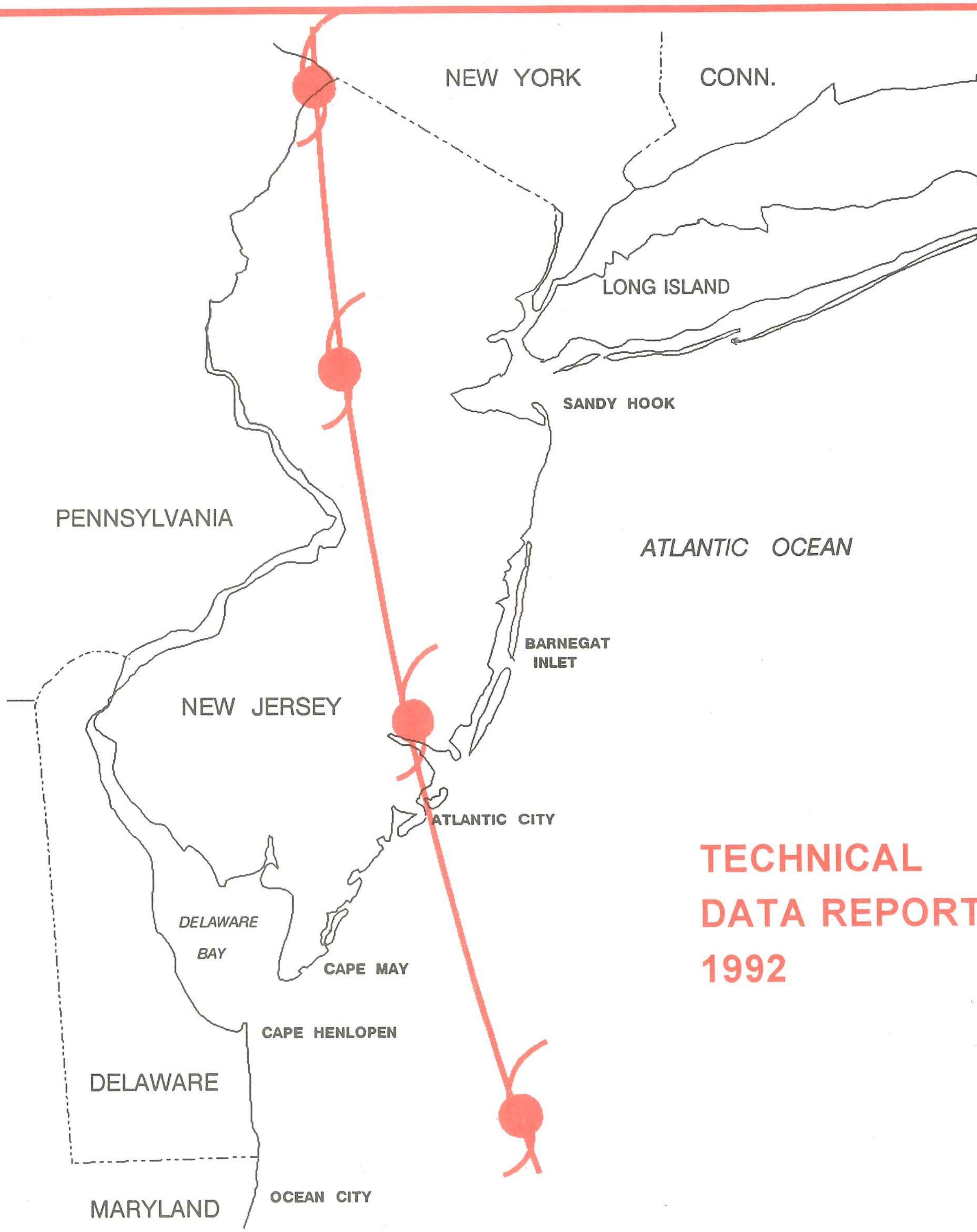
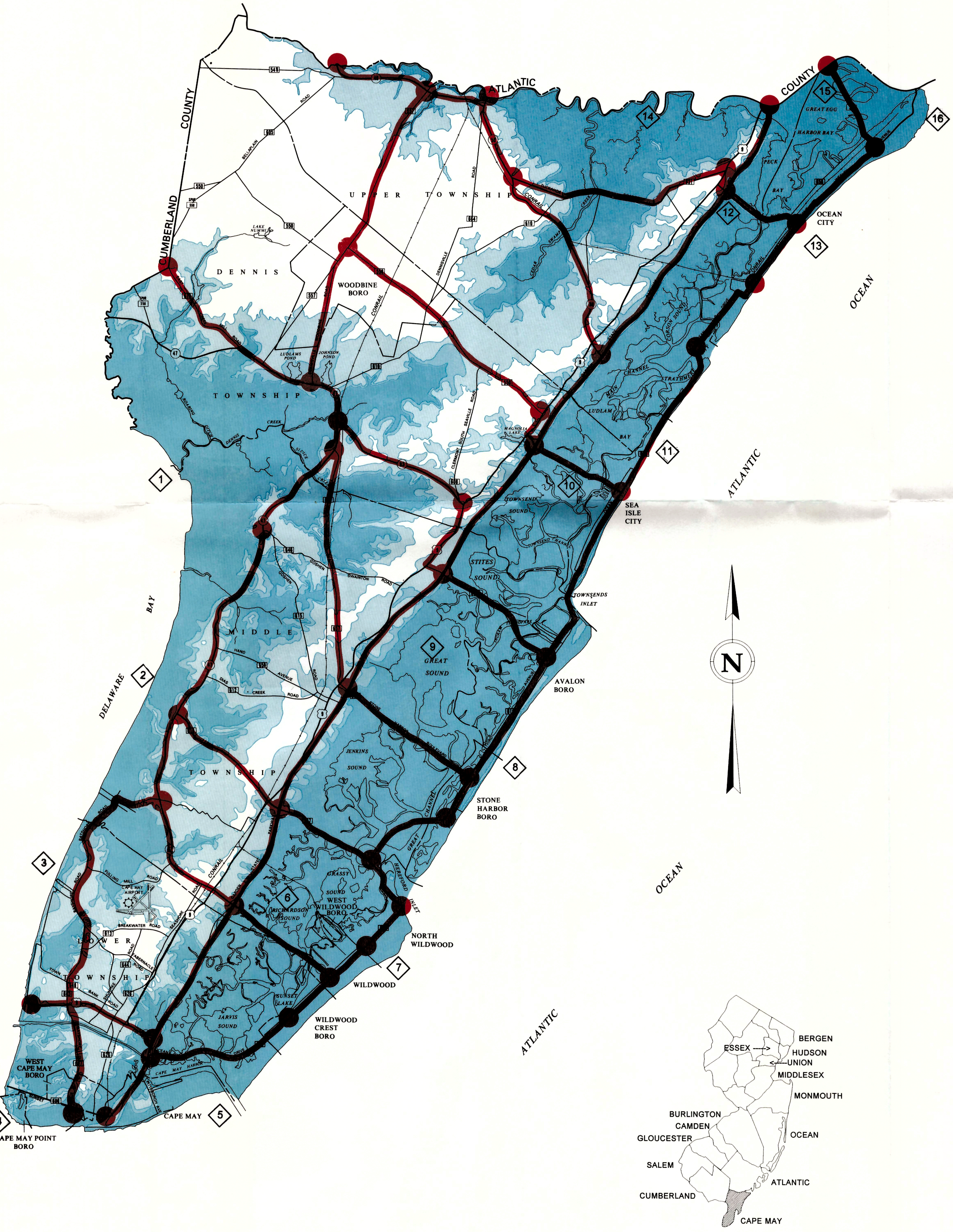


TECHNICAL DATA REPORT 1992

NEW JERSEY HURRICANE EVACUATION STUDY

NEW JERSEY STATE POLICE OFFICE OF EMERGENCY MANAGEMENT
FEDERAL EMERGENCY MANAGEMENT AGENCY, REGION II
NATIONAL WEATHER SERVICE
U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT



LEGEND

AREA OF POSSIBLE FLOODING CATEGORY 1 HURRICANES

AREA OF POSSIBLE FLOODING CATEGORY 2 HURRICANES

AREA OF POSSIBLE FLOODING CATEGORY 3/4 HURRICANES

SURGE ELEVATION LOCATIONS (SEE TABLE BELOW)

PRIMARY EVACUATION ROUTES

MUNICIPAL BOUNDARIES

STORM SURGE INUNDATION AREAS

This map reflects potential flooding from tidal sources only. It does not show areas subject to riverine (freshwater) flooding. The Flood Insurance Rate Maps (FIRM's) for each municipality should be checked to determine the extent and depths of potential riverine flooding.

In order to determine the depth of potential tidal surge flooding at a particular location, the ground elevation at that location must be known. The surge depth can be calculated by deducting the known ground elevation (using local survey data, referenced to the National Geodetic Vertical Datum - NGVD) from the respective hurricane category surge elevation.

The maximum surge elevations listed below were derived from the National Hurricane Center's application of the SLOSH (Sea, Lake and Overland Surge from Hurricanes) Model. Categories 1 through 4 refer to the Saffir-Simpson Scale of hurricane intensity. Elevations reflect "worst case" combinations of direction, forward speed, landfall point and high astronomical tide for each category. These surge elevations do not include wave heights that may accompany storm surge.

MAXIMUM HURRICANE SURGE ELEVATIONS[a]

MAP KEY	CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4
1	9.2	13.2	17.1	21.1
2	8.8	12.7	15.8	19.1
3	7.9	11.4	14.5	17.4
4	8.2	11.9	15.2	18.8
5	8.8	13.0	17.1	20.3
6	8.7	12.3	17.6	21.2
7	8.6	12.5	16.5	20.3
8	8.6	12.7	16.1	20.9
9[b]	8.6	9.4	18.0	22.7
10	8.5	12.8	17.1	21.4
11	8.6	12.9	17.1	20.7
12	8.8	12.0	17.3	21.4
13	8.8	13.2	17.3	21.0
14	7.5	11.3	16.4	21.5
15	10.0	12.7	17.5	21.6
16	8.8	13.1	17.4	21.1

[a] All elevations in feet, referenced to the National Geodetic Vertical Datum (NGVD). These elevations reflect occurrence of maximum hurricane induced surge coincident with a three foot astronomical tide.

[b] This point is located landward of a coastal barrier. The SLOSH elevations at this location are based on the assumed integrity of dunes or other barriers to influx of a higher ocean side surge. However, sand dunes are subject to erosion and breaching during hurricanes, allowing storm surge and waves to move freely inland. Mapping in this area reflects higher adjacent ocean surge elevations.

1 .5 0 1 2 3 4 MILES

SCALE

COUNTY LOCATOR DIAGRAM

STATE OF NEW JERSEY HURRICANE EVACUATION STUDY

CAPE MAY COUNTY

STORM SURGE INUNDATION AREAS AND EVACUATION NETWORK

PREPARED BY THE U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT, IN COOPERATION WITH THE FEDERAL EMERGENCY MANAGEMENT AGENCY, REGION II FOR THE NEW JERSEY STATE POLICE OFFICE OF EMERGENCY MANAGEMENT

EXECUTIVE SUMMARY

This report presents the results of the New Jersey Hurricane Evacuation Study. The Study was conducted by the Philadelphia District of the U.S. Army Corps of Engineers, in cooperation with the Federal Emergency Management Agency, for the New Jersey State Police Office of Emergency Management.

The primary purpose of this project is to provide New Jersey state and local emergency management agencies with data necessary to plan for evacuations of areas vulnerable to hurricane hazards. This information includes the extent and severity of potential flooding, vulnerable population, public shelter locations and capacities and evacuation clearance times. The report also provides guidance on how this information can be used with National Hurricane Center advisories in making evacuation decisions.

Following is a summary of the most significant information developed by the Study.

HAZARDS ANALYSIS

The National Hurricane Center applied the SLOSH (Sea, Lake and Overland Surge from Hurricanes) Model to the Study area and calculated the flooding effects that could be expected from each of a total of 370 hypothetical hurricanes, varied by intensity, direction, forward speed and point of landfall. The focus of the Hazards Analysis is on the maximum storm surges that can be expected from hurricanes of varying intensity. This focus on "worst-case" surges, and the use of worst-case scenarios in subsequent analyses, is justified by the purpose of hurricane evacuation planning, i.e. protection of the vulnerable population.

The table on the following page compares maximum hurricane surge elevations with 100 and 500 year tide frequency elevations for several New Jersey locations. The National Flood Insurance Program (NFIP) and local flood protection projects utilize tidal flooding probabilities in their assessment of the costs and benefits of protecting property. The SLOSH Model does not calculate probabilities of the occurrence of surge heights. Rather it calculates the resultant surge heights of possible meteorological events. It is important to keep this purpose in mind when comparing the SLOSH surge heights used in this Study with storm surge elevation data developed for use in the NFIP or for coastal flood protection projects.

SAMPLE SURGE ELEVATIONS

	SLOSH MODEL[1] MAXIMUM SURGE ELEVATIONS (Ft.)[3]				100 YEAR AND 500 YEAR[2] TIDE ELEVATIONS (Ft.)[3]	
	Cat. 1	Cat. 2	Cat. 3	Cat. 4	100 YR.	500 YR.
MAURICE RIVER (Delaware Bay)	9.2	13.5	17.4	21.3	10.2	11.4
ATLANTIC CITY (Open Coast)	8.1	11.6	15.8	19.3	9.5	11.8
BARNEGAT INLET (Open Coast)	7.5	10.7	13.9	16.2	9.5	11.8
PERTH AMBOY (Raritan Bay)	11.4	18.4	24.6	28.0	10.1	12.2
NEWARK (Newark Bay)	11.0	12.2	14.9	18.7	10.2	12.8
HOBOKEN (Hudson River)	13.5	19.0	26.4	31.4	9.5	10.5

[1] Elevations reflect "worst case" combinations of direction, forward speed, landfall point and high astronomical tide for each category. These elevations do not include wave heights that may accompany storm surge.
[2] These elevations were obtained from NFIP flood insurance studies and from Corps of Engineers flood frequency analyses. These elevations do not include wave heights that may accompany storm surge.
[3] National Geodetic Vertical Datum.

VULNERABILITY ANALYSIS

The majority of New Jersey's tidal flood-vulnerable housing units are in the four open coast counties: Cape May, Atlantic, Ocean and Monmouth. These counties also contain most of the Study area's seasonal housing units. With the exception of Salem County, which has several population centers in low lying areas, relatively small percentages of housing and population of the Delaware River counties are vulnerable to tidal surge. And, although some portions of the five New Jersey counties in the Metropolitan New York area are potentially subject to very high surge elevations, little of the region's housing and population is located in the tidal flood plain.

In addition to housing vulnerable to tidal flooding, all mobile homes in each county are counted among the hurricane-vulnerable housing units. The calamitous wind damages caused by recent hurricanes affecting the United States mainland have reinforced the planning assumption that mobile homes must be evacuated when a hurricanes threatens.

RANGES OF VULNERABLE POPULATION BY COUNTY

	RANGE OF VULNERABLE POPULATION[1]
DELAWARE RIVER AND BAY	
BURLINGTON COUNTY	7,498 -- 25,102
CAMDEN COUNTY	42,892
GLOUCESTER COUNTY	26,866
SALEM COUNTY	31,566 -- 40,360
CUMBERLAND COUNTY	18,962
ATLANTIC OCEAN COASTLINE	
CAPE MAY COUNTY	115,290 -- 566,434
ATLANTIC COUNTY	223,705 -- 409,139
OCEAN COUNTY	127,136 -- 263,277
MONMOUTH COUNTY	127,653 -- 332,135
NEW YORK CITY METRO AREA	
MIDDLESEX COUNTY	2,640 -- 11,540
UNION COUNTY	960 -- 9,140
ESSEX COUNTY	3,130 -- 17,540
HUDSON COUNTY	12,070 -- 35,312
BERGEN COUNTY	7,300

[1] The ranges of vulnerable population summarized here are based on groups of evacuation zones (evacuation scenarios) that have been grouped for evacuation planning purposes and on occupancy rates of seasonal housing units. Listing of a single number for a county indicates that all zones have been included in a single planning scenario and that the number of seasonal housing units is not significant. See Chapter Three (pp. 3-1 to 3-2) for additional detail.

BEHAVIORAL ANALYSIS

The behavioral analysis is intended to provide reliable estimates of how the public in the Study Area will respond to a variety of hurricane threats. These estimates are utilized in establishing assumptions to be used in other Study analyses and for guidance in emergency decision-making and public awareness efforts. The primary objectives of the behavioral analysis were to determine the following:

- The percentages of the affected and non-affected population that will evacuate under a range of hurricane threat situations or in response to evacuation advisories.
- The timing of the public's response.
- The number of vehicles that the evacuating population will use during a hurricane evacuation.
- The response and destinations of New Jersey's seashore tourist population.

A significant aspect of the New Jersey behavioral analysis is the large vacation population in late summer. With the majority of this population living within less than a day's drive from the New Jersey coast, the primary evacuation destination preference is home. One of the ramifications of this preference is that inland counties, e.g. those along the route to Delaware River crossings, will have to handle large volumes of through-county evacuation traffic, thus making most hurricane evacuations a regional concern.

SHELTER ANALYSIS

One of the major purposes of the Shelter Analysis was a determination of public hurricane shelter demand and capacity. The American Red Cross (ARC) provides congregate care for disaster victims as well as for evacuees seeking to avoid hazards such as those caused by hurricanes. Typically, care is provided in schools, churches, fire halls, armories or other public buildings. Well-equipped high schools are often the most desirable facilities for this purpose. Red Cross Disaster Services Regulations and Procedures, specifically *ARC 3031, Mass Care: Preparedness and Operations* call for written agreements with owners for use of potential shelters and for written agreements with local government jurisdictions regarding the responsibilities of each organization. The local ARC chapter completes a Mass Care Facility Survey for each building it identifies for potential use during a disaster operation. Along with a variety of information needed to facilitate effective use of the facility, the Survey is designed to assess its suitability. Vulnerability of buildings to hazards such as flooding or high wind is, of course, one of the criteria employed.

In many parts of the coastal United States, even in some of those frequently threatened by hurricanes, the shelter selection process has been difficult. Data necessary to evaluate the vulnerability of potential shelters was often not available or sufficiently detailed. Over the past decade the SLOSH Model has been applied to most of the Gulf and Atlantic coasts and has provided definition of the tidal flooding threat to facilities. But while attempts to define the wind threat to public shelters have been underway for some time, progress in providing specific guidance has been slower.

The Red Cross recently (July, 1992) established supplemental guidelines for selecting hurricane shelters, ***(ARC 4496: Guidelines for Hurricane Evacuation Shelter Selection).*** The guidelines, which were prepared by an interagency group, reflect the application of technical data compiled in Hurricane Evacuation Studies, other hazard information, and research findings related to wind loads and structural problems. They are intended to supplement guidance provided by ARC 3031. While the new guidelines do not solve all the problems inherent in finding shelter space that can withstand hurricane wind loads, they lay out a least-risk decision making process, and will help ensure careful consideration of wind hazards.

In some of the northeast states, including New Jersey, where hurricane threats are less frequent and less demanding of the attention of the ARC and local governments, the hurricane shelter selection process and the securing of agreements have not been emphasized. The Hurricane Evacuation Studies have had the effect of prompting more attention to shelter selection. In addition, the Red Cross has recently restructured its disaster services delivery components, including planning functions at the national and state level. These changes promise to be fruitful in meeting the challenges faced in preparing for public sheltering for hurricanes. Many changes in New Jersey's hurricane shelter space inventory can be expected as various chapters and local governments reexamine their shelters in light of the new ARC guidelines.

TRANSPORTATION ANALYSIS

The principal products of the transportation analysis are:

- estimates of clearance times (the time it takes to clear a county's roadways of all evacuating vehicles) under a variety of hurricane threats and seasonal housing occupancy percentages;
- traffic control measures that could improve traffic flow along critical roadway segments.

Results of this analysis are combined with hurricane data to determine when an evacuation advisory must be issued to allow all evacuees time to reach safe shelter before the arrival of pre-landfall hazards (flooding or winds).

The clearance times calculated for Cape May County are the highest in New Jersey and among the highest calculated in the United States. Cape May County, which has the greatest number of seasonal housing units in the state, can have a population of three-quarters of a million people on a summer weekend. In a major hurricane there would be very few safe refuges in the County; most of the County could be either inundated by tidal flooding, isolated by tidal flooding, or subject to very dangerous winds.

