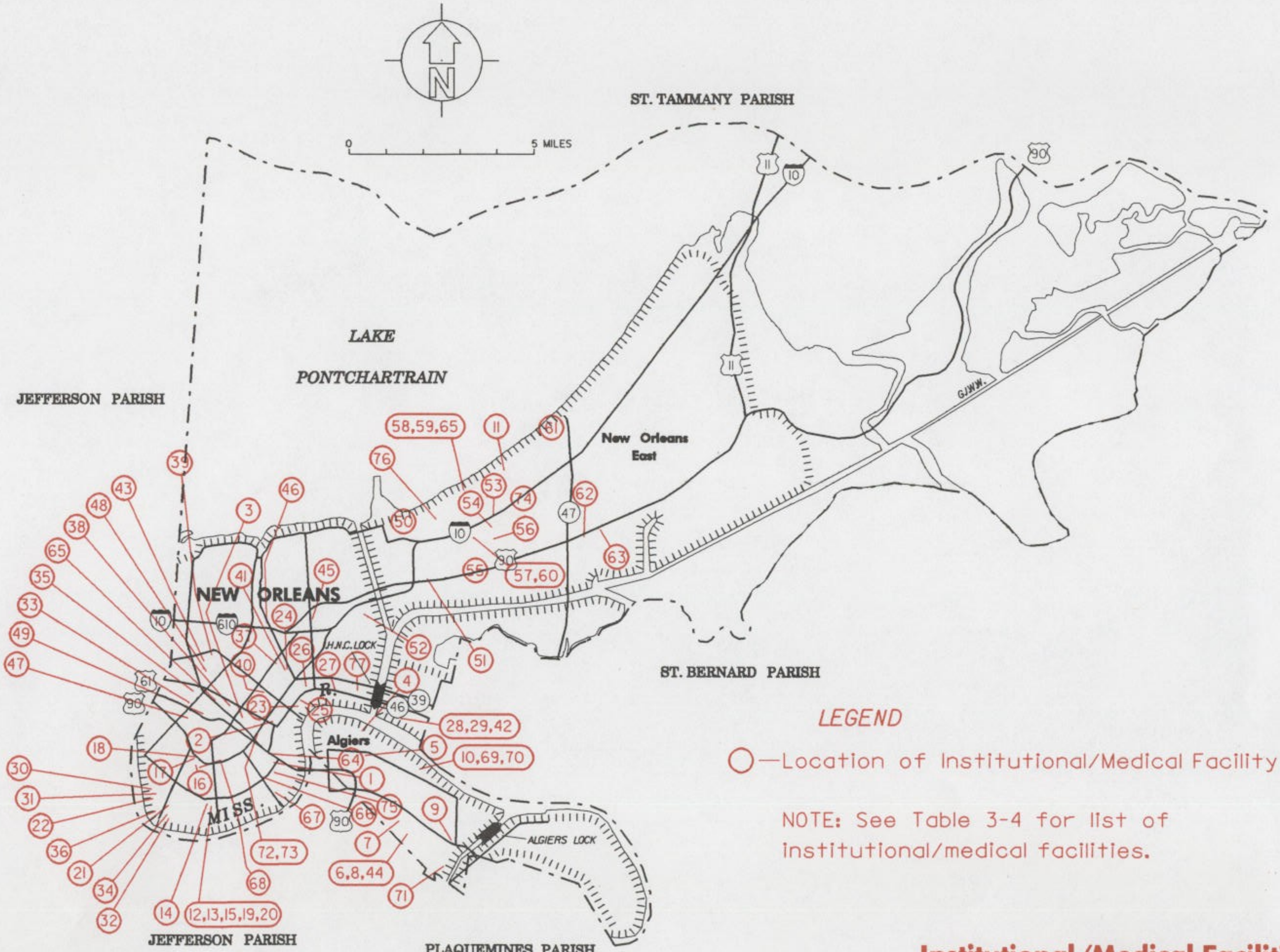
LEGEND

○—Location of Institutional/Medical Facility

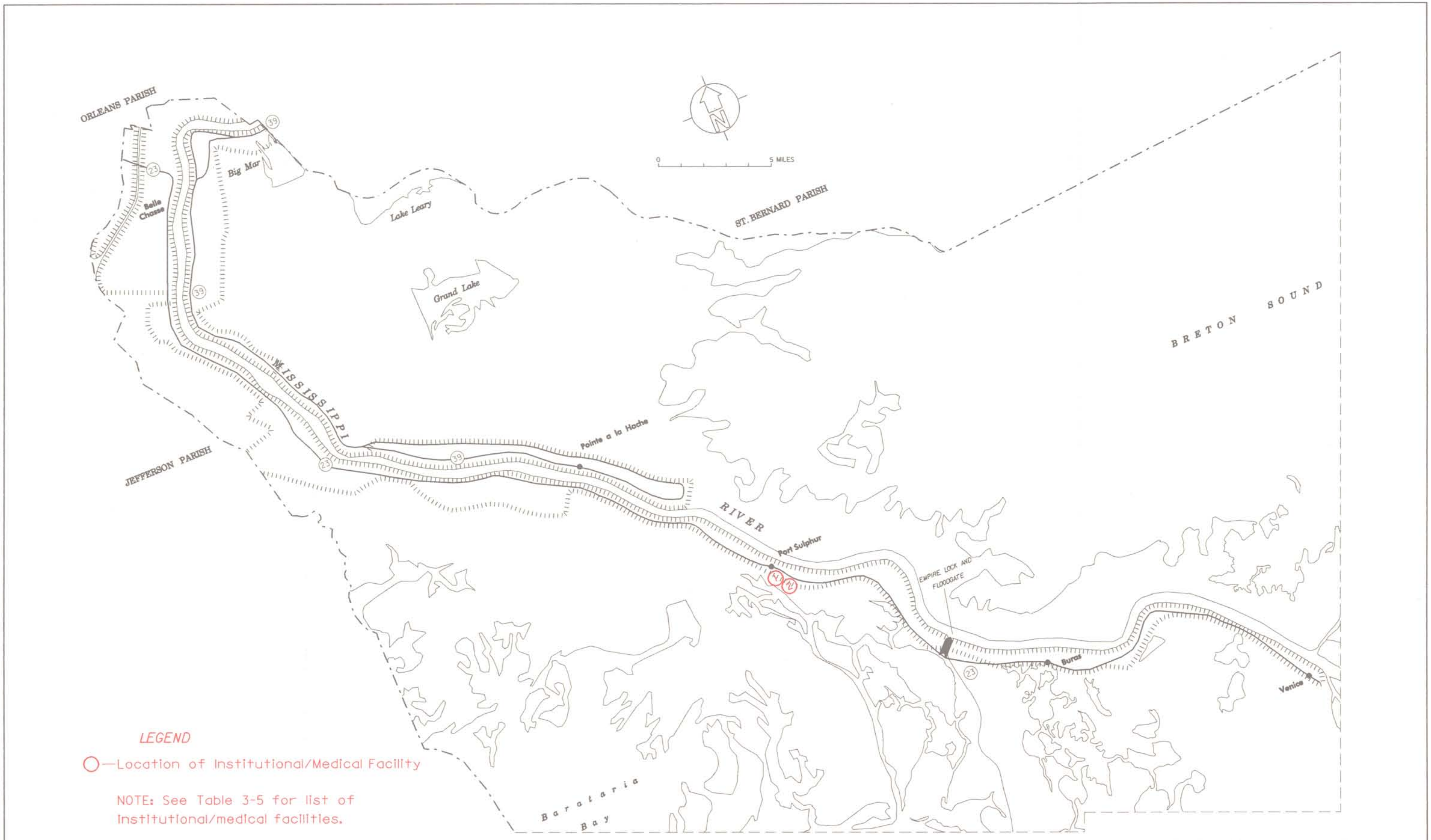
NOTE: See Table 3-2 for list of Institutional/medical facilities.

Institutional/Medical Facilities
JEFFERSON PARISH

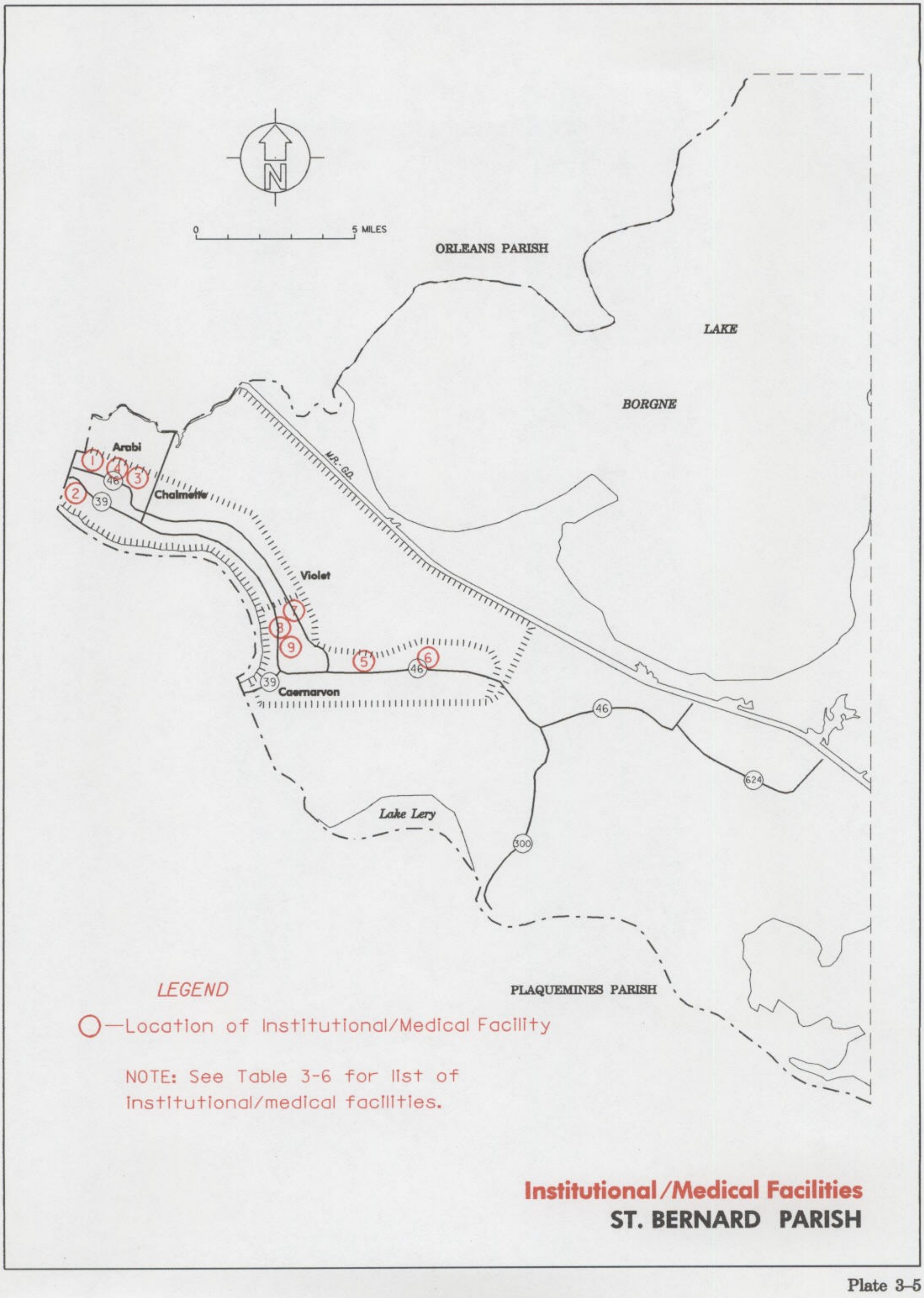

LEGEND
—Location of Institutional/Medical Facility
NOTE: See Table 3-3 for list of institutional/medical facilities.
ST. JOHN THE BAPTIST PARISH
ST. CHARLES PARISH
JEFFERSON PARISH
ST. JAMES PARISH
ASSUMPTION PARISH
TERREBONNE PARISH
Lake Salvador
Thibodaux
Larose
Golden Meadow
Bayou
Lafourche
LAROSE FLOODGATE
GOLDEN MEADOW FLOODGATE
INTRACOASTAL
GULF
WATERWAY
6 to 11
0
5 MILES
Institutional/Medical Facilities
LAFOURCHE PARISH



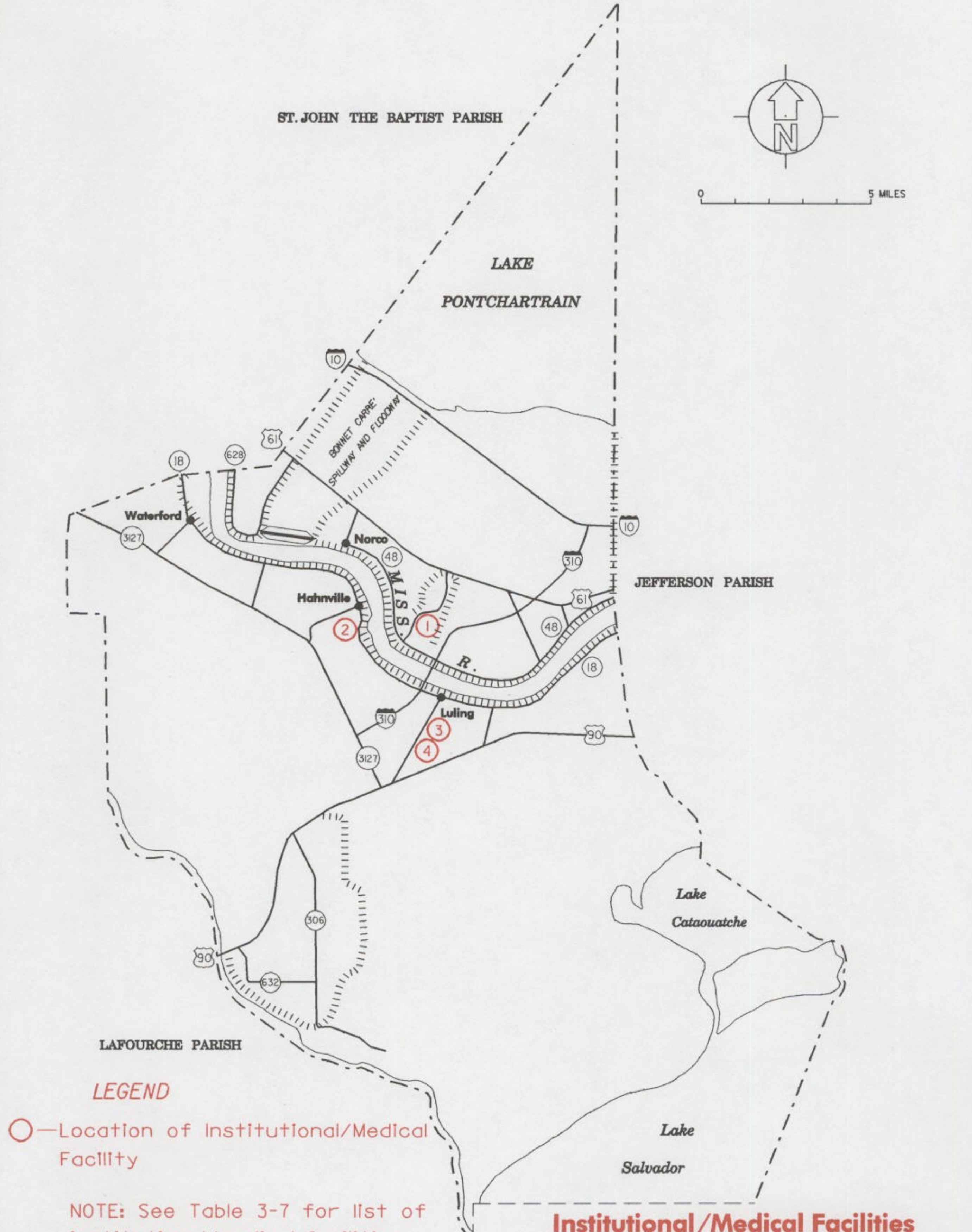
Institutional/Medical Facilities
ORLEANS PARISH



Institutional/Medical Facilities
PLAQUEMINES PARISH



Institutional/Medical Facilities
ST. BERNARD PARISH



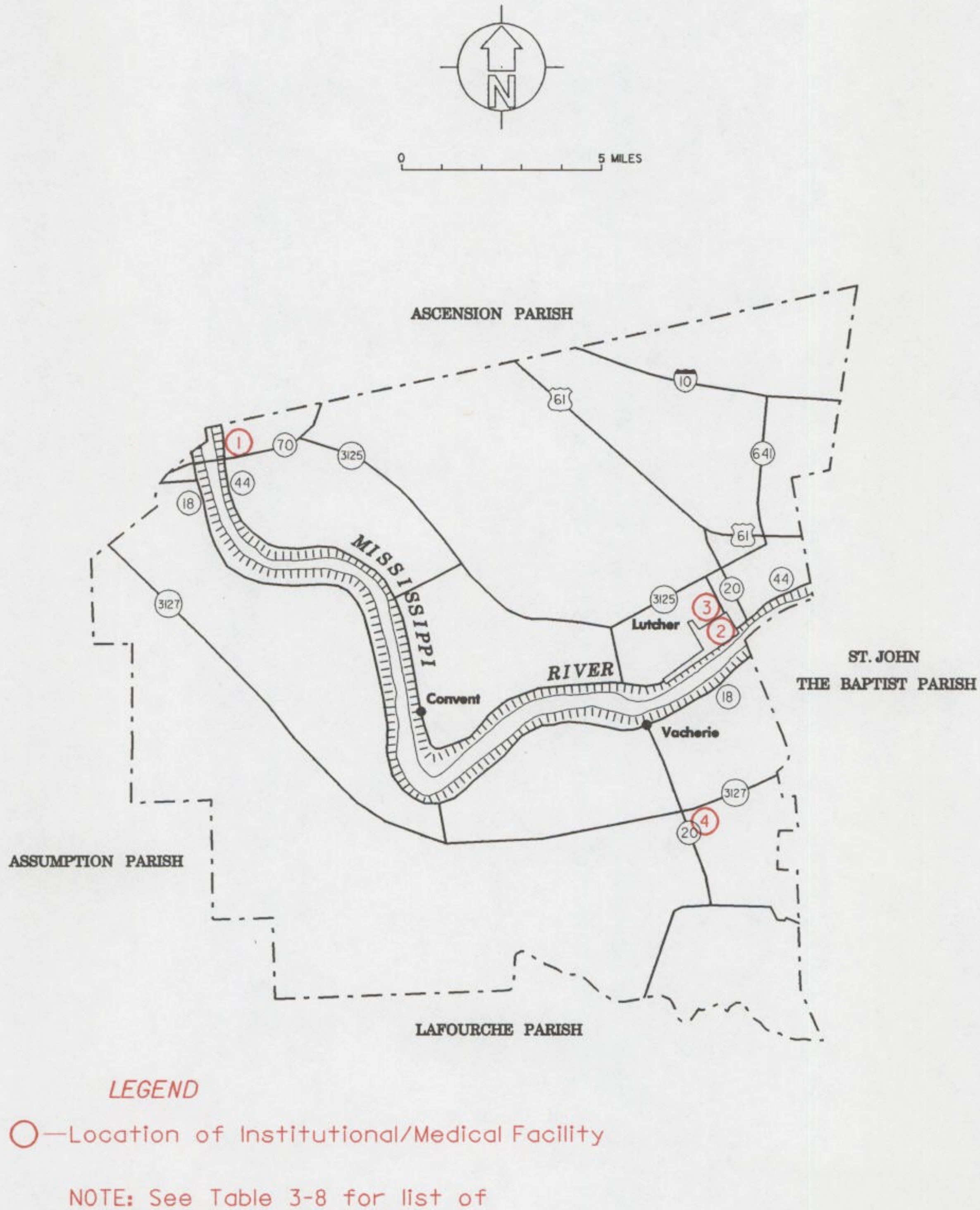
LEGEND

○—Location of Institutional/Medical Facility

NOTE: See Table 3-7 for list of institutional/medical facilities.

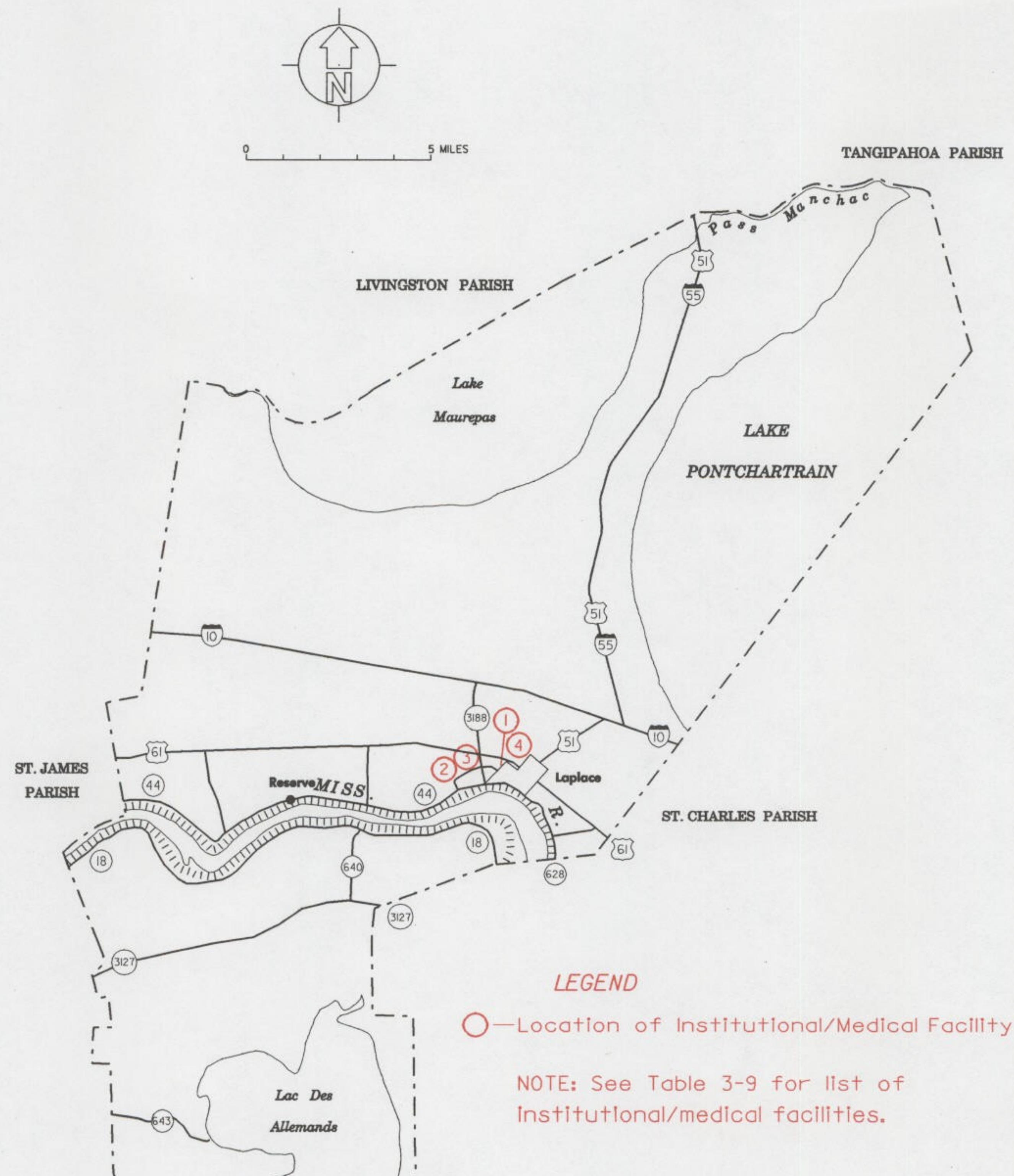
Institutional/Medical Facilities

ST. CHARLES PARISH



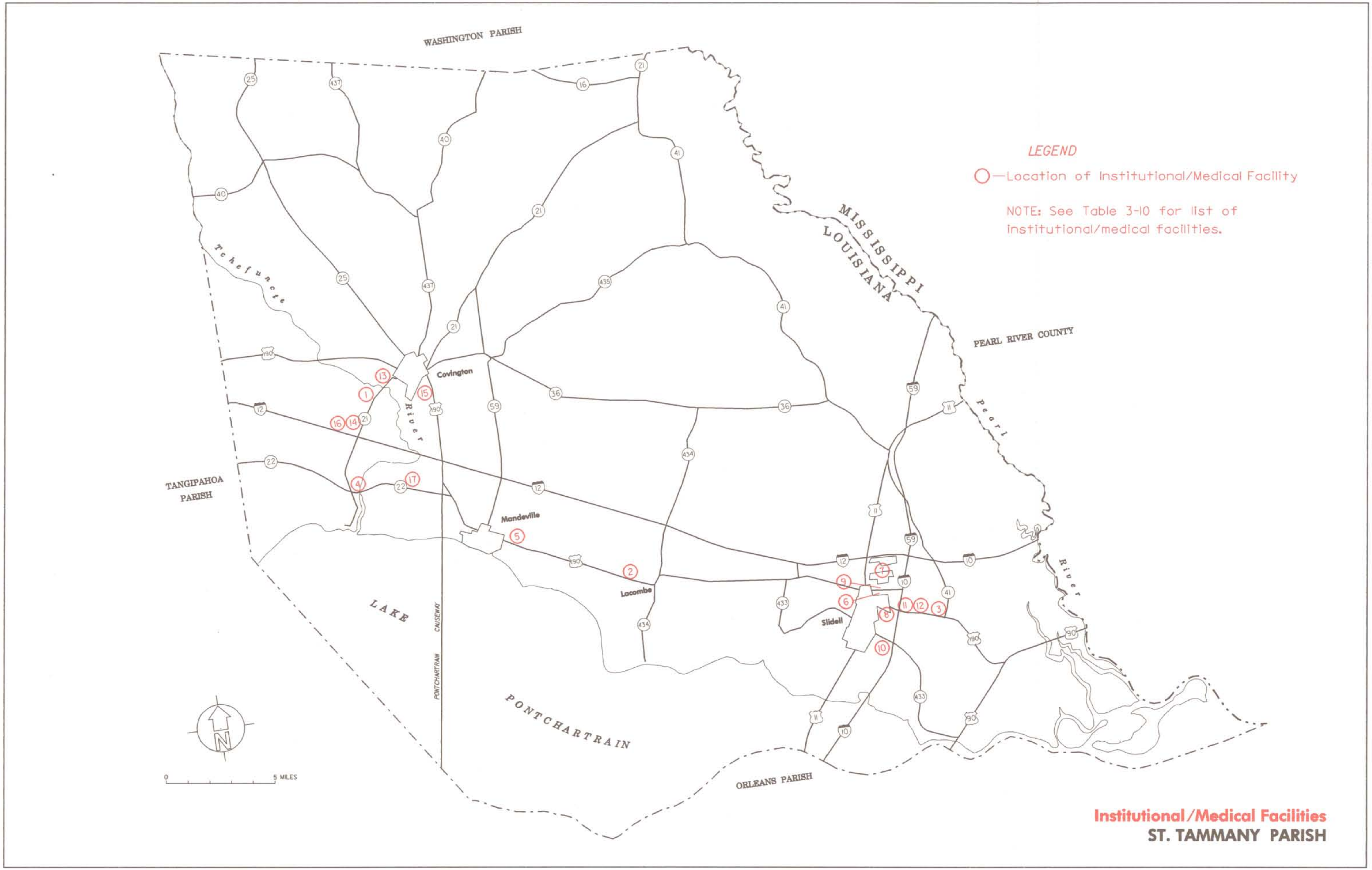
Institutional/Medical Facilities

ST. JAMES PARISH



Institutional/Medical Facilities

ST. JOHN THE BAPTIST PARISH



Institutional/Medical Facilities
ST. TAMMANY PARISH

CHAPTER FOUR

BEHAVIORAL ANALYSIS

I. PURPOSE.

The behavioral analysis is intended to provide reliable estimates of how the general public within the study area will respond to a variety of hurricane threats. These estimates include the percentages of persons in specific locations that can be expected to evacuate, when they will evacuate relative to an evacuation advisory, where they will go for shelter, and additional behavioral data which were utilized in conducting other analyses for the study.

II. OBJECTIVES.

The major objective of the Southeast Louisiana Hurricane Preparedness Study's behavioral analysis was to provide public evacuee response data for use in the shelter analysis and in the transportation analysis, and for guidance in emergency decision-making and public awareness efforts. The specific objectives of the behavioral analysis were to determine the following:

A. The percentages of the affected and non-affected population that will evacuate under a range of hurricane threat situations or in response to given evacuation orders or advisories. The term "affected population" refers to those persons residing in areas which have been determined to be vulnerable to inundation from storm surge. The affected population also refers to those persons residing in mobile homes or substandard housing which may be at risk from the high winds associated with a hurricane. The "non-affected population" is considered to be those individuals who are not threatened by storm surge or freshwater flooding and have substantial housing which affords protection against hurricane force winds. It is known that certain percentages of these individuals evacuate along with the vulnerable population and contribute to the evacuating traffic and shelter demand during a hurricane evacuation.

B. When the evacuating population will leave in relation to a given evacuation order or advisory by local officials or other persons of authority.

C. The number of vehicles that the evacuating population will utilize during a hurricane evacuation.

D. The percentage of evacuating vehicles which may be towing boats, camper trailers, or other high profile vehicles susceptible to high winds.

E. The probable destinations of the evacuating households. This data consists of percentages of the total number of evacuees utilizing public shelter locally, staying locally with friends or relatives, staying locally in a hotel/motel, or leaving the parish for out-of-region destinations.

F. How the threatened population will respond based upon forecasts of hurricane intensity, probability, or other forecast information provided during a hurricane emergency.

G. The evacuation response of tourists.

III. DATA SOURCES.

Several data sources were utilized for the Southeast Louisiana Hurricane Preparedness Study behavioral analysis. These data sources are as follows:

A. Sample Surveys. Telephone surveys of area residents were conducted to investigate likely evacuation responses under a variety of hurricane threat situations. The interview questionnaire conformed to the specific objectives to be accomplished by the study and addressed the respondents' actions in Hurricane Elena (1985). A survey was also conducted to assess residents' attitudes to vertical refuge. A copy of the questionnaire used in the survey is included as Appendix A of the Southeast Louisiana Hurricane Preparedness Study Behavioral Analysis. Copies of this report can be obtained through the U.S. Army Corps of Engineers, New Orleans District. The purpose of the telephone interviews was to provide a basis for comparing responses obtained in southeast Louisiana with those obtained elsewhere and to provide a baseline from which response forecasts could be made.

Hurricane response surveys were administered to a sample of 200 residents in the Chalmette area of St. Bernard Parish and a sample of 200 residents in the Norco area of St. Charles Parish. Residents in these communities were selected because they were located in areas ordered to evacuate during Hurricane Elena. Surveys were also administered to a sample of 100 Spanish surname residents in the Kenner area of Jefferson Parish and a sample of 100 Vietnamese residents from the Michoud and Chef Menteur areas of Orleans Parish and the Marrero and Westwego areas of Jefferson Parish. Residents in these communities were sampled to determine if there was a fundamental behavioral difference among ethnic groups in response to a hurricane threat. In addition to the four Hurricane Elena response surveys, a vertical refuge survey was conducted from a sample of 200 residents of mid-town New Orleans.

There is always some probability of error when generalizing from a sample to the larger population from which it was drawn. A sample size of 200 provides estimates which, 90 percent of the time, will be within 3 to 5 percentage points of the actual population values.

A sample size of 100 will be within 5 to 8 percentage points of the true population value 90 percent of the time. For this study, the survey data are but one component in a broader, more important methodology and provide sufficient precision for comparative purposes. The responses obtained in the sample surveys were compared to actual response patterns observed in previous hurricanes to assess whether the two are generally consistent.

B. Hypothetical Responses from Other Areas. Several thousand interviews comparable to those conducted as part of this study have been conducted as parts of hurricane evacuation studies for other coastal locations. Although hypothetical response data can hardly ever be used literally for quantitative forecasts, it is useful for comparative purposes. There are certain consistent biases in hypothetical response data and the data can be adjusted to account for these biases. Hypothetical data in one location can be compared with that collected elsewhere for an indication of relative variation between the samples. This can be particularly useful when actual response data is also available in the second location.

C. Post-Hurricane Response Studies. Post-hurricane response studies, many of which were conducted in the Gulf Coast area, were the most heavily utilized source of response data. These data are considered to be the most reliable indication of what people are most likely to do in future hurricane threats. The list of studies is large enough that a number of clear conclusions can be drawn about behavioral tendencies in a variety of hurricane threat situations. Although the studies show social variations from place to place, there are greater variations in public response between differing hurricane threats in the same location than there are between similar events in differing locations. Moreover, attempts to detect response differences along socioeconomic lines among residents of a given location have generally been inconclusive. These findings permit considerable confidence in applying conclusions drawn in one location to similar situations in another area. The list of post-hurricane response studies utilized in the Southeast Louisiana Hurricane Preparedness Study are as follows:

(1) Carla, 1961 (Moore et al., 1963)	Texas Calhoun, Galveston Baytown and Chambers Counties
(2) Camille, 1969 (Wilkinson and Ross, 1970)	Mississippi Pass Christian, Long Beach, Gulfport, Biloxi

(3) Eloise, 1975 (Windham et al., 1977) (Baker et al., 1976)	Florida Destin, Ft. Walton, Okaloosa Is., Panama City, Shalimar, Panama City Beach
(4) Frederic, 1979 (Leik, Carter and Clark, 1981) (Baker, 1980)	Mobile, Alabama Grand Isle, Louisiana Pass Christian, Mississippi Pensacola, Florida Panama City, Florida
(5) David, 1979 (Leik, Carter and Clark, 1981)	Florida Miami, Miami Beach
(6) Allen, 1980 (Baker, 1982)	Galveston, Texas
(7) Alicia, 1983 (Baker, 1984)	Galveston, Texas
(8) Diana, 1984 (Baker, 1985)	Southeastern North Carolina
(9) Elena, 1985 (Baker, 1989)	Southeastern Louisiana

IV. ANALYSIS RESULTS.

A. General. The following paragraphs address each of the specific objectives established for the behavioral analysis and present generalized results for each objective. A more detailed presentation of the results are contained in the Southeast Louisiana Hurricane Preparedness Study Behavioral Analysis.

B. Evacuation Participation Rates. Evacuation participation rates refer to the percentages of residents in high, moderate, and low risk areas that can be expected to evacuate under varying hurricane threats. Post-hurricane response studies indicate that a great amount of variation has occurred in evacuation participation from place-to-place in the same event as well as from storm-to-storm in the same location. However, generalizations can be drawn from the existing data from historic storms as well as from the sample surveys conducted for this study.

The two general overriding factors which influence whether or not residents evacuate are

(1) actions by public officials and (2) vulnerability of location. In flood prone areas near the open coast (high risk), 90 percent or more of the residents will evacuate if public officials take aggressive action in ordering an evacuation and are successful in communicating that message. Less aggressive or less successful dissemination of evacuation notices will generally result in evacuation rates closer to 80 percent in the most flood prone areas. The response rates will be somewhat lower in flood prone areas which are not along the open coast (moderate risk). If officials take aggressive action, an evacuation rate of about 80 percent can be expected. If actions are less aggressive or are not effectively communicated, rates can be expected to drop to around 60 percent. Outside of the flood prone areas (low risk) the evacuation rate is commonly 10 to 30 percent. Mobile home residents, wherever they reside, are more likely to evacuate than neighbors provided with more substantial housing.

The Hurricane Elena response surveys conducted to detect behavioral differences among ethnic groups suggest that Hispanics living in southeast Louisiana will respond to a hurricane threat in a manner similar to the general population. Based on these same response surveys, it does appear that greater effort will be required to convince the Vietnamese to respond to the threat of an approaching hurricane. For planning purposes, it would be prudent to assume that the evacuation rates among the Vietnamese will be about half that of other groups. Difficulties in disseminating evacuation notices to Vietnamese communities and the lack of experience in responding to the threat posed by an approaching hurricane are the main reasons for lower participation rates. The longer this group lives in southeast Louisiana, the more acculturated they will become and the more they will conform to social norms.

The evacuation rates observed in southeast Louisiana during Hurricane Elena, according to the response surveys, were comparable to what one would expect in relatively moderate to low risk areas. However, SLOSH model results indicate that the sample areas were at risk to flooding given an appropriate track of the storm. It does not appear that residents living in southeast Louisiana have an accurate perception of their risk to inundation from storm surge. One possible reason for these inaccurate perceptions might be the false sense of security provided by the extensive levee system. Another reason for the low participation rates was the apparent lack of an aggressive public information program. If the data collected for Hurricane Elena actually represents the pattern of perceived risk in southeast Louisiana, local officials face a considerable challenge in educating the populace on the actual distribution of risk. A breakdown of expected evacuation rates for southeast Louisiana are shown in Table 4-1. The table provides evacuation rates broken down by the intensity of the approaching storm, the success of local officials in disseminating the evacuation notice, and by the vulnerability of the area to storm surge.

TABLE 4-1

EVACUATION RATES

	STORM INTENSITY					
	Category 1		Category 3		Category 5	
	NOTICE DISSEMINATION					
	Successful	Less Successful	Successful	Less Successful	Successful	Less Successful
Surge-prone Open Coast	90%	80%+	95%+	85%+	95%+	85%+
Surge-prone Inland Areas	80%	60%+	90%	75%+	95%	80%+
River and Bayou Flood Areas	65%	30%	75%	40%	85%	50%
Non-flood Areas Near Others	15%	10%	20%	10%	30%	20%

C. Vehicle Use. The percentages of vehicle use developed for the Southeast Louisiana Hurricane Preparedness Study are based on the response surveys conducted as part of the behavioral analysis. These surveys included hypothetical responses, as well as actual percentages from the Hurricane Elena evacuation.

Evacuees do not utilize all of the vehicles available to them during an evacuation for fear of separating the family. The survey results indicate that persons living in the higher risk areas will utilize a greater percentage of the vehicles available to them than those residing in the less vulnerable areas. In southeast Louisiana the results varied from 75 percent of available vehicles in high risk areas to 65 percent in lower risk areas. These figures should be applied only to the households assumed to be evacuating, not all of the registered vehicles within the study area. Five percent of the respondents would expect to take motor homes or trailers. Survey results also indicate that up to 15 percent of residents living in the city of New Orleans are without their own transportation and would rely on public transportation for assistance in evacuating. The large number of residents reliant on public transportation could create significant problems during an evacuation and should be accounted for in the planning process. A list of the names and addresses of individuals requiring special assistance should be developed, maintained, and updated prior to each hurricane season. It should be noted that the need for special assistance can be highly variable from one community to the next and evidence suggests that many of those who claim to need outside assistance in evacuating actually receive such assistance from friends or relatives during actual evacuations. The vehicle use assumptions for southeast Louisiana are shown in Table 4-2.

TABLE 4-2

VEHICLE USE ASSUMPTIONS

Percent of Available Vehicles to Be Used in an Evacuation	
High Hazard Areas	75%
Other Areas	65%
Percent of Households Needing Public Transportation Assistance to Evacuate	
New Orleans	15%
Other Areas	2%-5%
Percent of Evacuating Households Pulling Trailers or Taking Motor Homes	< 5%

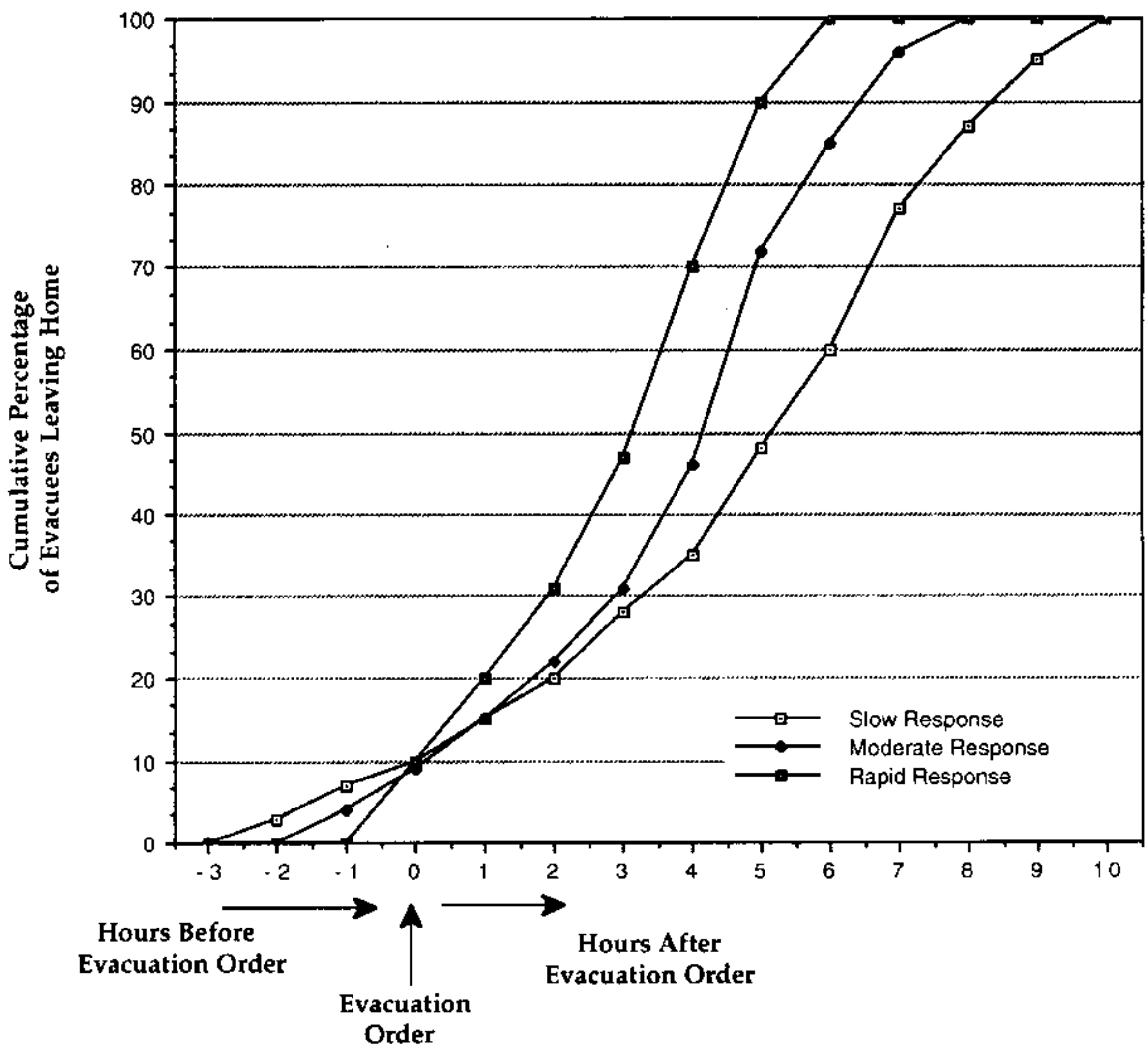
D. Evacuee Response Rates. The actual time required to complete a hurricane evacuation is not solely dependent on the number of people evacuating and the number of vehicles used. Two additional factors which effect the evacuation are (1) how quickly people respond after the notice to evacuate is given and (2) the rate at which they load the roadway system. The rate of loading is usually expressed as a response curve indicating the cumulative percentage of evacuees who had left at various times relative to the evacuation notice. Post-hurricane response studies have shown that people do not leave in significant numbers until someone in a position of authority tells them to, and evacuation timing will vary greatly from storm to storm.

Evacuation response curves based on post-hurricane surveys have shown an inherent diversity of slopes and shapes. This diversity can be primarily attributed to factors such as action by local officials, severity of the threatening hurricane, residents' perception of the probability of the hurricane striking their location, and the evacuation difficulties for their location. The primary factor consistent with most of the historic response curves is the sharp increase in evacuation response following the advice of local officials to evacuate. These increases in evacuation response following local advisements or orders show consistency regardless of location, magnitude of the threat, or information previously furnished to the threatened population in the form of hurricane watches, warnings, or other meteorological information. It should be noted that emergency managers in southeast Louisiana, may in the case of a major hurricane, need to issue evacuation orders well in advance of the hurricane watch and warnings issued by the National Weather Service.

The three most common response curves, as shown in Figure 4-1, are rapid, moderate, and slow. The rapid response curve is characteristic of a last minute and more or less desperate evacuation which is dictated by sudden changes in the storm's track. In contrast, the slow response curve is more likely to be observed in a situation in which local officials issue the evacuation notice in the morning and residents have until evening to evacuate safely. The moderate response curve falls somewhere between these two extremes. In these situations, local officials are somewhat slower in issuing the evacuation notice, but the threat is not as urgent as in the case of the rapid response.

FIGURE 4-1

EVACUATION RESPONSE CURVES

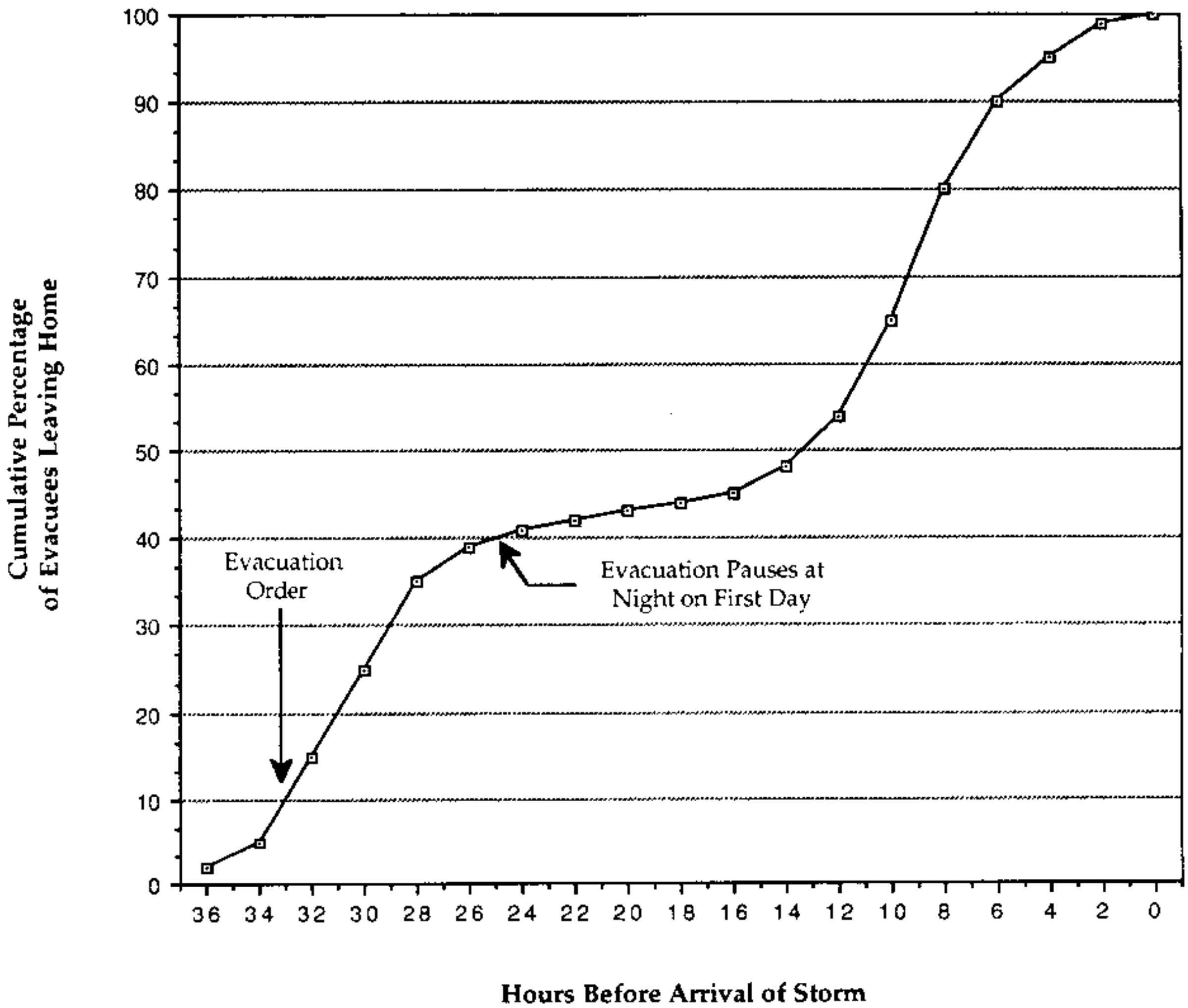


A severe hurricane threatening southeast Louisiana would require an evacuation to continue for a period of longer than 24 hours in order to evacuate the threatened population. A fourth curve, as shown in Figure 4-2, has been developed for these situations. Departures would begin soon after officials advise or order an evacuation on the first day and would increase until late that evening. The response would decrease overnight, then increase again the next morning. As circumstances vary from threat to threat, southeast Louisiana will eventually see all four response curves.

FIGURE 4-2

EARLY EVACUATION CURVE

(Extending Over Two Days)



E. Destinations of Evacuating Households. The destinations or types of refuge most commonly utilized by the evacuating population are local public shelter facilities, local friends or relatives, local hotels/motels, or out-of-parish locations. Significant variations in the percentage of persons utilizing various types of refuge can occur. Historically, this has occurred from storm to storm as well as from location to location. Based upon the array of historical response data available, the average percentages of evacuees utilizing the various types of refuge within the Southeast Louisiana Hurricane Preparedness Study area are shown in Figure 4-3.

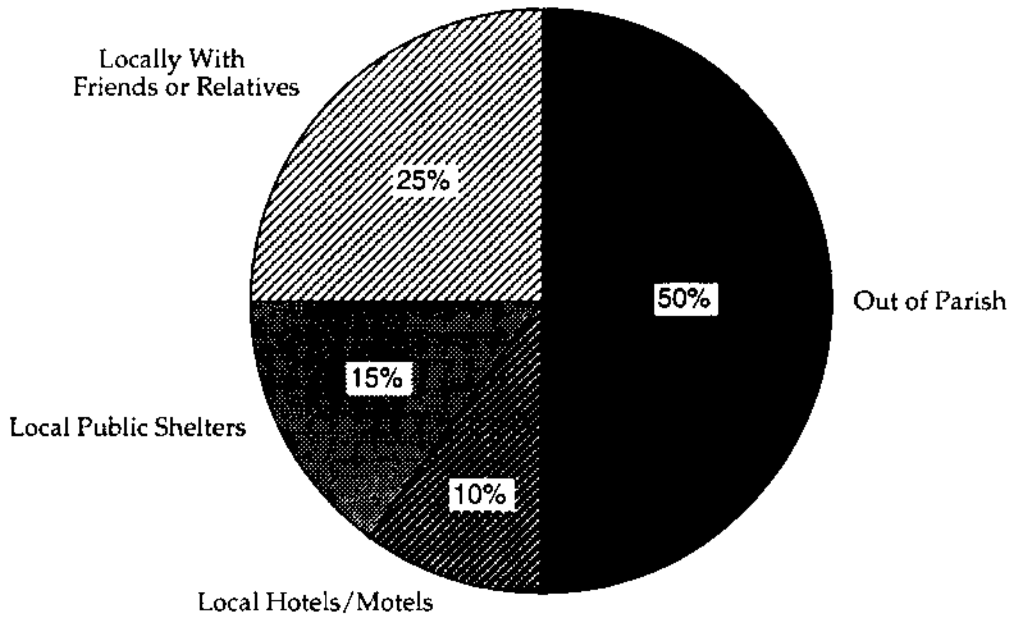


FIGURE 4-3

EVACUATION DESTINATIONS

The percentages listed above are considered to be good averages that may occur under the majority of hurricane threats; however, wide variations in these percentages have occurred on a locational as well as a storm threat basis. For example, in Hurricane Eloise (1975) it was found that 34 percent of the low risk residents utilized public shelter facilities compared to 15 percent of the residents of high risk areas. In Hurricane Frederic (1979), the highest public shelter rate occurred in Pass Christian, Mississippi, but there it was only 13 percent. Grand Isle, Louisiana, and Pensacola, Florida, both experienced only about a 2 percent public shelter use rate in Hurricane Frederic. In Hurricane Camille (1969), 31 percent of the Mississippi evacuees stayed in public shelters. The high percentage of evacuees utilizing public shelter during Hurricane Camille was probably due to the severity of the storm and the fact that many of the evacuees did not leave in sufficient time to reach out-of-county destinations.

The actions of local officials can greatly influence the sheltering rates within a parish. If, for example, public shelters are opened early and advertised, public shelter usage will most likely be significantly higher than for areas where the public is strongly advised to leave the parish or where shelter locations and availability are not widely advertised. Also, residents living in the more vulnerable coastal areas tend to utilize public shelter less than residents living further inland. Persons living in the more vulnerable locations usually evacuate earlier and have sufficient time to seek out of parish refuge.

F. Vertical Refuge. If the New Orleans area were struck by a catastrophic hurricane, the fear is that sufficient evacuation time may not be available to allow all threatened residents to leave the area. Residents living in mid-town New Orleans were sampled to determine the viability of incorporating the concept of vertical refuge into future evacuation plans. The mid-town location was chosen because residents of such seemingly low risk areas would be those least likely to leave the area. While only 20 percent of the respondents had previously heard of vertical refuge, almost twice as many claimed they had considered the possibility of vertically evacuating in the future. More than 60 percent of the respondents indicated they would actually prefer vertical refuge to leaving the area. Even more (85 percent) said they would use a vertical shelter if there was insufficient time to leave the area. On the other hand, it appears that the respondents have an unrealistic impression of what conditions would be like in vertical refuge facilities.

Vertical refuge is a concept for saving lives during a major hurricane event. Designated multistory buildings would only be opened at the last minute, when a traditional horizontal evacuation is no longer a feasible option. Vertical refuge facilities would not provide the care and amenities available at traditional public shelters; the facilities would be overcrowded (no set capacity); Red Cross personnel would not be present; and the availability of food, water, and restroom facilities would be very minimal. The potential for high winds and deteriorating weather conditions might also endanger the safety of evacuees seeking refuge in these facilities. Although vertical refuge may warrant future consideration based on the results of this survey, residents should be encouraged to leave the risk area if time permits. There are many unresolved behavioral, logistical, legal, political and structural issues that must be addressed before vertical refuge is incorporated into evacuation plans for southeast Louisiana.

G. Effect of Risk Perception. One of the most persistent findings in studies of actual hurricane evacuation behavior is that residents who perceive themselves to be at risk from the storm's effects evacuate at higher rates than those who do not perceive themselves to be at risk. Based on the findings from other studies around the Gulf and Atlantic coasts, one's perception of risk to flooding should decrease as you move farther away from water. It is also true, however, that proximity to water bodies is not always the best indicator of vulnerability to storm surge. This is especially true in southeast Louisiana where extensive systems of levees and floodwalls have been constructed to protect against hurricane surge. As a result, some of the homes very near bodies of water are as safe or safer than homes farther away. There is probably a certain amount of recognition among residents of the safety afforded by the levees and floodwalls, but this appears to have also led to a false sense of security, especially in severe hurricanes.

The results of this study indicate that the residents of southeast Louisiana are similar to other coastal residents in that their evacuation rate varies directly with the extent to which they consider themselves at risk. The problem is that they have inaccurate or not well defined risk perceptions. The most heavily relied upon source of information in evacuation decision-making by the general public is advice from local officials.

H. Evacuation Response of Tourists. Most data concerning how vacationers, tourists, and conventioneers respond to hurricane threats has been observed in beach communities. Specific responses might be different in New Orleans, but the factors which tend to be most influential are visitor characteristics, actions by hotel/motel management, and availability of options. Tourists depend heavily upon hotel management for guidance during hurricane threats, as well as upon explicit instructions from public officials. In most instances the vast majority with available transportation (90 percent) leave the threatened area and return home. During weaker storms or storms of indefinite threat, perhaps 50 percent will go a short distance away hoping to return if the storm misses. Tourists do not significantly impact public shelters (less than 10%), and they tend to leave at least as early as residents.

CHAPTER FIVE

SHELTER ANALYSIS

I. PURPOSE.

The shelter analysis serves two primary purposes. The most apparent use of the shelter analysis data is to develop the number of evacuees who will seek public shelter (shelter demand) within each parish and to determine the number of shelter spaces available for those evacuees (shelter capacity). This is referred to as the public shelter demand/capacity analysis. The total shelter capacity for each parish is subject to change with the severity of the storm and the availability of suitable facilities. This is especially apparent in southeast Louisiana where a majority of the shelters are subject to inundation from a category 4 or category 5 hurricane.

The second, and less apparent, purpose of the shelter analysis is to provide information for use in determining evacuation clearance times in the transportation analysis. A thorough discussion of the methodology involved in determining clearance times is found in Chapter 6.

The shelter analysis presents inventories, capacities, shelter demand, and the potential vulnerability of public shelters within the Southeast Louisiana Hurricane Preparedness Study area. Data developed in the hazards, vulnerability, and behavioral analyses were used in this shelter analysis. It should be noted that shelters listed in this report have only been identified as potential shelter facilities. The selection of evacuation shelters in response to a given threat is a decision made by both the American Red Cross and parish emergency management officials. Shelter vulnerability, potential shelter demand and the availability of qualified personnel to manage the facilities are all considerations that must be taken into account prior to the opening of a specific shelter. Additionally, available shelter space will change as buildings are constructed or demolished, as ownership changes, and as agreements are reached or cancelled with building owners and the American Red Cross.

II. SHELTER ANALYSIS.

A. General. The list of public shelters used in the analysis was developed through coordination with the American Red Cross and emergency management officials within each parish. The first step in determining shelter vulnerability was to establish the first floor elevation for each public shelter. The elevations were obtained, where available, through a review of construction drawings at local school boards. The elevations of many of the older structures were referenced to local geographic features and not to a datum of known elevation. Surveys were conducted to establish the first floor elevation of these shelters as well as shelters where the elevation obtained was inconsistent with other elevations in the area. This resulted in actual surveys being conducted on over 70 percent of the shelters within the study area. First floor elevations were also compared to ground elevations obtained from U.S. Geological Survey quadrangle maps. Shelter vulnerability was then determined by comparing first floor elevations to the potential surge heights developed in the hazards analysis.

The levees and floodwalls which have been constructed throughout southeast Louisiana are designed to protect low lying urban areas from hurricane surge. Pumping stations have also been constructed to maintain interior drainage within these leveed areas. Although designed to provide substantial levels of protection, these levees and floodwalls are subject to overtopping during catastrophic events. The surge inundation maps show that for slow moving category 3, category 4, or category 5 storms, only those reaches of St. Tammany Parish located north of I-12 would be outside of the potential limits of storm surge. Most of the shelters within the study area have been identified as being at risk to flooding from the surge produced by a catastrophic event. The American Red Cross and parish emergency management officials should carefully consider the intensity of the approaching hurricane and the vulnerability of each shelter before a decision is made on which shelters to open.

B. Selection Criteria. The American Red Cross published guidelines for the selection of hurricane evacuation shelters in July 1992. These guidelines were prepared by an interagency group and reflect the application of technical data compiled in previous hurricane evacuation studies, other hazard information, and research findings related to wind loads and structural problems. These guidelines are intended to supplement information contained in *ARC 3031, Mass Care: Preparedness and Operations*. The guidelines recommend shelter locations be selected based on a careful review of the surge inundation maps. All shelters should be located outside of category 4 surge inundation zones and locations subject to isolation by storm surge should be avoided. The guidelines also recommend avoiding shelters located in areas vulnerable to rainfall flooding. It is important to note that these are only guidelines prepared to assist in evaluating the suitability of a building or facility for use as a hurricane evacuation shelter. Exceptions to these guidelines should be considered on a case by case basis with the safety of the evacuees as the primary consideration.

In addition to avoiding locations vulnerable to hurricane surge, the guidelines also suggest that public shelters be certified as being capable of withstanding wind loads according to ASCE (American Society of Civil Engineers) 7-88 or ANSI (American National Standards Institute) A-58 structural design criteria. In the absence of certification by a structural engineer, any facility selected for use as a hurricane evacuation shelter must be in compliance with all local building and fire codes. Assessing the vulnerability of shelters to the effects of winds from hurricanes was beyond the scope of this study and the publication of these guidelines occurred after the shelter analysis had been completed.

Further analyses would be required by structural engineers to determine the integrity of the shelters and to certify them as being able to withstand hurricane force winds.

C. Shelter Inventories, Capacities, and Vulnerability. Tables 5-1 through 5-9 list the public shelters, capacities, and potential vulnerability to storm surge by parish for each of the seven storm scenarios developed for the Southeast Louisiana Hurricane Preparedness Study. A description of the parameters of each scenario as defined by the Saffir/Simpson Hurricane Scale is provided in Chapter 2. When using the information contained in these tables to evaluate the safety of a shelter, inaccuracies in hurricane forecasting and modeling should be taken into account. First floor elevations should be carefully compared to potential surge heights before a decision is made to use a particular facility as a public shelter. Only those shelters listed in Tables 5-1 through 5-9 have been evaluated for flood vulnerability. If additional facilities are selected for use as hurricane shelters, flood vulnerability surveys should be performed. The locations of public shelters which have been identified within the study area are shown on a parish by parish basis on Plates 5-1 through 5-9. The shelters listed in Tables 5-1 through 5-9 are identified by a number which corresponds to the location of the shelters shown on Plates 5-1 through 5-9.

III. PUBLIC SHELTER DEMAND/CAPACITY.

A. General. Results of the Southeast Louisiana Hurricane Preparedness Study behavioral analysis were used in determining potential shelter demand for a variety of hurricane scenarios. The shelter capacities used in the analysis were developed by the American Red Cross and parish emergency management officials.

B. Public Shelter Demand. Table 5-10 shows the public shelter demand (number of evacuees seeking public shelter) resulting from each evacuation scenario. The analysis is based on the percentage of evacuees who would likely utilize public shelter facilities in the event of an evacuation. The percentages were developed in the behavioral analysis and are based on an adequate warning period for an approaching hurricane and sufficient public knowledge concerning the locations and availability of public shelter facilities. Other assumptions used in developing the total number of evacuees and public shelter demand are as follows:

1. Local officials will educate the public as to hurricane vulnerability and take strong action to evacuate as storms threaten the area.

2. Participation rates of those residing in surge flooded zones were varied depending on the zone's proximity to significant flooding and depending on the assumed storm intensity.

3. Eighty to ninety-five percent of the residents living in flood-prone areas near the open coast will evacuate.

4. Evacuation rates in areas not along the open coast but subject to storm surge flooding will vary from sixty to eighty percent.

5. Non-flood prone areas will experience evacuation rates from ten to thirty percent.

6. Evacuation rates among mobile home residents will vary from eighty to ninety-nine percent depending on location and storm intensity.

7. Less than ten percent of the evacuees from areas along the open coast will utilize public shelter facilities.

8. Residents living in moderate to low risk areas will utilize public shelter facilities at a rate of ten to thirty percent.

C. Public Shelter Capacity. Most of the public shelter facilities within the study area are at risk to flooding from the surge produced by a slow moving category 3, category 4, or category 5 hurricane. Public shelter facilities at risk to flooding were assumed to have zero capacity for the scenarios which produced a storm surge capable of inundating the facility. The depth of flooding within a facility or the availability of a second or third floor were not considered for the purposes of this study. The total shelter capacity of the study area therefore decreases as the storm intensity increases.

D. Public Shelter Demand/Capacity Analysis. The results of the public shelter demand/capacity analysis are shown in Table 5-10. The table contains public shelter demand and capacity for each parish within the study area for each of the previously developed evacuation scenarios. Public shelter demand is directly related to the vulnerable population, as the storm intensity increases so does the demand for public shelters. The public shelter capacity, however, decreases with increasing storm intensity. This creates a severe lack of public shelter facilities within the study area for the upper categories of storms. The public shelter deficit for a slow moving category 3, category 4 or category 5 hurricane could potentially exceed 160,000. Those not able to find shelter space within the study area would be forced to seek shelter outside of the study area. This would place a tremendous strain on the host parishes/counties. A lack of adequate public shelter space within the study area could result in confusion among the evacuees and lead to problems endangering the overall effectiveness of the entire evacuation. Regional planning is needed to address the potential lack of shelter space and to develop alternative sheltering plans.

TABLE 5-1
PUBLIC SHELTER FACILITIES
JEFFERSON PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
01	McDonogh No. 26 School	625	5.6	Dry	Dry	8	8	14	15	23
02	Archbishop Blenk High School	850	1.2	Dry	Dry	7	7	14	15	23
03	P. J. Solis Elementary	300	-1.4	Dry	Dry	8	8	14	15	23
04	Gretna Jr. High School	456	-2.8	Dry	Dry	8	8	14	15	23
05	St. Rita's School	350	11.9	Dry	Dry	Dry	Dry	14	Dry	24
06	West Jefferson High School	925	5.4	Dry	Dry	8	8	14	15	23
07	St. Matthew the Apostle	115	6.6	Dry	Dry	Dry	Dry	14	4	24
08	Riverdale High School	1300	9.2	Dry	Dry	Dry	Dry	14	4	24
09	G. T. Woods Elementary	300	-4.3	Dry	Dry	Dry	Dry	14	4	24
10	Stephen J. Barbre Middle School	250	7.7	Dry	Dry	Dry	Dry	15	4	25
11	St. Lawrence the Martyr	100	-0.7	Dry	Dry	Dry	Dry	14	4	24
12	St. Clement of Rome	200	-2.7	Dry	Dry	Dry	Dry	14	4	22
13	Bonnabel High School	800	0.0	Dry	Dry	Dry	Dry	14	4	24
14	Audubon Elementary	300	-3.5	Dry	Dry	Dry	Dry	14	4	23
15	Lincoln Elementary School	338	5.8	Dry	Dry	8	9	14	15	23
16	Woodmere Elementary	329	2.3	Dry	Dry	8	9	14	15	23
17	Marrero Middle School	350	5.7	Dry	Dry	8	9	14	15	23
18	John Ehret High School	660	0.8	Dry	Dry	8	9	14	15	23
19	L. W. Higgins High School	465	4.2	Dry	Dry	8	9	14	15	23
20	Archbishop Shaw High School	400	3.7	Dry	Dry	8	9	14	15	24

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-1
PUBLIC SHELTER FACILITIES
JEFFERSON PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
21	Vernon Haynes High School	400	6.8	Dry	Dry	Dry	Dry	14	4	23
22	J. D. Meisler Jr. High	250	-2.4	Dry	Dry	Dry	Dry	14	4	23
23	Archbishop Rummel	500	0.2	Dry	Dry	Dry	Dry	14	4	23
24	Ella Delhonde Elementary	450	5.6	Dry	Dry	Dry	Dry	14	4	23
25	St. Agnes	280	6.2	Dry	Dry	Dry	Dry	14	4	23
26	St. Catherine of Sienna	300	4.5	Dry	Dry	Dry	Dry	14	4	23
27	East Jefferson High School	250	2.0	Dry	Dry	Dry	Dry	14	4	23
28	Grace King High School	500	-2.2	Dry	Dry	Dry	Dry	14	4	23
29	St. Ann's	110	-3.1	Dry	Dry	Dry	Dry	14	4	23
30	Chateau Estates Elementary	200	-2.7	Dry	Dry	Dry	Dry	14	4	23
31	St. Philip Neri	120	-1.4	Dry	Dry	Dry	Dry	14	4	23
32	St. Angela Merici	555	-0.6	Dry	Dry	Dry	Dry	14	4	23
33	T. H. Harris Jr. High	400	-0.6	Dry	Dry	Dry	Dry	14	4	24
34	Our Lady of Divine Providence	200	-0.6	Dry	Dry	Dry	Dry	15	4	24
35	All Saints Episcopal Church	120	9.1	Dry	Dry	Dry	Dry	15	4	24
36	John Curtis	275	6.6	Dry	Dry	Dry	Dry	15	4	24
37	Stella Worley Jr. High School	300	2.8	Dry	Dry	8	9	14	15	24
38	Westwego Elementary School	214	4.5	Dry	Dry	8	9	14	15	24
39	Live Oak Manor Elementary	150	12.3	Dry	Dry	Dry	Dry	14	15	24
40	Deckbar Special School	200	6.5	Dry	Dry	Dry	Dry	14	4	23

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-2
PUBLIC SHELTER FACILITIES
LAFOURCHE PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	L. C. O. Jr. High School	300	7.1	Dry	Dry	9	12	12	15	18
02	Chackbay Elementary School	200	2.0	Dry	Dry	3	Dry	11	7	20
03	Larose Civic Center	500	6.3	Dry	5	8	12	12	15	18
04	Larose Middle School	300	7.1	Dry	Dry	8	12	12	15	18
05	Larose Lower Elementary	300	6.5	Dry	4	9	12	12	15	18
06	Lockport Jr. High	400	10.4	Dry	Dry	9	10	12	15	19
07	Raceland Jr. High	400	10.2	Dry	Dry	5	Dry	11	9	19
08	Central Lafourche High	300	14.3	Dry	Dry	9	9	12	14	19
09	East Thibodaux Jr. High	400	13.0	Dry	Dry	Dry	Dry	12	13	20
10	South Thibodaux Elementary	400	13.1	Dry	Dry	Dry	Dry	12	13	20
11	Thibodaux Civic Center	500	11.4	Dry	Dry	Dry	Dry	11	7	20
12	Lafarque Elementary School	300	11.0	Dry	Dry	Dry	Dry	12	13	20
13	Nicholls St. Student Union	500	15.6	Dry	Dry	Dry	Dry	11	13	20
14	West Thibodaux Jr. High	300	14.9	Dry	Dry	Dry	Dry	11	13	19

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-3
PUBLIC SHELTER FACILITIES
ORLEANS PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
01	L. B. Landry High School	1250	3.8	Dry	Dry	7	7	14	15	23
02	St. Anthony of Padua	750	1.4	Dry	Dry	Dry	Dry	13	1	23
03	All Saints School	250	3.8	Dry	Dry	7	7	14	15	23
04	McDonogh 42 Elem. School	1000	1.8	Dry	Dry	Dry	Dry	13	1	22
05	Corpus Christi School	1000	0.8	Dry	Dry	Dry	Dry	13	1	22
06	St. Augustine High School	750	2.2	Dry	Dry	Dry	Dry	13	1	22
07	O. P. Walker High School	1000	4.6	Dry	Dry	7	7	14	15	23
08	Live Oak Jr. High School	500	7.3	Dry	Dry	Dry	Dry	13	Dry	24
09	Johnson Lockett Elem. School	1250	-3.0	Dry	Dry	Dry	Dry	13	2	22
10	George Washington Elementary School	1000	3.3	Dry	Dry	Dry	Dry	13	2	22
11	F. T. Nicholls High School	1000	5.5	Dry	Dry	Dry	Dry	13	2	22
12	Gentilly Terrace	1250	1.0	Dry	Dry	Dry	Dry	13	1	21
13	Jackson Elementary	250	7.0	Dry	Dry	Dry	Dry	13	Dry	24
14	Xavier Prep School	750	8.4	Dry	Dry	Dry	Dry	13	Dry	24
15	Sarah Reed School	1500	0.6	Dry	Dry	Dry	Dry	8	15	21
16	Abramson High School	2000	-1.4	Dry	Dry	Dry	Dry	8	15	20
17	St. Raphael	1250	-4.3	Dry	Dry	Dry	Dry	13	1	21
18	Alcee Fortier High School	1000	4.0	Dry	Dry	Dry	Dry	13	Dry	24
19	Livingston Middle School	600	-2.8	Dry	Dry	Dry	Dry	8	15	21
20	St. Dominic School	1250	-1.8	Dry	Dry	Dry	Dry	13	1	22

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-3
PUBLIC SHELTER FACILITIES
ORLEANS PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario 1	2	3	4	5	6	7
21	Southern University	1500	-3.0	Dry	Dry	Dry	Dry	13	1	21
22	St. Rita School	1000	2.1	Dry	Dry	Dry	Dry	13	1	24
23	Martin Behrman Middle School	750	6.9	Dry	Dry	7	7	14	15	23
24	Warren Easton	1000	-0.1	Dry	Dry	Dry	Dry	13	1	22
25	Gayarre Elementary	750	0.5	Dry	Dry	Dry	Dry	13	2	22
26	Allen Elementary	500	4.1	Dry	Dry	Dry	Dry	13	1	24

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-4
PUBLIC SHELTER FACILITIES
PLAQUEMINES PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Belle Chasse Middle School	400	7.6	Dry	8	10	13	14	18	23
02	Belle Chasse High School	1000	4.7	Dry	Dry	8	8	14	15	23
03	Naval Air Station	1000	0.5	Dry	Dry	8	9	14	15	23
04	Woodlawn Office Building	100	10.6	Dry	Dry	16	17	20	23	26
05	Belle Chasse Auditorium	225	7.9	Dry	Dry	8	8	14	15	23

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-5
PUBLIC SHELTER FACILITIES
ST. BERNARD PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Arabi Elementary	271	6.2	Dry	Dry	Dry	Dry	16	16	22
02	St. Claude Heights	315	2.3	Dry	Dry	Dry	Dry	16	16	22
03	Lacoste Elementary School	456	7.5	Dry	Dry	Dry	Dry	16	16	22
04	Chalmette High School	1542	7.1	Dry	Dry	Dry	Dry	16	16	22
05	Andrew Jackson High School	1264	4.1	Dry	Dry	Dry	Dry	16	16	22
06	Chalmette Middle School	537	3.6	Dry	Dry	Dry	Dry	16	16	22
07	Meraux Elementary School	246	4.8	Dry	Dry	Dry	Dry	16	16	22
08	St. Bernard High School	1045	7.2	Dry	Dry	Dry	Dry	17	20	24

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-6
PUBLIC SHELTER FACILITIES
ST. CHARLES PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Hahnville High School	500	6.0	Dry	Dry	8	7	13	12	22
02	Harry M. Hurst Middle School	350	11.6	Dry	Dry	10	Dry	15	11	25
03	New Destrehan High School	500	7.8	Dry	Dry	10	Dry	15	11	25
04	J. B. Martin School	350	3.0	Dry	Dry	8	7	13	12	22

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-7
PUBLIC SHELTER FACILITIES
ST. JAMES PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	St. Michael's Hall	100	18.0	Dry	Dry	10	Dry	19	11	30
02	Romeville Elementary	300	22.1	Dry	Dry	11	Dry	19	11	30
03	Gramercy Elementary	300	11.4	Dry	Dry	10	Dry	17	10	30
04	Sacred Heart Catecathical Center	100	13.1	Dry	Dry	10	Dry	17	10	30
05	Lutcher Jr. High School	400	11.2	Dry	Dry	10	Dry	17	10	30
06	Lutcher High School	500	14.0	Dry	Dry	10	Dry	17	10	30
07	Chanel Cafetorium	300	17.5	Dry	Dry	10	Dry	18	10	30
08	Paulina Elementary	300	17.7	Dry	Dry	10	Dry	18	10	30
09	St. James High School	500	17.0	Dry	Dry	Dry	Dry	13	Dry	23
10	Fifth Ward Elementary	300	12.9	Dry	Dry	Dry	Dry	14	Dry	23
11	Vacherie Elementary	300	6.2	Dry	Dry	5	Dry	12	7	23
12	St. James Jr. High	300	19.5	Dry	Dry	Dry	Dry	13	Dry	24
13	Our Lady of Peace Church Hall	150	11.4	Dry	Dry	5	1	12	7	23
14	West Bank Reception Hall	200	17.5	Dry	Dry	Dry	Dry	12.5	7	24

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-8
PUBLIC SHELTER FACILITIES
ST. JOHN THE BAPTIST PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	West St. John High School	500	6.2	Dry	Dry	6	Dry	13	8	24
02	West St. John Elementary (Edgard)	275	15.7	Dry	Dry	Dry	Dry	13	8	24
03	Garyville Elementary	250	8.7	Dry	Dry	10	8	16	10	29
04	Sixth Ward Elementary	250	10.6	Dry	Dry	10	8	16	10	29
05	Leon Godchaux Jr. High	700	14.5	Dry	Dry	9	Dry	15	10	29
06	East St. John High School	500	5.7	Dry	Dry	10	8	15	12	27
07	John L. Ory	700	15.0	Dry	Dry	10	8	15	12	26
08	Laplace Elementary	900	10.2	Dry	Dry	10	8	15	Dry	26