The two most significant evacuation routes for the County are the Garden State Parkway, which intersects with the Atlantic City Expressway and other east-west highways, and Route 47, which feeds traffic to Route 55, a limited access highway. Both of these routes serve the Philadelphia area, from which comes a major portion of Cape May and Atlantic County vacationer traffic. Route 47 is a two lane state highway which in summer frequently experiences major traffic backups of traffic seeking access to Route 55. Clearance times calculated for Route 47 are as high as 38 hours. Clearance times for the intersection of the Garden State Parkway and the Atlantic City Expressway can exceed 24 hours. The third ultra-critical traffic constriction point on the evacuation network is at the merger of Route 55 and Route 42 near the Camden-Gloucester county border. Route 42 at this point is the conduit for Atlantic City Expressway traffic toward the Delaware River crossings in the vicinity of Philadelphia.

Traffic modeling performed during the Transportation Analysis indicates that reversal of the southbound lane of Route 47 between Route 83 in Cape May County and Route 55 in Cumberland County would result in significant reductions in clearance times for Cape May, Cumberland, Gloucester and Camden Counties.

RANGES OF CLEARANCE TIMES[1]

	IN-COUNTY[2]	THRU-COUNTY[3]	REVERSE-LANE[4]
ATLANTIC OCEAN COASTLINE			
CAPE MAY COUNTY	7 - 36 HRS.		4 - 20 HRS.
ATLANTIC COUNTY	9 - 26		
OCEAN COUNTY	10 - 19		
MONMOUTH COUNTY	6 - 10		
DELAWARE RIVER AND BAY			
BURLINGTON COUNTY	4 - 9 HRS.	11 - 24 HRS.	
CAMDEN COUNTY	4 - 9	8 - 28	7 - 21
GLOUCESTER COUNTY	4 - 9	7 - 27	---[5]
SALEM COUNTY	6 - 9	9 - 22	---[5]
CUMBERLAND COUNTY	4 -9	10 - 38	6 - 22
NEW YORK CITY METRO AREA			
MIDDLESEX COUNTY	4 - 9		
UNION COUNTY	4 - 9		
ESSEX COUNTY	4 - 10		
HUDSON COUNTY	5 - 11		
BERGEN COUNTY	4 - 9		

[1] Clearance times shown in this table excerpted from Tables 6-7 to 6-20, beginning on page 6-28.
[2] These numbers indicate times needed for evacuating traffic originating in this county to reach in-county destinations or to leave the county.
[3] These numbers indicate times needed to clear county roads of evacuation traffic originating in other counties.
[4] These numbers indicate clearance times that would result from lane reversals on sections of Route 47 in Cape May and Cumberland Counties [Cape May: in-county times; Cumberland, Gloucester & Camden: thru-county times).
[5] Lane reversals on Route 47 can also be expected to result in reductions in Gloucester County thru-county clearance times. Salem County's highest clearance times result from queuing on U.S. 40.

EVACUATION DECISION MAKING

The Decision Arc Method presented in Chapter Seven is 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. For many hurricane scenarios, an evacuation, if it is to be safely completed, will need to begin while a hurricane is many hours and hundreds of miles away from New Jersey, at a time when National Hurricane Center forecasts will necessarily tend to be inconclusive about the probability of a hurricane impacting New Jersey. Thus, the decision of whether to order an evacuation will often be a difficult one. The methods presented in this chapter are designed to help compensate for forecast errors by relating evacuation operations to hurricane position.

It is recommended that hurricane vulnerable jurisdictions investigate the various hurricane evacuation decision-making computer programs in use today. These programs incorporate Hurricane Evacuation Study data, including some version of the decision arc method presented in this chapter; they can be very useful in speeding needed calculations and automatically using checklists of factors that should be considered in deciding both if and when to evacuate.

METROPOLITAN NEW YORK HURRICANE TRANSPORTATION STUDY

Concurrent with the New Jersey Study, Hurricane Evacuation Studies have also been conducted for Connecticut and New York. In the course of conducting the Transportation Analyses for the three studies, Corps study managers also identified potential vulnerability to parts of the Metropolitan New York City regional transportation infrastructure. State emergency management officials expressed concern that the regular, generalized treatment of transportation related issues planned for inclusion in the Technical Data Reports would be insufficient to support regional emergency transportation plans. These agencies requested that the Hurricane Studies for their respective states be expanded to provide additional information on which to base regional and local plans for operation of metropolitan area commuter networks during hurricane emergencies. The additional information would be used to plan coordinated bridge, tunnel, rail and highway closings and alternative routings in the face of a hurricane threat. In addition, the New Jersey State Police Office of Emergency Management requested that inland commuting areas with transportation links subject to riverine flooding be included because of the potential for region-wide network disruption beyond that caused by tidal flooding. In response to the states' requests, a Metropolitan New York Hurricane Transportation Study has been initiated. When completed the "Metro" Transportation Study will complement the New Jersey Hurricane Evacuation Study, as well as the Connecticut and New York Studies.

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APPENDIX A: DECISION-MAKING TOOLS

COUNTY STORM SURGE INUNDATION AREAS AND EVACUATION NETWORK MAPS

These wall size maps show potential inundation areas, maximum surge heights calculated by the SLOSH Model, and the primary evacuation routes modeled for the New Jersey Hurricane Evacuation Study. Maps of one county, several counties, or all counties maps have been distributed with this report depending on the location and type (municipal, county or state, etc.) of the agency receiving the report.

- BURLINGTON COUNTY
- CAMDEN COUNTY
- GLOUCESTER COUNTY
- SALEM COUNTY
- CUMBERLAND COUNTY
- CAPE MAY COUNTY
- ATLANTIC COUNTY
- OCEAN COUNTY
- MONMOUTH COUNTY
- MIDDLESEX COUNTY
- UNION, ESSEX, HUDSON AND BERGEN COUNTIES (ONE MAP)

SUPPORT DOCUMENTS (Available upon Request):

A STORM SURGE ATLAS FOR DELAWARE BAY

A summary of the SLOSH Modeling process and surge heights calculated by the Model for this Study.

TRANSPORTATION MODEL SUPPORT DOCUMENT

A detailed account of all transportation modeling activities and zone by zone data listings for each county included in this Study.

PREFACE

On September 3, 1821 the eye of a Category 3 hurricane passed directly over Cape Henlopen, Delaware, crossed Delaware Bay and came ashore just west of Cape May, New Jersey. The storm's center then moved at 50 mph along a track through southern New Jersey that approximated the current route of the Garden State Parkway, exiting New Jersey in the vicinity of the Ocean-Monmouth County line. The highest storm surge, generated by northwest winds on the "backside" of the hurricane, occurred on the Delaware Bay side of the Cape May peninsula near Dennisville where debris was deposited by waves well inland in tree branches nine feet above the ground.[1]

The alignment of the New Jersey coast significantly reduces the probability of direct hits by Atlantic hurricanes, which tend to curve toward the northeast as they reach the latitude of the Middle Atlantic states. Since 1821 portions of New Jersey have experienced hurricane force winds on a number of occasions, but no additional hurricane landfalls. A number of major hurricanes on tracks paralleling the 1821 storm have affected New Jersey, but all have either come ashore well to the south of the state or passed some distance offshore, thus diminishing their effect on the state (a 1903 hurricane weakened to tropical storm status shortly before landfalling near Atlantic City). Several of these storms, such as the 1889, 1938, 1944 and 1960 hurricanes, caused extensive damages and some loss of life. (The 1938 hurricane which passed about 100 miles east of Atlantic City and killed 3 people in New Jersey subsequently killed 600 people when it moved over Long Island and New England).

The development of coastal New Jersey has steadily intensified during the last several decades. While the state-wide population increased at a modest seven-and-a-half percent from 1970 to 1990, the year-round population of the four open ocean coast counties grew at much higher rates: Atlantic County saw a twenty-eight percent increase, Cape May sixty percent, Monmouth twenty percent, and Ocean County an over one hundred percent increase. The growth of seasonal housing of all types has continued unabated, even through several recessions.

New Jersey's heavy coastal development has obvious consequences for the planning and execution of hurricane evacuations. Fortunately, along with improvements in hurricane forecasting, enormous progress has been made in recent years in the rapid dissemination of advisories to the public and local government levels. But to make efficient use of information

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[1] Ludlum, David M., The New Jersey Weather Book, Rutgers University Press, New Brunswick, NJ 1983.

about threatening hurricanes, a local jurisdiction must have reliable information on which to base assumptions regarding evacuation clearance times. During the peak seashore vacation season it can be anticipated that hurricane evacuations will take many hours to complete. **In fact, an evacuation may take so long that, in order to be completed before the arrival of dangerously high winds, people must begin moving while the hurricane is still a great distance away, a distance that precludes any certainty in National Hurricane Center forecasts.**

While local clearance times can be estimated with some degree of assurance at the local level, the uncertainties of hurricane tracks and wide extent of areas potentially vulnerable to their fury demand a regional approach to both planning and operations. Traffic evacuating Atlantic City, New Jersey will be competing for road space with traffic evacuating other Absecon Island and Atlantic County shore towns. Traffic evacuating Atlantic County will be merging with traffic from Cape May and Ocean counties. In southern New Jersey an evacuation should perhaps not be considered complete until Salem, Gloucester, Camden and Burlington County roads have cleared. The destruction wrought well inland in South Carolina by Hurricane Hugo in 1989 suggests that automobiles on Camden County highways should not be included in the inventory of hurricane evacuation "safe destinations."

There are no anticipated advances in hurricane track forecasting that would make a timely hurricane evacuation decision easy. But it is essential that those public officials responsible for ordering or recommending an evacuation have at their disposal reliable data and systematic methods necessary for making this decision. The critical data necessary for the development of hurricane evacuation plans for many jurisdictions require comprehensive and specialized analyses. The fiscal and staffing limitations of most State and local emergency management agencies preclude the development of these data. In an effort to assist State and local governments by providing the needed technical information, the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Administration have joined New Jersey state and local emergency management agencies in conducting the New Jersey Hurricane Evacuation Study.

Chapter One

INTRODUCTION

1.1 PURPOSE

The purpose of this Study is to provide emergency management officials with realistic data, quantifying the major factors involved in hurricane evacuation decision-making. The technical data presented in this report **are not intended to replace the detailed operations plans developed by each of the counties and municipalities within the Study area.** Rather, these data will provide a framework within which each jurisdiction can update and revise hurricane evacuation plans and from which operational procedures and guides can be developed for future hurricane threats.

1.2 AUTHORITY

The U.S. Army Corps of Engineers authority for this Study is Section 206 of the Flood Control Act of 1960 (Public Law 86-645); the Federal Emergency Management Agency authority is the Disaster Relief Act of 1974 (Public Law 93-288). These laws authorize the allocation of resources for planning activities related to hurricane preparedness.

1.3 FUNDING

The New Jersey Hurricane Evacuation Study was equally funded by the Federal Emergency Agency and the U.S. Army Corps of Engineers.

1.4 DESCRIPTION OF STUDY AREA

1.4.1 Geography

This Study includes those portions of New Jersey potentially subject to hurricane storm surge. Tidal waters affecting the state are the Atlantic Ocean, including inland bays and lagoons from Cape May to Sandy Hook; the Delaware Estuary from Cape May Point to Burlington County; Sandy Hook and Raritan Bays; the Raritan River; Arthur Kill, which separates Union and Middlesex Counties from Staten Island, New York; Upper New York Bay and the Hudson River; and Newark Bay and its tributaries. A broad range of land uses exist in the Study area, from the recreational resorts of the ocean coast to the heavily industrial and commercial sites along portions of the Delaware and Raritan Rivers and the New York City metropolitan area waterways. Portions of the Study area are urbanized and densely populated, while other portions are very sparsely populated. In total fourteen counties are included (all subject to tidal flooding). The Study area is shown in Figure 1-1.

1.4.2 Topography and Landforms

The southern portion of the Study area lies in the Coastal Plain province of Eastern North America, which extends eastward to the edge of the continental shelf. Elevations rise very gradually. The greater part of the Atlantic coast is comprised of approximately 90 miles of a barrier island complex (from Bay Head south to Cape May Inlet--until recently called Cold Springs Inlet) situated between 19 miles of low headland shoreline to the north and 5 miles of low shoreline headlands to the south (the tip of Cape May Peninsula).[1] Maximum elevations on the barrier islands are generally less than 20 feet NGVD (National Geodetic Vertical Datum) and in many places less than 10 feet NGVD. Northern headland elevations range up to 25 feet, southern headland elevations are generally less than 15 feet. The shoreline of the tidal bays and lagoons separating the barrier islands from the mainland consists mainly of marshes, bulkheaded developments and short reaches of narrow sandy beaches. Beach slopes along most of the coast are relatively gentle. Slopes are relatively steep at Cape May Point (the entrance to Delaware Bay). There are a number of steep bluffs immediately adjoining the ocean in the northern headland area.

Along the Delaware Bay the shoreline is primarily flat, tidal marshland which in many locations extends several miles inland. Scattered waterside residential developments are fronted by narrow sandy beaches. Slopes become gradually steeper upstream along the Delaware River as the shoreline becomes highly developed and industrialized.

Terrain along the shoreline of Sandy Hook and Raritan Bays ranges from high bluffs, near the west and east ends, to low marshlands which are subject to frequent tidal inundation. The shoreline is fronted by low narrow beaches intersected by a number of tidal creeks.[1] The Raritan River has a broad tidal floodplain extending 8 to 10 miles upstream from Raritan Bay.

Most of the northern portion of the Study area lies within the Piedmont Lowland. Geologic processes have produced a wide variety of landforms bordering tidal waters. These include the Hackensack Meadowlands, a broad expanse of tidal marshland, and the Palisades, a steep escarpment which forms the western boundary of the Hudson River.

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[1] U.S. Army Corps of Engineers, New York District. National Shoreline Study: Regional Inventory Report--North Atlantic Region. New York, NY: USACE, 1971

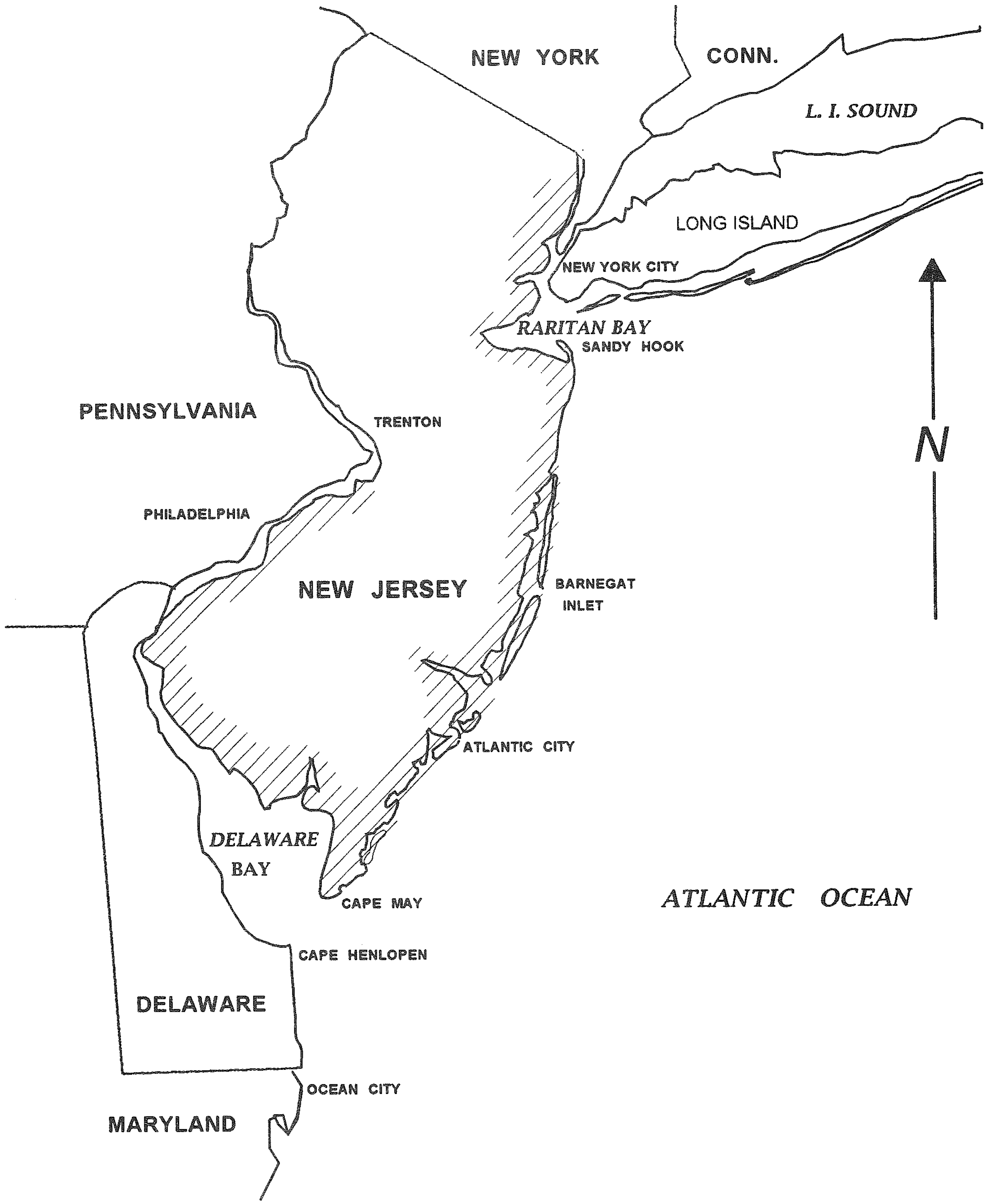


FIGURE 1-1
STUDY AREA

1.4.3 Bathymetry

Atlantic Coast and Inland Bay

Hurricane induced storm surges are increased by the local bathymetry because of the inverse relationship between surge height and water depth (see Section 2.3, p. 2-2, for an explanation of hurricane storm surge). From its southern extremity at Cape May to Barnegat Inlet, a distance of approximately 75 miles, the New Jersey ocean coast is oriented toward the northeast. From Barnegat Inlet to the northern extremity at Sandy Hook, a distance of approximately 48 miles, the coast is oriented to the north-northeast and then slightly to the east of north. The 10 fathom (-60 feet Mean Low Water [MLW]) contour lies approximately 10 miles off the coast of the Cape May Peninsula. Bottom slopes increase gradually to the north as the 10 fathom contour comes to within 5 miles of the coast at Barnegat Inlet. Moving north from Barnegat Inlet slopes further increase as the 10 fathom line stays within 2 or 3 miles of the coast to the vicinity of the Sandy Hook spit. The edge of the continental shelf approximately parallels the Cape May to Barnegat portion of the New Jersey Coast until it reaches the Hudson Canyon where the edge of the shelf begins to follow a more easterly direction. The 100 and 1000 fathom contours are respectively about 80 and 100 miles offshore from Barnegat Inlet.

The bays and lagoons separating the barrier islands from the mainland (Barnegat Bay to Cape May Harbor) are quite shallow, with average depths of approximately 4 to 6 feet (MLW). Storm surges in these waters can differ significantly from open coast elevations in both their magnitude and timing.

Delaware River Estuary

The western portion of southern New Jersey borders the Delaware Bay estuary, which is the submerged river valley of the Delaware River. The entrance to Delaware Bay is approximately 11 miles wide between Cape Henlopen, DE and Cape May, NJ. The main gorge of the bay lies just off Cape Henlopen with depths exceeding 60 feet (MLW) over a 2 mile wide area. Maximum depths within the gorge are between 120 and 150 feet (MLW). The mouth of the bay then shoals toward Cape May forming a 7 mile wide zone with depths between 10 and 25 feet (MLW). New Jersey's bay shoreline is bordered by a gently sloping bottom. Depths of less than 12 feet (MLW) may extend considerable distances offshore along the main portion of the bay. Depths for most of the Delaware Bay and River are less than 20 feet (MLW); however, the federal government maintains a 40 feet deep (MLW) navigation channel from the ocean to a point 24 miles above Philadelphia and then a 35 feet deep channel to Trenton, NJ.

Raritan and Sandy Hook Bays, Upper New York Bay, Newark Bay

The Lower Bay Complex, which includes Raritan, Sandy Hook and Lower New York Bays, is relatively shallow (16 to 66 ft), but has an irregular bathymetry due mainly to the presence of numerous ship channels. Waters of the Complex mix with waters of Upper New York Bay, the Hudson River and Newark Bay through the Narrows, a constriction between Staten Island and Brooklyn in New York City, and, to a lesser extent through Arthur Kill, a tidal channel along the west side of Staten Island.[2] The Upper Bay in turn is connected to Long Island Sound via the East River, which is also a tidal channel. The right angle configuration of the New Jersey-New York Atlantic Coast and the combination of shallow bathymetry and irregular shapes of bays in the New York City region combine to create very complicated tidal timing patterns, as well as the potential for very large storm surges.