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-9
PUBLIC SHELTER FACILITIES
ST. TAMMANY PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
01	Abita Springs Jr. HIgh	500	26.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
02	Fifth Ward Jr. High	500	75.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
03	William Pitcher Jr. High	500	24.2	Dry	Dry	Dry	Dry	Dry	Dry	21
04	Covington Special Education	500	22.4	Dry	Dry	Dry	Dry	Dry	Dry	21
05	Folsom Elementary	500	150.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
06	Folsom Jr. High	500	150.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
07	Bayou Lacombe Jr. High School	1000	16.5	Dry	Dry	9	11	13	15	20
08	Chahta-Ima School	1000	17.1	Dry	Dry	9	11	13	15	20
09	Lee Road Jr. High	500	98.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
10	Madisonville Jr. High	500	10.2	Dry	7	9	12	14	16	21
11	Mandeville Jr. High	500	10.7	Dry	7	9	11	13	15	20
12	Pearl River High	2000	31.0	Dry	Dry	Dry	Dry	Dry	Dry	Dry
13	Sixth Ward Jr. High	1000	54.7	Dry	Dry	Dry	Dry	Dry	Dry	Dry
14	Slidell Jr. High	2000	11.5	Dry	8	10	14	14	18	23
15	St. Tammany Jr. High	2000	5.9	Dry	8	10	14	14	18	23
16	Brock Elementary	1500	7.3	Dry	8	10	14	14	18	22
17	Aldersgate United Methodist Church	50	22.2	Dry	8	10	14	14	19	24
18	Bonne Ecole Elementary School	2000	15.1	Dry	8	10	14	14	19	23
19	Slidell High School	2000	12.6	Dry	8	10	14	14	19	23
20	Florida Avenue Elementary School	1000	11.4	Dry	8	10	14	14	19	23

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-9
PUBLIC SHELTER FACILITIES
ST. TAMMANY PARISH, LOUISIANA

Map Key	Facility	Capacity	First Floor Elevation	Potential Surge Heights for Each Scenario						
				1	2	3	4	5	6	7
21	Carolyn Park Middle School	1000	12.3	Dry	8	10	14	14	19	23
22	Boyet Jr. High School	2000	8.9	Dry	8	10	15	15	20	25

Elevations referenced in feet NGVD
Scenario 1 = All Category 1 Storms
Scenario 2 = Fast moving Category 2 Storms
Scenario 3 = Slow moving Category 2 Storms
Scenario 4 = Fast moving Category 3 Storms
Scenario 5 = Slow moving Category 3 Storms
Scenario 6 = Fast moving Category 4 Storms
Scenario 7 = Slow moving Category 4 Storms and all Category 5 Storms

TABLE 5-10

PUBLIC SHELTER DEMAND/CAPACITY STATISTICS

Parish	Storm Scenario	Public[1] Shelter Demand	Public[2] Shelter Capacity
Jefferson	Category 1/Fast Category 2	4,920	15,187
	Fast Category 3	27,440	8,975
	Slow Category 2	39,100	8,975
	Fast Category 4	46,800	4,040
	Slow Category 3-4/Category 5	56,000	0
Lafourche	Category 1/Fast Category 2	3,620	5,100
	Fast Category 3	6,615	3,700
	Slow Category 2	7,115	3,500
	Slow Category 3/Category 4-5	10,860	2,400
Orleans	Category 1/Fast Category 2	2,250	25,100
	Slow Category 2/Fast Category 3	6,800	21,850
	Fast Category 4	50,000	7,750
	Slow Category 3-4/Category 5	65,000	0
Plaquemines	Category 1/Fast Category 2	2,615	2,725
	Slow Category 2/Category 3-5	3,600	0
St. Bernard	Category 1-2/Fast Category 3	2,415	5,676
	Slow Category 3/Category 4-5	9,000	0
St. Charles	Category 1/Fast Category 2	1,045	1,700
	Fast Category 3	3,400	850
	Slow Category 2	4,055	350
	Slow Category 3/Category 4-5	5,610	0
St. James	Category 1/Fast Category 2		4,050
	Fast Category 3	565	4,050
	Slow Category 2/Fast Category 4	1,090	3,750
	Slow Category 3	1,865	1,300
	Slow Category 4/Category 5	2,690	0
St. John the Baptist	Category 1/Fast Category 2	850	4,075
	Fast Category 3	1,670	3,575
	Slow Category 2/Fast Category 4	2,450	2,825
	Slow Category 3-4/Category 5	4,700	0

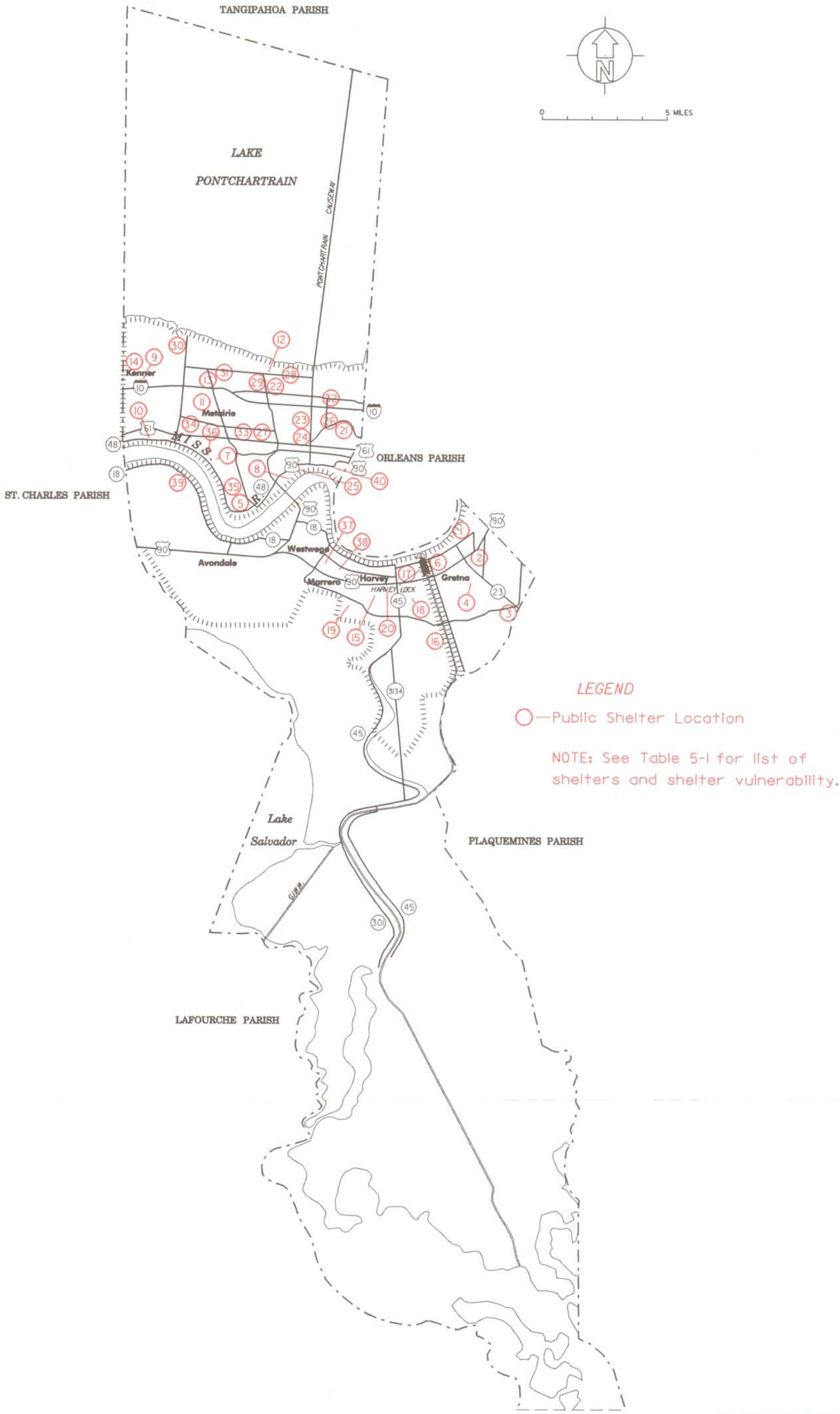
TABLE 5-10 (continued)

PUBLIC SHELTER DEMAND/CAPACITY STATISTICS

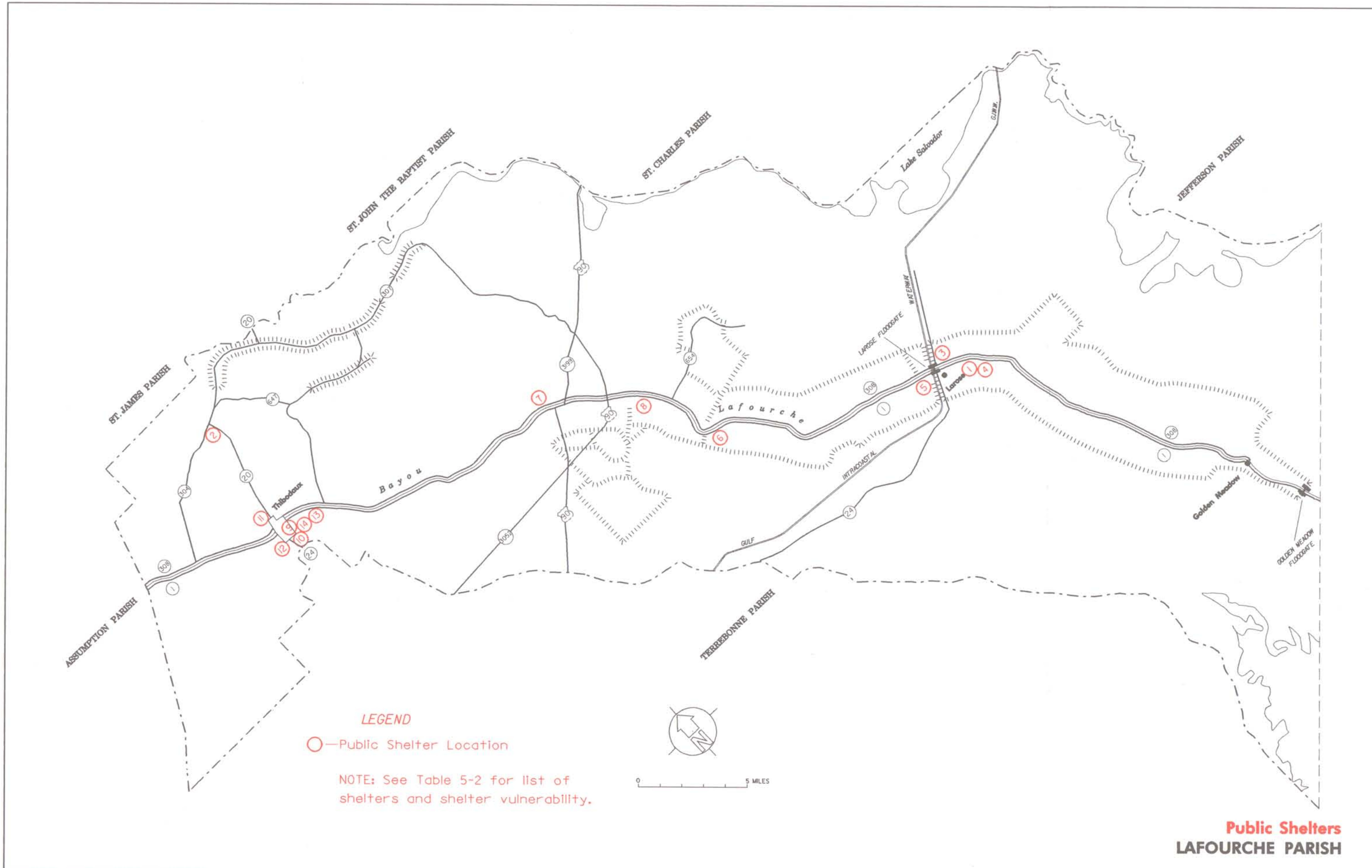
Parish	Storm Scenario	Public[1] Shelter Demand	Public[2] Shelter Capacity
St. Tammany	Category 1/Fast Category 2	4,045	23,100
	Slow Category 2/Fast Category 3	8,035	17,550
	Slow Category 3/Fast Category 4	11,250	10,550
	Slow Category 4/Category 5	13,985	6,500

(1) Figures are based on applying suggested planning assumptions outlined in the behavioral analysis by which suggests that participation rates, destination percentages, and vehicle usage rates be varied by evacuation zone depending on a zone's vulnerability to flooding and socioeconomic characteristics.

(2) Capacity of recognized Red Cross shelters.

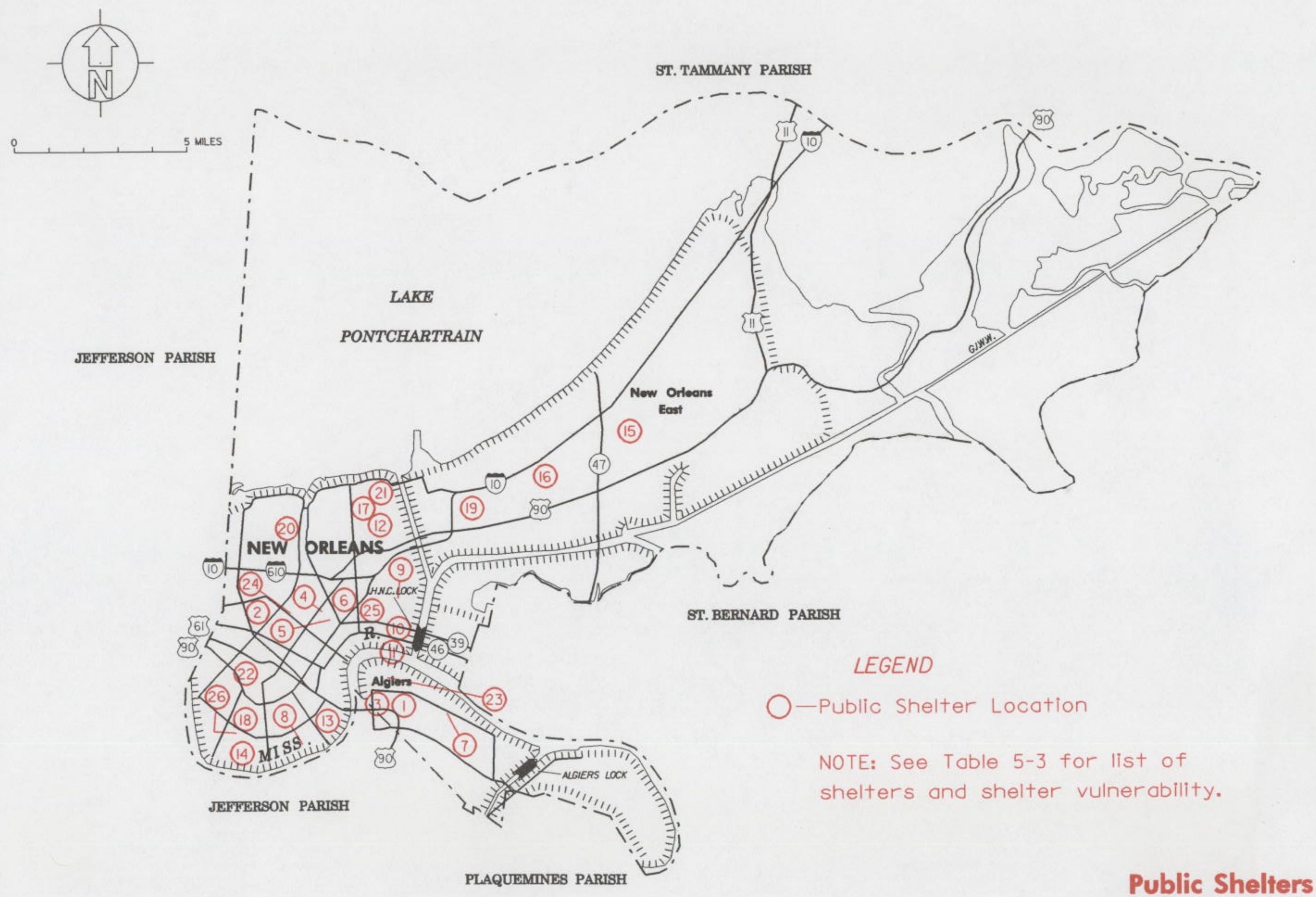


Public Shelters
JEFFERSON PARISH

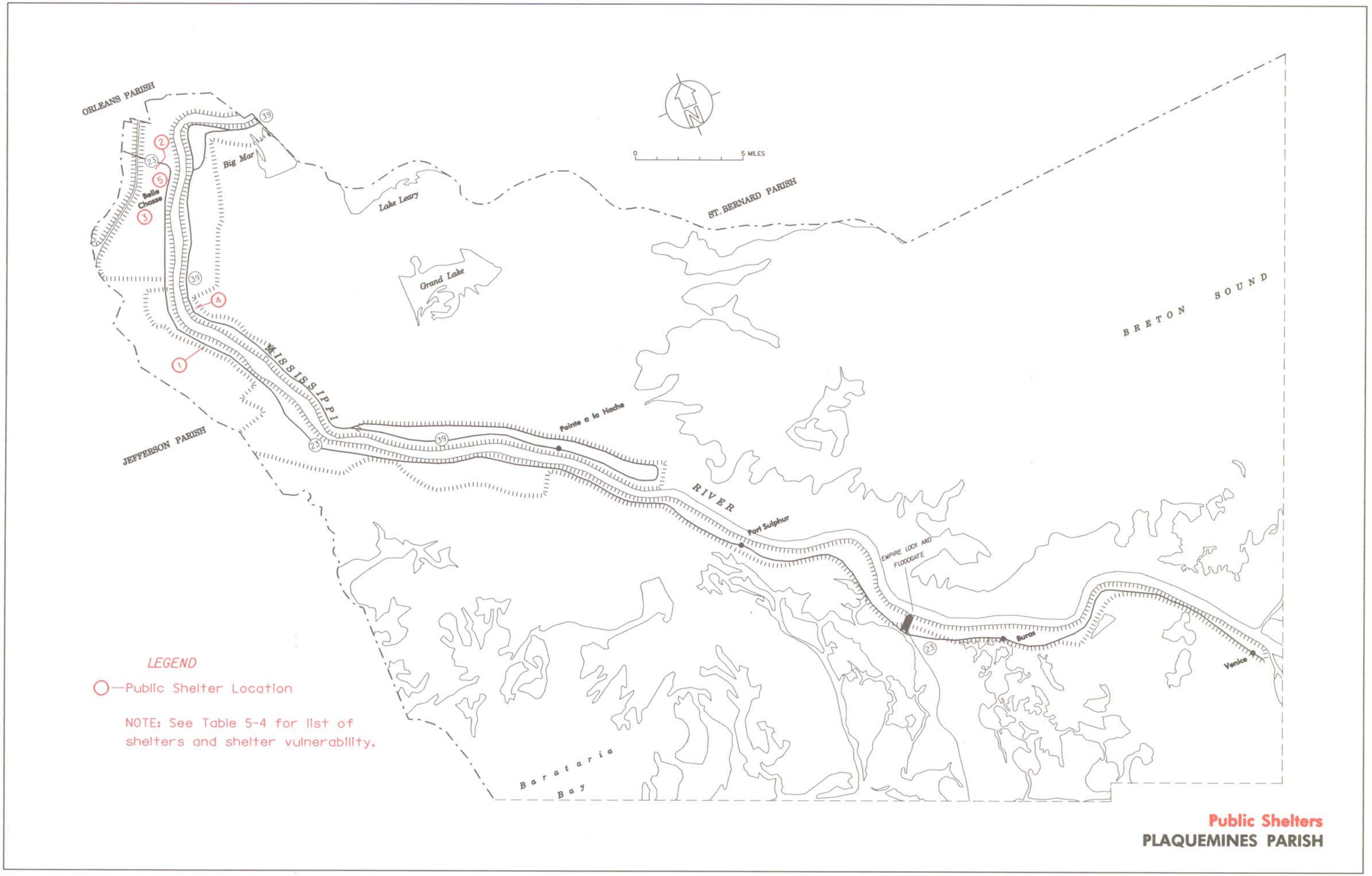


Public Shelters

LAFOURCHE PARISH

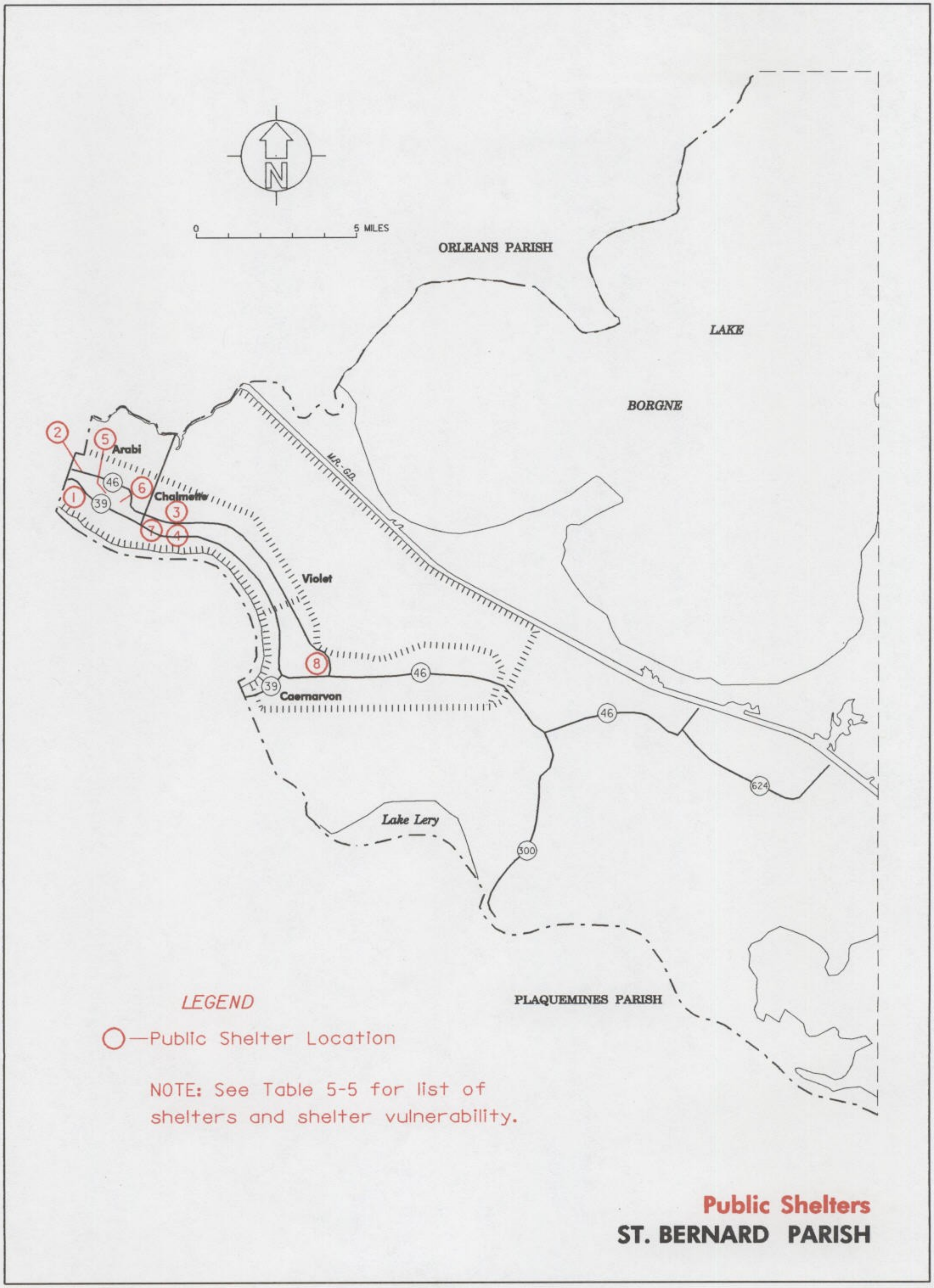


Public Shelters
ORLEANS PARISH

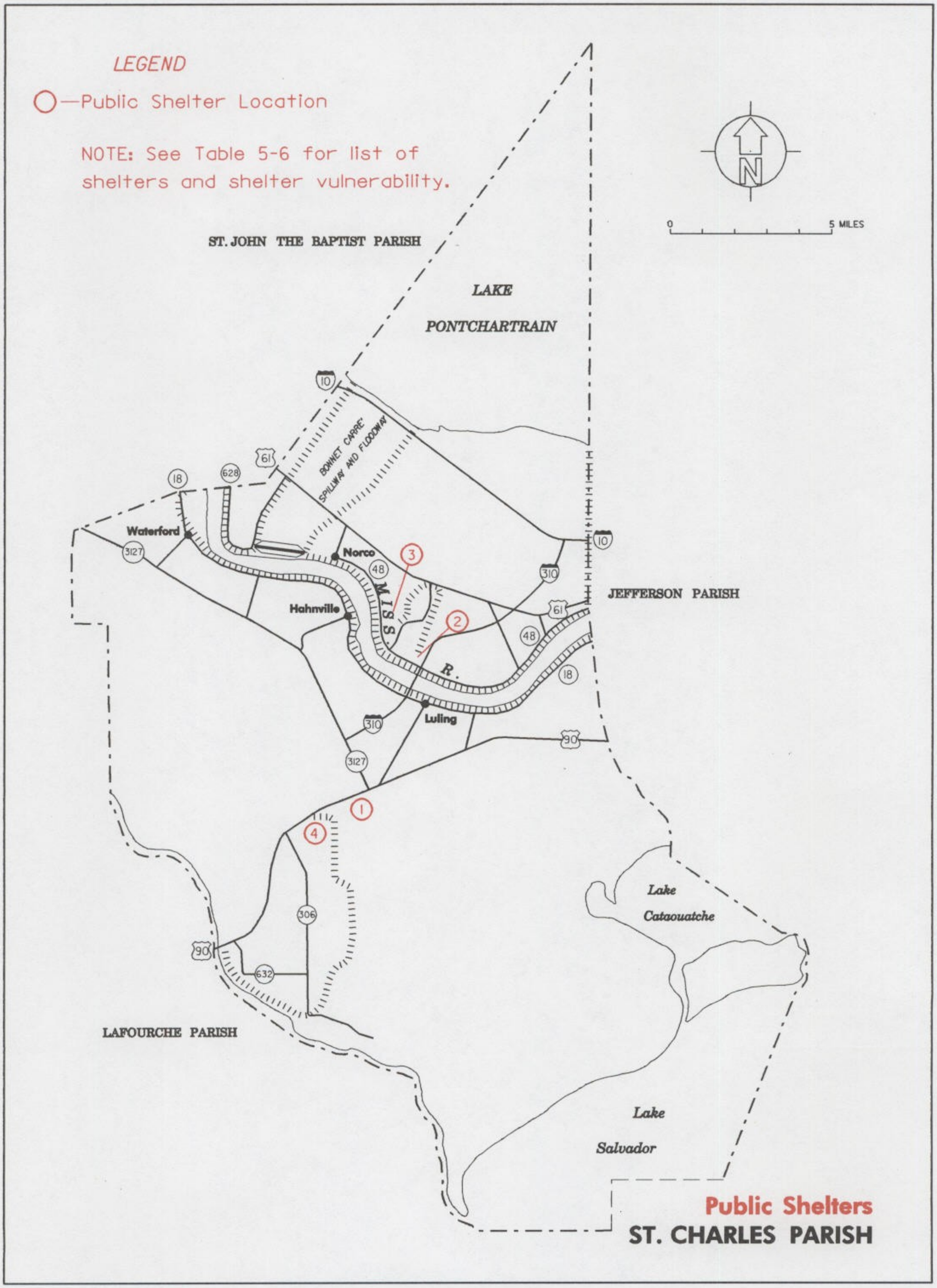


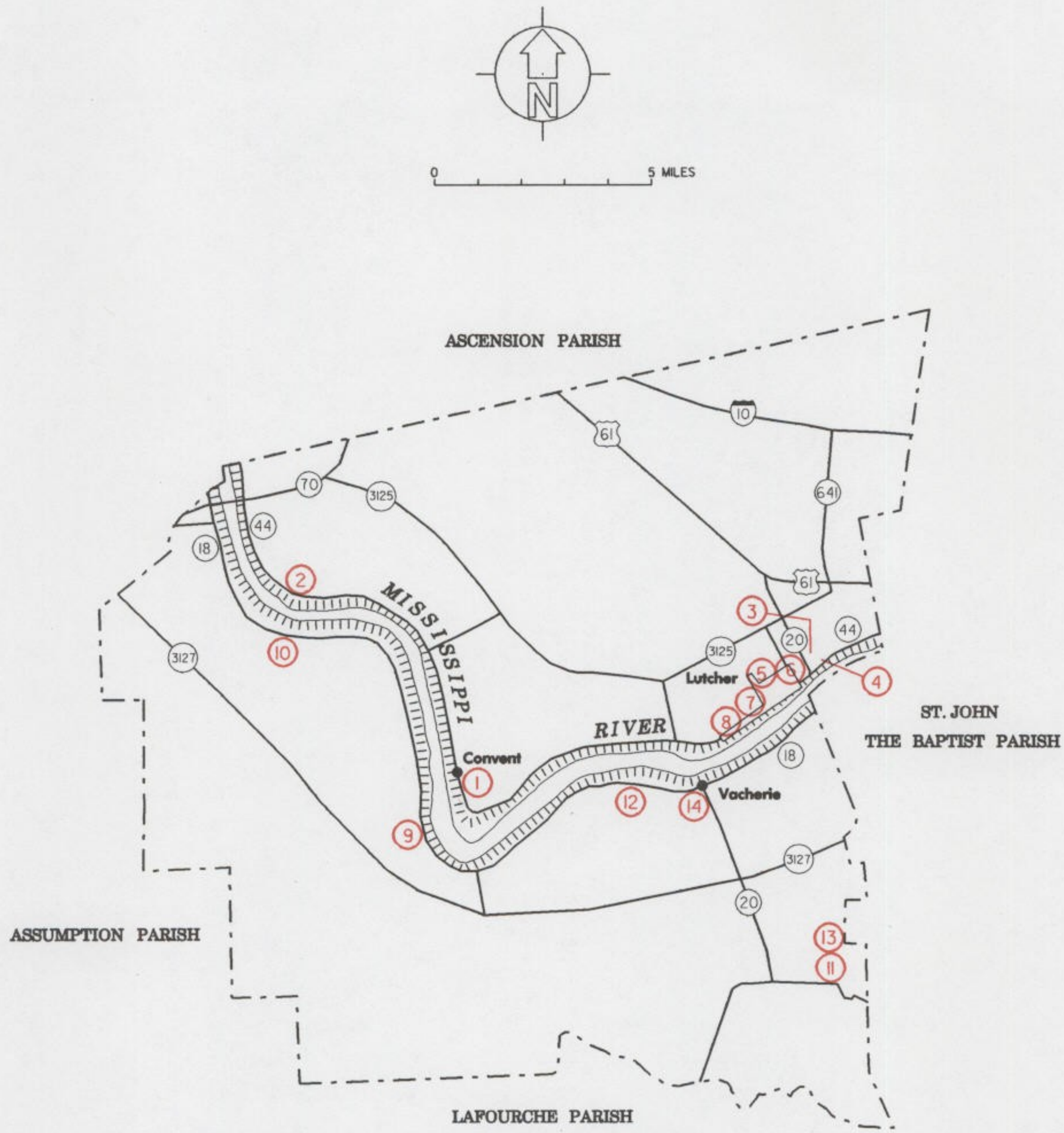
Public Shelters
PLAQUEMINES PARISH

Plate 5-4



Public Shelters
ST. BERNARD PARISH


LEGEND
—Public Shelter Location
NOTE: See Table 5-6 for list of shelters and shelter vulnerability.
0
5 MILES
N
ST. JOHN THE BAPTIST PARISH
LAKE
PONTCHARTRAIN
BONNET CARRE' SPILLWAY AND FLOODWAY
10
61
18
628
Waterford
3127
Norco
48
3
310
MISS. R.
Hahnville
2
61
JEFFERSON PARISH
48
18
Luling
310
90
3127
1
4
Lake
Cataouatche
306
90
632
LAFOURCHE PARISH
Lake
Salvador
Public Shelters
ST. CHARLES PARISH



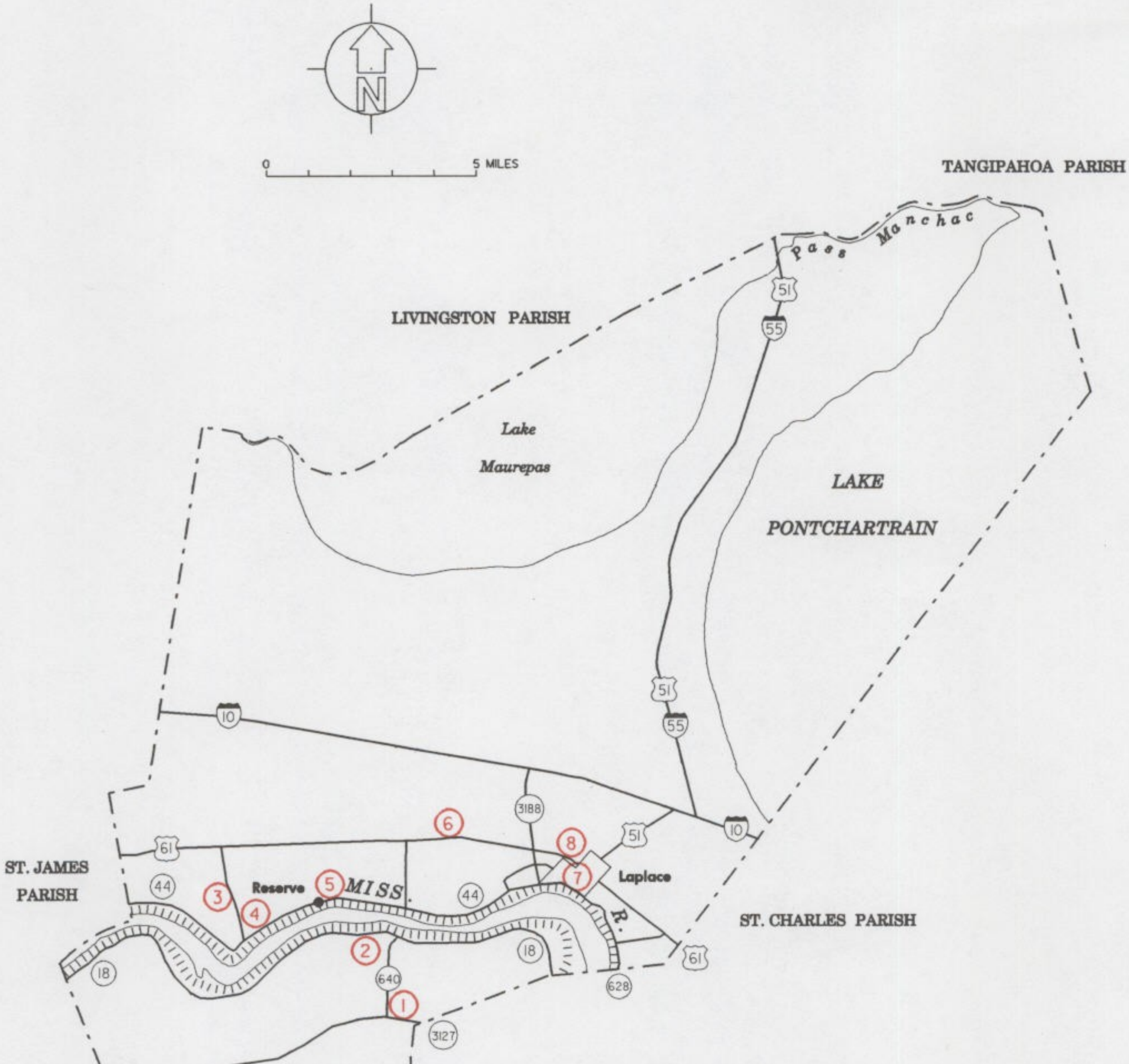
LEGEND

○—Public Shelter Location

NOTE: See Table 5-7 for list of shelters and shelter vulnerability.