1.5 HISTORICAL HURRICANE ACTIVITY

1.5.1 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 (1-minute average) surface wind near the center of the storm. These 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 official Atlantic hurricane season begins on June 1 and extends through November 30 of each year; however, occasional tropical cyclones occur outside of this period. Early season tropical cyclones 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 further 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. After mid-September, the frequency begins to decline and the formative area retreats westward. By early October, the area is generally confined to the western

[2]New York Bight Atlas Monograph 29, The Lower Bay Complex; I.W.Duedall, H.B. O'Connors, R.E.Wilson, J.H. Parker, New York Sea Grant Institute; Albany, New York May 1979.

Caribbean. In November, the frequency of tropical cyclone occurrence further declines.

1.5.2 Atlantic Tropical Cyclone Basin

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 121 year period 1871 through 1991 a total of nearly 1000 tropical cyclones have occurred within the Atlantic tropical cyclone basin; however, for the years 1871 through 1885 the existing data do not allow accurate determinations of the intensities of the tropical cyclones. The National Hurricane Center maintains detailed computer files of the Atlantic tropical cyclone tracks back to 1886. Of the 852 known Atlantic tropical cyclones of at least tropical storm intensity occurring during the period 1886 through 1986, 499 reached hurricane intensity.

1.5.3 Coastal New Jersey

Hurricane activity is not as frequent along coastal New Jersey as for some other regions within the Atlantic Tropical Cyclone Basin, yet the potential for hurricane disaster is still very great. Since 1893, 21 hurricanes have passed within a 125 statute mile radius from Atlantic City, NJ for an average of one hurricane every 4.7 years. Table 1-1 lists these hurricanes; their tracks are shown in Figure 1-2 (p. 1-8).

TABLE 1-1
HURRICANES WITHIN 125 STATUTE MILES OF ATLANTIC CITY 1893 TO 1991

DATE OF STORM[1]	STORM NAME[2]	AT CLOSEST POINT OF APPROACH MAXIMUM[3] WIND (MPH)	RANGE (MILES)	BEARING (DEGREES)	FORWARD SPEED (MPH)
1893 JUN 17	Unnamed	77	108	147	16
1893 AUG 24	Unnamed	98	31	83	24
1893 AUG 29	Unnamed	81	100	323	29
1894 SEP 30	Unnamed	79	77	125	8
1894 OCT 10	Unnamed	74	23	148	27
1903 SEP 16	Unnamed	84	13	030	20
1904 SEP 15	Unnamed	75	22	040	54
1933 SEP 17	Unnamed	85	109	136	11
1934 SEP 8	Unnamed	77	50	117	23
1936 SEP 18	Unnamed	98	51	127	26
1938 SEP 21	Unnamed	101	83	071	51
1944 SEP 14	Unnamed	96	47	122	35
1953 AUG 14	BARBARA	86	85	132	19
1954 AUG 31	CAROL	98	63	098	35
1954 SEP 11	EDNA	104	114	119	42
1958 AUG 29	DAISY	126	124	124	29
1960 SEP 12	DONNA	108	47	112	35
1967 SEP 16	DORIA	81	113	175	11
1976 AUG 10	BELLE	98	43	107	26
1985 SEP 27	GLORIA	99	26	154	44
1991 AUG 18	BOB	115	74	115	32

[1] Year, month and date that storm had maximum winds exceeding 74 MPH and was closest to Atlantic City, NJ.
[2] Storms were not formally named before 1950.
[3] Maximum sustained wind speed near storm center while center was within 125 statute miles of Atlantic City. This is not necessarily the wind recorded at a given site.

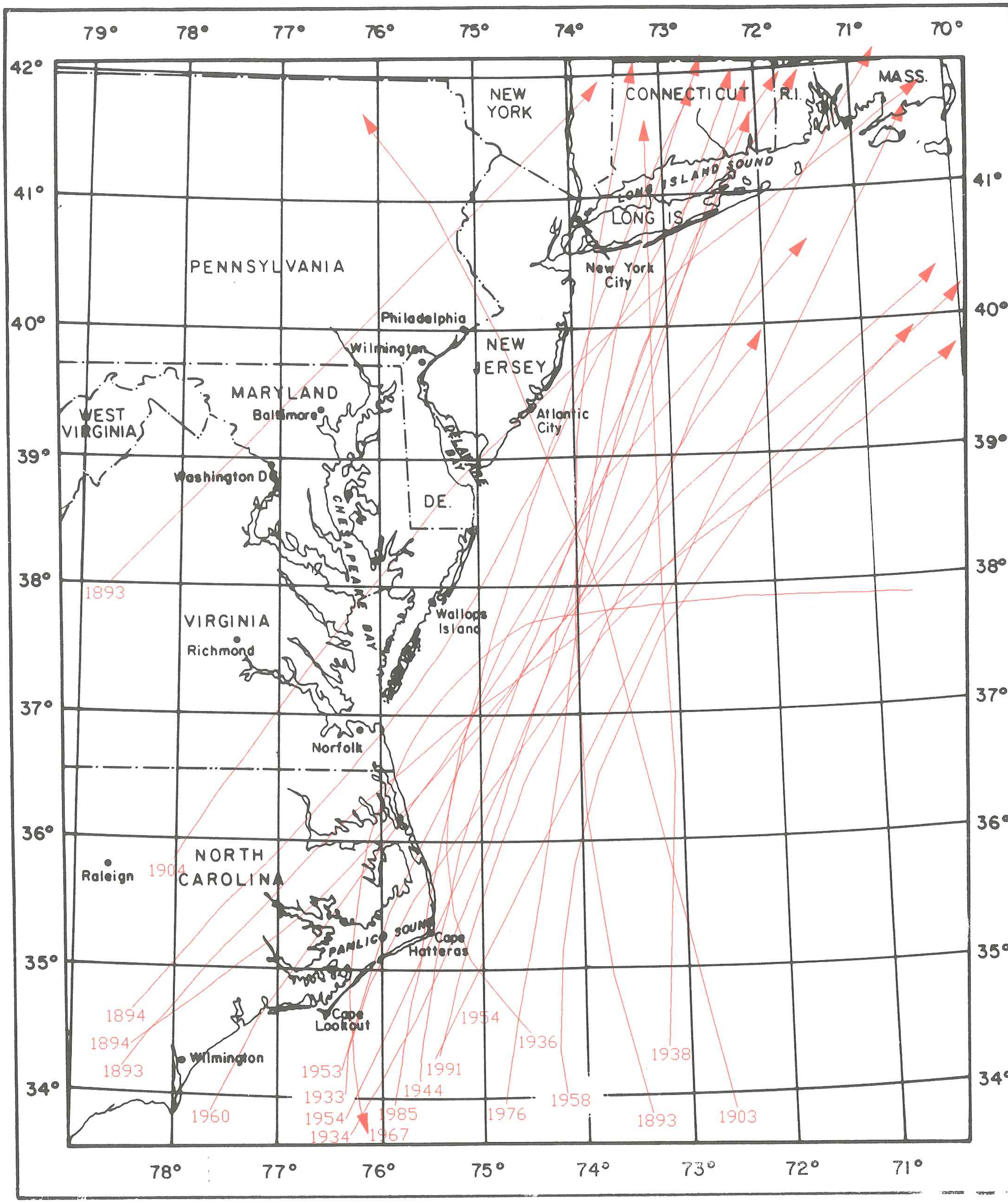


FIGURE 1-2
TRACKS OF HURRICANES PASSING
WITHIN 125 STATUTE MILES OF ATLANTIC CITY 1893-1991

1.6 STUDY ANALYSES

The New Jersey Hurricane Evacuation Study consists of several related analyses that develop technical data concerning hurricane hazards, vulnerability of the population, public response to evacuation advisories, timing of evacuations, and sheltering needs for various hurricane threat situations. The major analyses comprising the Study and a description of the methodologies for each are discussed in the following paragraphs.

1.6.1 Hazards Analysis (Chapter 2)

The hazards analysis determines the timing and sequence of wind and hurricane surge hazards that can be expected for hurricanes of various categories, tracks, and forward speeds impacting the Study Area. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Model was used to develop the data. **Inundation mapping (County Storm Surge Inundation Areas and Evacuation Network Maps) presented with this Study does not include riverine floodplains not subject to tidal flooding. It is assumed that local governments will use floodplain mapping (Flood Insurance Rate Maps) prepared in conjunction with the National Flood Insurance Program for evacuation planning in non-tidal areas.** Flood Insurance Rate Maps were used in this Study in the flood vulnerability analysis of public hurricane shelters.

1.6.2 Vulnerability Analysis (Chapter 3)

Utilizing the results of the hazards analysis, the vulnerability analysis identifies those areas, populations, and facilities that are vulnerable to specific hazards under a variety of hurricane threats. Evacuation zones were developed for each of the Study Area counties utilizing major natural or man-made geographic features. Hurricane evacuation scenarios, groups of evacuation zones that will be threatened by storm surge from specific hurricane intensity categories, were also developed for each county. New Jersey Department of Labor population estimates were used in determining the vulnerable population within each county for a range of hurricane threats. These population estimates were checked against 1990 census counts as they became available. Seasonal population estimates for resort areas were developed with the assistance of county planning agencies, Chambers of Commerce and municipal officials.

1.6.3 Behavioral Analysis (Chapter 4)

This analysis determines the expected response of the threatened population to various hurricanes in terms of the percentage of the population expected to evacuate, probable destinations of evacuees, use of public shelter, and utilization of available vehicles. The methodology employed in the New Jersey Hurricane Evacuation Study to develop the behavioral data consisted of telephone sample surveys, interviews within the Study Area, data from other hurricane evacuation studies, and data from post-hurricane evacuation studies. The New Jersey Behavioral Analysis was conducted as part of an Analysis performed for eight Middle Atlantic and New England states in support of hurricane evacuation studies.

1.6.4 Shelter Analysis (Chapter 5)

The shelter analysis presents an inventory of existing shelter facilities, capacities of the shelters, vulnerability of shelters to storm surge flooding, and identifies the range of potential shelter demand for each county. Lists of existing shelters and capacities were furnished by the American Red Cross and the county Emergency Management Coordinators. Lowest floor elevations for those shelters located in or near tidal or riverine inundation areas were established by the Corps of Engineers field surveys. Potential shelter demands for ranges of hurricane threats were developed using data from the behavioral analysis.

1.6.5 Transportation Analysis (Chapter 6)

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 threats. Transportation modeling techniques developed to simulate hurricane evacuation traffic patterns were used to conduct this analysis.

1.7 DECISION ARC METHOD AND WORKSHEET (Chapter 7 and Appendix A)

The Decision Arc Method is 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 the onset of hurricane hazards. Chapter 7 gives an overview of the decision arc method. Appendix A presents a step by step procedure and necessary supporting information.

1.8 COORDINATION/NEW JERSEY HURRICANE PREPAREDNESS COMMITTEE

At the outset of the Study a coordination program was established that included State and county emergency management officials and representatives from other organizations having responsibilities in hurricane emergencies. The New Jersey Hurricane Preparedness Committee met periodically to review Study progress. This committee is comprised of representatives of the American Red Cross, the New Jersey State Police Office of Emergency Management, the New Jersey Department of Environmental Protection and Energy, the New Jersey Department of Transportation, the National Weather Service, the Federal Emergency Management Agency Region II and the Philadelphia District Army Corps of Engineers.

1.9 METROPOLITAN NEW YORK HURRICANE TRANSPORTATION STUDY

Concurrent with the New Jersey Study, Hurricane Evacuation Studies have also been conducted for Connecticut and New York. In the course of conducting the Transportation Analyses for the three studies, Corps study managers also identified potential vulnerability to parts of the Metropolitan New York City regional transportation infrastructure. State emergency management officials expressed concern that the regular, generalized treatment of transportation related issues planned for inclusion in the Technical Data Reports would be insufficient to support regional emergency transportation plans. These agencies requested that the Hurricane Studies for their respective states be expanded to provide additional information on which to base regional and local plans for operation of metropolitan area commuter networks during hurricane emergencies. The additional information would be used to plan coordinated bridge, tunnel, rail and highway closings and alternative routings in the face of a hurricane threat. In addition, the New Jersey State Police Office of Emergency Management requested that inland commuting areas with transportation links subject to riverine flooding be included because of the potential for region-wide network disruption beyond that caused by tidal flooding. In response to the states' requests, a Metropolitan New York Hurricane Transportation Study has been initiated. When completed the "Metro" Study will complement the New Jersey Hurricane Evacuation Study, as well as the Connecticut and New York Studies.

Chapter Two

HAZARDS ANALYSIS

2.1 PURPOSE

The purpose of the Hazards Analysis is to quantify the surge heights and wind speeds for various intensities and tracks 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; however, due to the wide variation in amounts and times of occurrence from one storm event to another, rainfall can only be addressed in general terms.

The primary objective of the hazards analysis is to determine the worst-case effects from various intensity hurricanes which have the potential to strike the region. The term "worst-case" represents the peak surge height and wind speed which might be obtained for each category of storm by varying three critical parameters: landfall point, direction, and forward speed. This is important to note because the maximum storm surge elevations which were mapped for the Study area were not derived from a single hurricane event. Instead, the maximum surge elevations mapped for each hurricane category represents a composite of hurricane events of varying direction, landfall point and forward speed. The potential surge is maximized by making the surge arrival coincident with the astronomical high tide (See the detailed discussion which follows in Section 2.6.3 - p. 2-22). Emphasis of "worst-case" surge heights in this Analysis is justified by the purpose of hurricane evacuation planning, i.e. protection of the vulnerable population.

The majority of effort expended in the hazards analysis is related to the accurate estimation of potential surge heights. This focus on surge analysis does not reflect a discounting of the danger of winds associated with hurricanes. The magnitude, extent, timing and duration of winds of a threatening hurricane are the direct subjects of National Weather Service/ National Hurricane Center observations and forecasts. However, realistic surge height estimation is far more complex than wind speed estimation. In addition to wind speeds and direction, surge heights are also dependent on shoreline configuration, track direction, and, especially in back bay areas, on local channel geometry.

2.2 FORECASTING INACCURACIES

The "worst-case" approach was used in presenting possible hurricane effects because of the inaccuracies in forecasting the precise track and other parameters of approaching hurricanes. The magnitude of errors in 24 hour forecasts made by the National Hurricane Center is such that if a storm were forecast to make landfall at Cape Henlopen, Delaware in 24 hours, and if it in fact made landfall anywhere between Cape Charles, Virginia and Asbury Park, New Jersey, the error in forecast landfall position would be no worse than average.

During the year period 1970 to 1979, the average error in the official 24 hour wind speed forecast was 15 miles per hour (m.p.h.), and the average error in the 12 hour official forecast was 10 m.p.h. Emergency officials should note that an increase of 10 to 15 m.p.h. can raise the intensity category of the approaching hurricane one category on the Saffir/Simpson Hurricane Scale (see Table 2-1, p. 2-7).

2.3 STORM SURGE

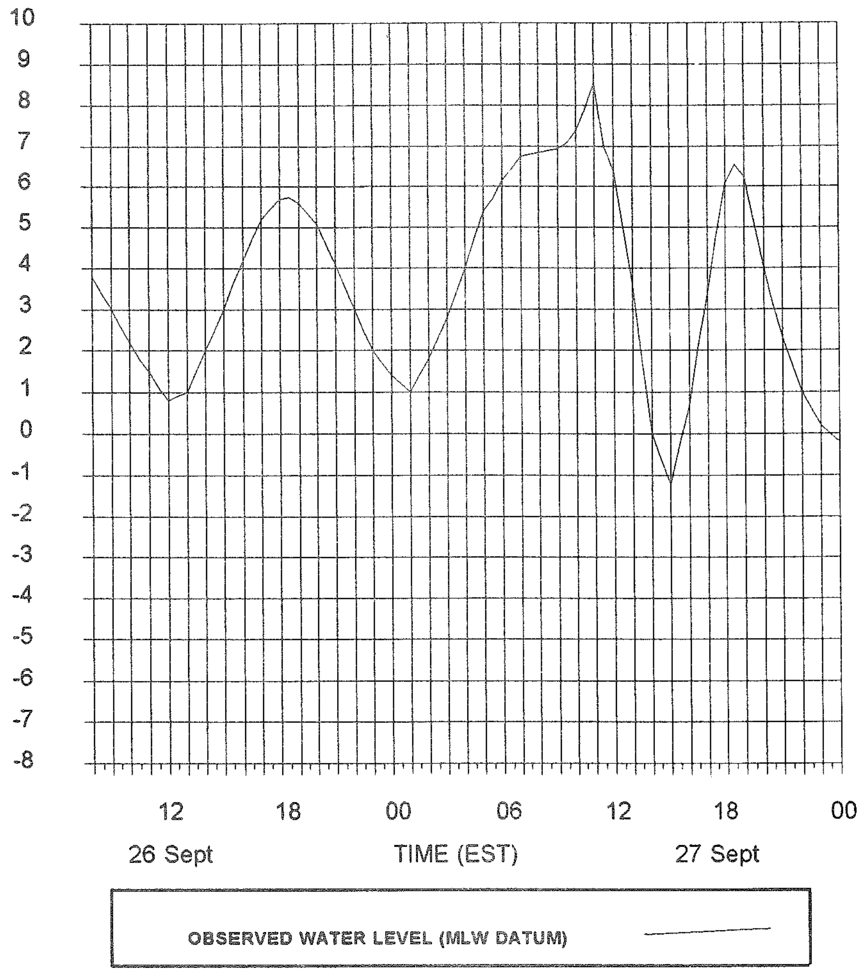
2.3.1 Introduction

Abnormally high water levels along ocean coasts and interior shorelines are commonly caused by storm events. These higher than expected water levels, known as storm surges, are generally the result of a synoptic scale meteorological disturbance. **Along the mid-atlantic seaboard, extratropical storms such as "northeasters" have produced some of the highest storm surges and resultant damages on record. However, hurricanes have the potential to produce much higher storm surges because of the vast amount of energy released by these storm systems.** Storm surges can affect a shoreline over distances of more than 100 miles; however, there may be significant spatial variations in the magnitude of the surge due to local bathymetric and topographic features.

A storm surge is defined as the difference between the observed water level and the normal astronomical tide. Astronomical tides represent the periodic rise and fall of the water surface resulting from the gravitational interactions between the Moon, Sun, and Earth. Positive surges occur when the observed water level exceeds the height of the predicted astronomic tide. Negative storm surges (lower than expected water levels) are produced primarily in lakes or semi-enclosed basins and bays. These negative surges are considered more of a nuisance, such as a temporary hinderance to navigation, than a true natural hazard. It is the positive surge which has the greatest potential for property damage and loss of life.

Figure 2-1 (p. 2-3) is an example of a hydrograph (a water level record) for Sandy Hook, NJ which depicts the water levels produced by the passage of hurricane Gloria in September 1985. The maximum observed water level occurred at approximately 1100 hours on September 27, with a surge of 7 feet above the predicted tide level. Although Gloria did not cause the damage that was originally anticipated, the potential for a much higher surge was still present if the storm had taken a slightly different track along New Jersey's coastline.

FIGURE 2-1
OBSERVED WATER LEVEL AT SANDY HOOK, NEW JERSEY
HURRICANE GLORIA, SEPTEMBER 1985



Gebert, J. and Jarvinen, B., 1986: NOAA Technical Memorandum NWS NHC 32, "Comparison of Observed versus SLOSH Model Computed Storm Surge Hydrographs Along the Delaware and New Jersey Shorelines for Hurricane Gloria, September 1985."

2.3.2 Generation of Storm Surge

There are a number of factors which contribute to the generation of storm surges but the fundamental forcing mechanism is wind and the resultant frictional stress it imposes onto the water surface. Winds blowing over a water surface generate horizontal surface currents flowing in the general direction of the wind. These surface currents in turn create subsurface currents which, depending on the intensity and forward speed of the hurricane, may extend from one to several hundred feet below the surface. If these currents are in the onshore direction, the water begins to pile up as it is impeded by the sloping continental shelf, causing a rise in the water surface. Therefore, a wide, gently sloping continental shelf is particularly conducive to the formation of large storm surges. The water level will increase shoreward until it reaches a maximum at, or some distance inland from, the shoreline. The ultimate slope of the water surface is directly proportional to the wind stress and inversely proportional to the water depth. Therefore, a wide gently sloping continental shelf is particularly conducive to the formation of large storm surges.

A secondary component of the storm surge exists if there are winds parallel to the coastline. These winds generate a current parallel to shore and, due to the Earth's rotation, the current will be accelerated to the right of the current direction (in the northern hemisphere). This is referred to as the Coriolis effect. If this current is obstructed by a coastline, the water level will begin to rise.