Public Shelters

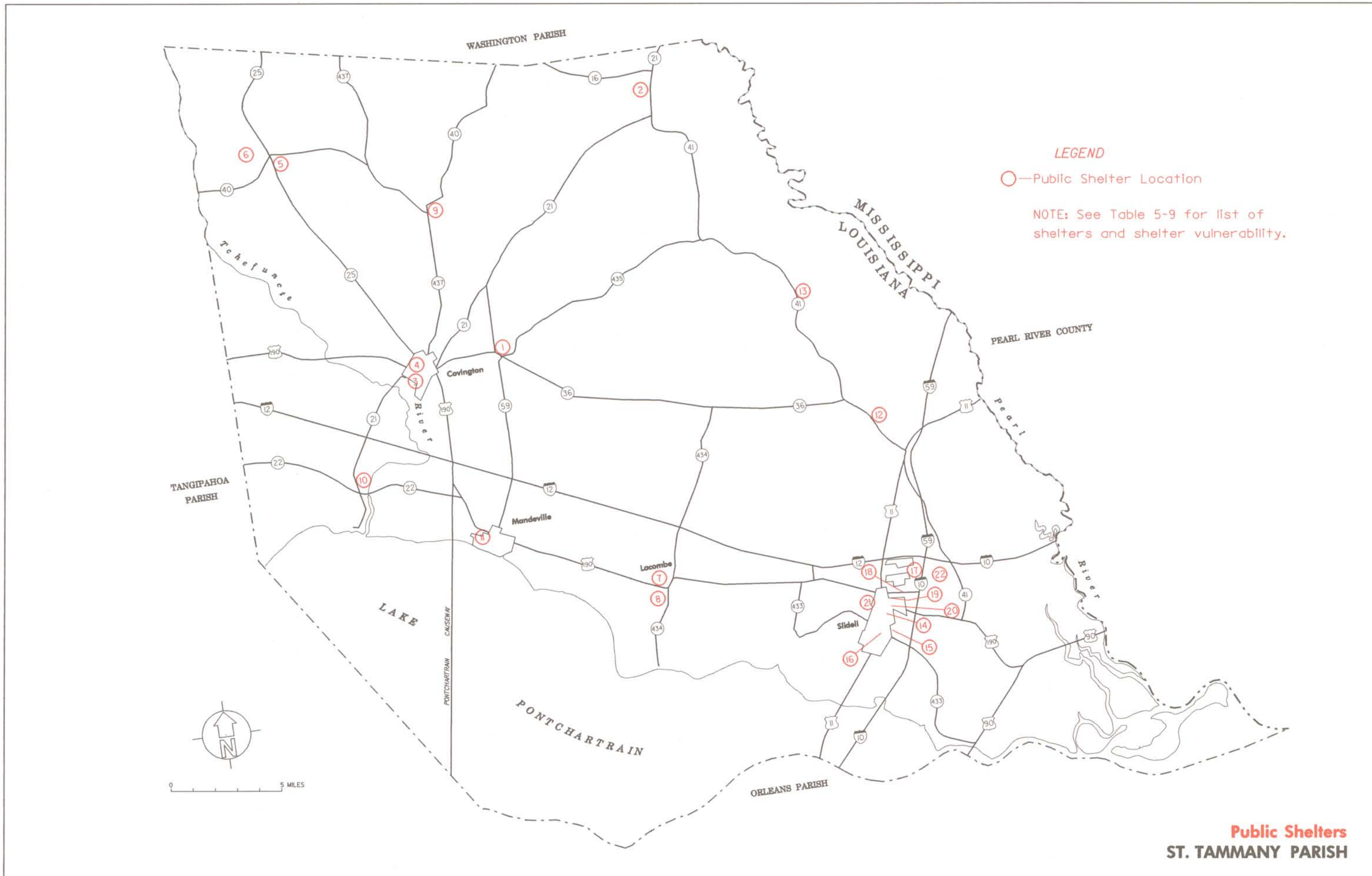
ST. JAMES PARISH



Public Shelters

ST. JOHN THE BAPTIST PARISH

Plate 5-8



Public Shelters
ST. TAMMANY PARISH

CHAPTER SIX

TRANSPORTATION ANALYSIS

I. PURPOSE

The overall goals of the transportation analysis performed for the Southeast Louisiana Hurricane Preparedness Study were to estimate clearance times (the time it takes to clear a parishes roadways of all evacuating vehicles), to define the evacuation roadway network, and to look at general traffic control issues that could affect traffic flow along critical roadway segments. Clearance time is a value resulting from transportation engineering analyses performed under a specific set of assumptions. It must be coupled with pre-landfall hazards data to determine when a strong evacuation advisory should be issued to allow all evacuees time to reach safe shelter before the arrival of sustained gale-force winds. Factors that influence clearance times must be studied intensively to determine which factors have the strongest influence. Therefore, a sensitivity analysis was performed and approximately 12 to 42 clearance times were calculated for each parish by varying key input parameters.

II. EVACUATION TRAVEL PATTERNS

A. General. During a hurricane evacuation effort, it is widely recognized that a large number of vehicles have to be moved across a roadway network in a relatively short period of time. The number of vehicles and evacuees becomes particularly significant for an area such as southeast Louisiana, where a major urban area and many low-lying communities are located. The magnitude of evacuating vehicles varies depending upon the intensity and forward speed of the hurricane, and certain behavioral response characteristics of the vulnerable population.

B. Traffic Movements. Vehicles enter the roadway network at different times depending on the evacuee's response relative to an evacuation order or advisory. Conversely, vehicles leave the roadway network depending on both the planned destinations of evacuees and the availability of acceptable destinations such as public shelters, hotel/motel units, and friends or relatives homes in non-flooded areas. Vehicles move across the roadway network from trip origin to destination at a speed dependent on the traffic loadings on various roadway segments and the ability of the segments to handle a certain volume of vehicles each hour.

The first task of the transportation analysis was to identify the kinds of traffic movements that are associated with a hurricane evacuation and that must be considered in the development of clearance times. Basic assumptions related to storm scenarios, population-at-risk, behavioral and socioeconomic characteristics, the roadway system, and traffic control were also developed. A transportation modeling methodology and a roadway system representation were developed for each parish in the study area to facilitate model application and development of clearance times. General information and data related to the transportation analysis are presented in summary form in this report. The Transportation Model Support Document includes a detailed account of all transportation modeling activities and zone by zone data listings for each parish. Copies of the Model Support Document are available through the U.S. Army Corps of Engineers, New Orleans District.

Traffic movements associated with hurricane evacuation have been identified for the purposes of this analysis by five general patterns:

1. In-Parish Origins to In-Parish Destinations. Trips made from storm surge vulnerable areas and mobile home units in one parish to destinations within the same parish, such as public shelters, hotel and motel units, and friends or relatives outside the storm surge vulnerable areas.

2. In-Parish Origins to Out-of-Parish Destinations. Trips made as in pattern 1 that originate in one parish but have destinations in other parishes of the study area or outside the study area entirely.

3. Out-of-Parish Origins to In-Parish Destinations. Trips made as in pattern 1 that enter one parish from other parishes in the study area.

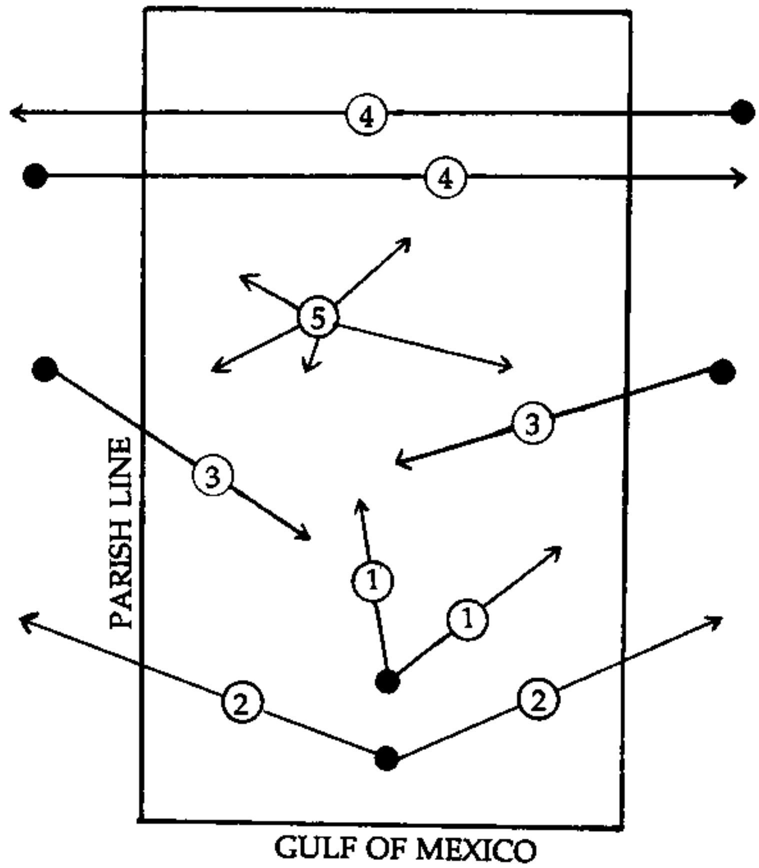
4. Out-of-Parish Origins to Out-of-Parish Destinations. Trips passing through one parish while traveling from another parish in the study area to a destination in either another parish or outside the study area entirely. This travel pattern is particularly significant due to the effects of Orleans - Jefferson traffic passing through St. Tammany and the river parishes.

5. Background Traffic. Trips made by persons preparing for the arrival of hurricane conditions; these include shopping trips to gather supplies and/or trips from work to home to assist the family in evacuation. This traffic can also include transit vehicles (vans/buses) used to pick up evacuees without personal transportation.

Figure 6-1 depicts the traffic movement patterns associated with hurricane evacuation situations in southeast Louisiana. It is important to recognize that three of the five defined patterns involve traffic movement patterns generated outside of one parishes boundaries. It is evident that, depending on the assumed storm track, these inter-parish movements result in a number of regional traffic impacts. During the transportation analysis, these movements were quantified to aid in estimating roadway congestion and resulting clearance times.

FIGURE 6-1

EVACUATION TRAVEL PATTERNS



(1) In-Parish Origins to In-Parish Destinations

(2) In-Parish Origins to Out-of-Parish Destinations

(3) Out-of-Parish Origins to In-Parish Destinations

(4) Out-of-Parish Origins to Out-of-Parish Destinations

(5) Background Traffic

III. TRANSPORTATION ANALYSIS INPUT ASSUMPTIONS

A. General. Since all hurricanes differ from one another in some respect, it becomes necessary to set forth clear assumptions about storm characteristics and evacuees' expected response before transportation modeling can begin. Not only does a storm vary in its track, intensity, forward speed and size, but also in the way it is perceived by residents in potentially vulnerable areas. These factors cause a wide variance in the behavior of the vulnerable population. Even the time of day at which a storm makes landfall influences the time parameters of an evacuation response.

The transportation analysis results in clearance times based on a set of assumed conditions and behavioral responses. It is likely that an actual storm will differ from a simulated storm for which clearance times are calculated in this report. Therefore, a sensitivity analysis was performed during the transportation modeling. Those variables that have the greatest influence on clearance time were identified and then varied to establish the logical range within which the actual input assumption values might fall.

Key assumptions guiding the transportation analysis are grouped into five areas:

1. Permanent and Tourist Population Data
2. Storm Scenarios
3. Evacuation Zones
4. Behavioral Characteristics of the Evacuating Population
5. Roadway Network and Traffic Control Assumptions

These five areas and their assumed parameters are briefly described in the following paragraphs. Those parameters which were varied for sensitivity analysis are noted.

B. Permanent Resident and Tourist Population Data. A population data base for each parish was developed using 1990 census data provided through the U.S. Department of Commerce, Bureau of the Census and the Louisiana Department of Transportation and Development. This source of data provided a base for permanent population parameters on a sub-parish basis. Since data are regularly updated for census units, their use provides a means to facilitate updating of the evacuation study in the future.

Seasonal and permanent dwelling unit data assembled for the study included the following resources:

1. U.S. Census Bureau - 1990 Population and Housing Units.

2. University of New Orleans, Division of Business and Economic Research - census data translations/tables.

3. U.S. Army Corps of Engineers, New Orleans District, Planning Division - 1989 hotel/motel estimates by sub-parish areas.

4. Louisiana Department of Transportation and Development - census tract mapping.

5. Regional Planning Commission, and South Central Planning and Development Commission - roadway mapping; various socio-economic data.

6. Local parish planning, traffic engineering, and causeway commission offices - roadway usage characteristics.

Current permanent population figures range from approximately 20,900 in St. James Parish to 500,000 in Orleans Parish. In Orleans Parish tourist/convention population can have some effect on the number of people residing in the surge vulnerable area. Table 6-1 lists the current permanent population and total number of permanent, mobile home, and hotel/motel dwelling units by parish.

In addition to the number of dwelling units, data was gathered concerning the number of people and number of vehicles per dwelling unit. This data was crucial in translating hurricane vulnerable housing units to vehicle demand for roadways and demand for shelter spaces. Based on 1990 census data, the number of people per permanent dwelling unit ranges from 2.22 in Orleans Parish to 3.01 in St. James Parish. The same figures were used for the number of people per mobile home unit. The number of vehicles per permanent dwelling unit ranges from 1.30 in Orleans Parish to 1.48 in St. Bernard Parish. Data obtained from state travel and tourism bureaus indicated an average of approximately 2.0 persons per tourist unit. An average of one vehicle per tourist unit was assumed in most cases.

C. Storm Scenarios. The hazards analysis identified those storm tracks causing the worst possible and probable storm surge in each parish of the study area for each of five hurricane intensity categories (corresponding to the Saffir-Simpson scale). When five storm intensities are factored by several varying behavioral parameters, the number of hypothetical hurricane situations can quickly reach several hundred. Calculation of clearance times for this many storm situations would be cumbersome and unusable by local emergency preparedness officials and would be inappropriate given the relative level of accuracy of hurricane storm forecasting. Storm forecasting for the period 12 to 24 hours prior to eye landfall is generally not precise enough to allow for more than 2 or 3 storm scenarios (grouping by intensity) per parish.

Enumeration districts, census tracts, and traffic analysis zones (where appropriate) were

TABLE 6-1

1990 POPULATION, PERMANENT AND TOURIST/SEASONAL DWELLINT UNIT DATA[1]

Parish	1990 Population	Dwelling Units Total Permanent	Mobile Home	Tourist/ Seasonal
Jefferson	448,306	185,665	3,130	3,825
Lafourche	85,860	31,330	2,555	-
Orleans	496,938	225,610	1,090	23,750
Plaquemines	25,575	9,430	2,615	-
St. Bernard	66,631	25,145	1,310	-
St. Charles	42,437	16,015	1,445	-
St. James	20,879	6,835	460	-
St. John the Baptist	39,996	14,255	1,200	-
St. Tammany	144,508	58,000	4,905	-

(1) Based on the U.S. Census Bureau - 1990 Population and Housing Units

compared with storm surge limits corresponding to the five hurricane categories. This procedure identified where major differences in storm surge limits and number of vulnerable population exist relative to each progressive step in hurricane intensity. The storm scenarios developed for each parish within the study area are shown in Table 3-1.

D. Evacuation Zones. Through the hazards analysis, those areas which will receive hurricane storm surge were identified and graphically shown on the surge inundation maps. This information became one of the key inputs to the transportation analysis. Those residents who must evacuate as well as those residents who should not evacuate were defined. Within the transportation analysis it was assumed that persons living in areas flooded by storm surge should be evacuated. This evacuee group included permanent residents living in single-family, multi-family, or mobile home units, as well as tourists staying in hotel/motel units located in storm surge vulnerable areas. In addition, mobile home residents living outside the hurricane flooded areas of each parish were assumed to evacuate due to high wind vulnerability.

Having established those persons who should evacuate during a particular storm situation, it was then necessary to develop a series of zones to geographically locate and quantify the vulnerable population. Evacuation zones also provide a base to model traffic movements from one geographic area to another. A series of zones were established for each parish based on the following factors.

1. Zones should relate to expected surge flooding limits (based on Maximum of the MEOWS - MOM's) for each storm scenario.

2. Zones should relate well to census tract boundary, traffic analysis zone, or other data base unit.

3. Zones should be set up, if possible, for ease of use in issuing an evacuation order or advisory.

4. Zonal boundaries should include natural features, roadways, landmarks, etc., which are identifiable by the general public.

5. Small "pocket" zones that would be isolated by surrounding surge should be avoided.

6. Zones should have direct access to major evacuation routes.

7. Zones must allow for appropriate transportation modeling.

Table 6-2 provides the number of evacuation zones in each parish and assumed vulnerability of each zone for the previously developed storm scenarios. The number of

TABLE 6-2

TRANSPORTATION ANALYSIS EVACUATION ZONES
ASSUMED VULNERABILITY BY STORM SCENARIO AND PARISH

Parish	Number of Zones	Storm Scenario	Saffir-Simpson Category	Surge Vulnerable Zones	Additional Mobile Home Vulnerable Zones
Jefferson	28	A	Category 1/Fast Category 2	1 - 2	3 - 28
		B	Fast Category 3	1 - 12	13 - 28
		C	Slow Category 2	1 - 17	18 - 28
		D	Fast Category 4	1 - 22	23 - 28
		E	Slow Category 3-4/Category 5	1 - 28	N/A
Lafourche	6	A	Category 1/Fast Category 2	1	2 - 6
		B	Fast Category 3	1 - 3	4 - 6
		C	Slow Category 2	1 - 4	5 - 6
		D	Slow Category 3/Category 4-5	1 - 6	N/A
Orleans	35	A	Category 1/Fast Category 2	1	2 - 35
		B	Slow Category 2/Fast Category 3	1 - 4	5 - 35
		C	Fast Category 4	1 - 27	28 - 35
		D	Slow Category 3-4/Category 5	1 - 35	N/A
Plaquemines	6	A	Category 1/Fast Category 2	1 - 4	5 - 6
		B	Slow Category 2/Category 3-5	1 - 6	N/A
St. Bernard	5	A	Category 1-2/Fast Category 3	1	2 - 5
		B	Slow Category 3/Category 4-5	1 - 5	N/A
St. Charles	15	A	Category 1/Fast Category 2	1 - 2	3 - 15
		B	Fast Category 3	1 - 7	8 - 15
		C	Slow Category 2	1 - 9	10 - 15
		D	Slow Category 3/Category 4-5	1 - 15	N/A
St. James	12	-	Category 1/Fast Category 2	N/A	1 - 12
		A	Fast Category 3	1	2 - 12
		B	Slow Category 2/Fast Category 4	1 - 4	5 - 12
		C	Slow Category 3	1 - 7	8 - 12
		D	Slow Category 4/Category 5	1 - 12	N/A
St. John the Baptist	12	A	Category 1/Fast Category 2	1 - 2	3 - 12
		B	Fast Category 3	1 - 4	5 - 12
		C	Slow Category 2/Fast Category 4	1 - 7	8 - 12
		D	Slow Category 3-4/Category 5	1 - 12	N/A
St. Tammany	23	A	Category 1/Fast Category 2	1 - 3	4 - 23
		B	Slow Category 2/Fast Category 3	1 - 8	9 - 23
		C	Slow Category 3/Fast Category 4	1 - 11	12 - 23
		D	Slow Category 4/Category 5	1 - 15	16 - 23

zones ranges from 5 zones in St. Bernard Parish to 35 zones in Orleans Parish. The evacuation zones established as part of the transportation analysis are illustrated on Plates 6-1 through 6-9.

E. Behavioral Assumptions. The data developed in the behavioral analysis was utilized to derive assumptions for the transportation analysis that are considered to be representative of southeast Louisiana. Specifically, for transportation modeling purposes, the following behavioral aspects were addressed. Results of the behavioral analysis are addressed in greater detail in Chapter 4.

1. Participation Rates. An important behavioral aspect is that of participation rates. Participation rates are the percentages of persons residing within various evacuation zones which will evacuate under a range of hurricane threats. Participation rates were varied depending on the zone's proximity to significant flooding and depending on the assumed storm intensity. The Transportation Model Support Document provides a listing of all participation rates assumed by storm scenario for each parish in the study area. Generally, an 80 to 99 percent participation rate was assumed by those evacuees living in areas predicted to be inundated by hurricane surge and by those living in mobile homes outside of the surge vulnerable areas. In addition, a small percentage (1 to 5% depending on storm intensity) of the non-vulnerable population that does not live in mobile homes was assumed to evacuate their dwelling units. These assumed participation rates have been supported by post-hurricane response studies.

2. Response Rates. In many study areas of the country, the most critical behavioral aspect that must be considered for the transportation analysis is the response rate of the evacuating population. Behavioral data from research of past hurricane evacuations show that mobilization and actual departures of the evacuating population occur over a period of many hours and sometimes several days. Clearance times for the Southeast Louisiana Hurricane Preparedness Study were tested for three evacuation rates represented by different behavioral response curves. Behavioral response curves describing mobilization by the vulnerable population define the rate at which evacuating vehicles load onto the evacuation roadway network for each hourly interval relative to an evacuation order or strong advisory. The percentage of evacuees leaving each evacuation zone is then available for the calculations relating to traffic loadings at critical links along the evacuation roadway network. Curves representing the three most common behavioral response rates (rapid, moderate and slow) are shown in Figure 4-1. A fourth response curve has also been developed for severe hurricanes in which an evacuation would need to begin in excess of 24 hours prior to landfall, see Figure 4-2. These response rates are intended to include the most probable range of mobilization times that might be experienced in a future hurricane evacuation. Sensitivity was determined by varying the mobilization/traffic loading time between four hours and nine hours.

3. Evacuee Destinations. The percentage of evacuees assumed to go to one of four

general destination types was another important behavioral input to the transportation analysis. Evacuee destinations were discussed with disaster preparedness officials after careful review of information available in past behavioral research. Figures were developed for the expected percent of evacuees going to public shelters, hotel/motel units, the home of a friend or relative, or out of the parish entirely. Destination percentages were varied for each evacuation zone in each parish depending on level of risk (flooding potential) or special characteristics of a zone such as a high number of substandard housing units or low income residents. Specific assumptions for each scenario and evacuation zone are provided in the Transportation Model Support Document. These assumptions are based on information presented in the behavioral analysis and discussed with local officials. It should be noted that these destination percentages refer to destination desires. Where destination desires could not be satisfied with in-parish capacities, the transportation analysis assumed that these evacuees would have to leave the parish to find acceptable sheltering.

4. Vehicle Usage Rates. The final behavioral assumption refers to vehicle usage and the percent of households expected to pull a trailer or recreational vehicle during an evacuation. Review of the behavioral survey and discussions with disaster preparedness officials produced the needed parameters. Vehicle usage percentages refer to the percent of vehicles available to evacuees that are assumed to be used in the evacuation. Vehicle usage percentages for the transportation analysis were varied from 65% to 85%, depending on zone vulnerability. The percent of households expected to pull a boat, trailer or RV was approximately 1 to 5 percent in the immediate coastal area zones. Survey results also indicate that up to 15 percent of residents living in the City of New Orleans are without their own transportation and would be reliant on public transportation.

F. Roadway Network and Traffic Control Assumptions. The last group of assumptions used for input to the transportation analysis were related to the roadway system chosen for the evacuation network and traffic control measures assumed for traffic movement. Although the assumptions developed for the transportation analysis are general, the efforts at parish levels regarding traffic control and roadway selection must be quite detailed. Detailed manpower allocations to major intersections, interchanges, and bridges involve extensive coordination among local and state officials. This study does not presume to replace those efforts, but seeks to quantify the time elements within which such manpower would operate.

In choosing roadways to be used for the evacuation network, it is desirable to include street facilities with sufficient elevation, little or no adjacent tree coverage, substantial shoulder width and surface, and roadways already contained in existing hurricane evacuation plans. However, with the extreme vulnerability to rainfall that many local streets display, this is not always possible in the study area. Another objective was to include arterials and bridge combinations that would provide the smoothest (least disjointed) possible traffic flow. In order to determine the routing of evacuation traffic, a representation of the roadway system was developed. A traditional "link-node" system was developed to identify roadway sections. Nodes are used to identify the intersection of two roadways or changes in roadway characteristics. Links are the roadway segments as defined by the nodes when connected. Each link is identified by a letter designation.

Once the links and nodes for the evacuation routes were identified, roadway characteristics were specified for each link. The characteristics of each link were defined by the following features.

1. Number of travel lanes
2. Type of facility (arterial, collector, freeway, etc.)

Roadway system representations (evacuation networks) for each of the nine parishes within the study area are shown on Plates 6-10 through 6-18. The significance of link node segments and zone connectors is explained in the Transportation Model Support Document. The plates consist of base maps showing all the major streets in the study area with identification of the links and nodes in color. Detailed roadway link information is contained in the Transportation Model Support Document.

An important assumption for the transportation modeling was that all drawbridges would be locked down and open to vehicular traffic during a hurricane warning period. U.S. Coast Guard regulation 33-117.1(c) may give Civil Defense authorities the ability to implement this procedure. At the present time, requests for closure prior to a major disaster occurring (and prior to the warning period) must be directed to the Coast Guard. The Coast Guard, however, has the capability of acting on these requests immediately. It is essential that appropriate bridge regulations be interpreted and implemented to allow for immediate response to an evacuation order. It may be prudent in some areas for boat owners to find safe harbor prior to/or during a hurricane watch period. The lives of citizens evacuating in vehicles could be at risk if bridges are not allowed to operate at near full capacity during a hurricane warning. Bridge openings obviously result in less than full hourly capacity for vehicular movement.

It was assumed that special manpower (state police, local police, sheriffs, deputies), will be assigned to some of the more critical intersections in the study area. This would allow for smoother traffic flow and would allow traffic movements more intersection "green time." The transportation modeling task also assumes that provisions would be made for removal of vehicles in distress during the evacuation. This is crucial to the operation of the Lake Pontchartrain Causeway.

Assumptions concerning the roadway network are that the evacuation of all vehicles will occur prior to the arrival of sustained gale-force winds (40 mph) and/or storm surge inundation.

In summary, data inputs to the transportation analysis can be classified into one of four categories:

1. Hazards Data
2. Socioeconomic Data
3. Behavioral Data
4. Roadway Network

Table 6-3 provides a listing of each major data input for each of the four categories.

TABLE 6-3

TRANSPORTATION ANALYSIS DATA INPUTS

Hazards Data

* Land Areas Flooded for each Category Hurricane
* Public Shelter Useability by Hurricane Category
* Time of Arrival of Gale Force Winds/Roadway Inundation

Behavioral Data

* Rapidity of Response
* Participation Rates
* Destination Percentages
* Vehicle Usage
* Percent Pulling Trailer/Boat
* Presence of Tourists

Socioeconomic Data

* Housing Unit Data
* People Per Housing Unit
* Vehicles Per Housing Unit
* Occupancy Information

Roadway Network

* Number of Lanes by Link
* Facility Types by Link (function of roadway)
* Drawbridge Operations
* Traffic Count Data
* Critical Links/Intersections Capacity Data

IV. TRANSPORTATION MODELING METHODOLOGY

A. General. The transportation modeling methodology developed and employed for the Southeast Louisiana Hurricane Preparedness Study area involved a number of manual and microcomputer techniques. The methodology, while very technical, was designed to be consistent with the accuracy level of the modeling inputs and assumptions. The methodology is unique in that it is sensitive to the key behavioral aspects of evacuees.

The Transportation Model Support document specifies and explains the steps carried out in the transportation modeling at a detailed technical level. In summary, the modeling methodology involved seven major steps. These steps are briefly described below:

B. Evacuation Zonal Data Development. Data gathered by census tract were stratified by evacuation zone. Numbers of permanent residential dwelling units, mobile homes, and hotel/motel units were compiled by zone and formatted for input into trip generation.

C. Evacuation Roadway Network Preparation. This step involved developing information for those roadways selected for inclusion in the evacuation roadway network. Information was coded into a "link file" for use by the assignment computer module. The end product of the step was a computerized representation of the roadway system.

D. Trip Generation. Specific dwelling unit variables were used in the trip generation calculations to produce a total number of people evacuating and vehicles originating from each evacuation zone. Originating vehicles and people were stratified by destination type based on behavioral and population parameters previously established. Hotel/motel information coupled with public shelter capacity information were used to develop estimates of the number of evacuating vehicles that would find acceptable destinations in each zone.

E. Trip Distribution. This step concentrated only on those trips originating in a parish and finding acceptable destinations within the same parish. Productions from each zone were matched with available attractions in all zones. The end product of this step was a trip table showing trips between each zone and all other zones for each evacuation destination type. A unique trip table was developed for each storm scenario, and for each tested behavioral assumption.

F. Roadway Capacity Development. Number of lanes and facility type information for each roadway link in the evacuation network were translated into a general hourly service volume for comparative purposes. Specific hourly flow rates were then developed for the most critical roadway segments and intersections.

G. Trip Assignment. This step included the use of another microcomputer program to assign zone to zone trips onto the roadway segments included in the computerized roadway system. All other categories of evacuation travel patterns (in-parish to out-of-parish, out-of-parish to in-parish, out-of-parish to out-of-parish, and background) were then added in to arrive at total evacuation vehicles per roadway segment. A series of evacuation vehicles to service volume ratios were then developed to determine which roadway segments would be most congested by evacuation vehicles. Those links with the highest vehicles to service volume ratio were identified for each parish.

H. Calculation of Clearance Times - Travel Time/Queuing Delay Analysis. This step involved a detailed look at the critical links and intersections identified for the nine parishes within the study area. Initially, evacuation zones using the critical link of interest were identified. Evacuation vehicles from each zone were then released to the network in accordance with a behavioral response curve. Based on assumed hourly flow rate for the critical link, the hourly volume desiring to use the link was then translated into a queuing delay time at the link and an evacuation travel time. The end product of this major step was a set of clearance times for each storm scenario.

V. MODEL APPLICATION

A. General. Application of the transportation modeling methodology produced several key data items for hurricane evacuation planning and preparedness. Completion of the transportation modeling produced the following items:

1. Evacuating people and vehicle parameters
2. Shelter demand and capacity considerations
3. Traffic volumes and critical roadway segments
4. Estimated clearance times

Although many pieces of information are produced in the transportation analysis, these data items are most critical to planning shelter needs, developing traffic control measures, and defining the timing requirements of an evacuation.

B. Evacuating Population and Vehicle Parameters. Using a microcomputer process, total evacuating vehicles and people produced by each zone were split by destination type (public shelter, hotel/motel unit, friend or relative's home, or out of the parish/region). This was accomplished for each storm scenario and further refined by assumed behavioral characteristics of the population-at-risk. The Transportation Model Support Document provides this data for the evacuation zones of each parish.

Table 6-4 provides ranges of evacuating population and vehicle statistics for each parish within the study area. The number of people evacuating and vehicles expected to be utilized in hurricane evacuations are given in a range due to the effect of testing different storm scenarios. Thus, the highest number relates to the most severe category of hurricane. Figures are based on 1990 population figures and previously discussed behavioral aspects of vulnerability areas relating to the limits of surge inundation for various hurricane directions and speeds. It is important to remember that statistics regarding the number of people evacuating includes all mobile home residents and a small percentage of persons who will evacuate although theoretically not vulnerable to storm surge.

TABLE 6-4

TRANSPORTATION ANALYSIS EVACUATING POPULATION AND VEHICLE STATISTICS BY PARISH

Parish	Number of People Evacuating	Number of Vehicles Used in Evacuation
Jefferson	33,635 - 371,435	13,500 - 147,280
Lafourche	28,640 - 72,395	10,710 - 25,575
Orleans	19,300 - 441,400	6,945 - 145,510
Plaquemines	16,410 - 24,135	5,875 - 8,335
St. Bernard	10,275 - 60,355	3,815 - 22,000
St. Charles	6,415 - 37,410	2,405 - 14,030
St. James	3,560 - 17,920	1,140 - 5,750
St. John the Baptist	4,910 - 31,325	1,695 - 10,845
St. Tammany	32,465 - 98,320	13,410 - 38,460

C. Shelter Demand/Capacity Considerations. While the data discussed above are extremely important, they are most useful when matched with available sheltering. It is important to note that evacuating people and vehicle statistics generated for each parish, evacuation zone, and destination type reflect where evacuees would go assuming enough safe destinations were available. The public shelter demand/capacity data produced by the shelter analysis were utilized to route evacuees to available public shelter within the study area. After matching evacuee's destination desires with available shelters, the transportation analysis revealed that public shelter and hotel/motel space will not be as widely available within the study area as perceived by the evacuating population. Table 5-10 provides the calculated public shelter demand and available capacity by storm scenario. The public shelter capacity within the study area is generally inadequate during a major hurricane. Each of the nine parishes would experience a significant lack of public shelter space for a category 4 or 5 hurricane. The public shelter deficit in Orleans and Jefferson Parishes alone could exceed 120,000 people. For transportation modeling purposes, those evacuees unable to be accommodated by public shelter and hotel/motel space within the study area were assumed to find such space outside the study area.

D. Traffic Volumes and Critical Roadway Segments. The Transportation Model Support Document provides the assigned evacuating vehicle figures for all roadway segments in the evacuation network for each parish. In addition, the appendix of the same document provides the evacuating vehicles to service volume ratios calculated for each link. Those roadway segments with the highest vehicles to service volume ratios were identified as the critical links for each jurisdiction. Table 6-5 lists the critical roadway segments by parish. Critical links and intersections are listed by parish in order of severity. These links control the flow of traffic during a hurricane evacuation and are key areas for traffic control and monitoring.

E. Estimated Clearance Times. The most important product of the transportation analysis is the clearance times developed by storm scenario and behavioral response. Clearance time is one of two major considerations (the other being the arrival of gale-force winds) involved in issuing an evacuation order or advisory. Clearance time must be weighted with respect to the arrival of gale-force winds to make a prudent evacuation decision. Figure 6-2 illustrates the relationship of these evacuation considerations.

Clearance time is the time required to clear the roadways of all vehicles evacuating in response to a hurricane situation. Clearance time begins once a decision to evacuate has been made and final preparations are initiated (as defined by a hurricane evacuation response curve) and does not end until the last evacuating vehicle reaches an assumed point of safety. Clearance time includes the time required by evacuees to secure their homes and prepare to leave (referred to as mobilization time), the time spent by evacuees traveling along the roadway network (referred to as travel time), and the time spent by evacuees waiting along the roadway network due to traffic congestion (referred to as queuing delay time). Clearance time does not relate to the time any one vehicle spends traveling on the roadway network.

The low lying topography of southeast Louisiana combined with the extensive system of levees and the interdependence of the evacuation roadway network are all factors which complicated the development of clearance times. As shown in the hazards analysis, the surge produced by a category 4 or 5 hurricane has the potential to overtop the levee

TABLE 6-5

CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS
S.E. LOUISIANA HURRICANE PREPAREDNESS STUDY

Jefferson Parish

Lake Pontchartrain Causeway (northbound)
Huey P. Long Bridge (northbound)
Causeway Blvd. north of I-10 (northbound)
I-10 and Lake Pontchartrain Causeway interchange (ramps)
I-10 between I-610 and Lake Pontchartrain Causeway (westbound)
I-10 west of Lake Pontchartrain Causeway (westbound)
West Bank Expressway and US 90 interchange
Clearview Pkwy and I-10 interchange
Airline Hwy west of Hickory Avenue
David Drive/Hickory Avenue and Airline Hwy intersection
Williams Blvd. and I-10 (on-ramp)
Veterans Memorial Blvd. at I-10 and Lake Pontchartrain Causeway
Loyola Drive at I-10
Belle Chasse Hwy south of and at West Bank Expressway
Barataria Blvd. and West Bank Expwy intersection
(Greater New Orleans Bridge in Orleans Parish)
River Road and US 90 intersection
(Hwy 1 through Lafourche Parish)

Lafourche Parish

Hwy 1 and Louisiana 308 intersections with US 90
Hwy 1 through Raceland
Hwy 1 and Louisiana 308 intersections with Hwy 20 at Thibodaux
Hwy 1 and Louisiana 3135 intersection

Orleans Parish

I-10 over Lake Pontchartrain (eastbound)
I-10 between I-610 and Lake Pontchartrian Causeway (westbound)
Greater New Orleans Bridge (toll booths)
I-10 and Paris Road interchange
Pontchartrain Expressway/I-10 interchange (near Superdome)
General De Gaulle Drive and West Bank Expressway interchange (on-ramp)
I-10 between Morrison Road and Paris Road
S. Carrollton Ave. at I-10 and US 61
Elysian Fields Avenue at I-10 and I-610 interchange
Gentilly Blvd. interchanges with I-10 and I-610
Earhart Blvd.
I-10 over the Inner Harbor Navigation Canal
(I-10 interchanges-on ramps)

TABLE 6-5 (continued)

CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS
S.E. LOUISIANA HURRICANE PREPAREDNESS STUDY

Plaquemines Parish

Belle Chasse Highway south of and through Belle Chasse
(Belle Chasse Highway at West Bank Expressway in Jefferson Parish)

St. Bernard Parish

St. Bernard Highway and Paris Road intersection
Judge Perez Drive and Paris Road intersection
(Paris Road at I-10 interchange in Orleans Parish)

St. Charles Parish

I-10
US 61 through Norco
Jefferson Highway between I-310 and New Sarpy

St. James Parish

US 61 at Louisiana 641 intersection near Gramercy
I-10 and Louisiana 641 interchange
(Louisiana 3127 and Hwy 70 intersection in Ascension Parish)

St. John the Baptist Parish

I-10 east of I-55
US 61 (Airline Highway) through LaPlace
US 51/US 61 intersection
I-10 west of I-55

St. Tammany Parish

Collins Blvd. through Covington
I-59 between I-10/I-12 and Hwy 41 interchange
Hwy 25 north of Covington
US 190 at I-12
Hwy 41 between I-59 and Hwy 21 at Bush
Hwy 21 between Covington and Bush
I-10 through Slidell
(Hwy 21 through Bogalusa and Hwy 25 through Franklinton in Washington Parish)

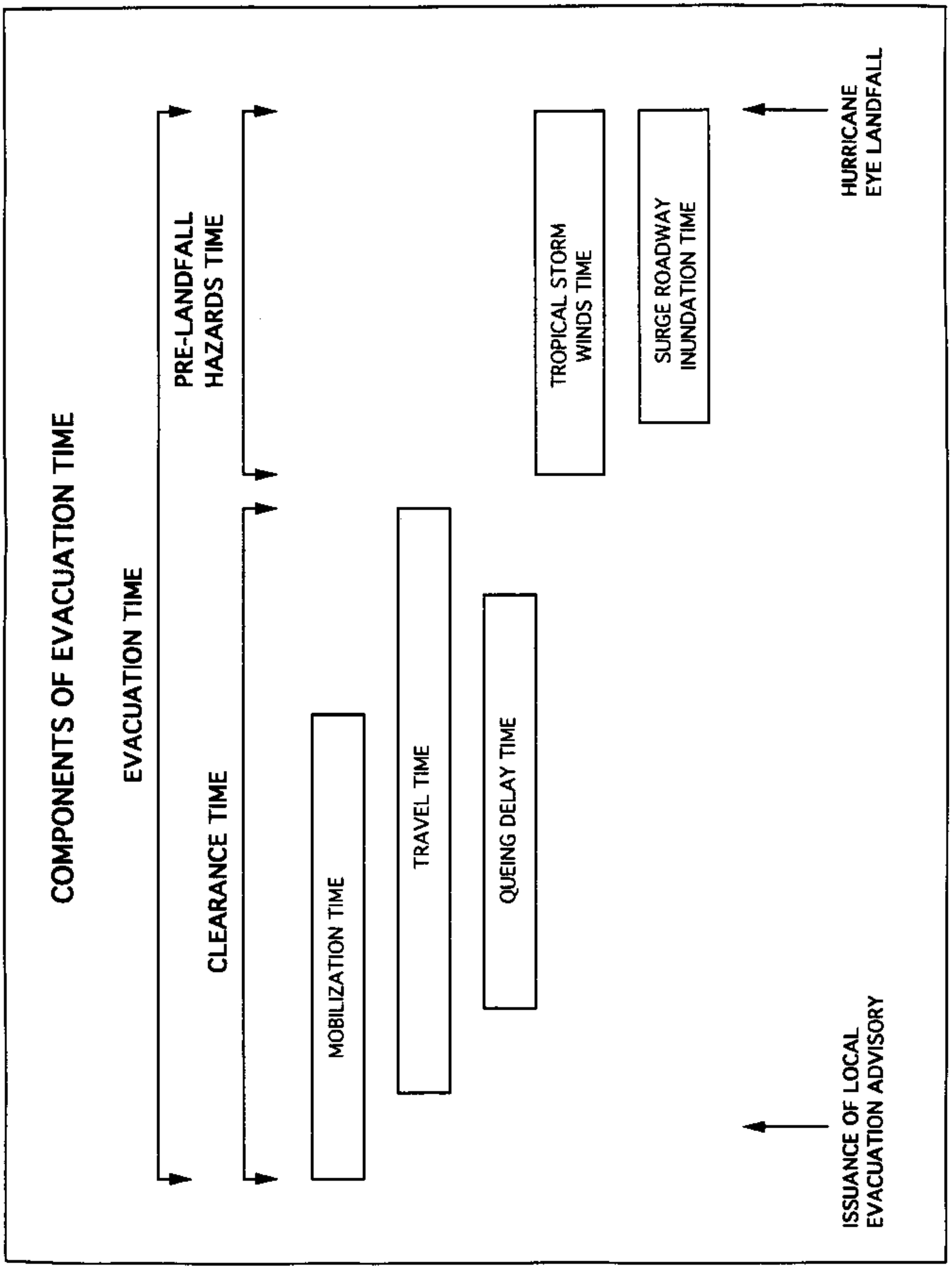

COMPONENTS OF EVACUATION TIME
EVACUATION TIME
PRE-LANDFALL HAZARDS TIME
CLEARANCE TIME
MOBILIZATION TIME
TRAVEL TIME
QUEING DELAY TIME
TROPICAL STORM WINDS TIME
SURGE ROADWAY INUNDATION TIME
ISSUANCE OF LOCAL EVACUATION ADVISORY
HURRICANE EYE LANDFALL

FIGURE 6-2

system resulting in widespread flooding throughout the study area. The northern reaches of St. Tammany Parish are the only portions of the study area that are not subject to storm surge inundation during a major hurricane. Coastal communities in Plaquemines, St. Bernard and Jefferson Parishes would be required to travel long distances to leave the risk area. Residents evacuating these communities would likely pass through Jefferson, Orleans and St. Tammany Parishes before reaching their destination. Although the clearance time for Plaquemines Parish or St. Bernard Parish alone might be relatively short, the effect of traffic evacuating the surrounding parishes must also be considered. In order to simplify the process, regional clearance times were developed based on the common use of roadways within the network. The largest and most heavily populated region consists of Jefferson, Orleans, Plaquemines, St. Bernard, and St. Tammany Parishes. Table 6-6 presents clearance times for parishes within this region for the previously developed hurricane scenarios. The evacuation roadway network for Lafourche Parish is not heavily influenced by evacuees from other parishes and clearance times were therefore presented separately. Clearance times for Lafourche Parish are shown in Table 6-7. The remaining river parishes of St. Charles, St. James, and St. John the Baptist were combined into another region. Clearance times for this region are shown in Table 6-8.