The reduction of atmospheric pressure within the storm system results in another surge-producing phenomenon known as the "inverted barometer" effect. Within the region of low pressure the water level will rise at the approximate rate of 13.2 inches per inch of mercury drop. This can account for a rise of one to two feet near the center of the hurricane. This effect is considered to be a more important factor in the open ocean where there is no depth related restriction to water flow.[3]

Waves and swells breaking at or near the shore also cause a transport of 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 was brought shoreward. This results in the phenomenon known as "wave setup" and causes a further increase of water level along the beachfront solely from wave action, in addition to any surge associated with the wind setup.[4] Waves are directly affected by the water depth and will break and dissipate their energy in shallow water. Therefore, a relatively steep offshore beachslope is particularly conducive to this process because large ocean waves can approach very near the shore before breaking.[5] Wave setup is primarily a concern near the beachfront because large waves are generally not transmitted inland of the coastline even if the beach has been overtopped.

2.3.3 Modifications to Surge

The magnitude of a storm surge within a coastal basin is governed by both the meteorological

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[3] Harris, D. Lee, 1963: U.S. Weather Bureau Technical Paper NO. 48, "Characteristics of the Hurricane Storm Surge."

[4] U.S. Army Corps of Engineers, Coastal Engineering Research Center, Shore Protection Manual Vicksburg, Mississippi, 1984

[5] Harris

parameters of the hurricane and the physical characteristics of the basin. The meteorological aspects include the hurricane's size, measured by the radius of maximum winds; the intensity, measured by sea level pressure and maximum surface wind speeds at the storm center; the path or forward track of the storm and the storm's forward speed. 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 radius may vary from as little as 4 miles to as much as 50 miles. Due to the counter-clockwise rotation of the wind field (in the northern hemisphere) **the highest surge levels are generally located to the right of the hurricane's forward track. 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 the left of the path of the landfalling hurricane. The timing of the storm surge arrival is important because of its potential coincidence with the time of high (astronomical) tide. Along the ocean coast of New Jersey the mean tidal range is approximately 4 feet and a surge may result in severe or only minor flooding, depending on whether it arrives at the time of high or low tide.**

An estuary's overall basin geometry can attenuate or amplify a storm surge. Such factors include the basin's local bathymetry, orientation in relation to the track of an approaching hurricane, and the interior shoreline topography and configuration. An estuary similar to the Chesapeake Bay in which the shoreline diverges inside the entrance will experience a decrease in the surge amplitude toward the head of the Bay. However, Delaware Bay converges toward the head of the estuary, and a surge entering the mouth may be amplified as the shores of the bay converge. Sites located along the perimeter of a large bay may also experience localized wind and wave setups independent from the main surge due to the bay's orientation and fetch length relative to the hurricane's wind direction.

Raritan and Sandy Hook Bays and the Lower New York Bay lie at the vertex of the New York Bight. This location further amplifies the storm surges to which these waters and the Upper Bay, Newark Bay and Hudson River are subject. A fast moving major hurricane on a north-northwest track striking the New Jersey coast at Ocean or Monmouth County has the potential of producing storm surges in excess of 20 feet in the vicinity of New York City.

2.4 THE SAFFIR/SIMPSON SCALE

The Saffir/Simpson Hurricane Scale, which has been adopted by the National Hurricane Center, categorizes hurricanes based upon their intensity, and relates this intensity to damage potential. The Scale also provides a range of wind speeds and potential surge heights associated with the five categories of hurricanes.

CATEGORY 1. WINDS OF 74 TO 95 MILES PER HOUR. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real wind damage to other structures. Some damage to poorly constructed signs. Storm surge possibly 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 wind damage to buildings. Storm surge possibly 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 island 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 possibly 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 possibly 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 scale. A condensed version of this scale with the inclusion of barometric pressure ranges by category is shown in Table 2-1 (p. 2-7).

The Saffir/Simpson Hurricane Scale assumes an average, uniform coastline for the continental United States and 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, astronomical tides, barriers or other factors which may modify surge heights at the local level during a single hurricane event.

TABLE 2-1
SAFFIR/SIMPSON HURRICANE SCALE WITH CENTRAL BAROMETRIC PRESSURE RANGES

CATEGORY	CENTRAL PRESSURE		WIND SPEED		SURGE	DAMAGE
	MILLIBARS	INCHES	MPH	KNOTS	(FEET)	POTENTIAL
1	>980	>28.94	74-95	64-83	4-5	Minimal
2	965-979	28.5-28.9	96-110	84-96	6-8	Moderate
3	945-964	27.9-28.5	111-130	97-113	9-12	Extensive
4	920-944	27.2-27.9	131-155	114-135	13-18	Extreme
5	<920	<27.2	>155	>135	>18	Catastrophic

2.5 STORM SURGE (SLOSH) MODEL

2.5.1 Introduction

Computer models have been developed for specific coastal basins to represent the varying bathymetry and other factors affecting surge heights calculated for a location. The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is the latest and most sophisticated mathematical model developed to calculate potential surge heights from hurricanes. The SLOSH model was developed by the National Weather Service for real-time forecasting of surges from actual hurricanes within selected Gulf of Mexico and Atlantic coastal basins. **As applied in this Study, the SLOSH model was utilized to simulate the effects of hypothetical hurricanes which could occur in the future, and to simulate actual hurricanes which have occurred in the past in the Atlantic coastal region which includes New Jersey.**

SLOSH Model coverage for the New Jersey Study area was provided by the model's application to a region designated the Delaware Bay Basin. As illustrated by Figure 2-2 (p. 2-11) the Delaware Bay Basin coverage extends from approximately Norfolk, VA to the eastern end of Long Island. The Long Island Sound Basin, which provides SLOSH coverage for the New York, Connecticut, Rhode Island and Southern Massachusetts Hurricane Evacuation Studies, overlaps the Delaware Basin from the New York City area and the southern coast of Long Island. Delaware Bay Basin output for Monmouth County and north was compared to Long Island Sound Basin output and found to be consistent. Long Island Sound Basin data was used for the northern reaches of Newark Bay and the reach of the Hudson River bordering Bergen County which are on the border, or just outside, the coverage of the Delaware Bay Basin.

A summary of the SLOSH Modeling process and surge heights calculated by the Model for this Study are available in the **A Storm Surge Atlas for Delaware Bay** prepared by the National Hurricane Center. [Copies of the Atlas can be obtained from the Philadelphia District, Corps of Engineers.]

The SLOSH model calculates storm surge heights for the open ocean and coastal region affected by a given hurricane. The model also calculates surge heights for bays, estuaries, coastal rivers, and adjacent upland areas susceptible to inundation from the storm surge. Significant manmade or natural barriers such as dunes, islands, etc. are represented in the model and their effects are simulated in the calculation of surge heights.

The initial step in applying the SLOSH model to a particular region (or "basin", as in the "Delaware Bay Basin" of this Study) is to incorporate the three-dimensional geometry of the features of interest. This includes specifying the depth structure (bathymetry) of the continental shelf, nearshore zone, and adjacent bodies of water, as well as the planform shape and elevations of the coastal intertidal and upland areas.

In the SLOSH model, a storm event is represented by the following types of data:

a. Latitude and longitude of storm positions at six-hour intervals for a 72 hour period.

b. The atmospheric pressure at sea level in the eye of the hurricane.

c. The storm size measured from the center to the region of maximum wind speed, referred to as the "radius of maximum wind".

The windspeeds in the hurricane are not directly input by the modeler; instead, the SLOSH model calculates the radial surface wind profile from the other meteorological parameters input by the user.

An additional parameter specified by the modeler is the starting water surface elevation for all "water" areas in the basin. This value is referenced to the vertical datum used to specify land elevations (and water depths) within the model. **The vertical datum used in the Delaware Bay Basin model is the National Geodetic Vertical Datum (NGVD), formerly known as mean sea level of 1929.** The initial water surface elevation is assumed to be higher, on the order of a foot or two, than the ordinary mean sea level for the modeled region. This increased elevation reflects the effects of the storm while it is still distant from the area of interest, typically 24 or more hours from landfall.

Astronomical tide height fluctuations are not directly input for a given storm simulation. Instead, the SLOSH model is run with an assumed uniform starting water surface elevation, and any subsequent deviation from this level is attributable to the effects of the storm. The possible effects of the storm surge occurring at a particular phase of the tide, such as at the time of high or low tide, are evaluated as an increment, either positive or negative, to the SLOSH-predicted surge level. This topic is addressed more fully in a following section.

2.5.2 Model Structure

The SLOSH model uses a telescoping polar coordinate grid system to represent a particular coastal region of interest. The grid developed for the Delaware Bay basin is shown on Figure 2-2 (p. 2-11). The grid consists of 76 arcs (the curved lines) and 81 radials (the straight lines). The spacing between successive arcs increases with distance from the center of the grid such that each grid cell has approximately equal length sides.

The telescoping polar grid has a number of advantages over a rectilinear grid in the efficiency of model computations. With a telescoping polar grid the area of greatest interest which in this Study is the coastal zone susceptible to hurricane surge inundation, is modeled with the highest resolution. The grid cell size is relatively smaller along the coast than the grid cell size in the deep, open water of the Atlantic. The smaller grid size allows more detailed representation of physical features, such as inlets, rivers, islands, dunes, etc., which can have important effects on the propagation of the storm surge.

The grid cell size is larger in the open ocean where less resolution of storm surge height is required. The reduced number of cells in the offshore area reduces the time and cost of each model run required. However, the larger grid cell size in the offshore region permits the inclusion of a large geographic area in the model, so that the effects of the model boundaries on the dynamics of the storm are diminished.

The grid for the Delaware Bay basin is tangent to the earth at Cape Henlopen, Delaware, latitude 38° 23' 40" N and longitude 75° 05' 50" W. At this location, the typical grid line spacing is 2.8 statute miles. The pole (or origin) of the grid is located about 40 miles northwest of Philadelphia at latitude 40° 23' 40" N and longitude 75° 48' 20" W.

2.5.3 Model Verification

In order to consider a model, such as the SLOSH model, as a reliable tool for predicting hurricane surge elevations for a particular region, 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 reliable measurements of storm surge elevations over a representative number of sites within a region due to the difficulty of making such measurements during hurricane conditions.

The SLOSH model was designed as a generalized, operational tool for storm surge forecasting which could be applied with confidence to any coastal area, regardless of previous hurricane history or availability of storm surge or meteorological data. The SLOSH model is not "tuned" for a particular area, other than in the sense that the geometry of the modeled region is reproduced as realistically as possible. The model uses universal specifications of parameters such as drag coefficient and bottom stress which are functions of the storm processes and independent of the area in which the hurricane occurs.

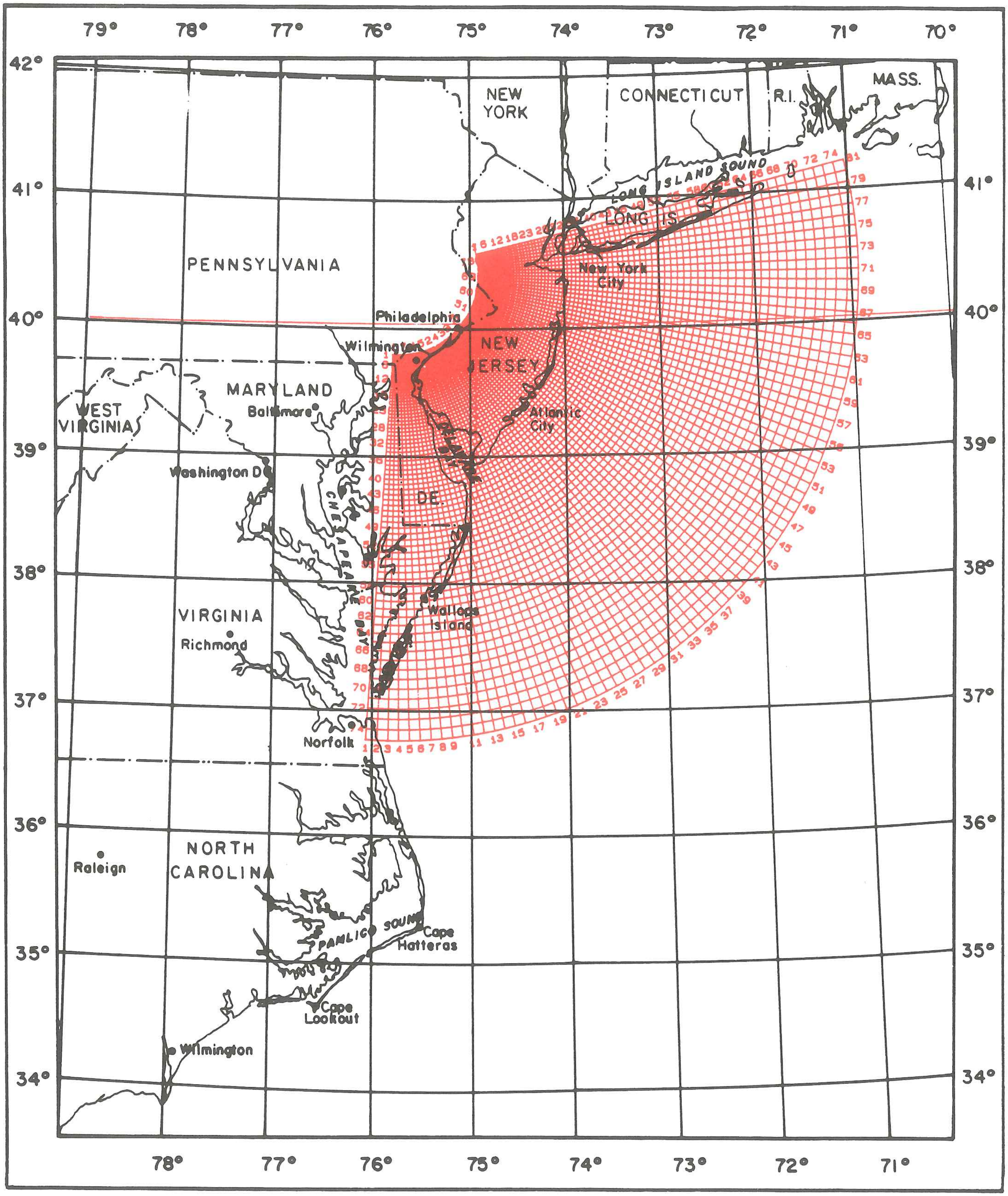


FIGURE 2-2
DELAWARE BAY SLOSH GRID

Prior to the widespread application of SLOSH as a tool in hurricane evacuation planning, the model underwent verification testing by the National Weather Service. Nine hurricanes with well documented meteorology and storm surge effects were each modeled for at least one of nine discrete basins. The success of SLOSH in these verifications justified its present use as a hurricane planning tool. The Delaware Bay basin is one of the regions of the United States coastline with a very sparse historical record of simultaneous storm meteorology and storm surge observations. However, the occurrence of Hurricane Gloria in September 1985 offered an opportunity to verify SLOSH model predictions within the basin at several Delaware and New Jersey locations.

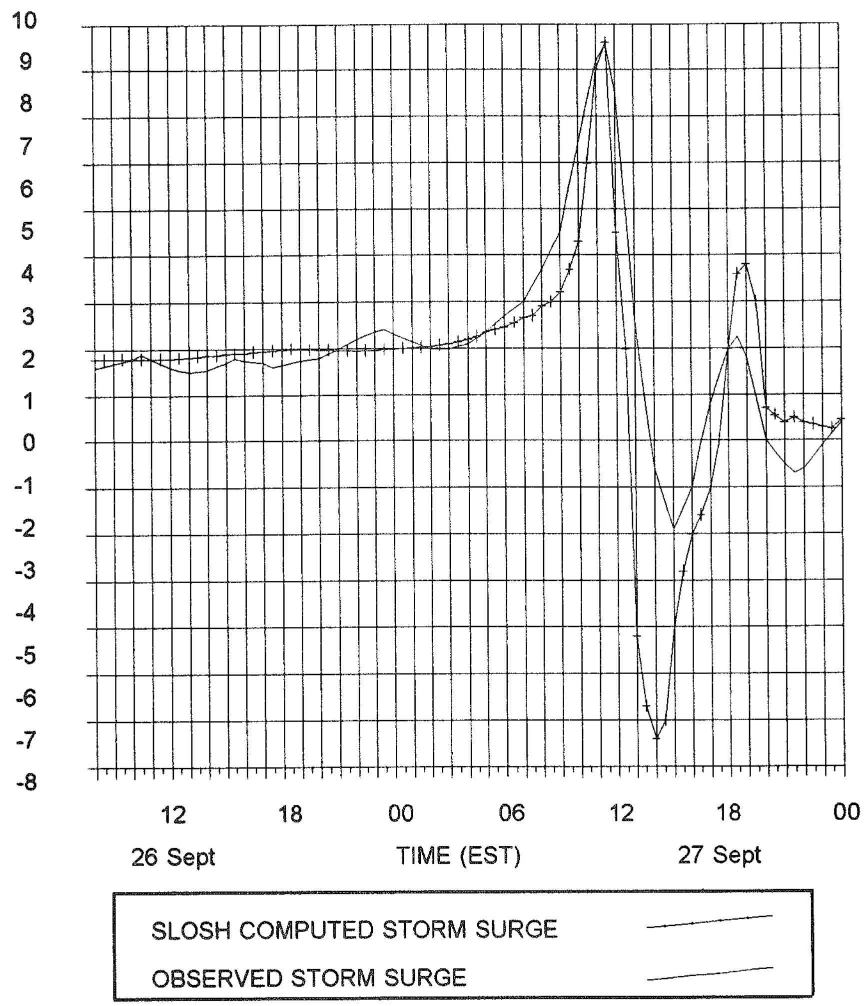
For the Hurricane Gloria verification, the track, atmospheric sea-level pressure in the eye, and the radius of maximum winds at specified time intervals were used as input to the SLOSH model. Observed storm surge data were obtained at seven recording tide gages within the Delaware Bay basin limits. The gages are all operated by the National Ocean Service and include open ocean, inlet, estuarine, and river locations susceptible to hurricane surge inundation. After removal of astronomical tide effects from the observed water level records, comparisons could be made between observed and predicted storm surge.

Figure 2-3 (next page) presents the time history of observed vs. computed storm surge at Sandy Hook during the passage of this hurricane. A comparison of the observed and computed results at Sandy Hook and seven other gage sites showed that the peak surge values generated by SLOSH were within $\pm$ 1 foot of the observed values at all sites, and that the times of peak surge generated by SLOSH were within $\pm$ 1 hour at five of the seven gage sites. At the Reedy Point, Delaware, and Philadelphia, Pennsylvania gages, the SLOSH model predicted times of peak surge which were about 5 hours later than observed. However, this is not considered a significant verification problem because these two sites are respectively about 60 and 100 miles above the Atlantic Ocean entrance to Delaware Bay. Hurricane Gloria moved rapidly past the entrance to Delaware Bay on its northward track and resulted in surge heights which decreased significantly with respect to distance above the Bay entrance. It is probable that tidal currents (which are not directly simulated in the SLOSH model) combined with the relatively small storm surge in this reach of the Delaware River led to the differences between predicted and observed times of peak surge at Reedy Point and Philadelphia. Overall the SLOSH model simulation of Hurricane Gloria is considered to have yielded an entirely satisfactory verification of the capabilities of the model to accurately predict both the height and timing of maximum hurricane surge effects for the Delaware Bay basin.

FIGURE 2-3

OBSERVED VS. COMPUTED STORM SURGE AT SANDY HOOK, NEW JERSEY

HURRICANE GLORIA, SEPTEMBER 1985



Gebert, J. and Jarvinen, B., 1986: NOAA Technical Memorandum NWS NHC 32, "Comparison of Observed versus SLOSH Model Computed Storm Surge Hydrographs Along the Delaware and New Jersey Shorelines for Hurricane Gloria, September 1985."

2.5.4 Model Output

The standard data products from a given SLOSH model run consist of both tabulated and graphical information. The tabulated output data consist of the following:

a. User input values of storm center latitude and longitude, central pressure differential, and radius of maximum winds, at six-hour intervals.

b. User input starting water surface elevation.

c. Model interpolated values, at one hour intervals, of storm location (latitude and longitude), forward speed, track direction, central pressure differential and radius of maximum winds.

d. Model computed values, at one-half hour intervals, of surge height, wind speed, and wind direction at a number of sites selected by the user. Sixty (60) sites were modeled throughout the Delaware Bay Basin--the area covered by the SLOSH application for the New Jersey Hurricane Evacuation Study--forty of these are in the State of New Jersey. These grid sites were selected to coincide with critical locations identified by the New Jersey State Police Office of Emergency Management, the Coastal Resources Division of the Department of Environmental Protection and the Philadelphia District, Corps of Engineers. They are located at low-lying roads and bridges that would be critical to an evacuation, at potentially vulnerable population centers, or at significant natural or manmade barriers (See Figure 2-10, p. 2-27) for the location of sites). The time-history information produced by the SLOSH model for critical points lists values for still-water surge heights, wind speeds, and wind direction at 30-minute intervals for 72 hours.