Clearance times are stratified by intensity of hurricane (storm scenario), and by rate of response on the part of the evacuating population. Jefferson and Orleans Parishes are heavily populated urban areas and the clearance times for these parishes have been stratified by off-peak and peak period. The peak period would be used for evacuations ordered in the middle of a normal work day. This would require the work to home movement of vehicles in addition to the movement of evacuating vehicles. The times are not additive - in other words, Jefferson Parishes times reflect Orleans traffic moving through and Orleans times reflect the effects of Jefferson generated traffic. It is important to note that clearance times are based on the assumptions that local officials will attempt to evacuate residents out of dwelling units located in the areas shown as flooded by the surge inundation maps. The hazards analysis chapter of this report defines these surge limits and the theory behind their derivation.

VI. TRAFFIC CONTROL ISSUES

The movement of vehicles during a hurricane evacuation requires extensive traffic control efforts to make maximum use of roadway capacity and to expedite safe escape from hurricane hazards. The development of traffic control techniques for critical evacuation roadway links and intersections should always be developed by local police, state police, state DOT, local traffic engineers, emergency management personnel and the U.S. Coast Guard working together cooperatively. The following traffic control issues are recommended for consideration:

1. As manpower supply allows, officers should be stationed at each critical intersection to move traffic, and to assist disabled vehicles. Critical links and intersections

TABLE 6-6

JEFFERSON - ORLEANS - PLAQUEMINES - ST. BERNARD - ST. TAMMANY
REGIONAL CLEARANCE TIMES (in hours)
S.E. Louisiana Hurricane Evacuation Study
Transportation Analysis

	Clearance Times[1]	
Category 1/Fast Category 2 Hurricane	Off-Peak	Peak-Period[2]
Rapid Response	5	5 3/4
Medium Response	7	8
Slow Response	10	11 3/4
Fast Category 3 Hurricane		
Rapid Response	13 3/4	14 3/4
Medium Response	14 1/4	16
Slow Response	15	17 1/2
Slow Category 2 Hurricane		
Rapid Response	14 1/2	17
Medium Response	15 1/4	19 1/4
Slow Response	16 1/4	22 1/2
Fast Category 4 Hurricane		
Rapid Response	37	39 1/2
Medium Response	37 3/4	41 3/4
Slow Response	38 3/4	45 1/4
Slow Category 3-4/Category 5 Hurricane		
Rapid Response	42 1/4	44 1/2
Medium Response	43	47
Slow Response	44	50 1/4

(1) Clearance times **do not** include pre-landfall hazards time.

(2) Background traffic conditions with a peak period condition include a normal work to home movement in addition to the movement of evacuating vehicles.

TABLE 6-7

LAFOURCHE PARISH
CLEARANCE TIMES (in hours)
S.E. Louisiana Hurricane Evacuation Study
Transportation Analysis

	Clearance Times[1]
Category 1/Fast Category 2 Hurricane	
Rapid Response	$6^{1/4}$
Medium Response	7
Slow Response	$9^{1/4}$
Fast Category 3 Hurricane	
Rapid Response	11
Medium Response	$11^{1/2}$
Slow Response	$12^{1/2}$
Slow Category 2 Hurricane	
Rapid Response	11
Medium Response	$11^{1/2}$
Slow Response	$12^{1/2}$
Slow Category 3/Category 4-5 Hurricane	
Rapid Response	13
Medium Response	$13^{1/4}$
Slow Response	$14^{1/4}$

(1) Clearance times **do not** include pre-landfall hazards time. The effects of Grand Isle traffic from Jefferson Parish have been included.

TABLE 6-8

ST. CHARLES - ST. JAMES - ST. JOHN THE BAPTIST PARISHES
REGIONAL CLEARANCE TIMES (in hours)
S.E. Louisiana Hurricane Evacuation Study
Transportation Analysis

	Clearance Times[1]
Category 1/Fast Category 2 Hurricane	
Rapid Response	$4^{1/2}$
Medium Response	$6^{1/2}$
Slow Response	$9^{1/2}$
Fast Category 3 Hurricane	
Rapid Response	$5^{1/2}$
Medium Response	$6^{1/2}$
Slow Response	$9^{1/2}$
Slow Category 2	
Rapid Response	$5^{1/2}/11^{1/2}/26^{3/4}$
Medium Response	$6^{1/4}/12/28$
Slow Response	$9^{1/4}/13/29^{1/2}$
Fast Category 4 Hurricane	
Rapid Response	$5^{1/2}/15^{1/2}/30^{1/2}$
Medium Response	$6^{1/4}/15^{3/4}/31^{1/2}$
Slow Response	$9^{1/4}/16^{1/2}/33$
Slow Category 3-4/Category 5 Hurricane	
Rapid Response	$8^{1/4}/23^{1/2}/35^{1/4}$
Medium Response	$9/23^{3/4}/36^{1/4}$
Slow Response	$10/24^{1/4}/38$

(1) Clearance times **do not** include pre-landfall hazards time. Times to the left of slash are for in-parish local traffic movements not using US 61 or I-10; middle number relates to US 61 local and through traffic; times to the right of slash are for I-10 traffic.

discussed previously should be used as a starting point in developing manpower assignments. However, in an urban area as densely developed as the New Orleans area, many intersections will have to operate by normal traffic signals.

2. All available tow trucks should be positioned or on call along key travel corridors and critical links. At a minimum, tow trucks should be at major bridge crossings to remove disabled vehicles. This is a critical issue for the Lake Pontchartrain Causeway where there are no shoulders for disabled vehicles to pull off to the side of the road.

3. Where intersections will continue to have signalized control, signal patterns providing the most "green time" for the approach leading away from the flood areas should be actuated by the local traffic engineer's office as appropriate.

4. All draw/swing bridges needed for evacuation should be locked in the "down" position during a hurricane warning if possible. Boat owners must be made aware of flotilla plans and time requirements for securing vessels. Optimally, recreational boats should be moved to safe harbor during or before a hurricane watch. This judgement will need to be made on a case-by-case basis through discussions between the U.S. Coast Guard, local emergency management officials, and the State DOT.

5. Manual direction of traffic should be supplemented by physical barrier/cones that are adequately weighted down and which are placed to channel traffic and minimize merging conflicts. This could help at major interchanges along I-10.

6. The movement of mobile homes, campers, and boat trailers along evacuation routes should be minimized or even prohibited late in an evacuation. A disabled camper/RV could block the only escape route available for evacuation in some areas. Such vehicles are difficult to handle late in an evacuation due to sporadic wind gusts. This could present a real problem on the many high level bridges located throughout the study area.

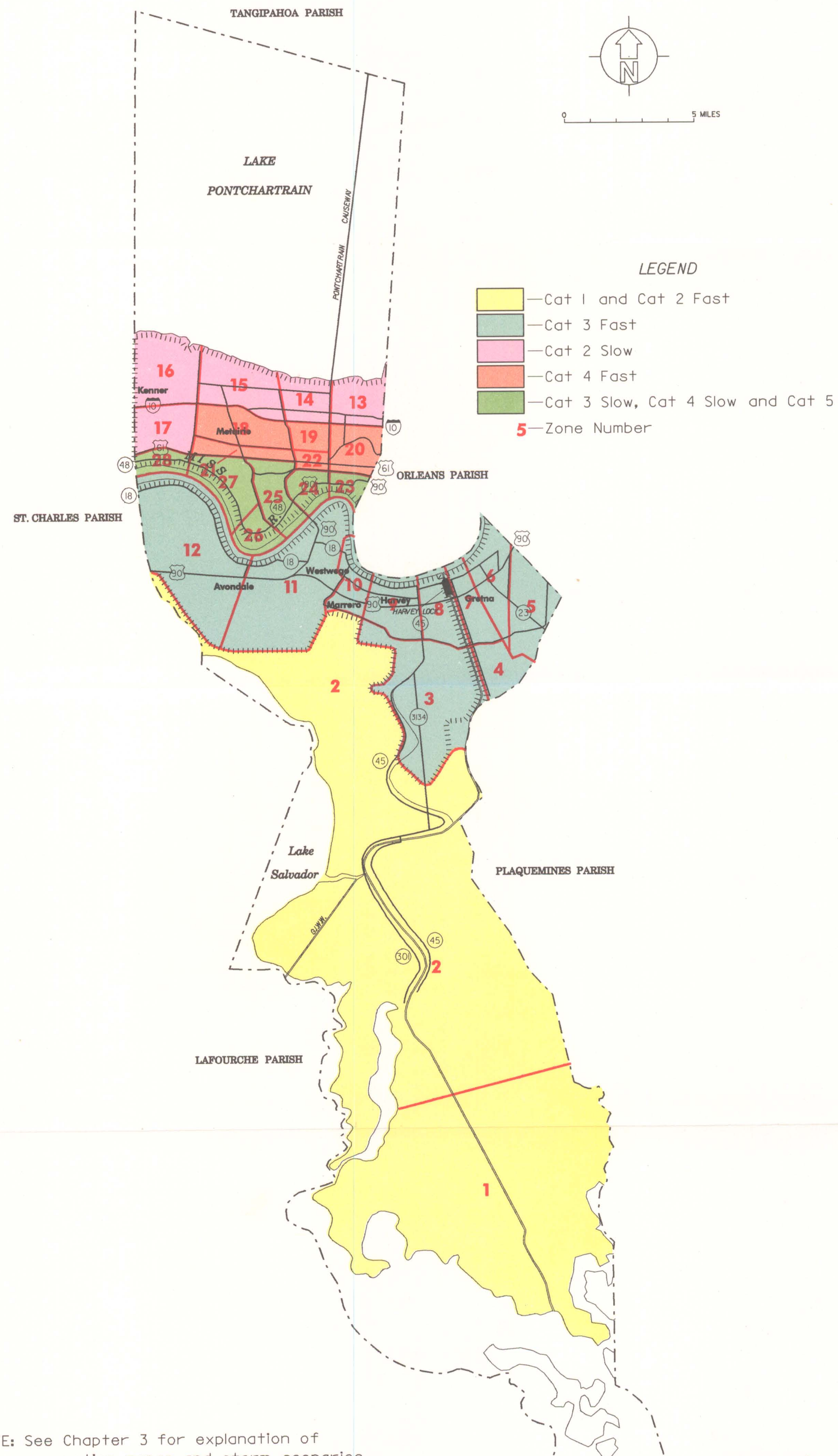
7. Tolls should be suspended on facilities such as the Lake Pontchartrain Causeway and the Crescent City Connection Bridge during an evacuation.

8. In the distribution of public information, evacuees in the river parishes should be encouraged to use U.S. 61 and U.S. 51 as alternatives to I-10 and I-55.

9. People should be encouraged to not come into the city for work if the timing of an evacuation and related decision making permits.

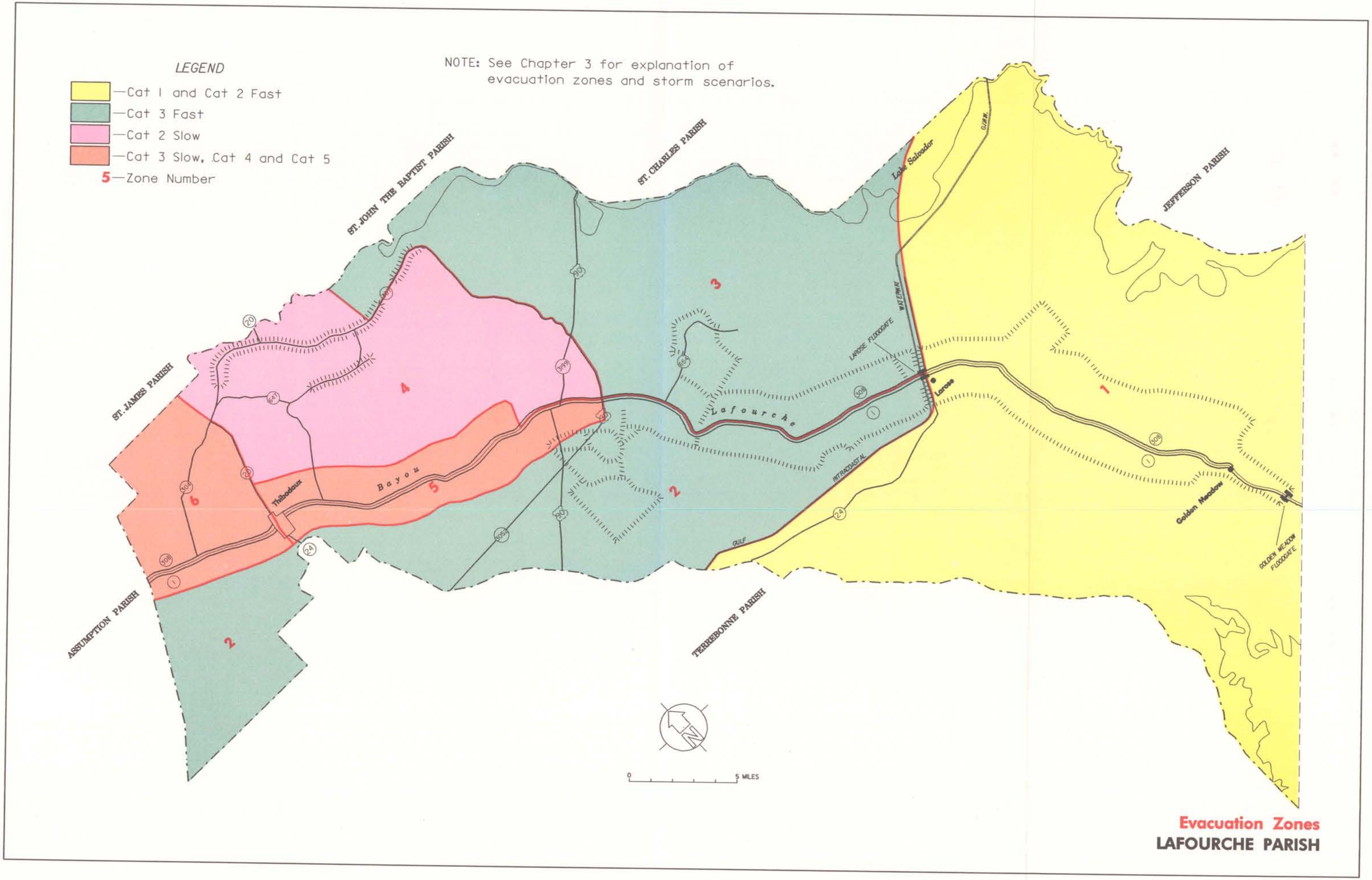
10. The lengthy clearance times suggest that traffic will come to a standstill in many network locations particularly during the middle of an evacuation just as Charleston experienced with Hurricane Hugo. The key is to keep traffic moving that is exiting the

region. It is critical to examine the operational feasibility of creating an additional temporary westbound lane on I-10 between Jefferson Parish and I-55 during an evacuation. This could possibly be accomplished using an existing shoulder. An additional eastbound lane on I-10 over Lake Pontchartrain should be implemented during an evacuation - there is plenty of pavement width on the bridge structure to develop this during an emergency.

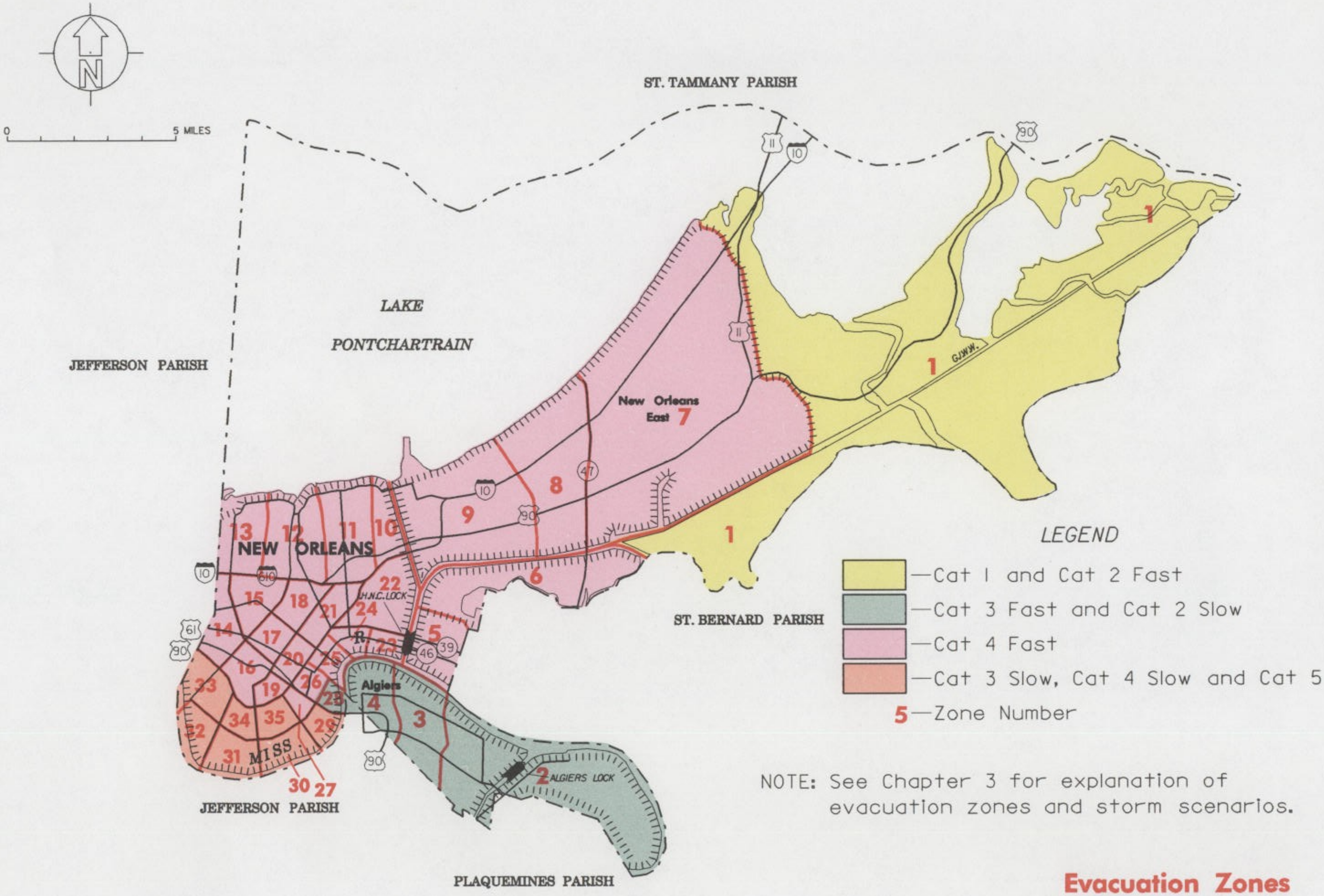


NOTE: See Chapter 3 for explanation of evacuation zones and storm scenarios.

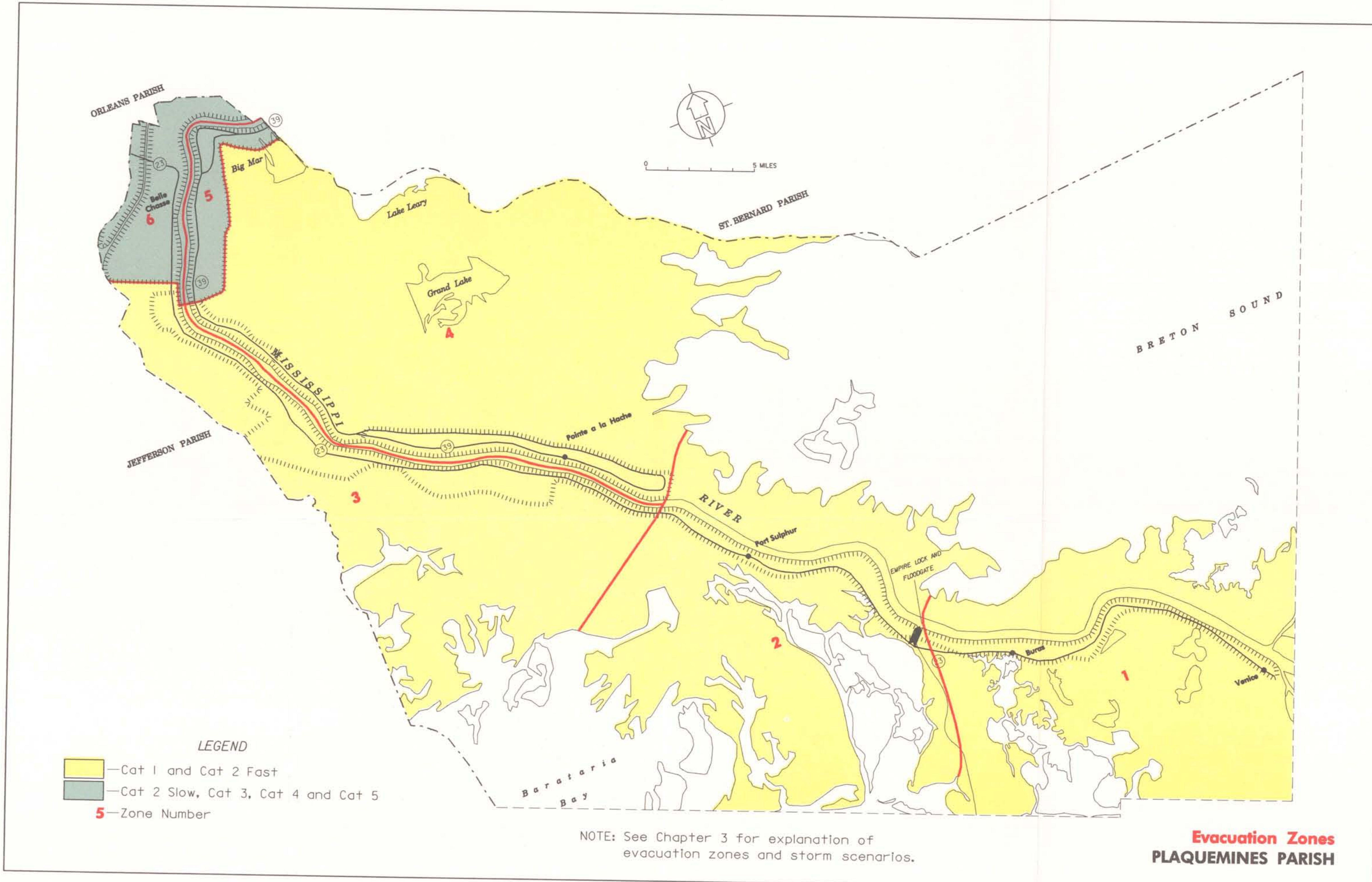
Evacuation Zones
JEFFERSON PARISH

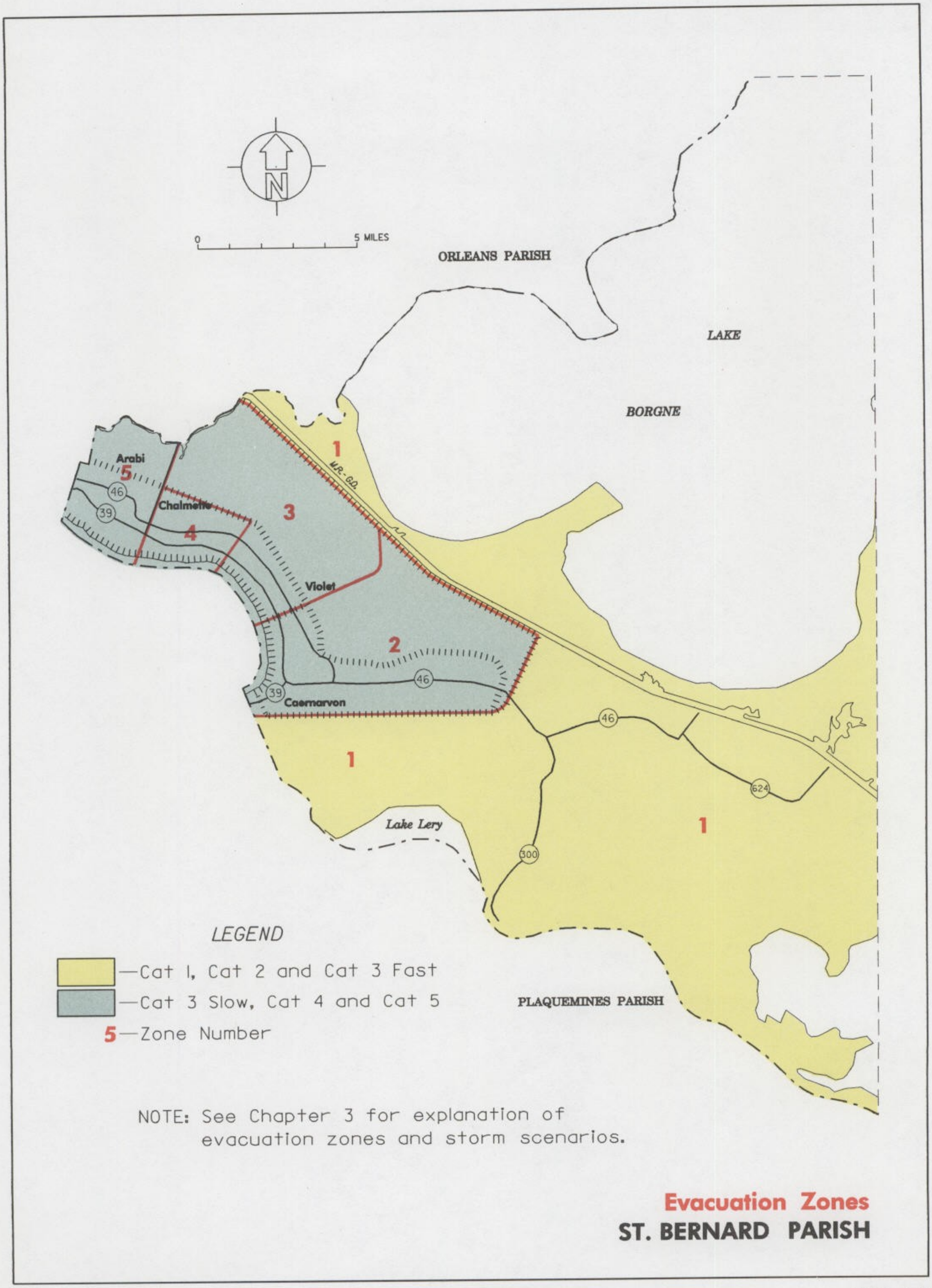


Evacuation Zones
LAFOURCHE PARISH

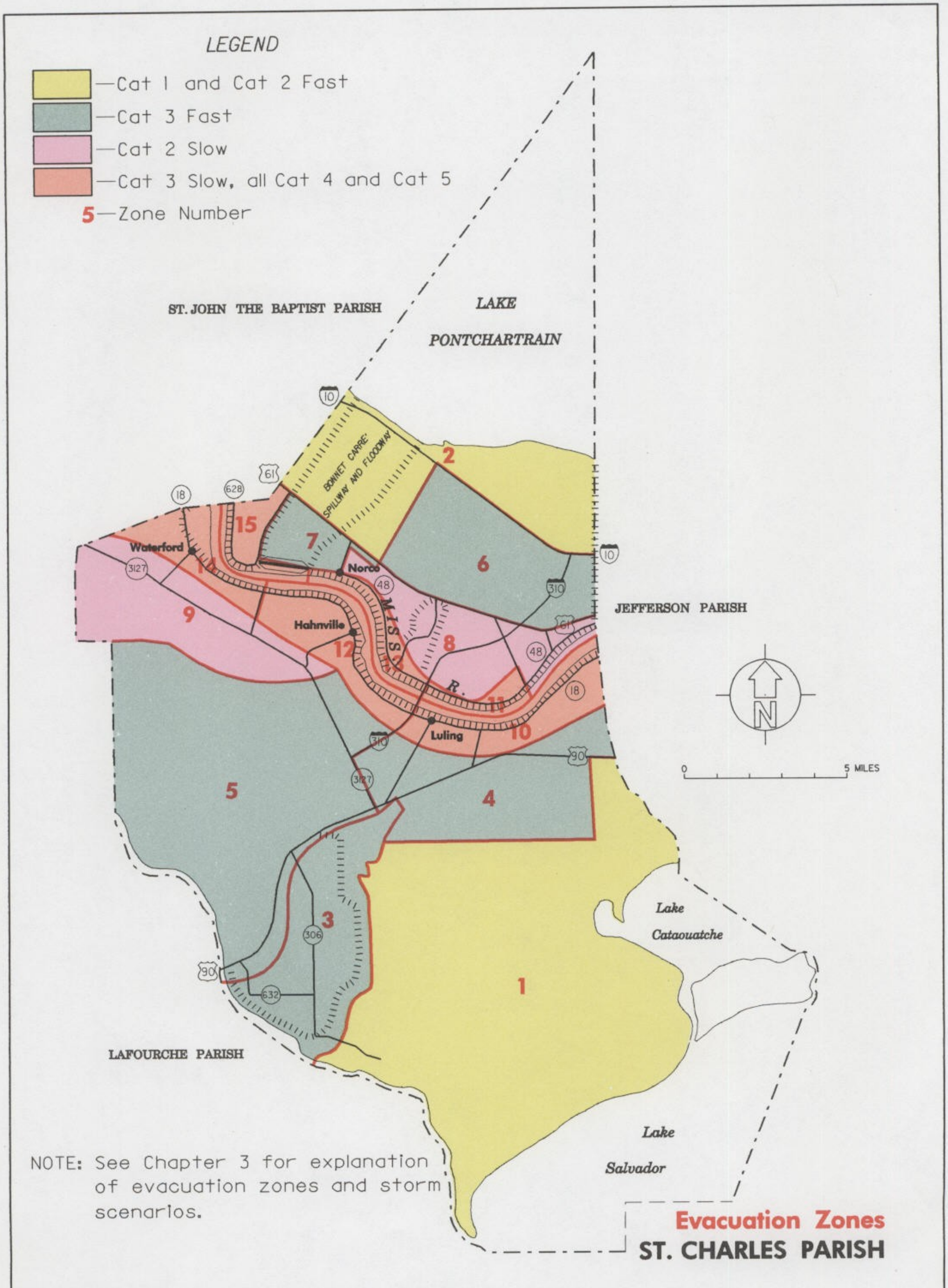


Evacuation Zones
ORLEANS PARISH

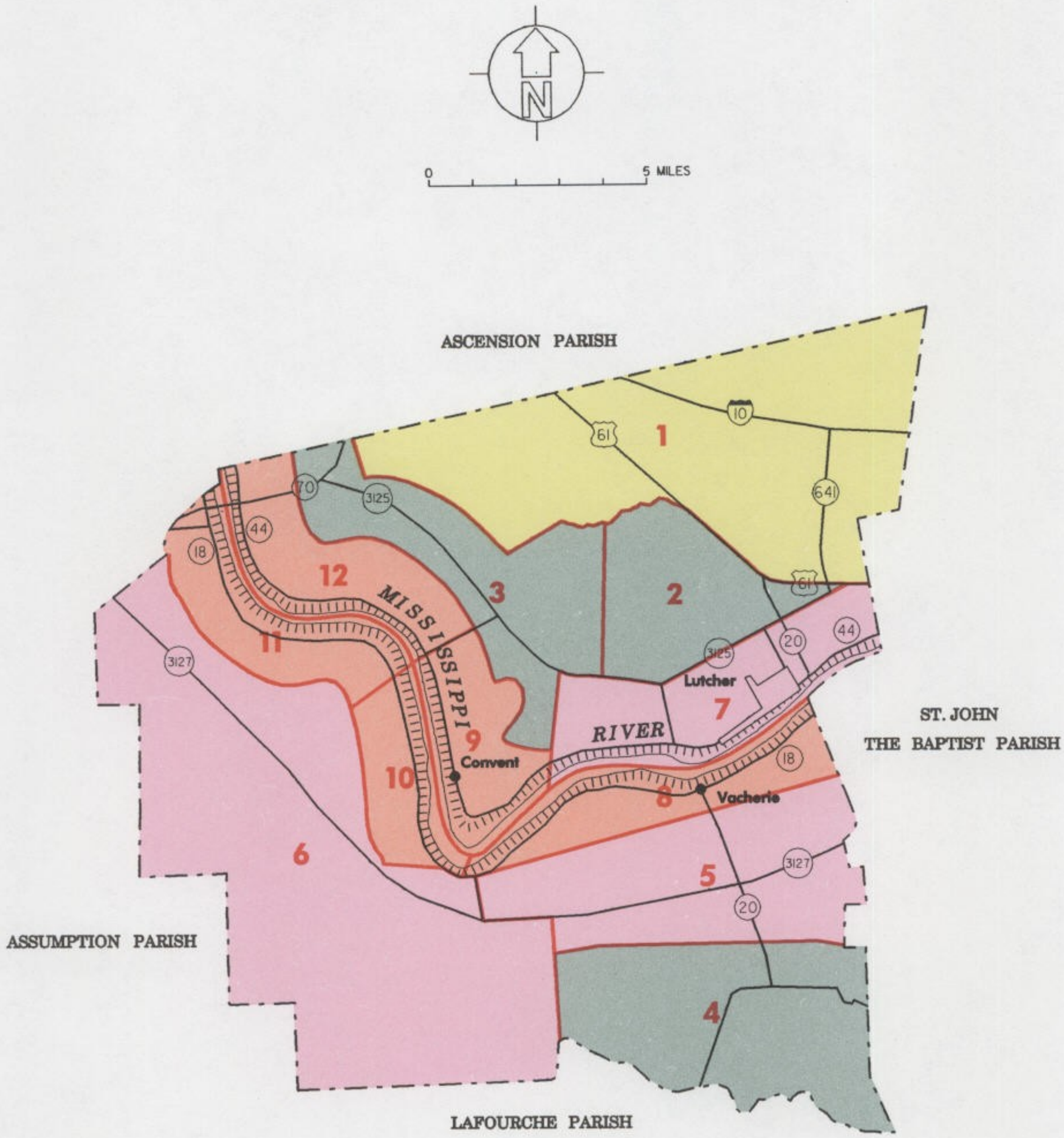

ORLEANS PARISH
ST. BERNARD PARISH
JEFFERSON PARISH
BRETON SOUND
Barataria Bay
MISSISSIPPI RIVER
Belle Chasse
Big Mar
Lake Leary
Grand Lake
Pointe a la Hache
Port Sulphur
EMPIRE LOCK AND FLOODGATE
Buras
Venice
0 5 MILES
N
23
39
1
2
3
4
5
6
LEGEND
Cat 1 and Cat 2 Fast
Cat 2 Slow, Cat 3, Cat 4 and Cat 5
5—Zone Number
NOTE: See Chapter 3 for explanation of evacuation zones and storm scenarios.
Evacuation Zones
PLAQUEMINES PARISH



Evacuation Zones
ST. BERNARD PARISH


LEGEND
—Cat 1 and Cat 2 Fast
—Cat 3 Fast
—Cat 2 Slow
—Cat 3 Slow, all Cat 4 and Cat 5
5—Zone Number
ST. JOHN THE BAPTIST PARISH
LAKE
PONTCHARTRAIN
BONNET CARRE' SPILLWAY AND FLOODWAY
Waterford
Norco
Hahnville
Luling
MISS. R.
JEFFERSON PARISH
LAFOURCHE PARISH
Lake
Cataouatche
Lake
Salvador
0
5 MILES
N
NOTE: See Chapter 3 for explanation of evacuation zones and storm scenarios.
Evacuation Zones
ST. CHARLES PARISH

NOTE: See Chapter 3 for explanation of evacuation zones and storm scenarios.

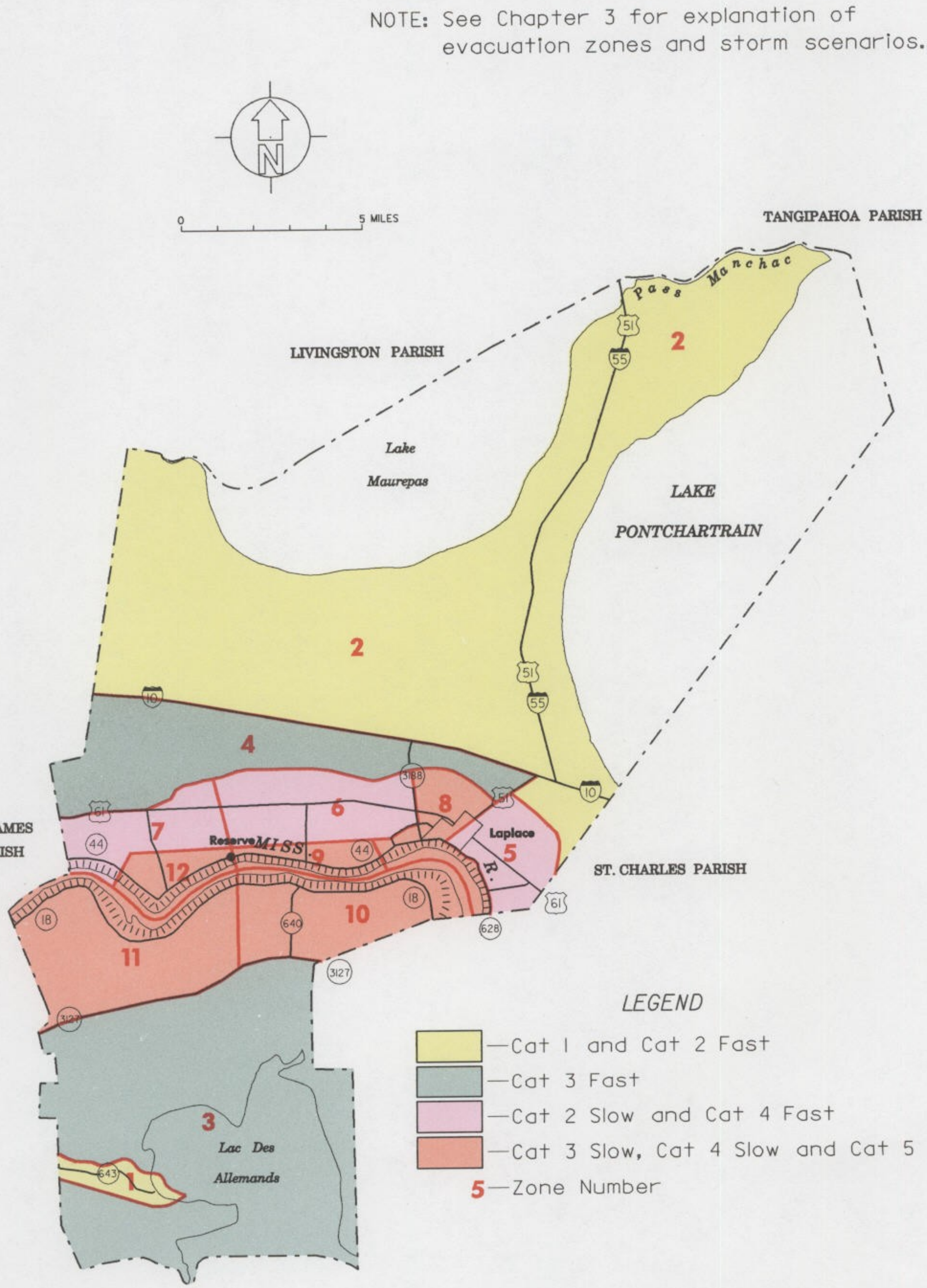


LEGEND

- —Cat 3 Fast
- —Cat 2 Slow and Cat 4 Fast
- —Cat 3 Slow
- —Cat 4 Slow and Cat 5
- 5—Zone Number

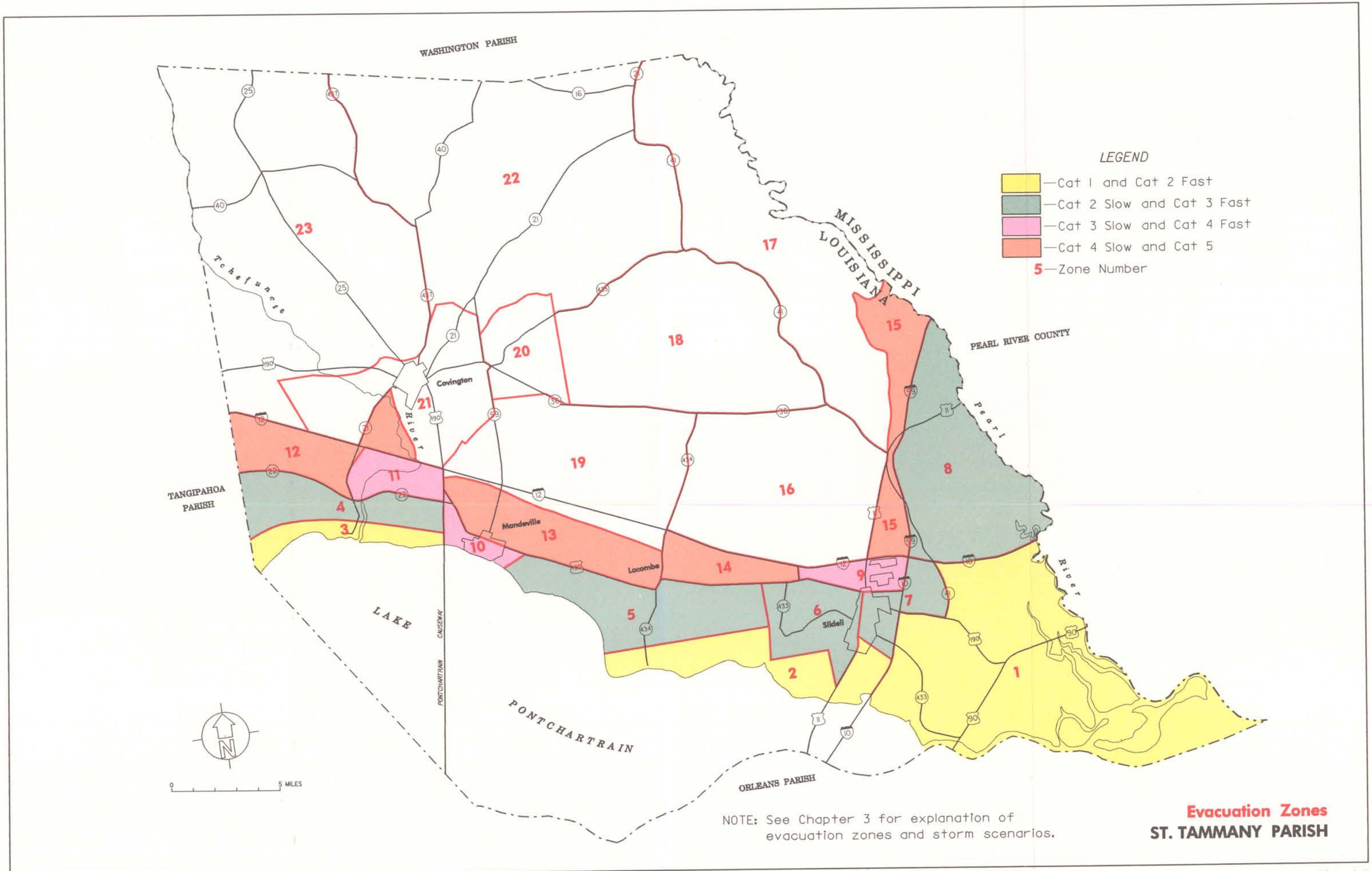
(No Surge Area for Cat I and Cat 2 Fast)

Evacuation Zones
ST. JAMES PARISH

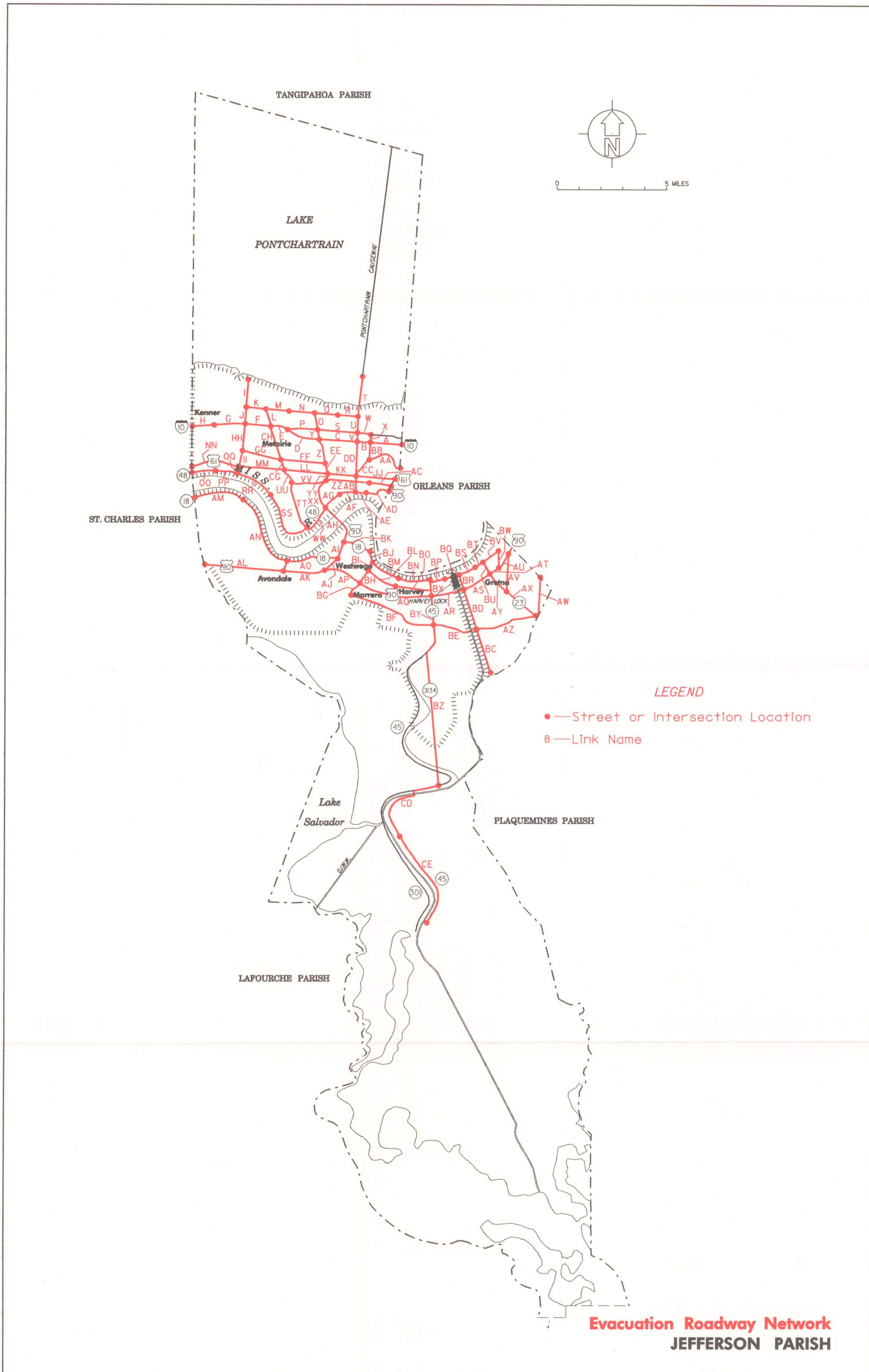


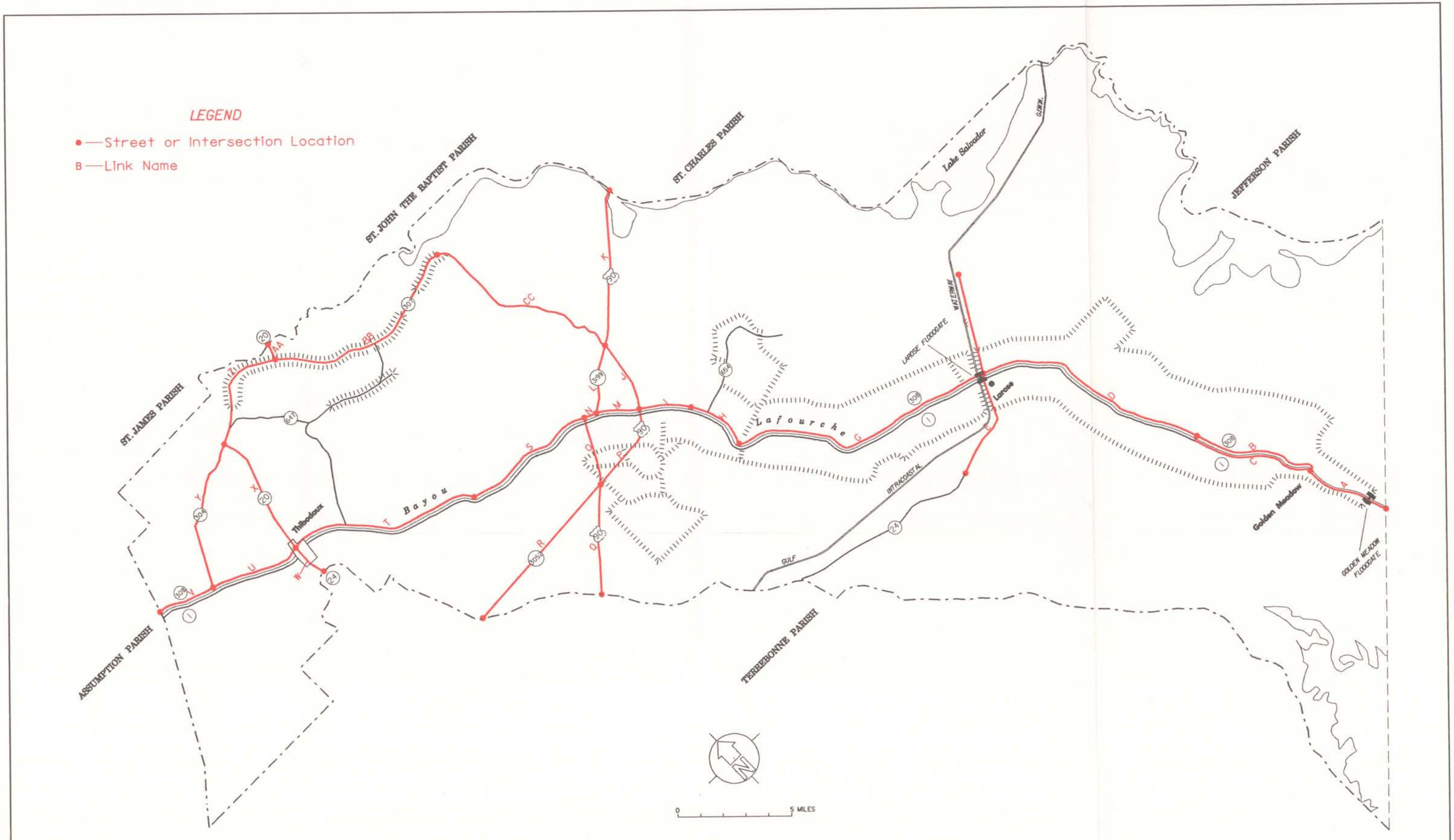
Evacuation Zones

ST. JOHN THE BAPTIST PARISH

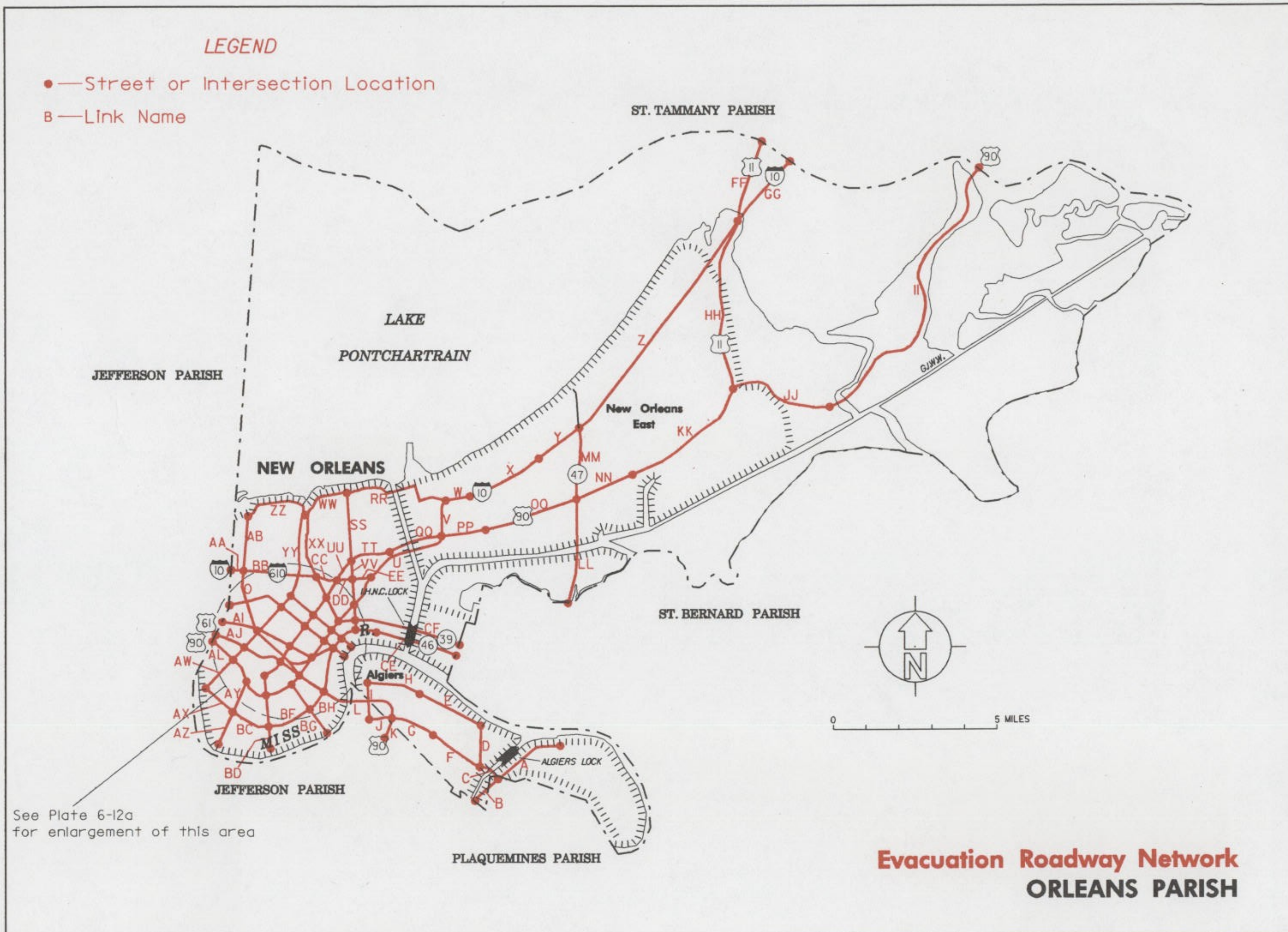


Evacuation Zones
ST. TAMMANY PARISH

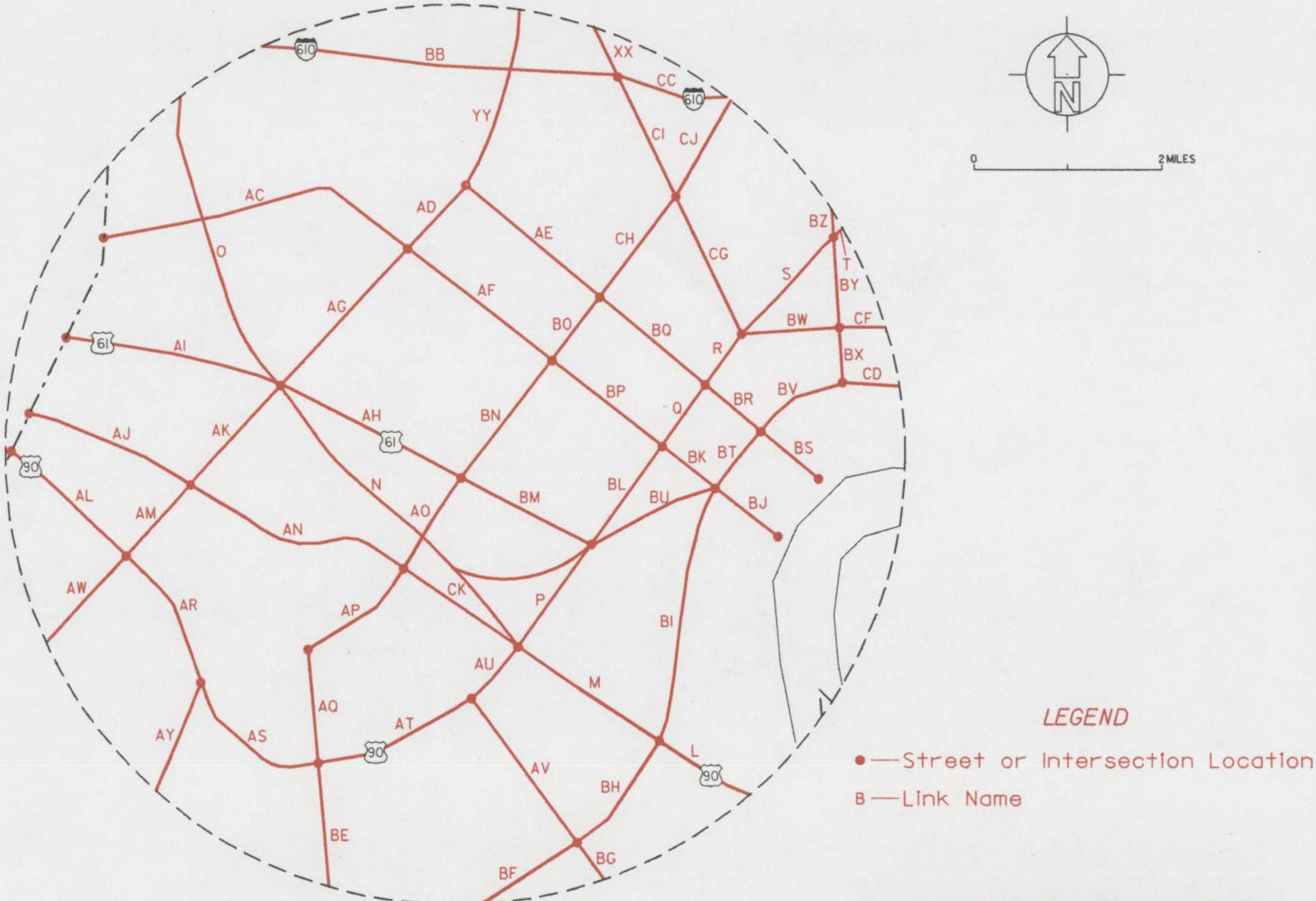

TANGIPAHOA PARISH
LAKE
PONTCHARTRAIN
PONTCHARTRAIN CAUSEWAY
ORLEANS PARISH
ST. CHARLES PARISH
PLAQUEMINES PARISH
LAFOURCHE PARISH
Lake
Salvador
Kenner
Metairie
Westwego
Avondale
Marrero
Harvey
Gretna
HARVEY LOCK
G.I.W.W.
N
0
5 MILES
LEGEND
●—Street or Intersection Location
B—Link Name
Evacuation Roadway Network
JEFFERSON PARISH



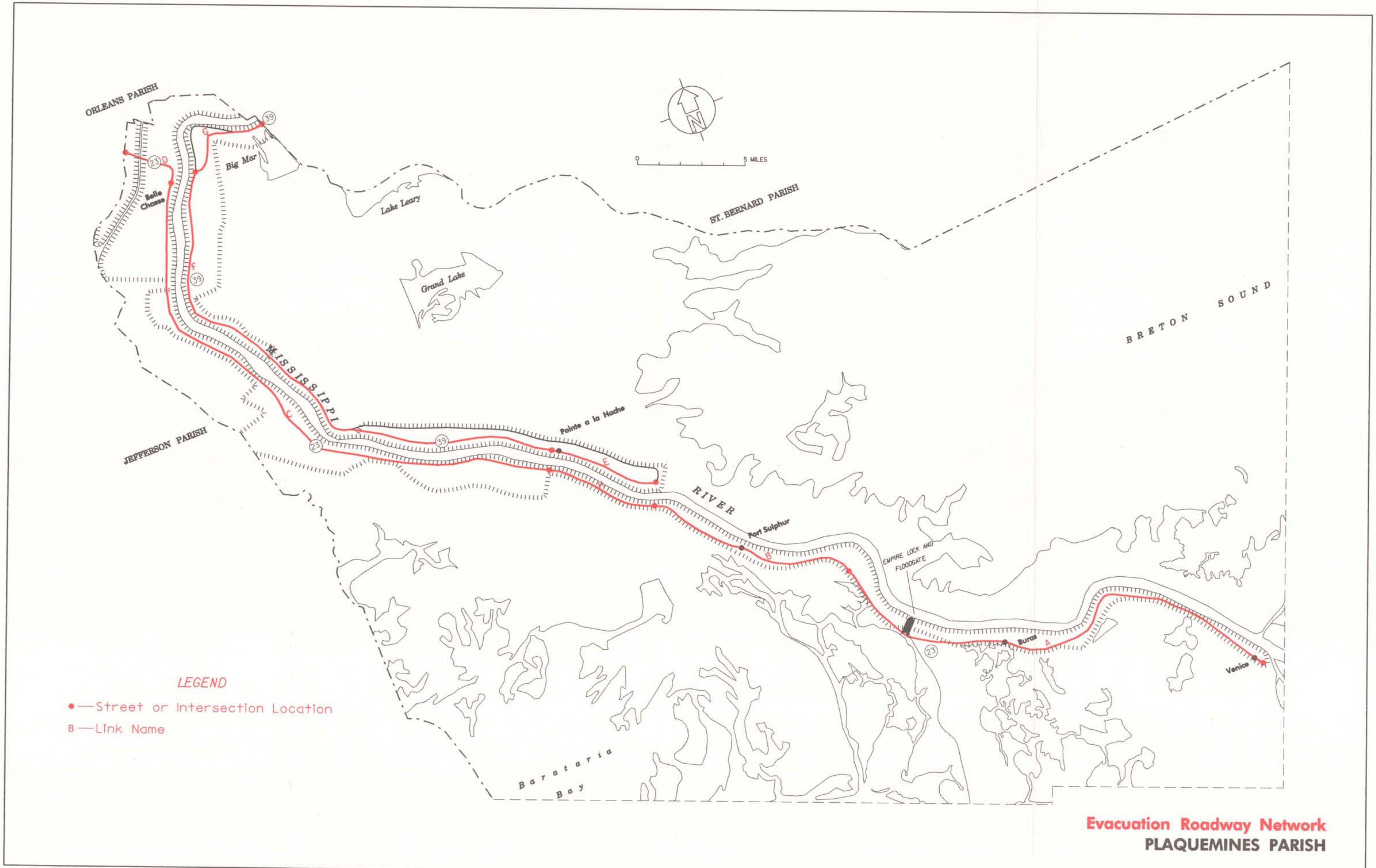
Evacuation Roadway Network
LAFOURCHE PARISH



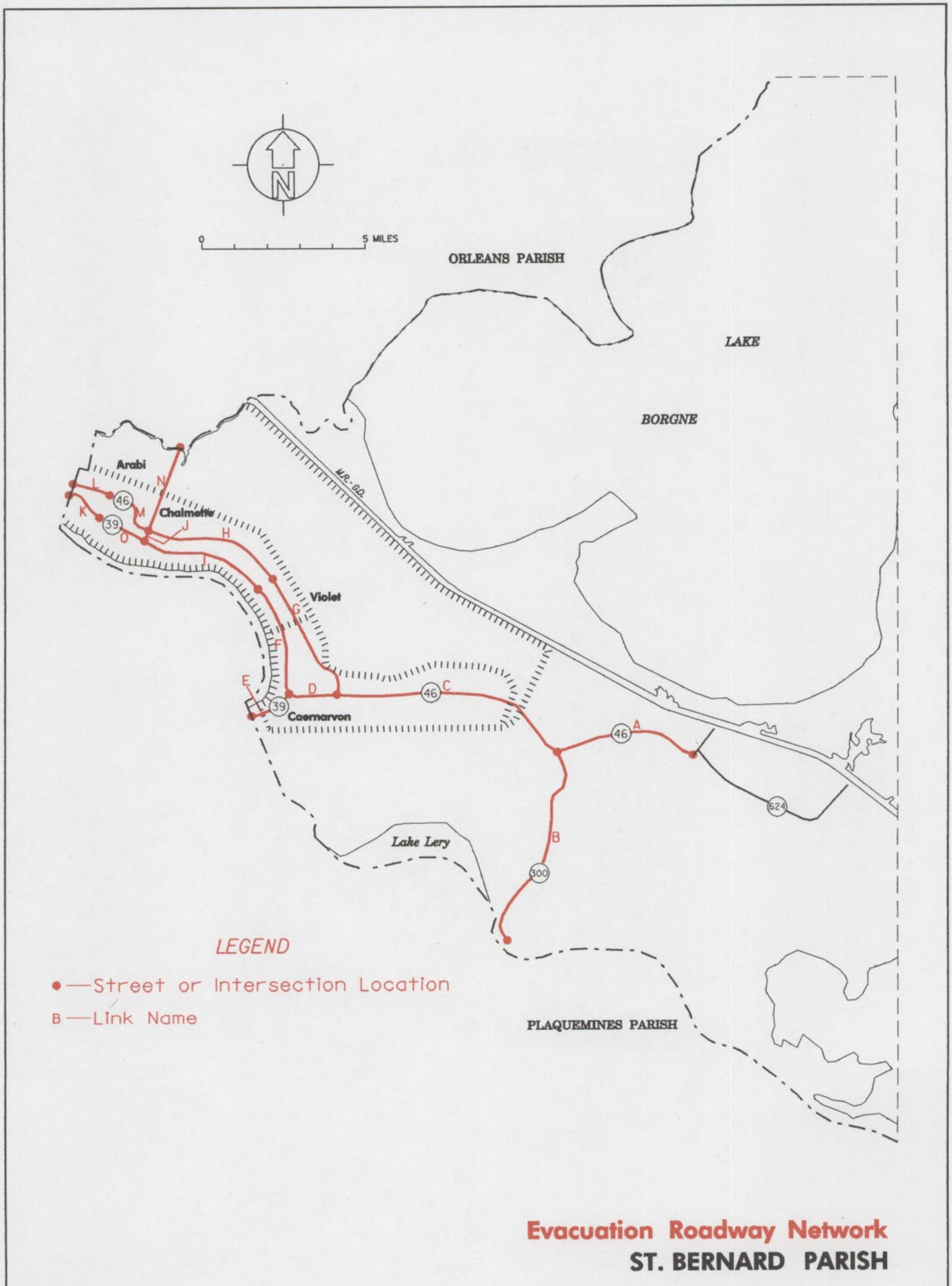
Evacuation Roadway Network
ORLEANS PARISH



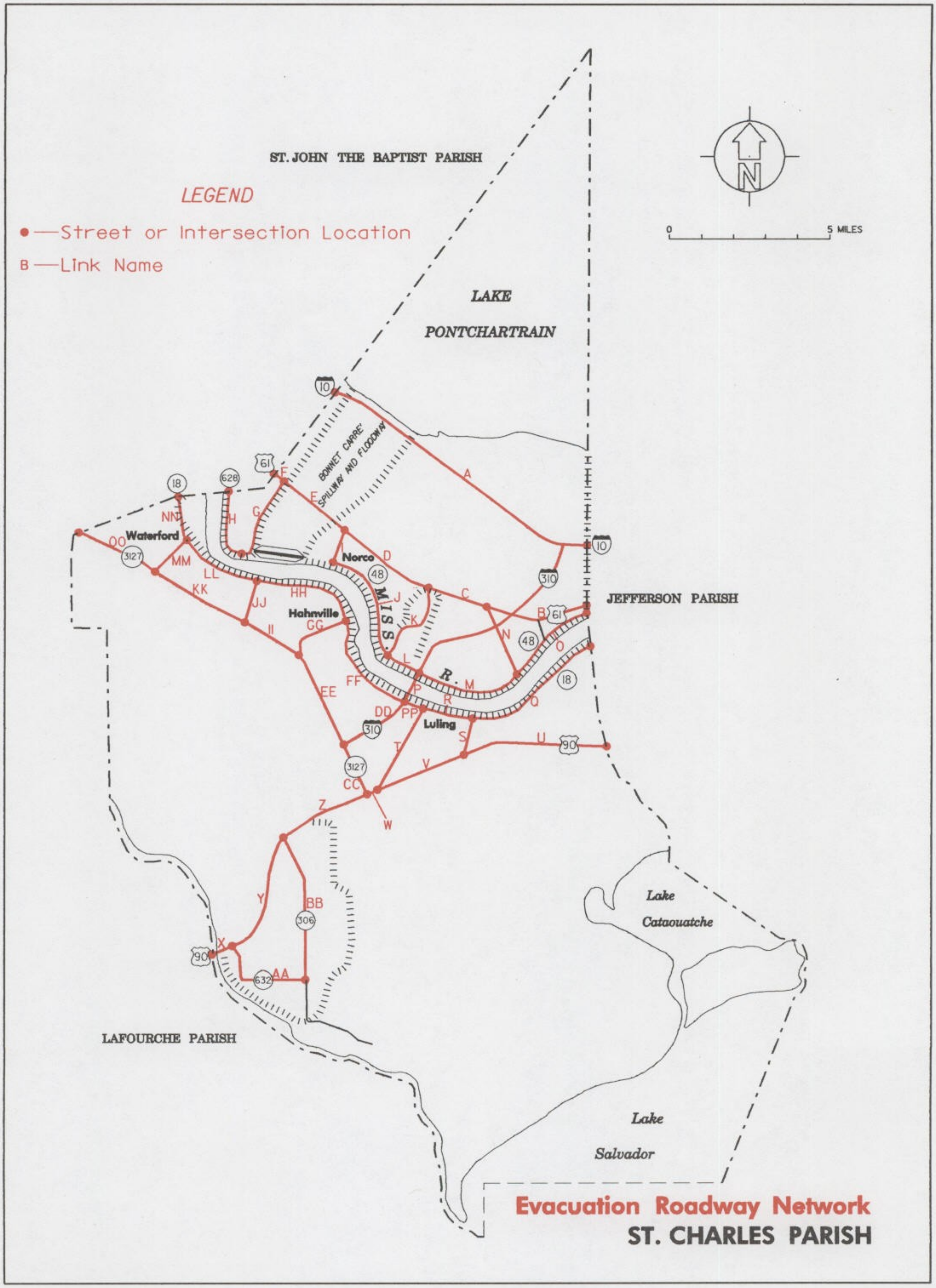
Evacuation Roadway Network
CITY OF NEW ORLEANS