Examples of the wind speed and wind direction and surge data products from a SLOSH run are displayed in Tables 2-4 and 2-5 (pp. 2-30 & 2-31) for Cape May, Atlantic City, Barnegat and Sandy Hook. These tables apply to a Category 3 hurricane, moving in a north-northwest direction at a forward speed of 40 MPH, with landfall at Avalon, NJ. Table 2-6 (p. 2-32) displays computed maximum surge heights at six coastal locations for the same hurricane but with additional landfall points. This table illustrates the significant differences in surge heights that can result from the same hurricane with relatively small differences in landfall point.

The graphical data output by the model consists of a plot of the original telescoping polar coordinate grid in a rectilinear format. Each grid cell is plotted at a uniform size, which has the effect of distorting the apparent shape of the coastline and other physical features. Cells near the origin of the polar grid are thus expanded relative to their original size; cells near the outer portion of the polar grid are contracted relative to their original size. (See Figure 2-9, p. 2-23 for an example of SLOSH output in this form.)

The rectilinear plot of the model basin for a given SLOSH simulation displays the following information:

a. The track of the hurricane being modeled.

b. The locations and names of selected geographic points.

c. The maximum water surface elevation attained at each grid cell over the duration of the storm being simulated. This plot does not represent a "snapshot" of the storm surge at an instant of time. Instead, it represents the highest water level at each grid point during a hurricane irrespective of the actual time of occurrence during that storm. This plot of maximum surge heights is referred to as the "envelope" of maximum surge for a particular storm acting on a specific SLOSH modeled basin.

2.6 THE MODELING PROCESS FOR THE DELAWARE BAY BASIN

2.6.1 Introduction

The geographic area covered by the SLOSH model of the Delaware Bay Basin includes: portions of coastal Maryland and Virginia and Chesapeake Bay; the entire state of Delaware; Delaware Bay to the head of tide at Trenton, New Jersey; coastal New Jersey (bay and ocean); and portions of southern New York, including New York City and Long Island.

2.6.2 Simulated Hurricanes

In the New Jersey Hurricane Evacuation Study, hurricane simulations were run on the SLOSH model by specifying four parameters for each storm event: the hurricane direction of travel, forward speed, intensity, and track location. The Saffir-Simpson scale was used as the indicator of storm intensity. Each class on this scale represented a particular combination of values for central pressure differential and radius of maximum wind. In addition, the starting water surface elevation is also defined.

For this Study, a total of 370 discrete hypothetical hurricanes were modeled. These hurricanes were specified to travel in one of five possible directions, some at one and others at two forward speeds. A range of track locations was used for each direction in order to evaluate the surge heights resulting from different storm landfall points. **Storms were modeled at categories 1 through 4 of the saffir-simpson scale of intensity. Storms were not modeled at Category 5 of the Saffir-Simpson scale because of the extremely low probability of occurrence of a storm of that intensity at the latitude of New Jersey.** The selection of storm parameters was based on advice of hurricane specialists at NOAA's National Hurricane Center. Table 2-2 (p. 2-16) summarizes the combinations of storm parameters which were applied in the SLOSH model of the Delaware Bay basin. Figures 2-4 through 2-8 (following p. 2-16) illustrate the storm tracks and landfall points for the five directions modeled.

A starting water surface elevation of + 1.0 feet NGVD was adopted for the 370 SLOSH model runs. This value represents the super-elevation of the ocean water level, independent of astronomical tide, which typically occurs as much as a day or more in advance of the arrival of a hurricane at a particular coastal location.

TABLE 2-2
STORM PARAMETERS FOR THE DELAWARE BAY BASIN

DIRECTION	FORWARD SPEED	INTENSITY	TRACKS	RUNS
WNW	20	1-4	16	64
NW	20	1-4	14	56
NNW	20 and 40	1-4	13	104
N	20 and 40	1-4	13	104
NNE	20 and 40	1	9*	42
		2	6	12
		3	4	12
		4	2	8
		TOTAL SLOSH RUNS:		370

* It is assumed that all storms of intensity 1 could run inland and still maintain that intensity. For storms of intensity 2, 3 and 4, however, it is assumed that progressively fewer of these storms could maintain their respective intensities over land.

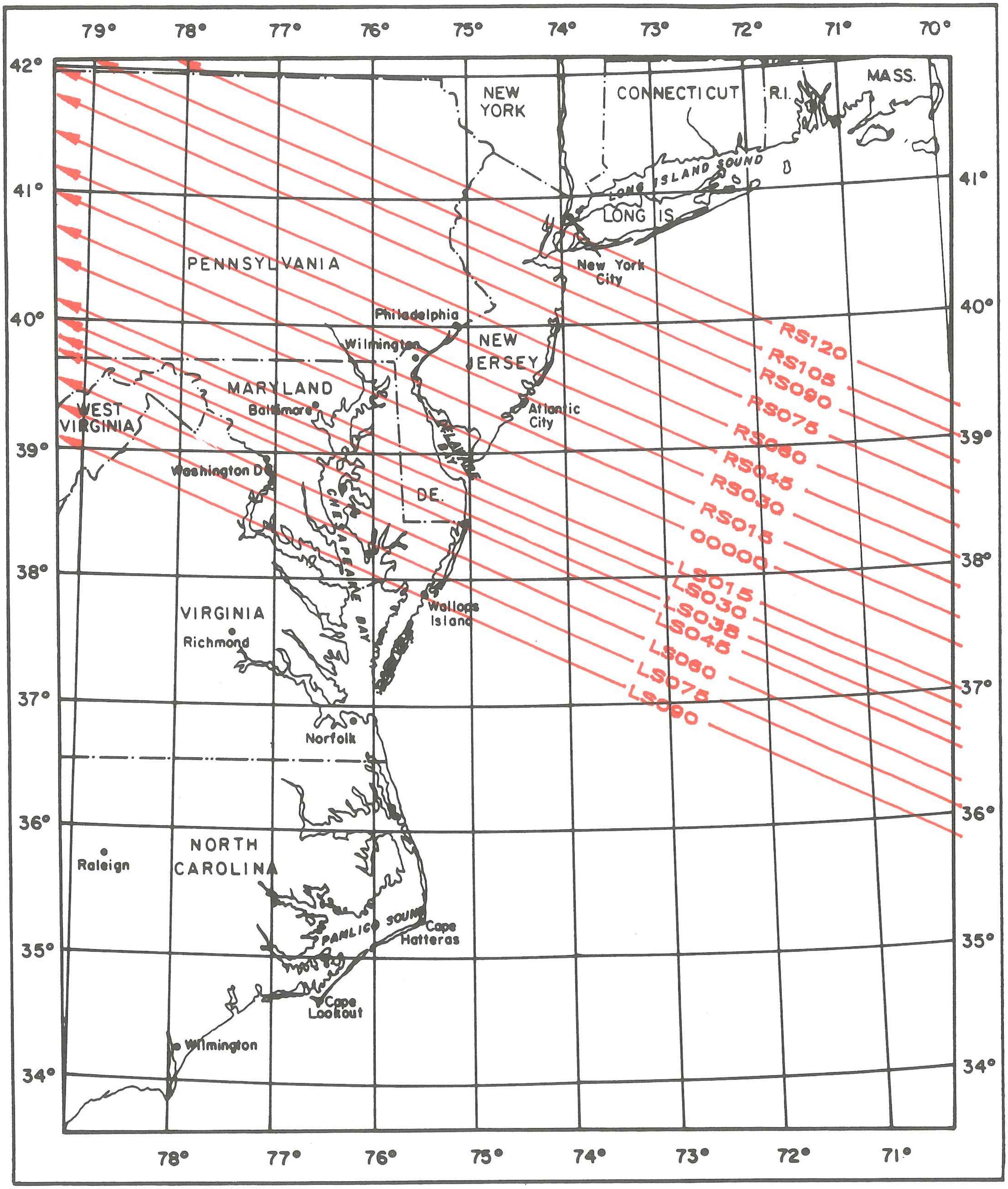


FIGURE 2-4
WEST-NORTHWESTWARD MOVING HURRICANES

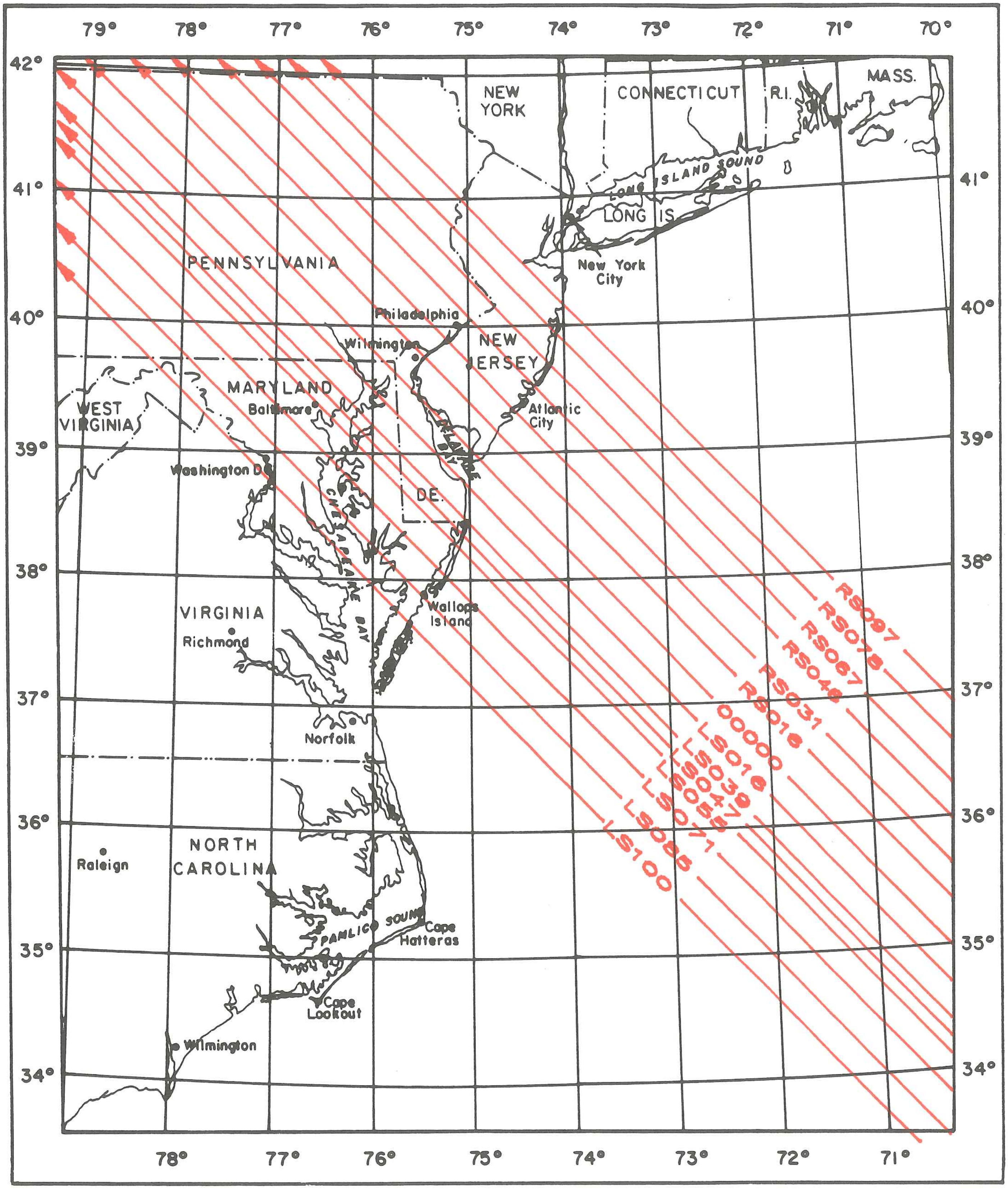


FIGURE 2-5
NORTHWESTWARD MOVING HURRICANES

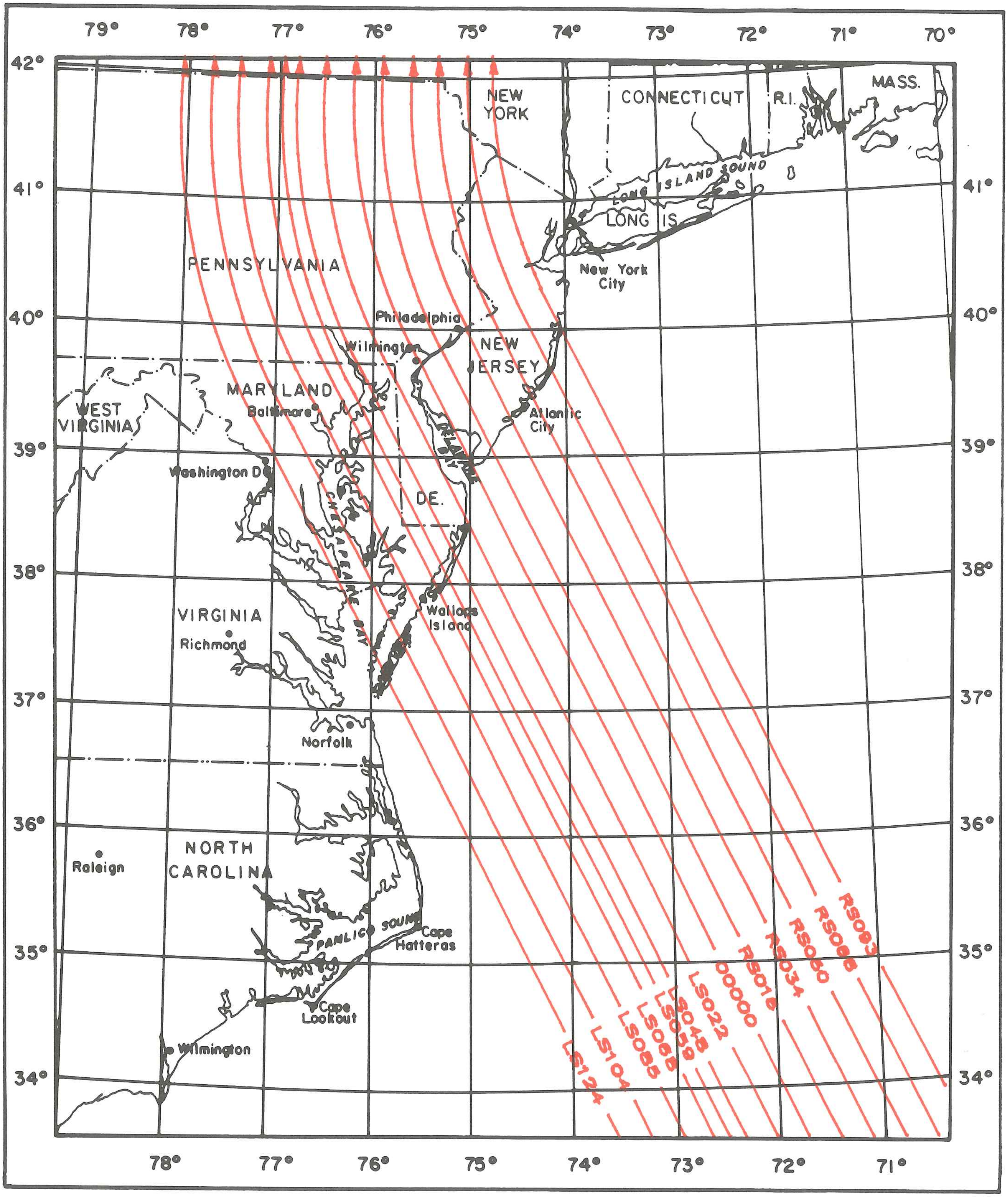


FIGURE 2-6
NORTH-NORTHWESTWARD MOVING HURRICANES

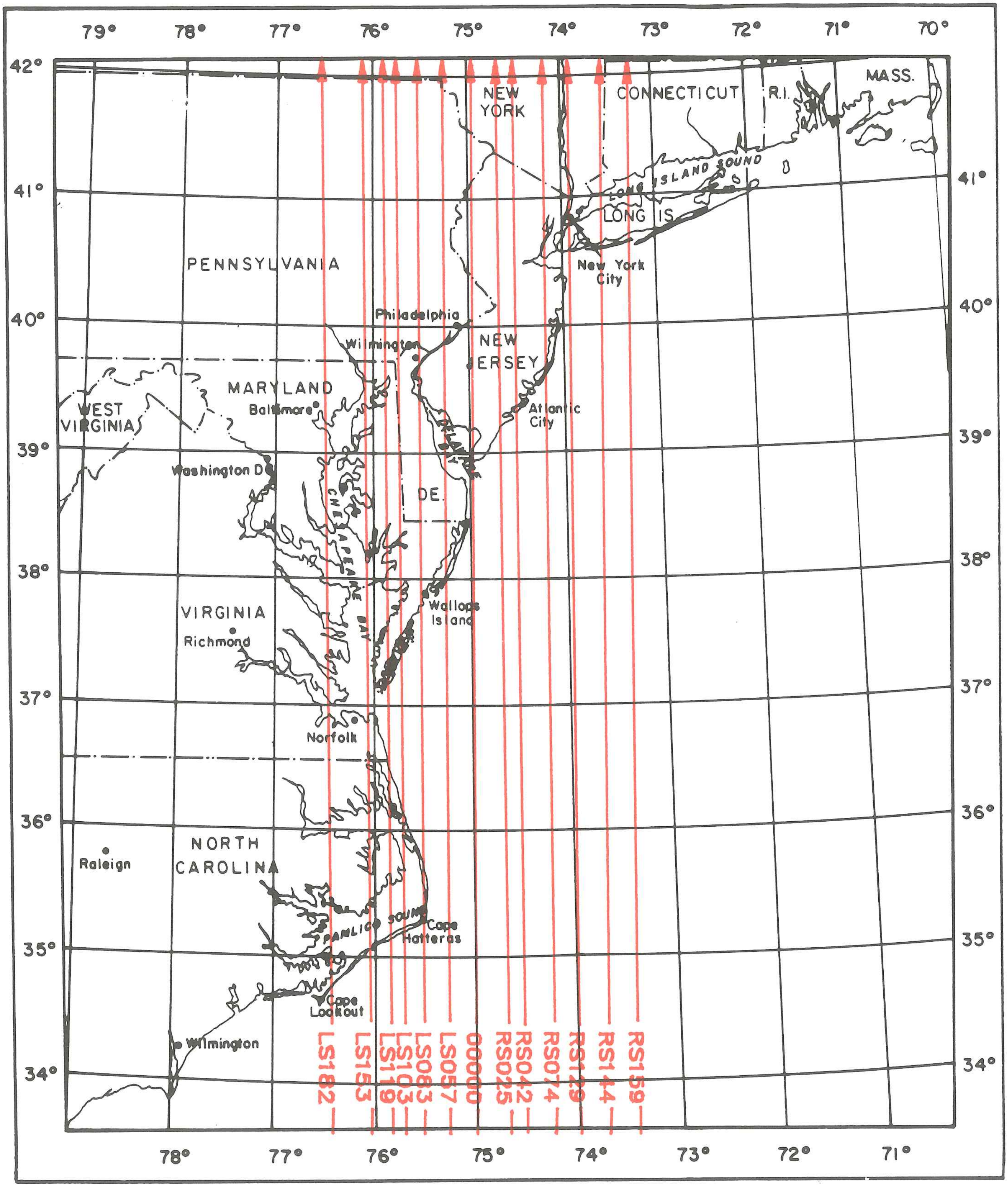


FIGURE 2-7
NORTHWARD MOVING HURRICANES

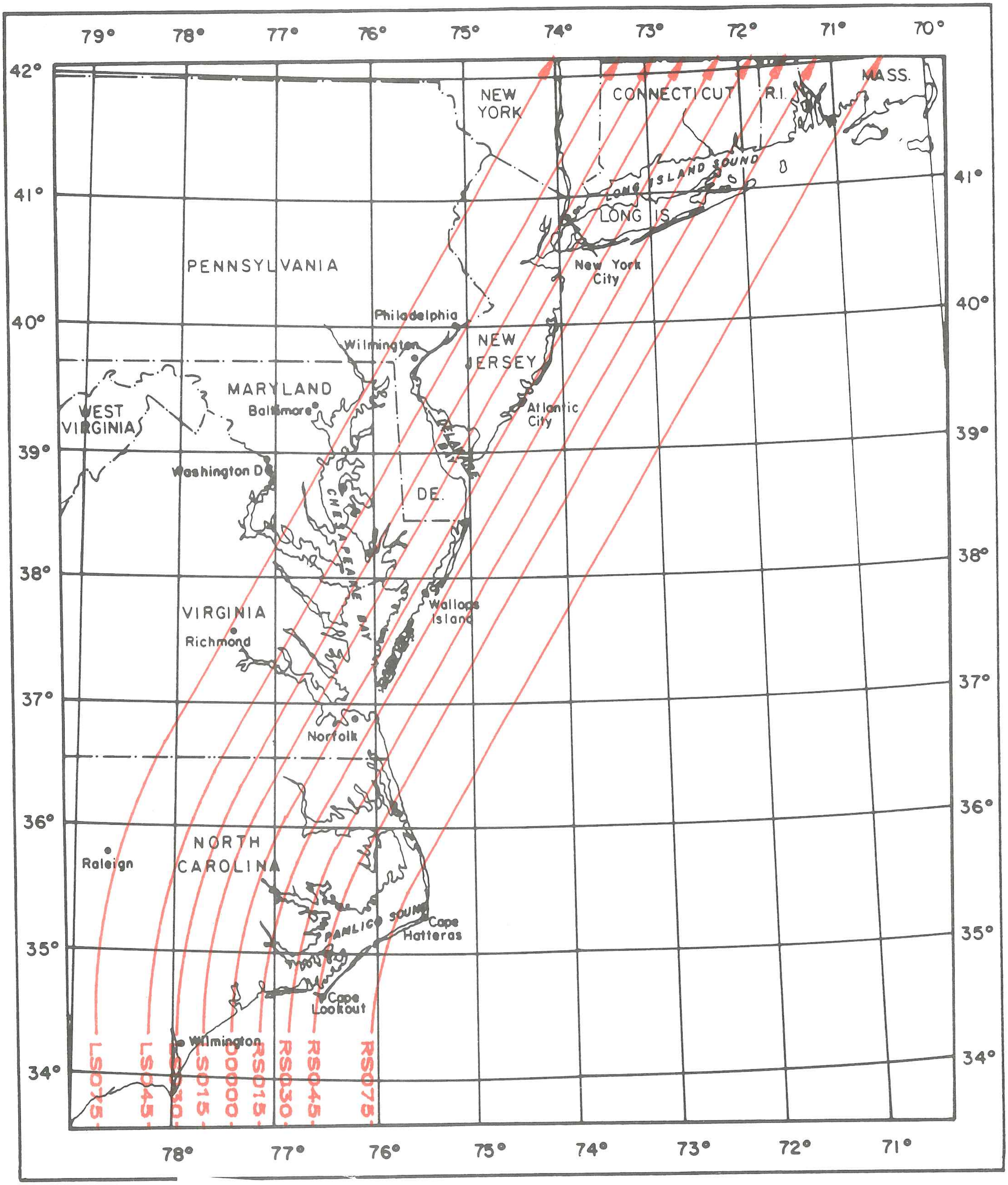


FIGURE 2-8
NORTH-NORTHEASTWARD MOVING HURRICANES

2.6.3 Maximum Envelopes of Water (MEOWS)

For a SLOSH model simulation of a discrete hurricane event, one of the data products is the plot of maximum water surface elevation at all grid cells affected by the storm, irrespective of when during the storm that maximum water level was attained. The imaginary surface defined by the maximum water level in each cell is termed the "envelope" of maximum water surface elevations for that storm. **The largest individual value of water surface elevation for a particular storm is termed the "peak" surge for that event. The location of the peak surge is highly dependent upon where the storm center crosses the coastline (the landfall point).** In most instances, the peak surge from a hurricane occurs to the right of the storm path and within a few miles of where the radius of maximum winds is located. This is largely due to the counter-clockwise rotation of the windfield surrounding the eye of the hurricane (in the northern hemisphere). To the right of the landfall point the winds blow toward the shoreline; to the left of the landfall point the winds blow away from the shoreline. **It is important to note, however, during an actual hurricane, the least accurately predictable parameter is the point of landfall.** The average error in the official twenty-four landfall position for Atlantic coast tropical cyclones over the 1970 to 1979 period was about 110 nautical miles. The average error in the 12 hour official forecast was 50 nautical miles. Table 2-6 (p. 2-32) illustrates the significant differences in surge heights that result from relatively slight differences in landfall location.

Because of the inability to predict exactly where a hurricane will make landfall, and because it may be necessary to begin evacuations of areas susceptible to hurricane surges as much as 18 hours before landfall, it is necessary to predict potential surge elevations for a given hurricane over a range of potential landfall points. In order to meet this need, the SLOSH model is used to develop a map termed a "MEOW", which is the maximum envelope of water from a number of individual hurricane simulations which differ only in point of landfall of the storm center. In this manner, the maximum water surface elevations for each grid cell are calculated for a particular class of hurricane, defined by direction, forward speed, and intensity, independent of where the storm actually crosses the coastline. An example of a MEOW for a Category 3 hurricane with a 40 MPH forward speed and a north-northwest track direction is shown on Figure 2-9 (p. 2-23). The MEOW displays the characteristic distorted geometry which results from transforming the telescoping polar coordinate grid into a rectilinear format. The contour lines show the maximum water surface elevations at all affected points on the grid for all possible landfall points modeled.

For the New Jersey Hurricane Evacuation Study, the original 370 SLOSH model runs were grouped so as to produce a total of 32 MEOWs. These 32 MEOWs were then analyzed to determine which changes in storm parameters (i.e., intensity, forward speed, direction) resulted in the greatest differences in the values of the peak surges for all locations in the modeled basin.

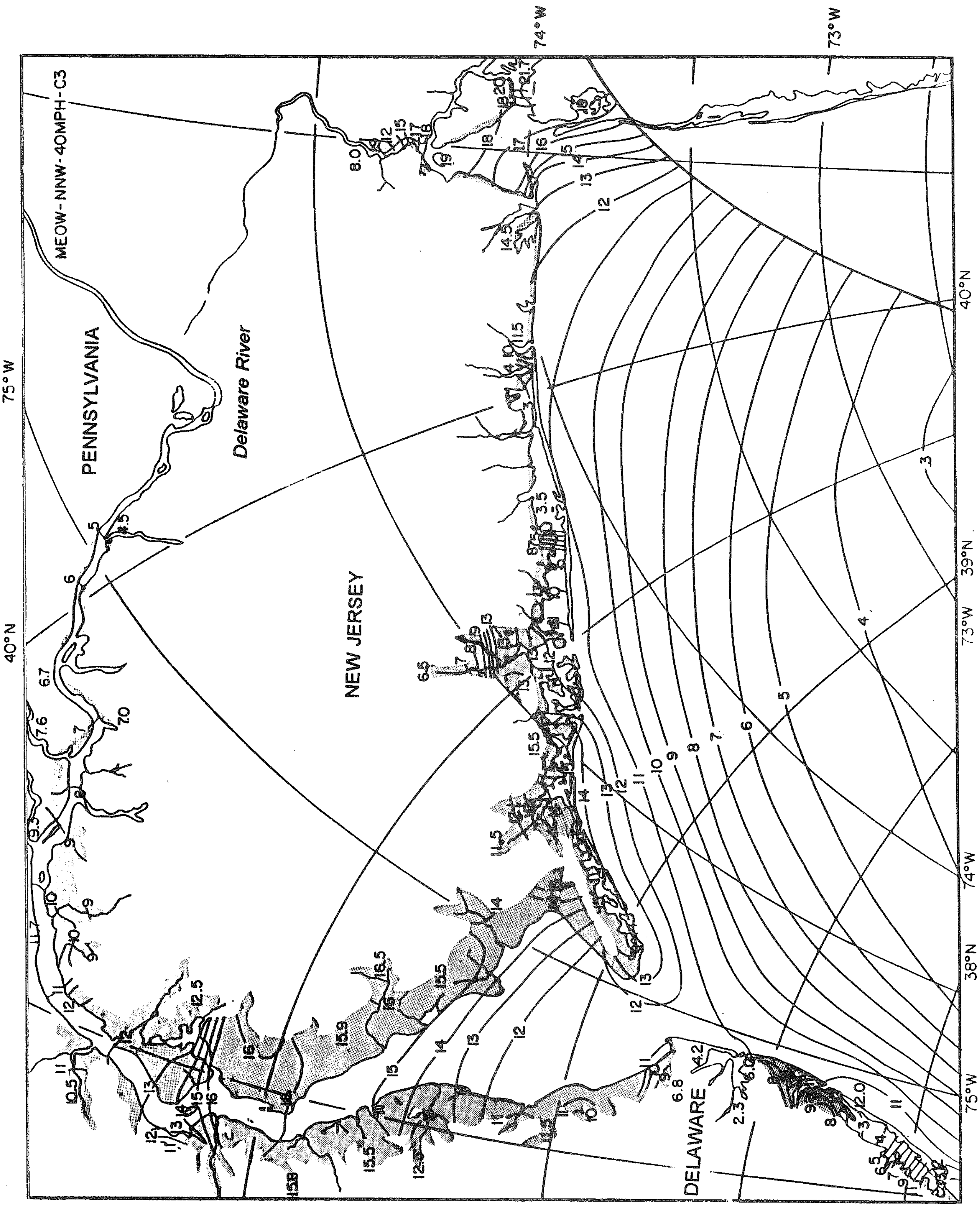


FIGURE 2-9
SLOSH MAXIMUM ENVELOPE OF WATER (MEOW)
NNW-40 MPH-C3

The MEOWs were then further grouped according to overall similarities of predicted envelopes of maximum water level over the entire modeled basin. In general, it was determined that the change in storm intensity accounted for the greatest change in potential surge height for sites on the open coast. Ultimately it was determined that the 32 MEOWs could effectively be grouped into distinct classes of hurricane events defined solely by the storm intensity. This final grouping was performed in order to provide for the development of hurricane scenarios to be used in the evacuation planning process.

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2.6.4 County Storm Surge Map

Areas potentially subject to flooding from Category 1, 2 and 3/4 hurricanes are presented for each County in maps provided with this report (County Storm Surge Inundation Areas and Evacuation Network Maps). The differences in areas inundated by Category 3 vs. Category 4 surges were not deemed significant enough to warrant creation of separate inundation mapping. For Categories 1, 2 and 4 the constituent MEOWs were evaluated to determine which MEOW produced the highest surge value for all grid cells in the New Jersey Study area. The highest surge value in each cell was then adopted to define the limits of hurricane surge inundation for each category. (Although the limits of Category 3 flooding are not delineated, applicable Category 3 surge values are included on a Surge Inundation Table included in the legend of each map.)

2.6.5 Adjustments to SLOSH Model Values

During coordination of the Study findings with local, State, and other Federal agencies, the topic of tide height effects was identified as an area requiring further evaluation. This was principally due to the fact that the mean astronomical tide (difference between low and high tide) range for the coastal areas of New Jersey is on the order of 4 to 5 feet, with spring tide ranges in excess of 6 feet in some portions of the state. It was recognized that the time of occurrence of the maximum surge relative to the time of high or low astronomical tide could have a significant effect on the limits of inundation, particularly in relatively flat areas where small changes in water elevation may have large effects on the extent of area inundated.

In order to test the sensitivity of the predicted surge heights to the stage of the tide at the time of hurricane passage, additional SLOSH model runs were performed. Four MEOWs were selected by Army Corps of Engineers and National Hurricane Center personnel as representative of a range of possible hurricane surge effects, from very large to very small, for coastal New Jersey. The four MEOWs represented 52 discrete storm events. Two new starting water surface elevations were specified, +3 feet and +5 feet NGVD, resulting in a total of 104 additional SLOSH model runs. The results of these model runs were compared to earlier counterpart runs made with a starting water surface elevation of 1 foot NGVD.

The results of this comparison showed that for the open coast areas of the Delaware Bay basin there was a simple, arithmetic relationship between the starting water surface elevation for a particular storm and the resultant maximum surge elevation. In other words, open coastal areas would experience an additional 2 or 4 feet of surge when the starting water surface elevation, representing a different, higher stage of the tide, were increased by 2 or 4 feet.

Areas located landward of the open coastal zone showed a somewhat more complicated response to changes in the starting water surface elevation. A good example is the upper reaches of Barnegat Bay where a two foot change in starting water surface elevation, from +1 to +3 feet NGVD, or from 3 to 5 feet NGVD, for example, resulted in model-predicted surge height increases of as much as 7 feet.

Differences of this magnitude occurred only for the most critical (NNW heading, 40 MPH, Category 4 storms) of the four MEOWs run in this comparison. The other three lower intensity MEOWs in this comparison displayed surge height increases which were closely related to the increase in the starting water surface elevation. Large differences between increased starting water surface elevation and resulting surge elevation are due to the manner in which certain topographic features, such as dune ridges, are represented in the SLOSH model. In actuality, the elevation and width of the dune ridge changes with distance along the shoreline. In some places, the dune may not exist as a continuous ridge, but as discontinuous individual dunes. However, the SLOSH model requires that a coastal barrier such a dune or dune ridge be represented as a continuous feature of constant elevation along a minimum of one side of a model grid cell. Further, the model assumes that no water overtops the dune ridge to flood areas behind barriers until the surge elevation exceeds the dune elevation specified in the model. In the model, a surge elevation of 8.9 feet NGVD will not overtop a dune ridge assigned an average elevation of 9 feet NGVD, whereas a surge of 9.1 feet NGVD will overtop the same feature. The model would then show a large increase in surge elevation behind the barrier for a very small (i.e., 0.2 foot) increase in surge elevation for the ocean coast.

Variations in height, width, and continuity of actual dunes are such that small increases of ocean surge height often lead to corresponding small increases in surge height landward of the dune. The resulting back barrier surge elevation may thus be close in elevation to the ocean surge level. For this reason, the surge inundation mapping for back barrier and inland bay areas was performed using the surge elevations from the adjacent open ocean shoreline grid cells to define the back barrier surge elevations. Any inaccuracies in resultant mapping would be in the direction of over-estimates of surge heights and extent of flooding and would be in keeping with the conservative "worst-case" approach followed throughout the Hazards Analysis.

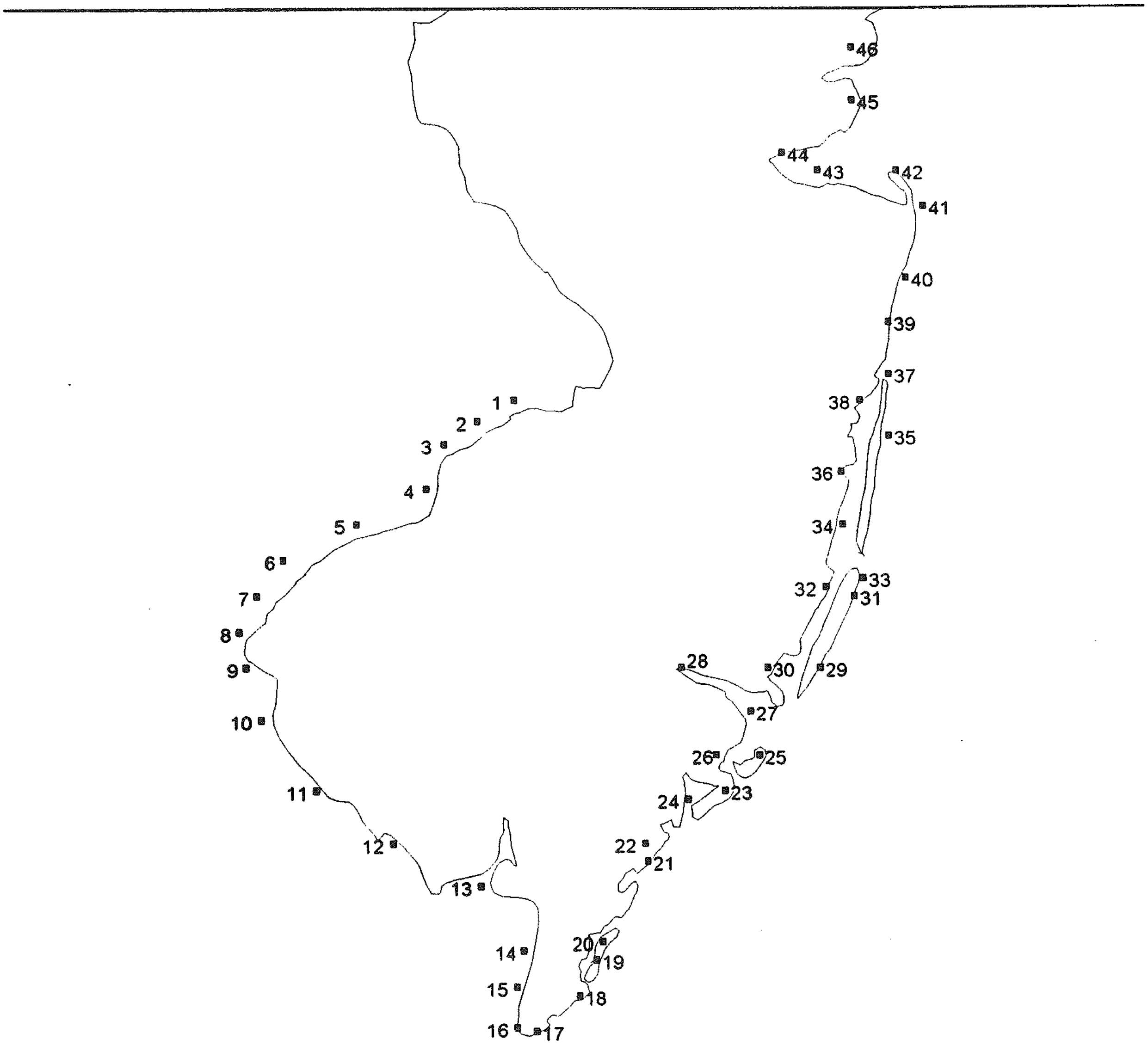
2.6.6 Astronomical Tide Height Effect

The initial 370 runs of the SLOSH model were made with a starting water surface elevation of +1 foot NGVD. This value was chosen to reflect the effects of a small but finite storm surge well in advance of the arrival of the storm center and its accompanying localized higher surge. SLOSH model runs with alternate increased starting water surface elevations (of +3 and +5 feet NGVD) demonstrated that for nearly all cases, a given increment in the starting water surface elevation leads to an approximately equal increment in the resulting maximum surge elevation value. A review of all sites in the New Jersey Coastal region at which there are recent tide gage records showed that the single value which best represented the elevation of the plane of mean high water (MHW) was 3 feet NGVD.

The coordination effort with local, State, and other Federal agencies led to a consensus to evaluate and map the effects of storm surge maximums occurring at the time of mean high water. **For the actual mapping of inundation areas, a value of 3 feet was added to the slosh predicted surge elevations for model runs originally made with an assumed starting water surface elevation of 1 foot NGVD. The inundation maps thus represent the areas inundated by storm surge from a hurricane whose maximum effects occur at the time of high tide, and for which there is a one-foot pre-arrival surge.** The occurrence of the maximum hurricane surge effects at times of tides higher (or lower) than the mean high tide elevation would result in a corresponding larger (or smaller) surge elevation than that shown on the inundation maps.

2.6.7 Time History Data

The purpose of the time-history data is to determine the pre-landfall hazards distance for each of the counties within the study area. **Pre-landfall hazards distance is the distance from the eye of the approaching hurricane to the nearest county (or state) boundary at the time an evacuation would be curtailed due to hazardous weather.** For the New Jersey Hurricane Evacuation Study, two conditions that could curtail hurricane evacuation were evaluated: the arrival of sustained gale-force winds (34-knot sustained wind speed, 1-minute average) and the



SLOSH Model time history data (wind speeds, wind directions and surge heights (at half-hour intervals) are available for these New Jersey locations as well as for fourteen other locations within the Delaware Bay SLOSH Basin.

Beverly	1	Maurice River	13	Atlantic City	25	Mantoloking	37
Palmyra	2	Reeds Beach	14	Absecon	26	Shore Acres	38
Philadelphia	3	Villas	15	Mystic Island	27	Manasquan	39
Intn'l Apt.	4	Cape May Point	16	Mullica River	28	Long Branch	40
Chester	5	Cape May	17	Beach Haven	29	Highlands	41
Claymont	6	Grassy Sound	18	Tuckerton	30	Sandy Hook	42
Marine Terminal	7	Stone Harbor Ocean	19	Surf City	31	Keyport	43
New Castle	8	Stone Harbor Bay	20	Manahawkin	32	Amboys	44
Salem	9	Sea Isle City Ocean	21	Barnegat Light	33	Verranzano Narrows	45
Salem Point	10	Sea Isle Bay	22	Oyster Creek	34	Jersey City	46
Greenwhich	11	Ocean City Ocean	23	Seaside Heights	35		
Bay Point	12	Ocean City Bay	24	Bay Shore	36		

FIGURE 2-10
SLOSH MODEL CRITICAL POINTS

onset of storm surge inundation of low-lying roads, bridges, or other critical areas. **The first of these two conditions to occur determines the pre-landfall hazard distance.**

The time of arrival of sustained gale-force winds is one selected goal for completing an evacuation because high-profile vehicles and vehicles pulling campers or boats could easily be overturned, especially on high bridges, by higher wind gusts accompanying those sustained winds.