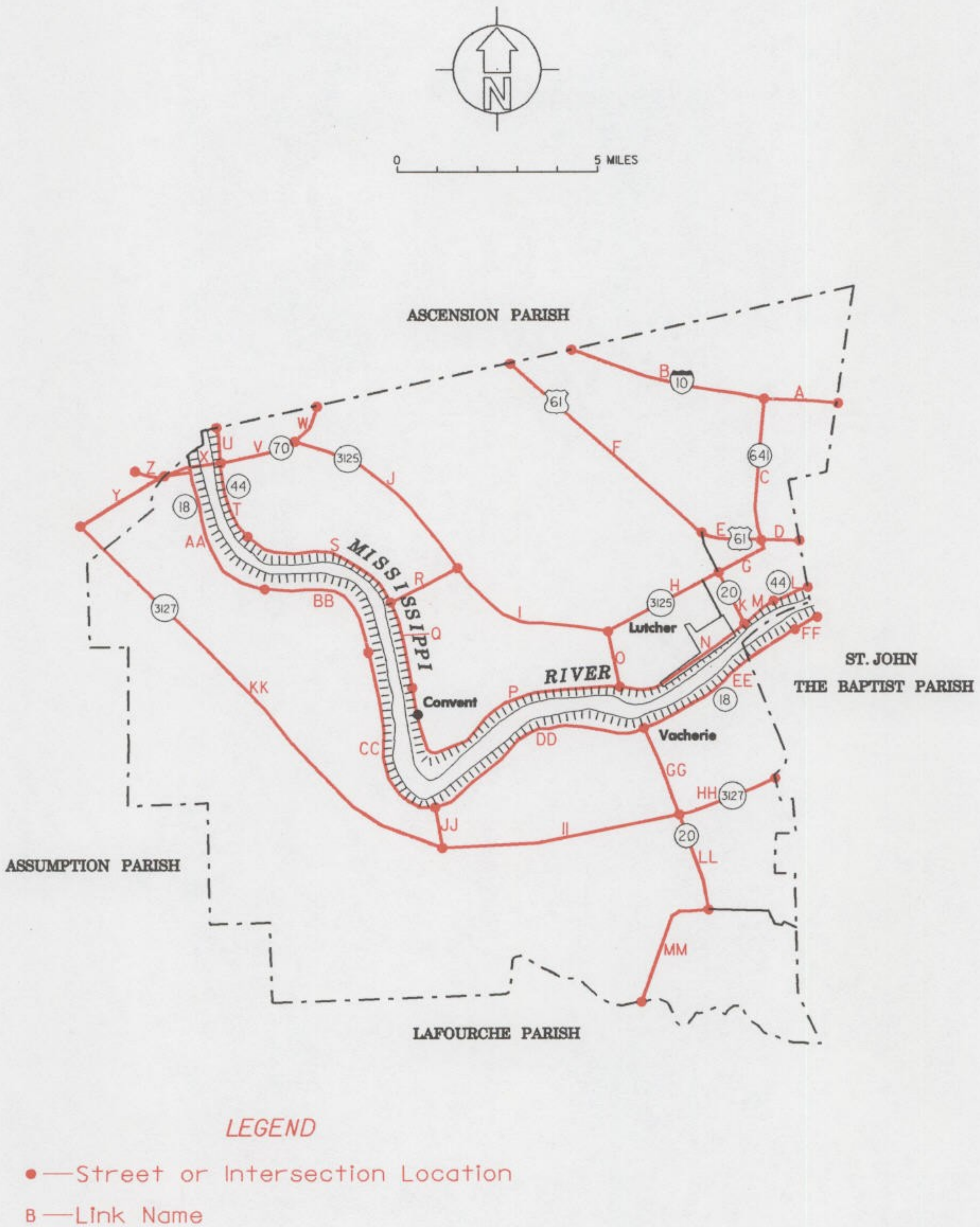
Evacuation Roadway Network
PLAQUEMINES PARISH



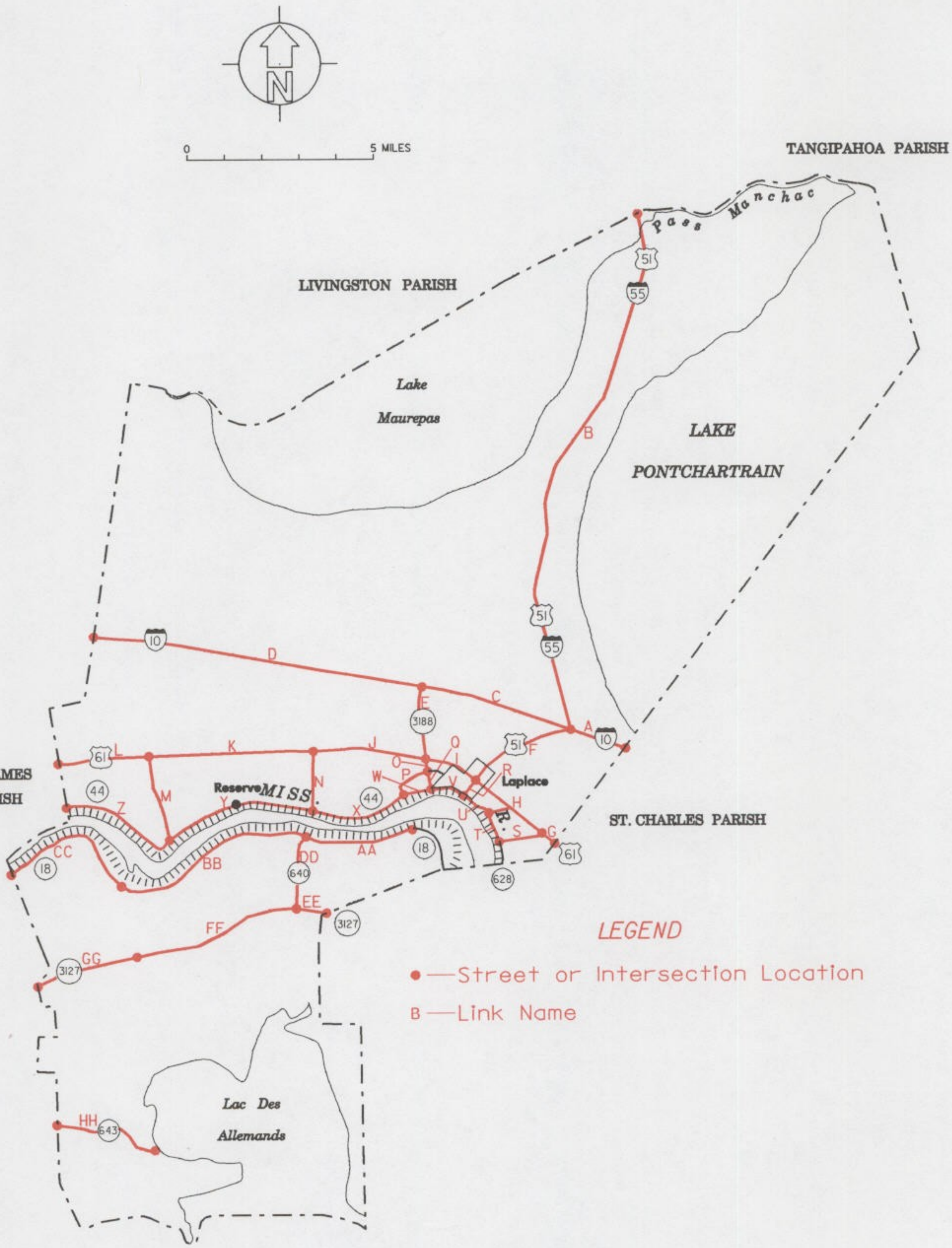
Evacuation Roadway Network
ST. BERNARD PARISH



ST. JOHN THE BAPTIST PARISH
LEGEND
● —Street or Intersection Location
B —Link Name
0
5 MILES
N
LAKE
PONTCHARTRAIN
BONNET CARRE' SPILLWAY AND FLOODWAY
Waterford
Norco
Hahnville
Luling
MISS.
R.
JEFFERSON PARISH
LAFOURCHE PARISH
Lake
Cataouatche
Lake
Salvador
Evacuation Roadway Network
ST. CHARLES PARISH

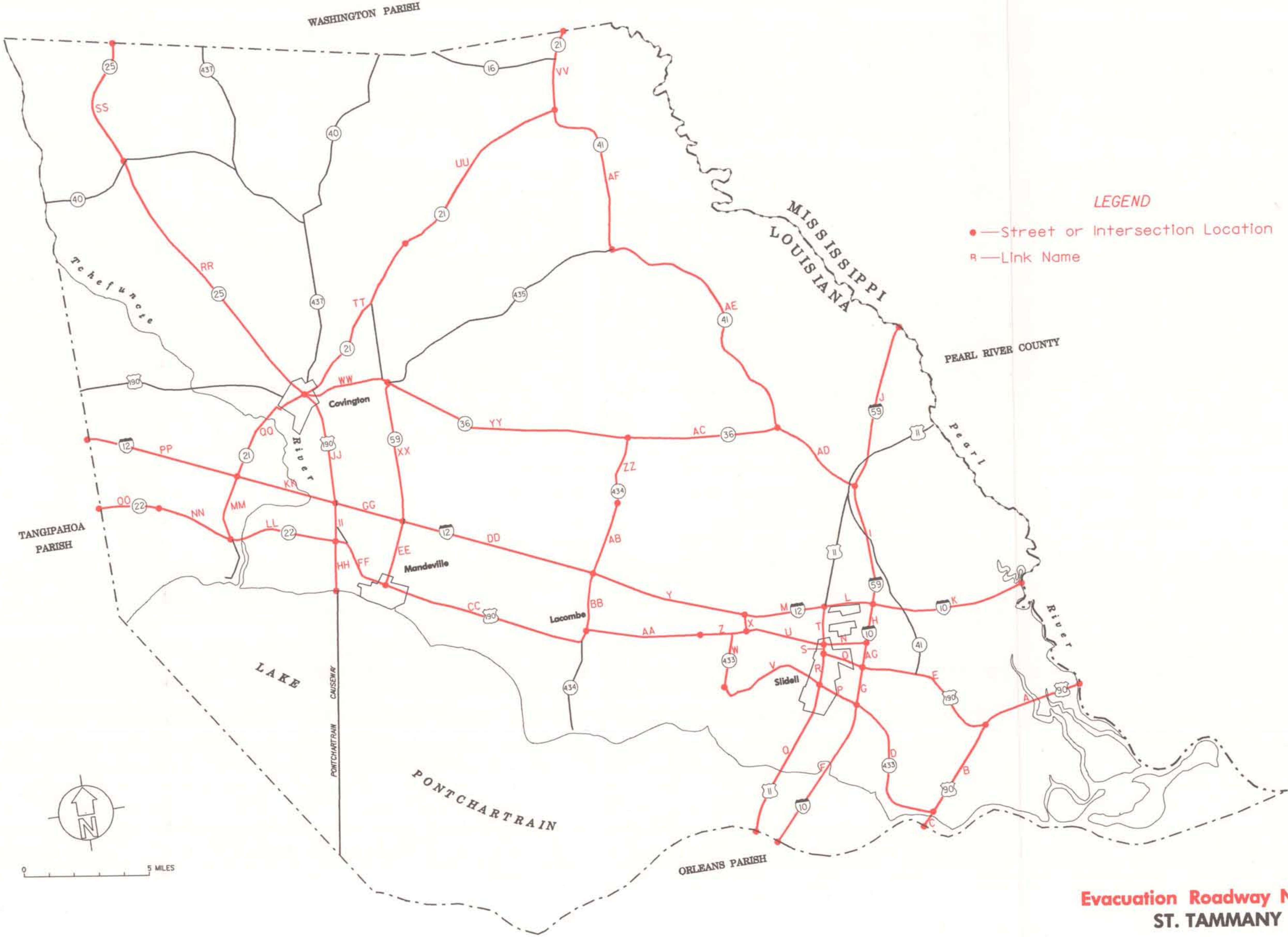


Evacuation Roadway Network
ST. JAMES PARISH



Evacuation Roadway Network

ST. JOHN THE BAPTIST PARISH



Evacuation Roadway Network

ST. TAMMANY PARISH

CHAPTER SEVEN

DECISION ARC METHOD

I. PURPOSE

This chapter describes the Decision Arc Method, a hurricane evacuation decision-making tool that uses the clearance times determined by the transportation analysis in conjunction with National Hurricane Center advisories to calculate when evacuations must begin in order for them to be completed prior to pre-landfall hazards.

II. BACKGROUND

The central Gulf of Mexico is one of the more hurricane vulnerable locations along the coastline of the United States. Between 1886 and 1992 a total of 35 tropical cyclones of hurricane intensity passed within 125 statute miles of New Orleans. An analysis of hurricane forecasts made by the National Hurricane Center indicates the magnitude of error that can be expected in forecasting the track of approaching hurricanes. The average error in the official hurricane track forecast between 1970 and 1979 was 51 miles for the 12-hour forecast, 109 miles for the 24-hour forecast, 247 miles for the 48-hour forecast, and 377 miles for the 72-hour forecast. Thus, if a storm were forecast to make landfall due south of New Orleans in 24 hours, and if, in fact, it made landfall anywhere between Dauphin Island, Alabama and Marsh Island, Louisiana, the error in forecast landfall position would be no worse than average. Although errors in the official forecast track have continued to decline on a yearly basis, errors during the 1993 hurricane season could be expected to average 95 miles for the 24-hour forecast, 200 miles for the 48-hour forecast, and 290 miles for the 72-hour forecast. Errors also occur in forecasting the forward speed and estimated time of landfall for approaching hurricanes.

In addition to the unpredictability of hurricane forecasting, southeast Louisiana must also deal with a large population base located in areas vulnerable to hurricane surge. The limited number of evacuation routes and the distance some evacuees must travel to reach safety creates exceedingly long clearance times, especially for the higher categories of hurricanes. The goal in hurricane preparedness is to begin an evacuation with sufficient lead time to allow all evacuees to safely reach their destinations. This requires sufficient knowledge regarding the estimated arrival time of pre-landfall hazards and the necessary clearance time based on the population at risk. The clearance times resulting from the transportation analysis represent the time required to clear the evacuation roadway network of the at risk population for a number of hurricane scenarios. The time of arrival of sustained gale-force winds in advance of landfall must also be considered to avoid exposing the evacuees to pre-landfall hazards. The Decision Arc Method combines these factors into a graphical representation of the approaching hurricane and determines a decision point for evacuation purposes.

The National Hurricane Center issues public advisories which provide the probabilities of a hurricane passing within 65 miles of specific coastal locations. The probabilities are based on the estimated time to landfall, see Appendix A, Table A-3. For example, the maximum probability that can be assigned to a specific coastal location 48 hours prior to landfall is 13 percent. With clearance times in southeast Louisiana exceeding 48 hours for a slow moving category 3, 4 or 5 hurricane, it becomes clear that the probabilities of being directly impacted by a storm would still be quite low at the point when an evacuation decision should be made. Waiting until the probabilities increase creates the potential for subjecting the evacuees to pre-landfall hazards. The methods presented in this chapter are designed to help compensate for forecast errors by relating evacuation operations to hurricane position.

A number of computer programs, including the HURREVAC Computer Model developed as part of this study, are available to assist state and local agencies involved in hurricane preparedness and response. These programs incorporate information developed in previous hurricane evacuation studies, including some version of the decision arc method presented in this chapter. Computer programs can be used to perform a number of valuable functions as a hurricane approaches, these include tracking the storm, maintaining a list of institutional/medical facilities, identifying major evacuation routes, presenting hurricane strike probabilities, estimating time and distance to landfall, and presenting potential surge inundation limits. Even if a computer program is used, familiarity with the concepts presented in this chapter is of utmost importance. This will enhance confident use of the software and will also insure the ability to function in the event of power outages or computer failure.

III. DECISION ARC COMPONENTS

A. General. The Decision Arc Method employs two separate but related components which, when used together with information presented in the National Weather Service advisories, graphically depict the hurricane situation as it develops. A specialized hurricane tracking chart, the Decision Arc Map, is teamed with a transparent two-dimensional hurricane graphic, the STORM, to describe the approaching hurricane and its location in relation to southeast Louisiana. It is important to think of the storm as a large entity, not just a point on a map designating the eye of the hurricane.

B. Hurricane Advisories. As a hurricane develops and begins to threaten the United States, public and marine advisories are issued by the National Weather Service at 6 hour increments (a sample marine advisory and public advisory are presented in Appendix A). These advisories define the size, intensity, forward speed, and direction of forward movement of the hurricane. The marine advisory also includes forecast locations for the eye of the hurricane 12, 24, 36, 48, and 72 hours from the time of the advisory. The two advisories use different units of measurement to define these parameters, knots and nautical miles in the marine advisory and miles per hour and statute miles in the public advisory. The decision arc method, which requires the forecast locations of the approaching hurricane, has been developed to utilize information taken directly from the marine advisory. The public advisory should only be used to obtain the probabilities of a hurricane passing within 65 miles of specific coastal locations.

C. Decision Arc Map. In order to properly evaluate the last reported position and forecast track of an approaching hurricane, special hurricane tracking charts have been developed for southeast Louisiana (Plates 7-1 through 7-4). Superimposed on ordinary tracking charts are series of concentric arcs with their centers on four points: New Orleans, which serves as the decision arc map for Jefferson, Orleans and St. Bernard Parishes; Buras, which serves as the decision arc map for Lafourche and Plaquemines Parishes and Grand Isle; Slidell, which serves as the decision arc map for St. Tammany Parish; and Laplace, which serves as the decision arc map for St. Charles, St. John the Baptist and St James Parishes. The concentric arcs, spaced at 25 mile intervals measured from their center, are labeled both in nautical miles and alphabetically. Plates 7-1 through 7-4 show the decision arc maps for the study area.

D. STORM. The Special Tool for Omnidirectional Radial Measurements (STORM) is used as a two-dimensional depiction of an approaching hurricane. It is a transparent disk with concentric circles spaced at 25 nautical mile intervals, their center representing the hurricane eye (Figure 7-1). These circles form a scale used to note the radius of gale-force winds reported by the National Hurricane Center in the marine advisory. The STORM disk should only be used with Plates 7-1 through 7-4.

IV. DECISION ARC METHOD

A. General. The decision arc method is a tool which allows emergency managers to create a graphical representation of an approaching hurricane and to determine when preparations for an evacuation must begin. In order to avoid exposing evacuees to pre-landfall hazards, an evacuation should be completed prior to the arrival of sustained gale-force winds or the onset of storm surge inundation, whichever occurs first. In southeast Louisiana, the limiting factor for safely completing a hurricane evacuation is the arrival of sustained gale-force winds.

The two most prominent considerations in determining when to issue an evacuation notice are the clearance time and the arrival of gale-force winds. Clearance time is the time required to clear the roadway network of all evacuating vehicles. It also determines the time period in hours prior to the arrival of gale-force winds necessary for a safe evacuation. Three primary factors are required to determine the appropriate clearance time: (1) the Saffir/Simpson hurricane category, (2) the expected evacuee response rate, and (3) the forward speed of the storm. Decision arcs can be viewed simply as a graphical representation of the clearance time.

The decision arc method converts clearance times to distances by accounting for the forward speed of the hurricane. To translate a clearance time into nautical miles (a decision arc distance) for use with a decision arc map, a simple calculation of multiplying the clearance time by the forward speed of the hurricane in knots is necessary. This calculation yields the distance in nautical miles that the radius of gale-force winds will move while the evacuation is underway. For convenience, a decision arc table has been developed for each parish that converts an array of clearance times and forward speeds to respective decision arcs. Tables 7-1 through 7-9 present the decision arcs for each parish within the study area.

B. Recommending an Evacuation. Behavioral patterns suggest that residents living in threatened communities do not begin evacuating in significant numbers until an evacuation order has been issued. The lengthy clearance times for southeast Louisiana may force emergency managers to make evacuation decisions before a hurricane watch or warning has been issued by the National Hurricane Center. This would require residents to begin evacuating when a storm is still hundreds of miles away and the probabilities of being directly impacted by the storm are quite low. A phased evacuation might warrant consideration in these instances. A phased evacuation would involve evacuating the most vulnerable segments of the population first and escalating the evacuation over time, as the threat of the hurricane becomes more eminent.

The probability values contained in both the marine advisory and the public advisory, issued by the National Hurricane Center at 6 hour increments, describe in percentages the chance that the center of a storm will pass within 65 miles of specific coastal locations (sample advisories are presented in Appendix A). To check the relative probability for a particular area, the total probability value for the closest location, shown on the right side of the probability table in the advisory, should be compared to other locations. A comparison should also be made with the possible maximums shown in Table A-3. There is no one threshold probability which should prompt an evacuation under any and every hurricane threat. The size, intensity and forward speed of the storm, as well as its anticipated track will need to be considered. Decisions for or against an evacuation should be coordinated with the Louisiana Office of Emergency Preparedness, the National Weather Service, and adjacent parishes.

C. Timing of an Evacuation Notice. As a hurricane approaches, the decision arc method requires officials to make evacuation decisions prior to the time at which the radius of gale-force winds touches the appropriate decision arc (the Decision Point). For example, with a clearance time of 20 hours and a forward speed of 15 knots, the evacuation should be initiated before the sustained gale-force winds approach within 300 nautical miles (decision arc I). Once the sustained gale-force winds move across the decision arc (within 300 nautical miles of your location), there may not be sufficient time to safely evacuate the affected population.

It is imperative that emergency managers and local officials also account for the time required to implement a decision to evacuate. The preparation of press releases, the implementation of traffic control measures, and the accomplishment of other related activities, average approximately 6 hours in most emergency management offices. Completion of these activities are essential to the successful dissemination of an evacuation notice. Decisions regarding some of the more significant traffic control measures discussed in Chapter 6, particularly the decision as to when to lock all draw/swing bridges in the down position, when to suspend tolls on the Causeway and Crescent City Connection, and the possibility of creating an additional lane on I-10 west between Jefferson Parish and I-55 and on I-10 east over Lake Pontchartrain, should be resolved prior to the start of each hurricane season.

V. EVACUATION DECISION WORKSHEET

Appendix A contains a step by step description of the Decision Arc Method. A worksheet has also been included to guide the decision-maker through each step of the process. Also included are sample National Hurricane Center marine and public advisories, a time conversion table, a Saffir/Simpson Hurricane Scale, a maximum probability values table, tables for converting from knots to miles per hour and nautical miles to statute miles and a general decision arc table that can be used for those situations when the parish decision arc tables do not apply.

TABLE 7-1

JEFFERSON PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1] Off-Peak	Peak-Period
CAT 1/05	Rapid	5/A	6/A
CAT 1/05	Medium	7/A	8/A
CAT 1/05	Slow	10/A	12/A
CAT 1/15	Rapid	5/A	6/A
CAT 1/15	Medium	7/B	8/B
CAT 1/15	Slow	10/C	12/E
CAT 2/05	Rapid	15/A	17/A
CAT 2/05	Medium	16/A	20/A
CAT 2/05	Slow	17/A	23/B
CAT 2/15	Rapid	5/A	6/A
CAT 2/15	Medium	7/B	8/B
CAT 2/15	Slow	10/C	12/E
CAT 3/05	Rapid	43/F	45/F
CAT 3/05	Medium	43/F	47/G
CAT 3/05	Slow	44/F	51/H
CAT 3/15	Rapid	14/F	15/F
CAT 3/15	Medium	15/F	16/G
CAT 3/15	Slow	15/F	18/H
CAT 4/05	Rapid	43/F	45/F
CAT 4/05	Medium	43/F	47/G
CAT 4/05	Slow	44/F	51/H
CAT 4/15	Rapid	37/T	40/U
CAT 4/15	Medium	38/T	42/W
CAT 4/15	Slow	39/U	46/Y
CAT 5/05	Rapid	43/F	45/F
CAT 5/05	Medium	43/F	47/G
CAT 5/05	Slow	44/F	51/H
CAT 5/15	Rapid	43/W	45/X
CAT 5/15	Medium	43/W	47/Z
CAT 5/15	Slow	44/X	51/BB

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-2

LAFOURCHE PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1]
CAT 1/05	Rapid	7/A
CAT 1/05	Medium	7/A
CAT 1/05	Slow	10/A
CAT 1/15	Rapid	7/B
CAT 1/15	Medium	7/B
CAT 1/15	Slow	10/C
CAT 2/05	Rapid	11/A
CAT 2/05	Medium	12/A
CAT 2/05	Slow	13/A
CAT 2/15	Rapid	7/B
CAT 2/15	Medium	7/B
CAT 2/15	Slow	10/C
CAT 3/05	Rapid	13/A
CAT 3/05	Medium	14/A
CAT 3/05	Slow	15/A
CAT 3/15	Rapid	11/D
CAT 3/15	Medium	12/E
CAT 3/15	Slow	13/E
CAT 4/05	Rapid	13/A
CAT 4/05	Medium	14/A
CAT 4/05	Slow	15/A
CAT 4/15	Rapid	13/E
CAT 4/15	Medium	14/F
CAT 4/15	Slow	15/F
CAT 5/05	Rapid	13/A
CAT 5/05	Medium	14/A
CAT 5/05	Slow	15/A
CAT 5/15	Rapid	13/E
CAT 5/15	Medium	14/F
CAT 5/15	Slow	15/F

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-3

ORLEANS PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1] Off-Peak	Peak-Period
CAT 1/05	Rapid	5/A	6/A
CAT 1/05	Medium	7/A	8/A
CAT 1/05	Slow	10/A	12/A
CAT 1/15	Rapid	5/A	6/A
CAT 1/15	Medium	7/B	8/B
CAT 1/15	Slow	10/C	12/E
CAT 2/05	Rapid	15/A	17/A
CAT 2/05	Medium	16/A	20/A
CAT 2/05	Slow	17/A	23/B
CAT 2/15	Rapid	5/A	6/A
CAT 2/15	Medium	7/B	8/B
CAT 2/15	Slow	10/C	12/E
CAT 3/05	Rapid	43/F	45/F
CAT 3/05	Medium	43/F	47/G
CAT 3/05	Slow	44/F	51/H
CAT 3/15	Rapid	14/F	15/F
CAT 3/15	Medium	15/F	16/G
CAT 3/15	Slow	15/F	18/H
CAT 4/05	Rapid	43/F	45/F
CAT 4/05	Medium	43/F	47/G
CAT 4/05	Slow	44/F	51/H
CAT 4/15	Rapid	37/T	40/U
CAT 4/15	Medium	38/T	42/W
CAT 4/15	Slow	39/U	46/Y
CAT 5/05	Rapid	43/F	45/F
CAT 5/05	Medium	43/F	47/G
CAT 5/05	Slow	44/F	51/H
CAT 5/15	Rapid	43/W	45/X
CAT 5/15	Medium	43/W	47/Z
CAT 5/15	Slow	44/X	51/BB

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-4

PLAQUEMINES PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1]
CAT 1/05	Rapid	5/A
CAT 1/05	Medium	7/A
CAT 1/05	Slow	10/A
CAT 1/15	Rapid	5/A
CAT 1/15	Medium	7/B
CAT 1/15	Slow	10/C
CAT 2/05	Rapid	15/A
CAT 2/05	Medium	16/A
CAT 2/05	Slow	17/A
CAT 2/15	Rapid	5/A
CAT 2/15	Medium	7/B
CAT 2/15	Slow	10/C
CAT 3/05	Rapid	43/F
CAT 3/05	Medium	43/F
CAT 3/05	Slow	44/F
CAT 3/15	Rapid	14/F
CAT 3/15	Medium	15/F
CAT 3/15	Slow	15/F
CAT 4/05	Rapid	43/F
CAT 4/05	Medium	43/F
CAT 4/05	Slow	44/F
CAT 4/15	Rapid	37/T
CAT 4/15	Medium	38/T
CAT 4/15	Slow	39/U
CAT 5/05	Rapid	43/F
CAT 5/05	Medium	43/F
CAT 5/05	Slow	44/F
CAT 5/15	Rapid	43/W
CAT 5/15	Medium	43/W
CAT 5/15	Slow	44/X

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-5

ST. BERNARD PARISH DECISION ARCS

Storm Category/Speed(knots)	Evacuee Response	Clearance Time/Decision Arc[1]
CAT 1/05	Rapid	5/A
CAT 1/05	Medium	7/A
CAT 1/05	Slow	10/A
CAT 1/15	Rapid	5/A
CAT 1/15	Medium	7/B
CAT 1/15	Slow	10/C
CAT 2/05	Rapid	15/A
CAT 2/05	Medium	16/A
CAT 2/05	Slow	17/A
CAT 2/15	Rapid	5/A
CAT 2/15	Medium	7/B
CAT 2/15	Slow	10/C
CAT 3/05	Rapid	43/F
CAT 3/05	Medium	43/F
CAT 3/05	Slow	44/F
CAT 3/15	Rapid	14/F
CAT 3/15	Medium	15/F
CAT 3/15	Slow	15/F
CAT 4/05	Rapid	43/F
CAT 4/05	Medium	43/F
CAT 4/05	Slow	44/F
CAT 4/15	Rapid	37/T
CAT 4/15	Medium	38/T
CAT 4/15	Slow	39/U
CAT 5/05	Rapid	43/F
CAT 5/05	Medium	43/F
CAT 5/05	Slow	44/F
CAT 5/15	Rapid	43/W
CAT 5/15	Medium	43/W
CAT 5/15	Slow	44/X

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-6

ST. CHARLES PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1] Local	US 61	I-10
CAT 1/05	Rapid	5/A	---	---
CAT 1/05	Medium	7/A	---	---
CAT 1/05	Slow	10/A	---	---
CAT 1/15	Rapid	5/A	---	---
CAT 1/15	Medium	7/B	---	---
CAT 1/15	Slow	10/C	---	---
CAT 2/05	Rapid	6/A	12/A	27/C
CAT 2/05	Medium	7/A	12/A	28/C
CAT 2/05	Slow	10/A	13/A	30/C
CAT 2/15	Rapid	5/A	---	---
CAT 2/15	Medium	7/B	---	---
CAT 2/15	Slow	10/C	---	---
CAT 3/05	Rapid	9/A	24/B	36/E
CAT 3/05	Medium	9/A	24/B	37/E
CAT 3/05	Slow	10/A	25/B	38/E
CAT 3/15	Rapid	6/A	---	---
CAT 3/15	Medium	7/B	---	---
CAT 3/15	Slow	10/C	---	---
CAT 4/05	Rapid	9/A	24/B	36/E
CAT 4/05	Medium	9/A	24/B	37/E
CAT 4/05	Slow	10/A	25/B	38/E
CAT 4/15	Rapid	6/A	16/G	31/P
CAT 4/15	Medium	7/B	16/G	32/Q
CAT 4/15	Slow	10/C	17/H	33/Q
CAT 5/05	Rapid	9/A	24/B	36/E
CAT 5/05	Medium	9/A	24/B	37/E
CAT 5/05	Slow	10/A	25/B	38/E
CAT 5/15	Rapid	9/C	24/L	36/S
CAT 5/15	Medium	9/C	24/L	37/T
CAT 5/15	Slow	10/C	25/L	38/T

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-7

ST. JAMES PARISH DECISION ARCS

Storm	Evacuee	Clearance Time/Decision Arc[1]		
Category/Speed(Knots)	Response	Local	US 61	I-10
CAT 1/05	Rapid	5/A	---	---
CAT 1/05	Medium	7/A	---	---
CAT 1/05	Slow	10/A	---	---
CAT 1/15	Rapid	5/A	---	---
CAT 1/15	Medium	7/B	---	---
CAT 1/15	Slow	10/C	---	---
CAT 2/05	Rapid	6/A	12/A	27/C
CAT 2/05	Medium	7/A	12/A	28/C
CAT 2/05	Slow	10/A	13/A	30/C
CAT 2/15	Rapid	5/A	---	---
CAT 2/15	Medium	7/B	---	---
CAT 2/15	Slow	10/C	---	---
CAT 3/05	Rapid	9/A	24/B	36/E
CAT 3/05	Medium	9/A	24/B	37/E
CAT 3/05	Slow	10/A	25/B	38/E
CAT 3/15	Rapid	6/A	---	---
CAT 3/15	Medium	7/B	---	---
CAT 3/15	Slow	10/C	---	---
CAT 4/05	Rapid	9/A	24/B	36/E
CAT 4/05	Medium	9/A	24/B	37/E
CAT 4/05	Slow	10/A	25/B	38/E
CAT 4/15	Rapid	6/A	16/G	31/P
CAT 4/15	Medium	7/B	16/G	32/Q
CAT 4/15	Slow	10/C	17/H	33/Q
CAT 5/05	Rapid	9/A	24/B	36/E
CAT 5/05	Medium	9/A	24/B	37/E
CAT 5/05	Slow	10/A	25/B	38/E
CAT 5/15	Rapid	9/C	24/L	36/S
CAT 5/15	Medium	9/C	24/L	37/T
CAT 5/15	Slow	10/C	25/L	38/T

[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-8

ST. JOHN THE BAPTIST PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1] Local	US 61	I-10
CAT 1/05	Rapid	5/A	---	---
CAT 1/05	Medium	7/A	---	---
CAT 1/05	Slow	10/A	---	---
CAT 1/15	Rapid	5/A	---	---
CAT 1/15	Medium	7/B	---	---
CAT 1/15	Slow	10/C	---	---
CAT 2/05	Rapid	6/A	12/A	27/C
CAT 2/05	Medium	7/A	12/A	28/C
CAT 2/05	Slow	10/A	13/A	30/C
CAT 2/15	Rapid	5/A	---	---
CAT 2/15	Medium	7/B	---	---
CAT 2/15	Slow	10/C	---	---
CAT 3/05	Rapid	9/A	24/B	36/E
CAT 3/05	Medium	9/A	24/B	37/E
CAT 3/05	Slow	10/A	25/B	38/E
CAT 3/15	Rapid	6/A	---	---
CAT 3/15	Medium	7/B	---	---
CAT 3/15	Slow	10/C	---	---
CAT 4/05	Rapid	9/A	24/B	36/E
CAT 4/05	Medium	9/A	24/B	37/E
CAT 4/05	Slow	10/A	25/B	38/E
CAT 4/15	Rapid	6/A	16/G	31/P
CAT 4/15	Medium	7/B	16/G	32/Q
CAT 4/15	Slow	10/C	17/H	33/Q
CAT 5/05	Rapid	9/A	24/B	36/E
CAT 5/05	Medium	9/A	24/B	37/E
CAT 5/05	Slow	10/A	25/B	38/E
CAT 5/15	Rapid	9/C	24/L	36/S
CAT 5/15	Medium	9/C	24/L	37/T
CAT 5/15	Slow	10/C	25/L	38/T

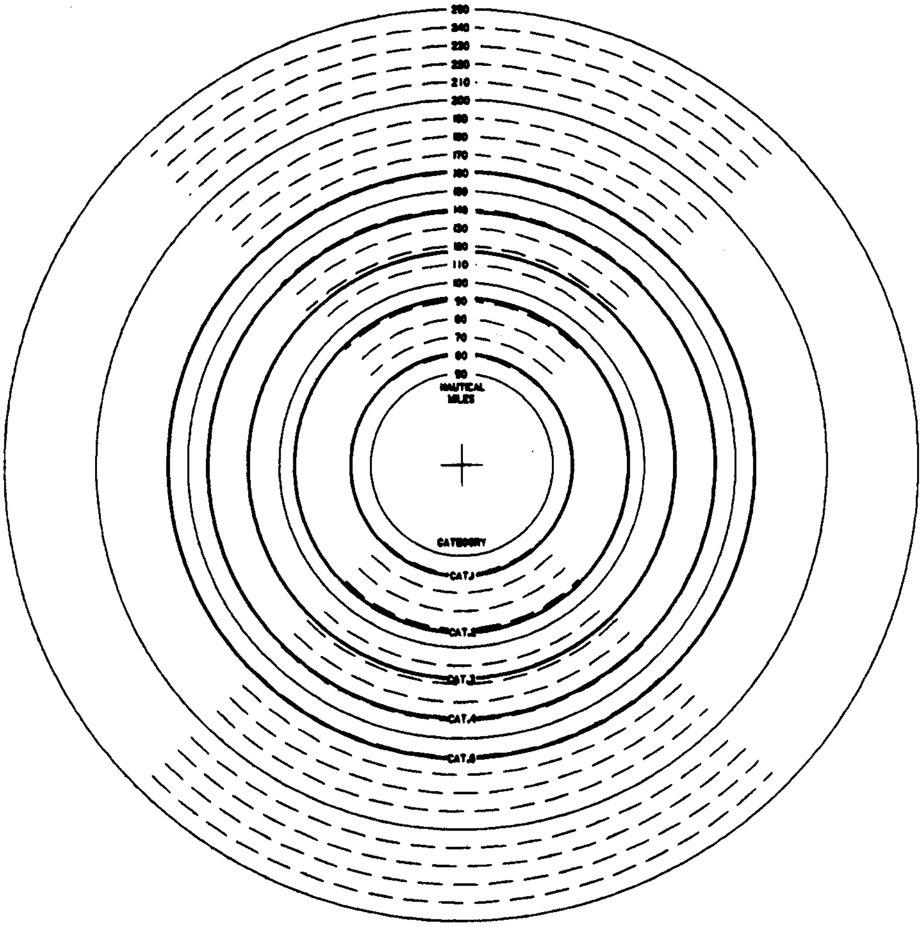
[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.