Such an accident would most certainly cripple or stop traffic flow on that evacuation route. The arrival of sustained gale-force winds is also the time, under the majority of hurricane threats, when the heaviest rainfall begins. Generally, one-half of the total amount of rainfall received from a hurricane occurs from the time of arrival of sustained gale-force winds until the eye reaches the coastline.

The other condition limiting evacuation, the onset of storm surge inundation, will not be a significant factor in most of the study area prior to the arrival of sustained gale-force winds. Storm surge is the increase in height of the surface of the sea due to the forces of the approaching hurricane. At all 60 SLOSH time-history critical points the arrival of sustained gale-force winds occurs before the onset of storm surge inundation and, therefore, determines the pre-landfall hazards distance. Evacuation decision making officials should be aware that the coincidence of high astronomical tide with storm surge could cause moderate flooding at low-lying critical points prior to the arrival of sustained gale-force winds.

Since the limiting factor for hurricane evacuation used in this study is the arrival of sustained gale-force winds, the pre-landfall hazards distance for any county 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 New Jersey Hurricane Evacuation Study area, the pre-landfall hazards distance and the radius of sustained gale-force winds are synonymous.

Although the windfields 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 windfield. 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 Delaware Bay Basin SLOSH model, the National Hurricane Center has concluded that the radii 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 the study.

Table 2-3 (p. 2-29) lists the SLOSH assumed radii of sustained gale-force (34-knot) winds by category of hurricane for the New Jersey Hurricane Evacuation Study area. 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. These distances could be used operationally, if, for some reason, actual observed values were not available. Marine advisories, produced by the National Hurricane Center 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, southwest). Forecasts of these distances for 12, 24, 48, and 72 hours into the future are also given. The largest measured distances of the radius of 34-knot, 1-minute sustained winds should be used for evacuation decision-making. Further discussion of the application of the radius of gale-force winds to hurricane evaluation decision-making is contained in Chapter 7, Decision Arcs. [A sample Marine Advisory, issued for Hurricane Hugo in 1989, including current and forecast radii of 34-knot winds, is presented on page A-6 of this report.]

Tables 2-4 and 2-5 (pp. 2-30 & 2-31) present time history data for locations in New Jersey. Table 2-4 reflects wind speeds and wind directions, Table 2-5 storm surge elevations for a North-northwest bound Category 3 hurricane with a forward speed of 40 MPH, making landfall in the vicinity of Avalon in Cape May County.

TABLE 2-3
SLOSH RADII OF GALE-FORCE WINDS

SAFFIR/SIMPSON HURRICANE CATEGORY	RADIUS OF GALE-FORCE (34-Knot) WINDS (NAUTICAL MILES)
1	60
2	85
3	105
4	125
5	140

TABLE 2-4

SLOSH MODEL TIME HISTORIES OF WIND SPEED/DIRECTION
AT SELECTED NEW JERSEY COASTAL SITES
NORTH-NORTHWEST-BOUND CATEGORY 3 HURRICANE
40 MPH FORWARD SPEED
LANDFALL: 16 STATUTE MILES RIGHT (NORTH) OF CAPE MAY, NJ

	CAPE MAY	ATLANTIC CITY	BARNEGAT	SANDY HOOK
HOUR	SPEED (MPH)/ DIRECTION[1]	SPEED (MPH)/ DIRECTION	SPEED (MPH)/ DIRECTION	SPEED (MPH)/ DIRECTION
0600	22/ 53°	21/ 62°	20/ 67°	17/ 53°
0630	24/ 53	23/ 62	22/ 68	18/ 54
0700	26/ 53	25/ 63	24/ 69	19/ 55
0730	29/ 52	28/ 64	26/ 70	21/ 56
0800	32/ 51	31/ 65	28/ 72	22/ 57
0830	36/ 50	35/ 65	31/ 74	24/ 59
0900	41/ 48	39/ 66	35/ 75	27/ 60
0930	48/ 46	45/ 67	39/ 77	29/ 62
1000	57/ 45	53/ 69	45/ 79	32/ 64
1030	69/ 45	64/ 73	52/ 83	36/ 66
1100	83/ 49	79/ 82	61/ 89	40/ 69
1130	74/ 38	97/100	72/ 98	45/ 72
1200	51/311	108/128	85/111	52/ 76
1230	86/250	111/165	96/130	60/ 81
1300	87/228	104/184	96/148	65/ 89
1330	74/219	88/189	87/162	62/107
1400	61/216	72/192	76/167	61/119
1430	52/218	61/199	66/182	60/127
1500	44/219	52/203	57/188	53/134
1530	39/222	45/208	50/196	48/145
1600	34/224	39/212	44/201	42/156
1630	31/227	35/217	39/208	37/164
1700	28/228	31/219	35/212	32/172
1730	25/229	28/222	31/215	28/179
1800	23/230	25/223	28/218	25/185
1830	20/230	23/224	25/219	21/189
1900	19/230	21/225	23/220	19/192
1930	17/231	19/226	21/222	17/194
2000	16/232	18/227	19/223	16/196

[1] WIND DIRECTION REFERENCE: Wind is <u>from</u> direction indicated on table.
North = 360° East = 90° South = 180° West = 270°

TABLE 2-5
SLOSH MODEL TIME HISTORIES OF STORM SURGE AT SELECTED NEW JERSEY COASTAL SITES NORTH-NORTHWEST-BOUND CATEGORY 3 HURRICANE 40 MPH FORWARD SPEED LANDFALL: 16 STATUTE MILES RIGHT (NORTH) OF CAPE MAY, NJ

	CAPE MAY	ATLANTIC CITY	BARNEGAT	SANDY HOOK
HOUR	ELEVATION[1]	ELEVATION	ELEVATION	ELEVATION
0600	1.65	1.61	1.55	1.37
0630	1.72	1.69	1.63	1.42
0700	1.82	1.77	1.71	1.49
0730	1.94	1.89	1.81	1.57
0800	2.08	2.02	1.92	1.68
0830	2.26	2.20	2.08	1.78
0900	2.48	2.43	2.26	1.91
0930	2.79	2.77	2.50	2.02
1000	3.25	3.24	2.83	2.17
1030	4.12	4.10	3.31	2.32
1100	5.87	5.62	4.05	2.55
1130	8.27	8.41	5.27	2.81
1200	9.14	11.26	6.92	3.22
1230	6.99	12.14	8.71	3.71
1300	2.44	10.19	8.58	4.59
1330	-0.40	4.18	6.25	6.26
1400	-1.64	-0.73	3.22	8.30
1430	-1.69	-3.19	0.06	9.59
1500	-1.53	-3.53	-2.00	9.45
1530	-1.46	-2.25	-2.06	7.63
1600	-1.62	-0.65	-1.07	5.84
1630	-1.54	0.21	-0.78	3.77
1700	-1.26	0.30	-1.55	-0.05
1730	-0.74	-0.32	-2.66	-3.40
1800	-0.36	-1.36	-3.26	-5.63
1830	-0.28	-2.23	-3.59	-6.39
1900	-0.21	-2.07	-2.41	-6.01
1930	-0.47	-1.92	-0.55	-4.67
2000	-1.16	-1.62	0.88	-2.44

[1] Elevations in feet, National Geodetic Vertical Datum.

TABLE 2-6
COMPARISON OF MAXIMUM COMPUTED STORM SURGE FOR FOUR DIFFERENT LANDFALL POINTS NORTH-NORTHWEST-BOUND CATEGORY 3 HURRICANE 40 MPH FORWARD SPEED

	LANDFALL RS000[1]	LANDFALL RS016[2]	LANDFALL RS034[3]	LANDFALL RS050[4]
LOCATION	ELEVATION[5]	ELEVATION	ELEVATION	ELEVATION
OCEAN CITY	14.07	13.21	10.13	8.41
ATLANTIC CITY	11.32	12.14	10.44	8.91
BEACH HAVEN	9.15	11.08	11.54	10.76
BARNEGAT	7.27	8.71	10.40	10.40
MANTOLOKING	6.23	7.75	9.43	10.88
LONG BRANCH	6.16	7.65	9.35	11.04

[1] Landfall over Cape May.
[2] Landfall 16 statute miles to the right of Cape May (vicinity of Avalon).
[3] Landfall 34 statute miles to the right of Cape May (vicinity of Longport).
[4] Landfall 50 statute miles to the right of Cape May (vicinity of Beach Haven).
[5] Elevations in feet, National Geodetic Vertical Datum.

2.6.8 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 area flooded by storm surge and can usually be ignored except for locations immediately along the open coastline or the shorelines of very large bays and estuaries where significant fetch lengths and water depths may exist. Since nearshore wave phenomena under hurricane conditions are not well understood, it is assumed that for the open coast, maximum theoretical wave heights based upon relationships of fetch length to water depth occur near the time of landfall. Due to the presence of structures, dunes, or vegetation, the waves break and their energy dissipates within a few hundred yards of the coastline.

It is perhaps more important for evacuation planning purposes to consider potential wave effects for less than sustained gale-force wind speeds. The rationale here is to determine if wave action above still-water surge heights will exceed the elevations of roads, bridges, or other critical areas near the coastline, thereby increasing the pre-landfall hazards distances.

Before making calculations of wave height and runup at critical locations within the Study area, surge heights at the time of arrival of sustained gale force winds should be considered. A review of the SLOSH time histories show that maximum surges at critical points within the Study area at the time of arrival of gale-force winds are on the order of 3.0 feet or less. Since tides of this magnitude are experienced fairly routinely without major traffic problems, calculations of wave height and runup were not made; however, **evacuation planners should be aware that low-lying sections of some highways could be subject to inundation from wave action prior to the arrival of sustained gale-force winds. This would be especially true with the occurrence of high astronomical tides.**

2.7 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, excessive rainfall 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. **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 New Jersey hurricane evacuation Study area. Areas and facilities which have historically flooded during periods of heavy rainfall are assumed to be vulnerable to freshwater flooding under hurricane threats. Additionally, evacuation planners should be aware of the possibility of rainfall induced ground saturation, which may increase the possibility of trees being overturned, causing road obstructions, power outages, traffic light failures, etc.** The Flood Insurance Studies published by FEMA for municipalities within the Study area should be consulted for specific potential freshwater flooding information.

Chapter Three

VULNERABILITY ANALYSIS

3.1 PURPOSE

The primary purpose of the vulnerability analysis is to identify the areas, populations, and facilities which are vulnerable to flooding associated with hurricanes. The storm surge data from the hazards analysis were used to map inundation areas (County Storm Surge Inundation Areas and Evacuation Network Maps); to determine evacuation zones and evacuation scenarios for each of the Study area counties; 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 are the only type of housing specifically addressed in the analysis of populations vulnerable to hurricane winds. No attempt was made to identify other housing particularly vulnerable to wind damage.

3.2 HURRICANE EVACUATION ZONES

Evacuation zones have been developed for each of the New Jersey Hurricane Evacuation Study area counties. Each of the evacuation zones were delineated using major natural or man-made features and conform to existing political or planning boundaries (e.g. census tracts) within each county. (See Section 6.3.3, p. 6-8, for additional information on the bases of evacuation zone delineation.) The purpose of 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. County evacuation zones are delineated on Plates 6-1 to 6-14 (following p. 6-9).

3.3 HURRICANE EVACUATION SCENARIOS

Hurricane evacuation scenarios have been developed for each of the fourteen New Jersey counties in the Study area. The evacuation scenarios are groups of evacuation zones that will be threatened by storm surge from specific hurricane intensity categories. In many instances, the same evacuation zones are threatened by a range of intensity categories. In those cases, the zones requiring evacuation have been combined into evacuation scenarios based on combinations of hurricane intensities. Table 6-3 (p. 6-9) contains the hurricane evacuation scenarios developed for each of the Study area counties and lists the evacuation zones comprising each scenario. These scenarios are illustrated on County Evacuation Zone maps, Plates 6-1 through 6-14 (following p. 6-9).

3.4 VULNERABLE POPULATION

The vulnerable population within each of the Study area counties is comprised of those persons residing within the evacuation zones subject to storm surge, as well as the residents of mobile homes located elsewhere in the county. Due to their greater vulnerability to the strong winds associated with hurricanes mobile home residents are included in calculations of vulnerable population. The potential tourist population, based on the number of occupied tourist units, is also included in the population of each evacuation zone. Table 3-A & 3-B (pp. 3-3 & 3-4) list the vulnerable population for each of the hurricane evacuation scenarios based on 1987 population data.

3.5 INSTITUTIONS/MEDICAL FACILITIES

Inventories of institutions/medical facilities have been compiled for each of the Study area counties. The purpose of this analysis is to identify facilities which may require evacuation, or may have access affected under various hurricane threats. Adjacent ground elevations of several medical facilities in or near areas vulnerable to storm surge have been established. Lists of major institutions/ medical facilities in or near inundated areas are presented in Tables 3-1 through 3-14. The approximate locations of the facilities are shown with the public shelter locations in Chapter 5 (Plates 5-1 through 5-14, following p. 5-30). Tables and maps are presented in counter-clockwise order, beginning with Burlington County.

TABLE 3-A
SOUTHERN NEW JERSEY
VULNERABLE POPULATION
BY STORM SCENARIO AND COUNTY

COUNTY	ZONES	STORM SCENARIOS	SAFFIR-SIMPSON CATEGORY	VULNERABLE POPULATION (BY SEASONABLE OCCUPANCY WHERE APPLICABLE)		
BURLINGTON	14	A	1	7,498		
		B	2-4	25,102		
CAMDEN	13	A	1-4	42,892		
GLOUCESTER	12	A	1-4	26,866		
SALEM	16	A	1-2	31,566		
		B	3-4	40,360		
CUMBERLAND	15	A	1-4	18,962		
				LOW	MEDIUM	HIGH[2]
CAPE MAY	25	A	1-2	115,290	221,682	540,858
		B	3-4	140,866	247,258	566,434
				LOW	MEDIUM	HIGH[3]
ATLANTIC	31	A	1-2	223,705	349,523	369,793
		B	3-4	263,501	388,869	409,139
				LOW	HIGH[4]	
OCEAN	37	A	1-2	127,136	198,635	
		B	3-4	191,778	263,277	
				LOW	HIGH[5]	
MONMOUTH	28	A	1-2	127,653	257,031	
		B	3-4	202,757	332,135	

[1] Seasonal occupancies do not include day visitors. Varying levels of day visitors were included in the assumed number of evacuating people in each scenario.
[2] Seasonal occupancies tested for Cape May County ranged from 10% to 90%
[3] Seasonal occupancies tested for Atlantic County ranged from 45% to 95%
[4] Seasonal occupancies tested for Ocean County ranged from 30% to 90%.
[5] Seasonal occupancies tested for Monmouth County ranged from 15% to 90%.

TABLE 3-B
VULNERABLE POPULATION
BY STORM SCENARIO AND COUNTY
NORTHERN NEW JERSEY

COUNTY	ZONES	STORM SCENARIOS	SAFFIR-SIMPSON CATEGORY	VULNERABLE POPULATION
MIDDLESEX	8[1]	A	2	2,640
		B	3-4	11,540
UNION	12[2]	A	1	960
		B	2-4	9,140
ESSEX	8[3]	A	1	3,130
		B	2-4	17,540
HUDSON	23	A	1	12,070
		B	2-4	35,312
BERGEN	9[4]	A	1-4	7,300

[1] The population of Middlesex County vulnerable to tidal flooding is concentrated in the Woodbridge-Carteret area. Plate 6-10 (following p. 6-9) shows area for which transportation modeling was performed.
[2] Union County municipalities with population potentially vulnerable to tidal flooding include: Rahway, Linden, and Elizabeth. See Plate 6-11 (following p. 6-9).
[3] The City of Newark is the sole Essex County municipality subject to tidal flooding and the only portion of the County included in the transportation analysis. See Plate 6-12 (following p. 6-9).
[4] The population of Bergen County vulnerable to tidal flooding is located in a limited number of municipalities (those subject to tidal flooding) in the southeastern portion of the County. Plate 6-14 (following p. 6-9) indicates area for which transportation modeling was performed.

TABLE 3-1
BURLINGTON COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Burlington City	Garden State Rest Home	Nurs.	See Note[3]
2	Burlington City	Home For Aged Women of Burlington	Nurs.	"
3	Burlington City	Burlington Manor Apartments	Nurs.	See Note[4]
4	Burlington Twp.	Burlington Woods Conv. Center	Nurs.	None[5]
5	Cinnaminson Twp.	Cinnaminson Home Inc.	Nurs.	"
6	Cinnaminson Twp.	Cinnaminson Manor Nurs. & Conv. Ctr.	Nurs.	"
7	Florence Twp.	Florence Nursing Home	Nurs.	"
8	Riverside Twp.	Zurbrugg Memorial Hospital Riverside Division	Hosp.	See Note[6]
9	Riverton Bor.	Baptist Home of S. Jersey	Nurs.	None[5]
10	Willingboro Twp.	Zurbrugg Memorial Hospital Rancocas Valley Division	Hosp.	"

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

2 See Plate 5-1, (following p. 5-30) for approximate locations of facilities.

3 Much of the City of Burlington is within the one hundred year floodplain (elevation: 11.0 ft. NGVD); additional portions of the City are potentially subject to inundation [see Burlington County Hurricane Storm Surge Map].

4 Burlington Manor Apartments, subsidized housing for the elderly is located adjacent to the Delaware River. For a detailed assessment of potential flood vulnerability lowest floor elevations should be compared to flood elevations determined by the FIS (100 yr. elevation: 11 ft. NGVD) and maximum surge elevations calculated by the SLOSH Model [see Burlington County Hurricane Storm Surge Map].

5 "None" indicates facility is not in a tidal or riverine flood hazard area.

6 The hospital is located just outside the limits of the five hundred year flood as mapped on the January 1979 Flood Insurance Study (FIS) for the Township of Riverside. For a detailed assessment of potential flood vulnerability lowest floor elevations should be compared to flood elevations determined by the FIS (100 yr. elevation: 11 ft. NGVD) and the Burlington County Hurricane Storm Surge Map.

TABLE 3-2
CAMDEN COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Camden	Camden County Jail	Corr.	See Note[3]
2	Camden	Cooper Medical Center	Hosp.	None[4]
3	Camden	Daytona Manor	Nurs.	"
4	Camden	Mediplex	Nurs.	"
5	Camden	Our of Lady Lourdes Hospital	Hosp.	"
6	Camden	Plaza Medical Center	Hosp.	"
7	Camden	Riverfront State Prison	Corr.	See Note[3]
8	Camden	West Jersey Health Systems Northern Division	Hosp.	None[4]
9	Camden	Woodland Care Center	Nurs.	See Note[5]
10	Pennsauken	Cooper River Convalescent Center	Nurs.	See Note[6]
11	Pennsauken	Cooper River Convalescent Center West	Nurs.	"

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

2 See Plate 5-2, (following p. 5-30) for approximate locations of facilities.

3 This facility is in or near an area subject to tidal and riverine flooding. For a more precise determination of flood vulnerability, facility elevations should be compared to the following maximum SLOSH Model surge elevations (worst case scenario including high astronomical tide): 8.5 ft. NGVD (Cat. 1), 9.5 (Cat. 2), 9.8 Cat. 3), 13.1 (Cat. 4).

4 "None" indicates facility is not in an identified tidal or riverine flood hazard area.

5 This facility is located near a potential tidal flooding area. For a more precise determination of flood vulnerability, facility elevations should be compared to the maximum SLOSH Model surge elevations shown in Note 2 above.

6 This facility is in or near an area subject to tidal and riverine flooding. For a more precise determination of flood vulnerability, facility elevations should be compared to flood elevations for the Cooper River determined by the Flood Insurance Study for the Township of Pennsauken. Flood elevations in the vicinity of these facilities are as follows: 100 year flood = 13 ft. NGVD; 500 year flood = 18 ft. NGVD.

TABLE 3-3
GLOUCESTER COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Deptford Twp.	Greenbriar East Nursing Home	Nurs.	None[3]
2	E. Greenwich Twp.	Shady Lane Nursing Home	Nurs.	"
3	Greenwich Twp.	Woods of Troy	Nurs.	Cat. 3/4[4]
4	National Park Bor.	Shady Oaks Rest Homes	Nurs.	None[3]
5	Paulsboro Bor.	Green Pines Rest Homes	Nurs.	Cat. 3/4[4]
6	W. Deptford Twp.	Leader Nursing and Rehabilitation Ctr.	Nurs.	None[3]
7	Woodbury Bor.	Greenbriar Nursing Center	Nurs.	"
8	Woodbury Bor.	Underwood Memorial Hospital	Hosp.	See Note[5]

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
[2] See Plate 5-3 (following p. 5-30) for approximate locations of facilities.
[3] "None" indicates facility is not in an identified tidal or riverine flood hazard area.
[4] "Cat. 3-4" indicates facility is located in an area potentially vulnerable to inundation from hurricanes of Category 3 or higher intensity.
[5] The hospital is located across Redbank Avenue from a tidal flooding source, but is situated beyond the limits of flooding [No elevation survey].