TABLE 7-9

ST. TAMMANY PARISH DECISION ARCS

Storm Category/Speed(Knots)	Evacuee Response	Clearance Time/Decision Arc[1]
CAT 1/05	Rapid	5/A
CAT 1/05	Medium	7/A
CAT 1/05	Slow	10/A
CAT 1/15	Rapid	5/A
CAT 1/15	Medium	7/B
CAT 1/15	Slow	10/C
CAT 2/05	Rapid	15/A
CAT 2/05	Medium	16/A
CAT 2/05	Slow	17/A
CAT 2/15	Rapid	5/A
CAT 2/15	Medium	7/B
CAT 2/15	Slow	10/C
CAT 3/05	Rapid	43/F
CAT 3/05	Medium	43/F
CAT 3/05	Slow	44/F
CAT 3/15	Rapid	14/F
CAT 3/15	Medium	15/F
CAT 3/15	Slow	15/F
CAT 4/05	Rapid	43/F
CAT 4/05	Medium	43/F
CAT 4/05	Slow	44/F
CAT 4/15	Rapid	37/T
CAT 4/15	Medium	38/T
CAT 4/15	Slow	39/U
CAT 5/05	Rapid	43/F
CAT 5/05	Medium	43/F
CAT 5/05	Slow	44/F
CAT 5/15	Rapid	43/W
CAT 5/15	Medium	43/W
CAT 5/15	Slow	44/X

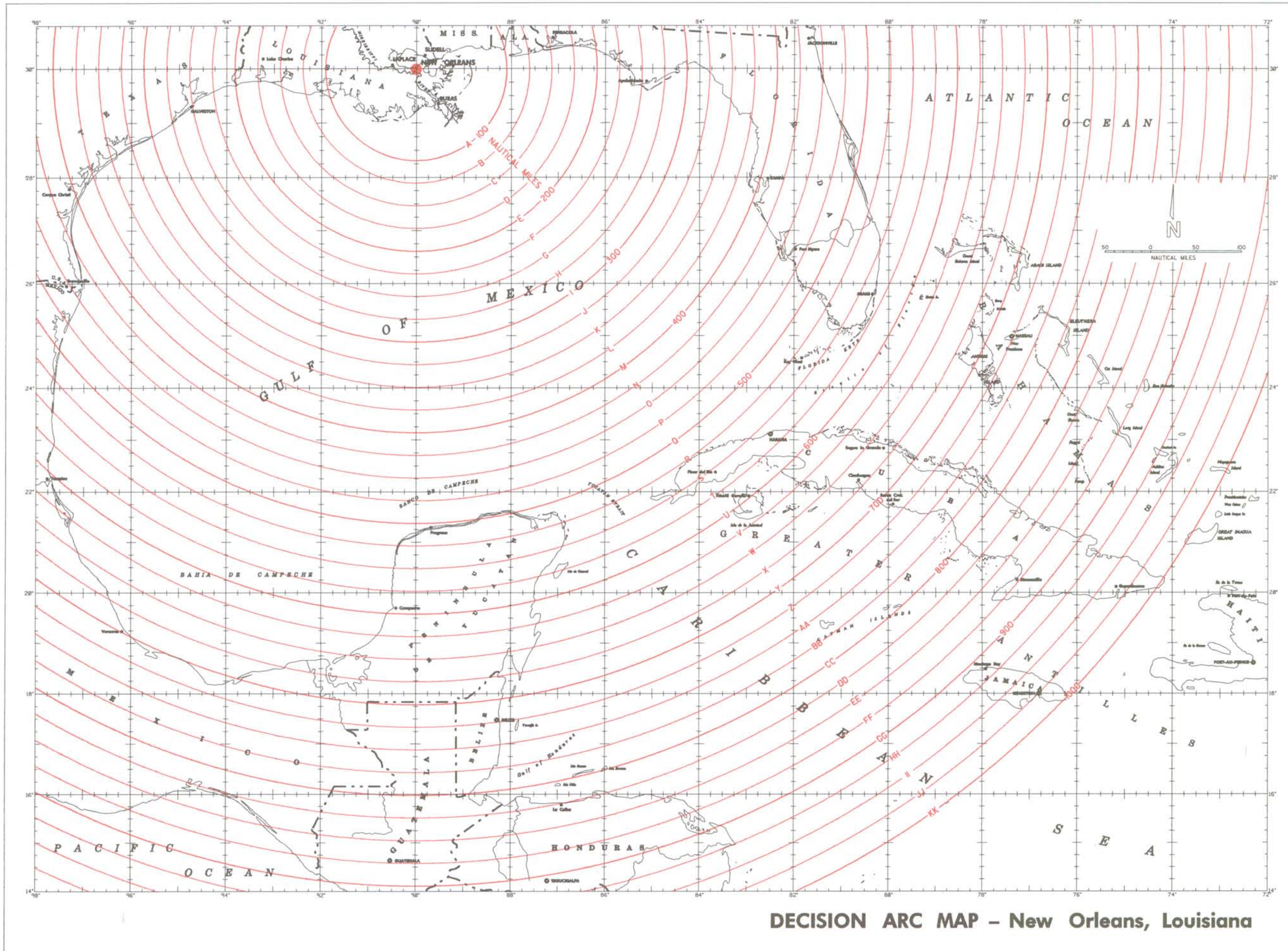
[1] Clearance times and decision arcs were rounded up for the purposes of evacuation decision making.



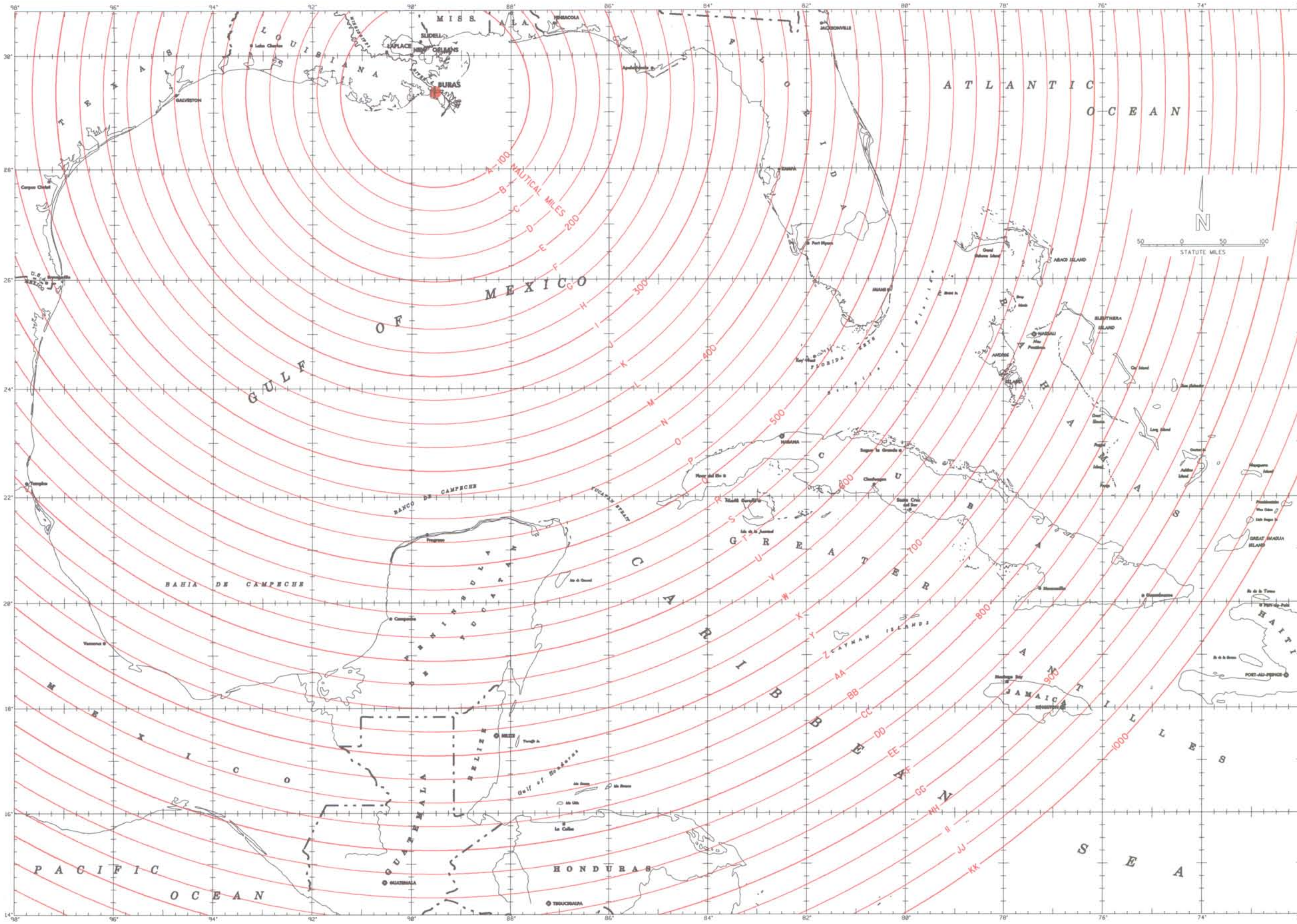
NOTE: For use with Plates 7-1 through 7-4 only.

STORM DISK

Figure 7–1

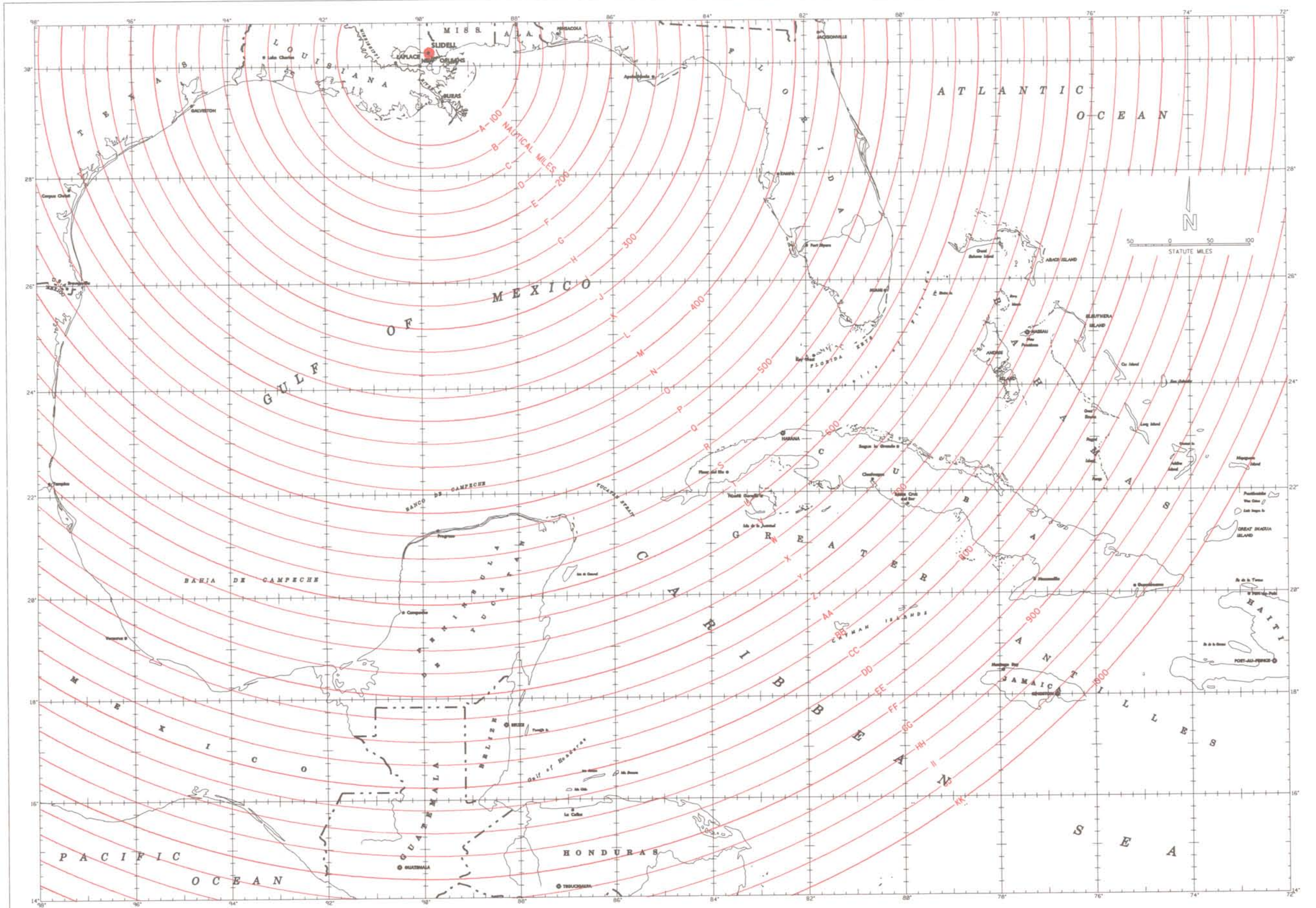


DECISION ARC MAP - New Orleans, Louisiana



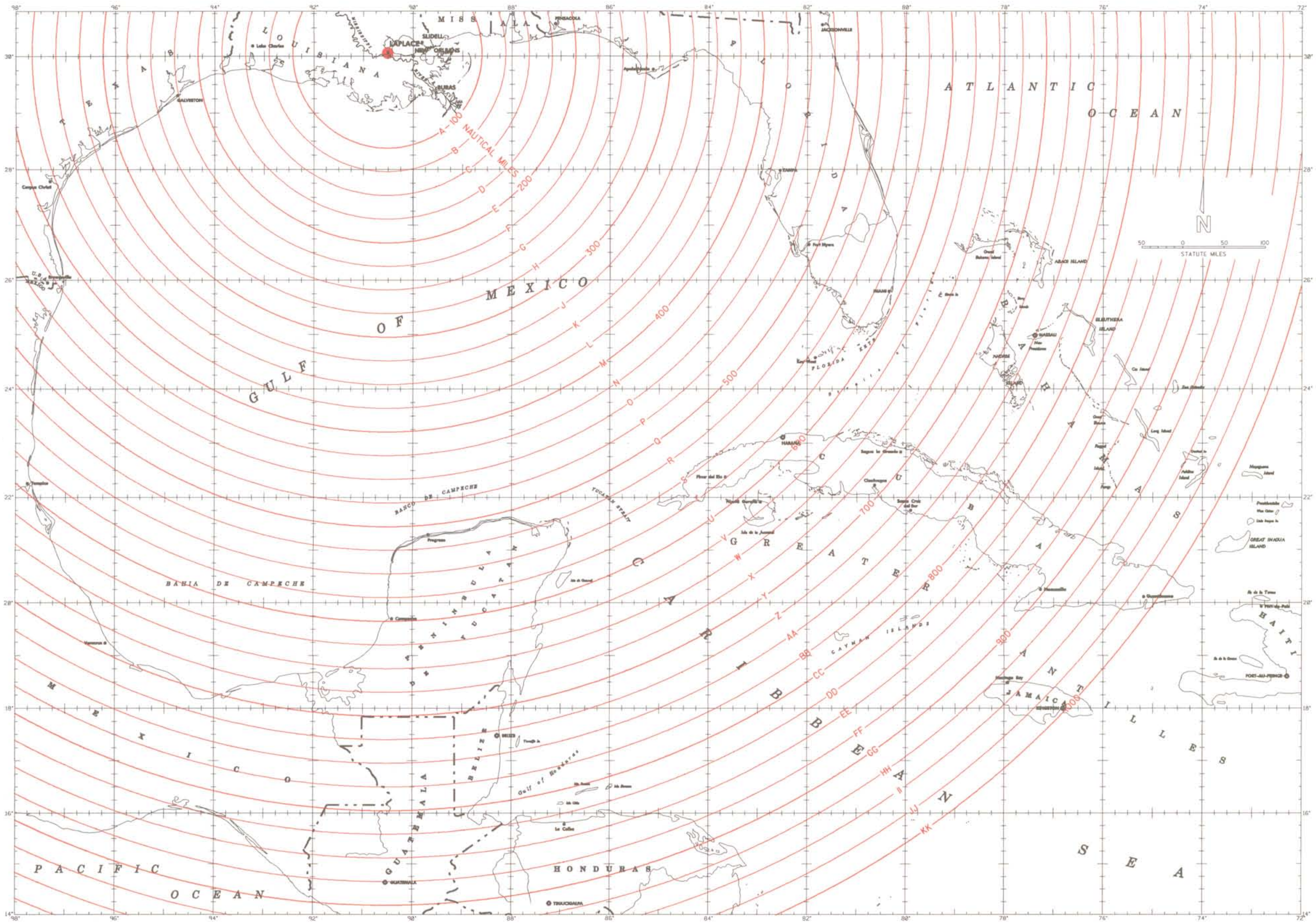
DECISION ARC MAP – Buras, Louisiana

gom182.dgn



DECISION ARC MAP – Slidell, Louisiana

gom103.dgn



DECISION ARC MAP – Laplace, Louisiana

gom104.dgn

APPENDIX A

EVACUATION DECISION WORKSHEET

EVACUATION DECISION WORKSHEET

The following procedure has been developed to utilize information presented in this report and to provide emergency managers with a tool to assist in the evacuation decision making process. Emergency managers must not only determine if an evacuation is warranted, but must also allow sufficient time for an evacuation to be completed in advance of pre-landfall hazards. Hurricane probabilities which are included in advisories issued by the National Weather Service (NWS) can also be used to assist in the decision making process.

There are four basic "tools" needed in this evacuation decision procedure: (1) decision arc map; (2) decision arc table; (3) transparent STORM disk; and (4) the NWS marine advisory. The decision arc worksheet included at the end of this appendix can be used to record the necessary information.

PROCEDURE

1. From the NWS marine advisory, plot the latest reported position of the hurricane eye on the appropriate decision arc map. A total of four decision arc maps were developed for southeast Louisiana, each map is centered around one of the following geographic locations: (1) New Orleans, Louisiana; (2) Buras, Louisiana; (3) Slidell, Louisiana; and (4) Laplace, Louisiana. Select the decision arc map which best approximates the location of the areas being considered for evacuation. Notate the hurricane position with date and time. ZULU time (Greenwich mean time) used in the marine advisory should be converted to central daylight time by subtracting five (5) hours, see Table A-1. Plot and notate the five forecast positions (12 hr, 24 hr, 36 hr, 48 hr, and 72 hr) of the hurricane from the marine advisory. It will be helpful to differentiate between the latest observed position of the hurricane and the five forecast positions.

2. Using the same marine advisory, note the maximum radius of gale-force (34 knot) winds and the maximum sustained wind speed observed or forecast to occur during the entire 72 hour period. Also note the current forward speed of the storm. To avoid the need for conversions, these parameters should only be obtained from the marine advisory. Plot the maximum radius of gale-force winds onto the STORM disk.

3. Determine the forecast forward speed of the hurricane in knots. The forecast speed can be determined by measuring the distance in nautical miles between the first and second forecast positions and dividing that distance by 12 (forecast positions are provided for 12 hour intervals). Compare the forecast forward speed to the current forward speed noted previously. A forecast speed greater than the current forward speed will indicate that the hurricane is forecast to accelerate, reducing the time available to the decision-maker. A forecast speed slower than the current forward speed will indicate that the hurricane is forecast to slow down. Although this would appear to increase the time available to the decision maker, a slower storm has the potential to significantly increase the vulnerable population, thereby increasing the required clearance time.

4. Using the maximum sustained wind speed previously noted, enter the Saffir/Simpson hurricane scale (Table A-2) and determine the category of the approaching hurricane. Saffir/Simpson hurricane scales typically list maximum sustained wind speeds in both mph and knots. Exercise caution when selecting the appropriate column. With the category of hurricane, the greater of the current or forecast forward speed, and the predicted response rate, enter the parish decision arc table and select the appropriate clearance time and corresponding decision arc. Mark this arc on the appropriate decision arc map.

5. Using the center of the STORM disk as the hurricane eye, place the disk on the decision arc map at the last reported hurricane position. Determine if the radius of gale-force (34 knots) winds falls within the selected decision arc. If so, the hurricane has passed the decision point (the point at which the radius of gale-force winds crosses the selected decision arc). Immediate steps should then be taken to issue public advisories and to implement traffic control measures in order to ensure a prompt public response and completion of the evacuation prior to the arrival of gale-force winds.

6. Move the STORM to the first forecast position. Determine if the radius of gale-force winds crosses the selected decision arc. If so, the decision point will be reached prior to the hurricane eye reaching the first forecast position.

7. Estimate the hours remaining before a decision must be made by dividing the number of nautical miles between the radius of gale-force winds and the decision arc, by the forward speed of the hurricane. Determine if the next NWS marine advisory will be received prior to the decision point.

8. Determine how an evacuation of your parish would affect the readiness of surrounding parishes, and when other parishes should be notified. Check inundation maps to determine where flooding may occur, and evacuation zone maps for zones that should prepare to evacuate.

9. You may also want to check the probability table included in the public or marine advisory and compare the probability for your location to the possible maximum. There is no one threshold probability which should prompt an evacuation under any and every hurricane threat. The size, intensity and forward speed of the storm, as well as its approach track will need to be considered.

10. Steps 1 through 8 should be repeated after each NWS advisory until a decision is made by the parish or the threat of hurricane impacts has passed.

NOTES:

a. As new information becomes available in subsequent NWS advisories, evacuation operations should progress so that, if evacuation becomes necessary, preparations will be completed and the recommendation to evacuate can be given at the decision point. It should be noted that there is no built-in provision in the Decision Arc Method to allow time for evacuation decision-making or for mobilizing support personnel. These activities should be completed in advance of the hurricane reaching the decision point.

b. Parameters which define the size, intensity, and forward speed of a hurricane are measured in knots and nautical miles in the marine advisory. The scales of the decision arc maps and the STORM disk are therefore also shown in nautical miles. When utilizing hurricane information from sources other than the marine advisory, care should be taken to assure that distances are given in/or converted to nautical miles and speeds to knots. Statute miles can be converted to nautical miles by dividing the statute miles by 1.15. Similarly, miles per hour can be converted to knots by dividing the miles per hour by 1.15.

c. Probability values shown in either the marine advisory or the public advisory describe in percentages the chance that the center of a storm will pass within 65 miles of the listed locations. To check the relative probability for your particular area, the total probability value for the closest location, shown on the right side of the probability table in the marine advisory, should be compared to other locations. A comparison should also be made with the possible maximums for the applicable forecast period shown in the table of maximum probability values included in this appendix. These comparisons will show the relative vulnerability of your location to adjacent locations and to the maximum possible probability.

d. In addition to the parish decision arc tables presented in Chapter 7, a general decision arc table has also been prepared (Table A-5) to use when the parish tables do not apply. This table provides decision arcs for four different forward speeds (as opposed to two forward speeds in the parish tables) for a variety of clearance times. Utilization of this table requires knowledge of the clearance time and the forward speed of the hurricane.

TABLE A-1

TIME CONVERSION TABLE

	Central Daylight Time	
Zulu Time	Military Time (24 HR)	Civilian Time (AM/PM)
00Z	1900	7 PM
01Z	2000	8 PM
02Z	2100	9 PM
03Z	2200	10 PM
04Z	2300	11 PM
05Z	0000	12 MIDNIGHT
06Z	0100	1 AM
07Z	0200	2 AM
08Z	0300	3 AM
09Z	0400	4 AM
10Z	0500	5 AM
11Z	0600	6 AM
12Z	0700	7 AM
13Z	0800	8 AM
14Z	0900	9 AM
15Z	1000	10 AM
16Z	1100	11 AM
17Z	1200	12 NOON
18Z	1300	1 PM
19Z	1400	2 PM
20Z	1500	3 PM
21Z	1600	4 PM
23Z	1700	5 PM

Underlined times are standard time of issuance of National Hurricane Center advisories.

TABLE A-2

SAFFIR/SIMPSON HURRICANE SCALE
WITH
CENTRAL BAROMETRIC PRESSURE RANGES

	CENTRAL PRESSURE		WIND SPEED		SURGE	
CATEGORY	MILLIBARS	INCHES	MPH	KNOTS	FT	DAMAGE
1	>980	>28.94	74 - 95	64 - 83	4 - 5	Minimal
2	965 - 979	28.50 - 28.91	96 - 110	84 - 96	6 - 8	Moderate
3	945 - 964	27.91 - 28.47	111 - 130	97 - 113	9 - 12	Extensive
4	920 - 944	27.17 - 27.88	131 - 155	114 - 135	13 - 18	Extreme
5	<920	<27.17	>155	>135	>18	Catastrophic

TABLE A-3

MAXIMUM PROBABILITY VALUES
(Based on Time to Landfall)

Forecast Period Hours	Maximum Probability Percent
72	10
60	11
48	13
42	16
36	20
30	27
24	35
18	45
12	60

Probabilities listed are the maximum assigned to any location in advance of predicted landfall. This means that the National Hurricane Center would not assign a probability of greater than 20 percent to any location 36 hours prior to landfall, or greater than 35 percent 24 hours prior to landfall.

TABLE A-4

M.P.H. TO KNOTS CONVERSION TABLE

MPH	KNOTS	MPH	KNOTS	MPH	KNOTS
5	4.3	19	16.5	85	74
6	5.2	20	17.4	90	78
7	6.1	25	22.0	95	83
8	7.0	30	26	100	87
9	7.8	35	30	105	91
10	8.7	40	35	110	96
11	9.5	45	39	115	100
12	10.4	50	43	120	104
13	11.3	55	48	125	109
14	12.2	60	52	130	113
15	13.0	65	56	135	117
16	13.9	70	61	140	122
17	14.8	75	65	145	126
18	15.6	80	70	150	130

TABLE A-5

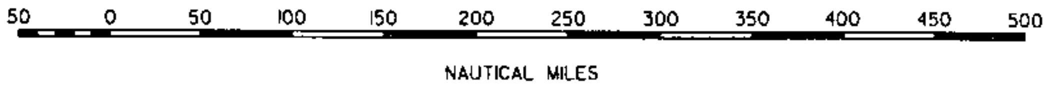
DECISION ARC TABLE [1]

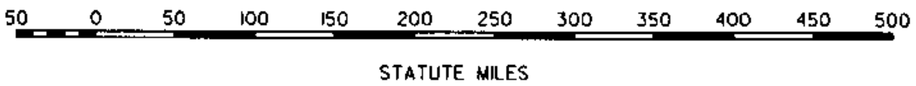
	Hurricane Forward Speed (Knots)			
Estimated Clearance Time (hrs)	5	10	15	20
5	A	A	A	A
6	A	A	A	B
7	A	A	B	C
8	A	A	B	D
9	A	A	C	E
10	A	A	C	E
12	A	B	E	G
14	A	C	F	I
16	A	D	G	J
18	A	E	H	L
20	A	E	I	M
22	B	F	K	O
24	B	G	L	Q
26	C	H	M	R
28	C	I	N	T
30	C	I	O	U
32	D	J	Q	W
34	D	K	R	Y
36	E	L	S	Z
38	E	M	T	BB
40	E	M	U	CC
42	F	N	W	EE
44	F	O	X	GG
46	G	P	Y	HH
48	G	Q	Z	JJ
50	G	Q	AA	KK

[1] This table can be used with any combination of clearance time and forward speed.

STATUTE MILES/NAUTICAL MILES

1 statute mile = 0.87 nautical miles
1 nautical mile = 1.15 statute miles





These scales are to be used only with the STORM disk and the decision arc maps included in this report.

MILES PER HOUR/KNOTS

1 mile per hour = 0.87 knots
1 knot = 1.15 miles per hour

SAMPLE MARINE ADVISORY

NNNN
ZCZC MIATCMAT4
TTAAOO KNHC 251502
HURRICANE ANDREW MARINE ADVISORY NUMBER 38
NATIONAL WEATHER SERVICE MIAMI FL
1500Z TUE 25 AUG 1992

AT 10 AM CDT HURRICANE WARNINGS ARE EXTENDED WESTWARD THROUGH THE BOLIVAR PENINSULA OF TEXAS. HURRICANE WARNINGS ARE NOW IN EFFECT FROM PASCAGOULA MISSISSIPPI WESTWARD THROUGH THE BOLIVAR PENINSULA OF TEXAS.

THE HURRICANE WATCH IS EXTENDED SOUTHWESTWARD TO FREEPORT TEXAS. THE HURRICANE WATCH NOW EXTENDS FROM WEST OF THE BOLIVAR PENINSULA TO FREEPORT TEXAS...AND FROM EAST OF PASCAGOULA EASTWARD TO MOBILE ALABAMA...INCLUDING ALL OF MOBILE AND BALDWIN COUNTIES.

HURRICANE CENTER LOCATED NEAR 27.5N 89.2W AT 25/1500Z
POSITION ACCURATE WITHIN 15 NM

PRESENT MOVEMENT TOWARD THE WEST NORTHWEST OR 300 DEGREES AT 15 KT

ESTIMATED MINIMUM CENTRAL PRESSURE 944 MB
EYE DIAMETER 30 NM
MAX SUSTAINED WINDS 120 KT WITH GUSTS TO 145 KT
64 KT 60NE 25SE 25SW 25NW
50 KT 90NE 50SE 50SW 50NW
34 KT 150NE 100SE 100SW 150NW
12 FT SEAS .. 150NE 100SE 100SW 150NW
ALL QUADRANT RADII IN NAUTICAL MILES

REPEAT ... CENTER LOCATED NEAR 27.5N 89.2W AT 25/1500Z
AT 25/1200Z CENTER WAS LOCATED NEAR 27.3N 88.4W

FORECAST VALID 26/0000Z 28.7N 91.0W
MAX WIND 120KT ... GUSTS 145 KT
50 KT ... 90NE 50SE 50SW 50NW
34 KT ... 150NE 100SE 100SW 150NW

FORECAST VALID 26/1200Z 29.7N 92.4W
MAX WIND 110 KT ... GUSTS 135 KT
50 KT ... 90NE 50SE 50SW 50NW
34 KT ... 150NE 100SE 100SW 150NW

FORECAST VALID 27/0000Z 30.6N 93.0W ... INLAND
MAX WIND 90 KT ... GUSTS 110 KT
50 KT ... 90NE 50SE 50SW 50NW
34 KT ... 150NE 100SE 100SW 150NW

REQUEST FOR 3 HOURLY SHIP REPORTS WITHIN 300 MILES OF 27.5N 89.2W

EXTENDED OUTLOOK....USE FOR GUIDANCE ONLY....ERRORS MAY BE LARGE

OUTLOOK VALID 27/1200Z 31.1N 93.4W
MAX WIND 80 KT ... GUSTS 95 KT
50 KT ... 50NE 50SE 50SW 50NW

OUTLOOK VALID 28/1200Z 32.0N 94.0W
MAX WIND 65 KT ... GUSTS 80 KT
50 KT ... 40NE 40SE 40SW 40NW

NEXT ADVISORY AT 25/2100Z

MAYFIELD
ADVISORY NUMBER 38 HURRICANE ANDREW
PROBABILITIES FOR GUIDANCE IN HURRICANE PROTECTION
PLANNING BY GOVERNMENT AND DISASTER OFFICIALS

CHANCES OF CENTER OF THE HURRICANE PASSING WITHIN 65 MILES OF
LISTED LOCATIONS THROUGH 7AM CDT FRI AUG 28 1992

LOCATION	A	B	C	D	E	LOCATION	A	B	C	D	E
29.7N 92.4W	38	X	X	X	38						
30.6N 93.0W	23	1	1	1	26	FREEPORT TX	8	5	2	2	17
31.1N 93.4W	15	4	2	1	22	PORT O CONNOR TX	2	4	4	3	13
APALACHICOLA FL	X	X	2	4	6	CORPUSCHRISTI TX	X	2	3	4	9
PANAMA CITY FL	X	1	2	4	7	BROWNSVILLE TX	X	X	1	4	5
PENSACOLA FL	1	3	3	4	11	GULF 29N 85W	X	X	1	4	5
MOBILE AL	5	4	3	2	14	GULF 29N 87W	1	1	3	4	9
GULFPORT MS	13	3	1	1	18	GULF 28N 89W	99	X	X	X	99
BURAS LA	50	X	X	X	50	GULF 28N 91W	63	X	X	X	63
NEW ORLEANS LA	35	X	X	1	36	GULF 28N 93W	19	1	X	1	21
NEW IBERIA LA	37	1	X	X	38	GULF 28N 95W	5	4	3	2	14
PORT ARTHUR TX	20	2	1	1	24	GULF 27N 96W	X	2	3	4	9
GALVESTON TX	13	4	1	2	20	GULF 25N 96W	X	X	1	3	4

COLUMN DEFINITION PROBABILITIES IN PERCENT
A IS PROBABILITY FROM NOW UNTIL 7AM WED
FOLLOWING ARE ADDITIONAL PROBABILITIES
B FROM 7AM WED TO 7PM WED
C FROM 7PM WED TO 7AM THU
D FROM 7AM THU TO 7AM FRI
E IS TOTAL PROBABILITY FROM NOW TO 7AM FRI
X MEANS LESS THAN ONE PERCENT

SAMPLE PUBLIC ADVISORY

ZCZC MIATCPAT
TTAAOO KHNC 215010
HURRICANE ANDREW ADVISORY NUMBER 38
NATIONAL WEATHER SERVICE MIAMI FL
10 AM CDT TUE AUG 25 1992

AT 10 AM CDT HURRICANE WARNINGS ARE EXTENDED WESTWARD THROUGH THE BOLIVAR PENINSULA OF TEXAS. HURRICANE WARNINGS ARE NOW IN EFFECT FROM PASCAGOULA MISSISSIPPI WESTWARD THROUGH THE BOLIVAR PENINSULA OF TEXAS.

THE HURRICANE WATCH IS EXTENDED SOUTHWESTWARD TO FREEPORT TEXAS. THE HURRICANE WATCH NOW EXTENDS FROM WEST OF THE BOLIVAR PENINSULA TO FREEPORT TEXAS...AND FROM EAST OF PASCAGOULA EASTWARD TO MOBILE ALABAMA...INCLUDING ALL OF MOBILE AND BALDWIN COUNTIES.

ALL PRECAUTIONS TO PROTECT LIFE AND PROPERTY...INCLUDING EVACUATIONS ORDERED BY EMERGENCY MANAGEMENT OFFICIALS...SHOULD BE RUSHED TO COMPLETION.

AT 10 AM CDT...1500Z...THE CENTER OF ANDREW WAS LOCATED NEAR LATITUDE 27.5 NORTH...LONGITUDE 89.2 WEST OR ABOUT 175 MILES SOUTH SOUTHEAST OF NEW ORLEANS LOUISIANA.

ANDREW IS MOVING TOWARD THE NORTHWEST AT NEAR 17 MPH. A LITTLE MORE NORTHWESTWARD MOTION IS EXPECTED DURING THE NEXT 24 HOURS WITH A DECREASE IN FORWARD SPEED.

MAXIMUM SUSTAINED WINDS ARE NEAR 140 MPH...225KM/HR...AND LITTLE SIGNIFICANT CHANGE IN STRENGTH IS LIKELY BEFORE LANDFALL.

HURRICANE FORCE WINDS EXTEND OUTWARD UP TO 30 MILES...45 KM... FROM THE CENTER...AND TROPICAL STORM FORCE WINDS EXTEND OUTWARD UP TO 175 MILES...280 KM. TROPICAL STORM FORCE WINDS ARE NOW SPREADING OVER EXTREME SOUTHEAST LOUISIANA NEAR THE MOUTH OF THE MISSISSIPPI RIVER.

ESTIMATED MINIMUM CENTRAL PRESSURE IS 944 MB...27.88 INCHES.

STORM SURGES OF 10 TO 15 FEET ARE POSSIBLE NEAR AND TO THE EAST OF WHERE THE CENTER MAKES LANDFALL.

ISOLATED TORNADOES ARE POSSIBLE OVER PORTIONS OF LOUISIANA.

LOCALLY HEAVY RAINS ARE EXPECTED IN THE PATH OF THE HURRICANE.

SMALL CRAFT SHOULD STAY IN PORT FROM MOBILE ALABAMA TO APALACHICOLA FLORIDA. SMALL CRAFT ADVISORIES REMAIN IN EFFECT FOR OTHER PORTIONS

OF THE FLORIDA COAST..AND RESIDENTS IN THOSE AREAS SHOULD SEE LOCAL NWS COASTAL FORECASTS FOR CONDITIONS IN THEIR AREA.

REPEATING THE 10 AM CDT POSITION...27.5N...89.2W. MOVEMENT TOWARD ...WEST NORTHWEST NEAR 17 MPH. MAXIMUM SUSTAINED WINDS...140 MPH. MINIMUM CENTRAL PRESSURE...944 MB.

AN INTERMEDIATE ADVISORY WILL BE ISSUED BY THE NATIONAL HURRICANE CENTER AT 1 PM CDT FOLLOWED BY THE NEXT COMPLETE ADVISORY ISSUANCE AT 4 PM CDT.

MAYFIELD

ADVISORY NUMBER 38 HURRICANE ANDREW
PROBABILITIES FOR GUIDANCE IN HURRICANE PROTECTION
PLANNING BY GOVERNMENT AND DISASTER OFFICIALS

CHANCES OF CENTER OF THE HURRICANE PASSING WITHIN 65 MILES OF LISTED LOCATIONS THROUGH 7AM CDT FRI AUG 28 1992

LOCATION	A	B	C	D	E	LOCATION	A	B	C	D	E
29.7N 92.4W	38	X	X	X	38						
30.6N 93.0W	23	1	1	1	26	FREEPORT TX	8	5	2	2	17
31.1N 93.4W	15	4	2	1	22	PORT O CONNOR TX	2	4	4	3	13
APALACHICOLA FL	X	X	2	4	6	CORPUSCHRISTI TX	X	2	3	4	9
PANAMA CITY FL	X	1	2	4	7	BROWNSVILLE TX	X	X	1	4	5
PENSACOLA FL	1	3	3	4	11	GULF 29N 85W	X	X	1	4	5
MOBILE AL	5	4	3	2	14	GULF 29N 87W	1	1	3	4	9
GULFPORT MS	13	3	1	1	18	GULF 28N 89W	99	X	X	X	99
BURAS LA	50	X	X	X	50	GULF 28N 91W	63	X	X	X	63
NEW ORLEANS LA	35	X	X	1	36	GULF 28N 93W	19	1	X	1	21
NEW IBERIA LA	37	1	X	X	38	GULF 28N 95W	5	4	3	2	14
PORT ARTHUR TX	20	2	1	1	24	GULF 27N 96W	X	2	3	4	9
GALVESTON TX	13	4	1	2	20	GULF 25N 96W	X	X	1	3	4

COLUMN DEFINITION PROBABILITIES IN PERCENT
A IS PROBABILITY FROM NOW UNTIL 7AM WED
FOLLOWING ARE ADDITIONAL PROBABILITIES
B FROM 7AM WED TO 7PM WED
C FROM 7PM WED TO 7AM THU
D FROM 7AM THU TO 7AM FRI
E IS TOTAL PROBABILITY FROM NOW TO 7AM FRI
X MEANS LESS THAN ONE PERCENT

DECISION ARC WORKSHEET

Name of Storm ___________ Number of Advisory _____

Standard Issuance Time of Advisory:

*03Z=10:00pm CDT 09Z=4:00am CDT 15Z=10:00am CDT 21Z=4:00pm CDT

Date of Advisory _____ Time of Advisory _____

Initial Position Latitude _____ Longitude _____
* Note - 03Z is previous day CDT.

12 Hour Forecast Latitude _____ Longitude _____

24 Hour Forecast Latitude _____ Longitude _____

36 Hour Forecast Latitude _____ Longitude _____

48 Hour Forecast Latitude _____ Longitude _____

72 Hour Forecast Latitude _____ Longitude _____

Maximum Radius of Gale-Force Winds _____ nautical miles[1] (the maximum existing or forecast to exist anywhere in the 72 hour period)

Maximum Sustained Winds _____ knots[1] (the maximum existing or forecast to exist anywhere in the 72 hour period)

Selected Clearance Time _____

Corresponding Decision Arc _____

Distance from Decision Arc to Radius of Gale-Force Winds _____

Time Before Decision Point is Reached [2] _____

Time Until Next Advisory _____

[1] The radius of gale-force winds and maximum sustained wind speed should be obtained from the marine advisory and recorded in nautical miles and knots.
[2] The time before the decision point is reached is obtained by dividing the distance from decision arc to radius of gale-force winds by the current forward speed of the hurricane. This time is referenced to the time of the advisory upon which this worksheet is based--<u>not</u> the current time.