TABLE 3-4
SALEM COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Carney's Point	Parkview Nursing Center	Nurs.	Cat. 1[3]
2	Carney's Point	Southgate Health Care Center Inc.	Nurs.	Cat. 2[4]
3	Pedricktown	Lynn Haven Rest Home	Nurs.	Cat. 3/4 [5]
4	Salem	Linden Manor	Nurs.	Cat. 2[4]
5	Salem	Midtown Rest Home	Nurs.	"
6	Salem	Salem County Jail	Corr.	Cat. 3/4[5]
7	Salem	Salem County Memorial Hospital	Hosp.	See Note[6]

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas listed.

[2] See Plate 5-4, (following p. 5-30) for approximate locations of facilities.

[3] "Cat. 1" indicates facility is in an area subject to tidal flooding from hurricanes of Category 1 or higher intensity.

[4] "Cat. 2" indicates facility is in an area subject to tidal flooding from hurricanes of Category 2 or higher intensity.

[5] Cat. 3/4" indicates facility is in an area subject to tidal flooding from hurricanes of Category 3 or higher intensity.

[6] This facility is near an area subject to tidal flooding from major hurricanes, but is situated well above potential flood levels.

TABLE 3- 5
CUMBERLAND COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Bridgeton	Bridgeton Hospital	Hosp.	None[3]
2	Bridgeton	Bridgeton Nursing Center	Nurs.	"
3	Hopewell Twp.	Cumberland Manor	Nurs.	"
4	Millville	Meridian Village Nursing Home	Nurs.	"
5	Millville	Millvile Hospital	Hosp.	"
6	Fairfield Twp.	Fairton Federal Correction Facility	Corr.	"
7	Maurice R. Twp.	Southern State Correction Facility	Corr.	Cat. 3/4[4]
8	Maurice R. Twp.	NJ State Prison Farm	Corr.	"
9	Port Norris	Holly Manor	Nurs.	Cat. 1/2[5]
10	Vineland	Bishop McCarthy Residence	Nurs.	None[3]
11	Vineland	Cumberland Convalescent Center Inc.	Nurs.	"
12	Vineland	Newcomb Medical Center	Hosp.	"
13	Vineland	NJ Memorial Home for Disabled Soldiers	Hosp.	"

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

2 See Plate 5-5, (following p. 5-30) for approximate locations of facilities.

3 "None" indicates facility is not in an identified tidal or riverine flood hazard area.

4 "Cat. 3-4" indicates facility is located in an area potentially vulnerable to inundation from hurricanes of Category 3 or higher intensity.

5 "Cat. 1-2" indicates facility is located in an area potentially vulnerable to inundation from hurricanes of any intensity.

TABLE 3-6
CAPE MAY COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Dennis Twp.	East Creek Manor Nursing Home	Nurs.	See Note[3]
2	Dennis Twp.	Lutheran Home at Oceanview	Nurs.	See Note[4]
3	Lower Twp.	Victoria Manor Nursing Center	Nurs.	Cat. 3/4[5]
4	Middle Twp.	Burdette Tomlin Memorial Hospital	Hosp.	"
5	Middle Twp.	Cape May Care Center	Nurs.	"
6	Middle Twp.	Cape May County Correctional Center	Corr.	"
7	Middle Twp.	Court House Convalescent Center	Nurs.	"
8	Middle Twp.	Crest Haven Nursing Home	Nurs.	"
9	Middle Twp.	Eastern Shore Nursing & Convalescent Center	Nurs.	See Note[4]
10	Middle Twp.	South Cape Nursing Home	Nurs.	Cat. 3/4[5]
11	Ocean City	Trace House	Nurs.	Cat. 1[6]
12	Ocean City	Wesley Manor	Nurs.	Cat. 1[6]
13	Wildwood Crest	Lavendar Hall	Nurs.	Cat. 1[6]

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
2 See Plate 5-6, (following p. 5-30) for approximate locations of facilities.
3 East Creek Manor is located in an area potentially vulnerable to inundation from Category 2 or higher intensity.
4 This facility is located outside the limits of Category 4 surge elevations calculated by the SLOSH Model: there is, however, potential for inundation of Route 9 in the vicinity of the facility in a Category 3 or 4 hurricane.
5 Cat. 3/4" indicates facility is in an area subject to possible tidal flooding from hurricanes of Category 3 or higher intensity.
6 This facility is located on a barrier island and is subject to potential inundation from hurricanes of any intensity.

TABLE 3-7
ATLANTIC COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Absecon	Absecon Manor	Nurs.	None[3]
2	Absecon	Bayview Cottage	Nurs.	See Note[4]
3	Atlantic City	Atlantic City Medical Center	Hosp.	See Note[5]
4	Atlantic City	Beachgate Rest Home Inc.	Nurs.	"
5	Atlantic City	Eastern Pines Convalescent Center	Nurs.	"
6	Atlantic City	Hebrew Old Age Center	Nurs.	"
7	Atlantic City	King David Care Center of A.C.	Nurs.	"
8	Atlantic City	Novel Flanders Hotel Inc.	Nurs.	"
9	Atlantic City	Oceanside Convalescent & Rehab.	Nurs.	"
10	Atlantic City	Oceanview Facility Unit #2	Nurs.	"
11	Atlantic City	Oceanview Facility Unit #1	Nurs.	"
12	Atlantic City	Seashore Gardens	Nurs.	"
13	Atlantic City	Westside Convalescent Center	Nurs.	"
14	Hammonton	William B. Kessler Memorial Hospital	Hosp.	None[3]
15	Linwood	Linwood Convalescent Center	Nurs.	"
16	Longport	Gospel Hall Home For The Aged	Nurs.	See Note[5]
17	Mays Landing	Lake Lenape Home	Nurs.	None[3]
18	Mays Landing	Smiley Madelyn Nursing Home	Nurs.	"
19	Northfield	Atlantic County Home & Annex	Nurs.	"
20	Northfield	Meadowview Nursing Home	Nurs.	"
21	Pleasantville	Greenwood Health Care Center	Nurs.	"
22	Pleasantville	Hensen Home	Nurs.	"
23	Pleasantville	Our Lady's Residence	Nurs.	See Note[6]
24	Pleasantville	Pleasant Manor Retirement Home	Nurs.	None[3]
25	Pomona	Atlantic City Medical Center Mainland Division	Hosp.	"
26	Pomona	Betty Bacharach Rehabilitation Hospital	Hosp.	"
27	Somers Point	Ocean Point Health Care Center	Nurs.	See Note[7]
28	Somers Point	Shore Memorial Hospital	Hosp.	See Note[8]

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
2 See Plate 5-7, (following p. 5-30) for approximate locations of facilities.
3 "None" indicates facility is not in an identified tidal or riverine flood hazard area.
4 This facility is located just above the maximum Category 4 surge elevations calculated by the SLOSH Model: there is some potential for inundation of Route 9 in the vicinity of the facility in a Category 3 or 4 hurricane.
5 This facility is located on a barrier island and is subject to potential inundation from hurricanes of any intensity.
6 Ground elevation adjacent to this facility (sidewalk at front door just inside metal railing) is approximately 19.5 ft. (NGVD). Category 4 SLOSH Model surge elevation (worst case scenario) is 21.9 ft.
7 Ground elevations adjacent to this facility (elevated sidewalk on Harbor Lane side of building) are approximately 16.5 ft. (NGVD). Category 3 SLOSH Model surge elevation (worst case scenario) is 18.1 ft.
8 Ground elevations adjacent to this facility (sidewalk outside main entrance door) are approximately 14.5 ft. (NGVD). Category 3 SLOSH Model surge elevation (worst case scenario) is 18.1 ft.

TABLE 3-8
OCEAN COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Barnegat	Barnegat Nursing Center	Nurs.	None[3]
2	Bayville	Bayview Nursing & Convalescent Center	Nurs.	"
3	Bayville	Berkeley Retirement Home	Nurs.	"
4	Brick Twp.	Burnt Tavern Convalescent Center	Nurs.	"
5	Brick Twp.	Laurelton Village	Nurs.	"
6	Brick Twp.	Ocean County Medical Center Brick Division	Hosp.	"
7	Dover Twp.	Ocean County Juvenile Center	Corr.	"
8	Forked River	Lacey Nursing and Rehab. Center	Nurs.	None
9	Lakewood Twp.	Dover Retirement Hotel	Nurs.	None
10	Little Egg Har.	Seacrest Village Care Center	Nurs.	Cat. 1-2[4]
11	Pt. Pleasant	Claremont Care Center	Nurs.	Cat. 3/4[5]
12	Pt. Pleasant	Ocean County Medical Center Pt. Pleasant Division	Hosp.	Cat. 3/4[6]
13	Pt. Pleasant	The Townhouse	Nurs.	Cat. 3/4[5]
14	Pt. Pleasant Bch.	Keifers Quarters Senior Citizen Home	Nurs.	Cat. 1/2[4]
15	Pt. Pleasant Bch.	Pt. Pleasant Beach Nursing Home	Nurs.	Cat. 3/4[5]
16	Pt. Pleasant Bch.	Pt. Pleasant Residence	Nurs.	Cat. 3/4[5]
17	Pt. Pleasant Bch.	Triton House	Nurs.	Cat. 1/2[4]
18	Toms River	Community Medical Center	Hosp.	None[3]
19	Toms River	Garden State Rehabilitation	Nurs.	"

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
2 See Plate 5-8, (following p. 5-30) for approximate locations of facilities.
3 "None" indicates facility is not in an identified tidal or riverine flood hazard area.
4 "Cat. 1-2" indicates facility is located in an area potentially vulnerable to inundation from hurricanes of any intensity.
5 "Cat. 3-4" indicates facility is located in an area potentially vulnerable to inundation from hurricanes of Category 3 or higher intensity.
6 This hospital is located in an area potentially vulnerable to tidal flooding. The main and emergency entrances to the hospital have elevations of approximately 16 feet. The entrance to the lower level of the hospital has an elevation under 5 ft (top of stairwell = 11 ft). Potential hurricane surge inundation levels in the area are 8 ft. (Cat.1), 11.5 ft. (Cat.2), 15 ft. (Cat.3) and 18.5 ft. (Cat.4).

TABLE 3-9
MONMOUTH COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Aberdeen Twp.	Cliffside Health Care Center	Nurs.	Cat. 3/4[3]
2	Aberdeen Twp.	Cliffwood Boarding Home	Nurs.	None[4]
3	Asbury Park	Asbury Carlton Hotel	Nurs.	Cat. 1-2[5]
4	Asbury Park	Gill Residential Health Care Facility	Nurs.	Cat. 3-4[3]
5	Asbury Park	James House	Nurs.	None[4]
6	Asbury Park	Salvation Army Retired Officer Res.	Nurs.	Cat. 3-4[3]
7	Atlantic Hlands	Atlantic Highlands Nursing Home	Nurs.	None[4]
8	Hazlet Twp.	Arnold Walter Nursing Home	Nurs.	"
9	Hazlet Twp.	Hazlet Manor Care Center	Nurs.	"
10	Holmdel Twp.	Bayshore Community Hospital	Hosp.	"
11	Keansburg	Beachview Intermediate Care Facility	Nurs.	Cat. 1/2[5]
12	Keansburg	Oceanview Manor Rest Home	Nurs.	"
13	Keyport	Fisher's Residential Health Care Facility	Nurs.	Cat. 3/4[3]
14	Long Branch	Chelsea Rest	Nurs.	None[4]
15	Long Branch	Dobbs Res. Health Care Home Inc.	Nurs.	Cat. 3-4[3]
16	Long Branch	Lugene's Boarding Home	Nurs.	Cat. 1-2[5]
17	Long Branch	Monmouth Convalescent Center	Nurs.	Cat. 3-4[3]
18	Long Branch	Monmouth Medical Center	Hosp.	See Note[6]
19	Long Branch	The Willows	Nurs.	"
20	Long Branch	Todd A Rest Home	Nurs.	Cat. 3-4[3]
21	Long Branch	Westwood Hall Hebrew Home	Nurs.	None[4]
22	Long Branch	Witmer House	Nurs.	Cat. 1-2[5]
23	Manasquan	South Shore Haven Rest Home	Nurs.	None[4]
24	Matawan	Mount Pleasant Manor	Nurs.	"
25	Middletown Twp.	King James Care Center	Nurs.	"
26	Middletown Twp.	Red Bank Convalescent Center	Nurs.	See Note[7]
27	Middletown Twp.	Riverview Extended Care Residence	Nurs.	None[4]
28	Neptune Bor.	Conv-A-Center	Nurs.	"

(TABLE CONTINUED)

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
[2] See Plate 5-9, (following p. 5-30) for approximate locations of facilities.
[3] "Cat. 3-4" indicates facility is in or near an area potentially subject to inundation from a Category 3 or 4 hurricane.
[4] "None" indicates facility is not in an identified tidal or riverine flood hazard area.
[5] "Cat. 1-2" indicates facility is in or near an area potentially subject to inundation from a Category 1 or 2 hurricane.
[6] This facility is near the edge of an area potentially subject to inundation from a Category 3 or 4 hurricane.
[7] Facility is adjacent to Swimming River and may be subject to tidal or riverine flooding.

TABLE 3-9 (CONTINUED)
MONMOUTH COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
29	Neptune Twp.	Epworth Manor & Francis Asbury Manor	Nurs.	Cat. 1-2[3]
30	Neptune Twp.	Jersey Shore Medical Center Fitkin Memorial Hospital	Hosp.	None[4]
31	Neptune Twp.	King Manor	Nurs.	"
32	Neptune Twp.	Medi-center of Neptune	Nurs.	"
33	Neptune Twp.	Ocean Grove Nursing Home	Nurs.	Cat. 1-2[3]
34	Red Bank	Navesink House	Nurs.	See Note[5]
35	Red Bank	Red Bank Medical Center	Hosp.	None[4]
36	Red Bank	Riverview Hospital	Hosp.	"
37	Shrewsbury	Shrewsbury Manor	Nurs.	"
38	Spring Lake	Spring Lakes Heights Rest Home	Nurs.	"
39	W. Long Branch	Maplerest Rest Home	Nurs.	"
40	Wall Twp.	Crest Manor Rest Center	Nurs.	"
41	Wall Twp.	Sunnyside Farms N & C Home	Nurs.	"
42	Wall Twp.	Tower Lodge Nursing Home	Nurs.	"

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
[2] See Plate 5-9, (following p. 5-30) for approximate locations of facilities.
[3] "Cat. 1-2" indicates facility is in or near an area potentially subject to inundation from a Category 1 or 2 hurricane.
[4] "None" indicates facility is not in an identified tidal or riverine flood hazard area.
[5] Facility is located adjacent to Swimming River; lower level is just above the river.

TABLE 3-10
MIDDLESEX COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Edison	John F. Kennedy Medical Center	Hosp.	None[3]
		Robert Wood Johnson Jr. Rehab.	Nurs.	"
2	Matawan	Emery Manor Nursing Home	Nurs.	"
3	Morgan	Oakview Care Center	Nurs.	"
4	Old Bridge	Raritan Bay Health Services Corp. Old Bridge Regional Hospital	Hosp.	"
5	Perth Amboy	Amboy Care Center	Nurs.	"
6	Perth Amboy	Perth Amboy Nursing Home	Nurs.	"
7	Perth Amboy	Raritan Bay Health Services Corp. Perth Amboy General Hospital	Hosp.	"
8	South Amboy	South Amboy Regional Hospital	Hosp.	"
9	Woodbridge	East Jersey State Prison	Corr.	See Note[4]
10	Woodbridge	St. Josephs Senior Residence	Nurs.	None[3]

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

[2] See Plate 5-10, (following p. 5-30) for approximate locations of facilities.

[3] "None" indicates facility is not in an identified tidal or riverine flood hazard area.

[4] Portions of the grounds of this facility are subject to tidal inundation from a Category 3 or 4 hurricane. Facility ground elevations should be compared to the following maximum SLOSH Model surge elevations for a more precise determination of flood vulnerability (worst case scenario including high astronomical tide): 10.9 (Cat. 1), 13.0(Cat. 2), 16.0(Cat. 3), 19.1(Cat. 4).

TABLE 3-11
UNION COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Elizabeth	Alexian Brothers Hospital	Hosp.	None[3]
2	Elizabeth	Elizabeth General Medical Center	Hosp.	"
3	Elizabeth	Elizabeth Nursing Home	Nurs.	"
4	Elizabeth	Home for Aged Women Inc.	Nurs.	"
5	Elizabeth	N.J. Geriatric Ctr. of Workmens Circle	Nurs.	"
6	Elizabeth	Plaza Nursing & Convalescent Center	Nurs.	"
7	Elizabeth	St. Elizabeth Hospital	Hosp.	"
8	Rahway	Rahway Geriatrics Center	Nurs.	"

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.
[2] See Plate 5-11, (following p. 5-30) for approximate locations of facilities.
[3] "None" indicates facility is not in an identified tidal or riverine flood hazard area.

TABLE 3-12
ESSEX COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Newark	Mount Carmel Guild	Nurs.	None[3]
2	Newark	Northern State Prison	Corr.	Cat. 1-2[4]
3	Newark	South Street Home	Nurs.	None[3]
4	Newark	St. James Hospital	Hosp.	See Note[4]
5	Newark	St. Michaels Medical Center	Hosp.	None[3]

NOTES

1 Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

2 See Plate 5-12, (following p. 5-30) for approximate locations of facilities.

3 "None" indicates facility is not in an identified tidal or riverine flood hazard area.

4 "Cat. 1-2" indicates facility is located in an area subject to inundation from hurricanes of Category 1 or higher intensity. For a more precise determination of flood vulnerability, facility ground elevations should be compared to the following maximum SLOSH Model surge elevations (worst case scenario including high astronomical tide): 11.0 (Cat. 1), 12.2 (Cat. 2), 14.9 (Cat. 3), 18.3 (Cat. 4).

TABLE 3-13
HUDSON COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Gutenberg	Palisade Nursing Home	Nurs.	None[3]
2	Hoboken	St. Mary's Hospital	Hosp.	See Note[4]
3	North Bergen	Palisades General Hospital	Hosp.	See Note [5]
4	Jersey City	Christ Hospital	Hosp.	None[3]
5	Jersey City	Harborview Health Care Center	Nurs.	"
6	Jersey City	St. Francis Community Hospital	Hosp.	See Note[6]
7	Kearney	Northern Regional Pre-Admission Unit	Corr.	See Note[7]
8	Secaucus	Hudson County Meadowview Hospital	Hosp.	None[3]
9	Secaucus	Northern Regional Pre-Release Center	Corr.	See Note[8]
10	Secaucus	Riverside General Hospital	Hosp.	See Note[9]

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

[2] See Plate 5-13, (following p. 5-30) for approximate locations of facilities.

[3] "None" indicates facility is not in an identified tidal or riverine flood hazard area.

[4] Hospital is in the one hundred year flood plain as identified on the City of Hoboken Flood Insurance Rate Map. Streets in the vicinity of the hospital have potential for flooding from a Category 1 hurricane and catastrophic flooding from a hurricane of higher intensity.

[5] Hospital is in the one hundred year flood plain as identified on the North Bergen Flood Insurance Rate Map. The hospital site and River Road have potential for flooding from a Category 1 hurricane and catastrophic flooding from a hurricane of higher intensity.

[6] Streets in the vicinity of the hospital have potential for flooding from Category 1 hurricanes. The immediate hospital site has potential for flooding from Category 2 hurricanes and catastrophic flooding from a Category 3 or 4 hurricane.

[7] This facility is in an area that has potential for flooding from Category 1 or higher hurricanes. Facility ground elevations should be compared to the following maximum SLOSH Model surge elevations for a more precise determination of flood vulnerability (worst case scenario including high astronomical tide): 8.4 (Cat. 1), 9.8 (Cat. 2), 11.1 (Cat. 3), 14.8 (Cat. 4).

[8] This facility is in the one hundred year flood plain as identified on the Town of Kearney Flood Insurance Rate Map. The area has potential for flooding from Category 1 or higher hurricanes. Facility ground elevations should be compared to the following maximum SLOSH Model surge elevations for a more precise determination of flood vulnerability (worst case scenario including high astronomical tide): 9.8 (Cat. 1), 11.9(Cat. 2), 14.6 (Cat. 3), 17.2 (Cat. 4).

[9] The hospital is sited in the 100 year flood plain as identified on the Flood Insurance Rate Map for the Hackensack Meadowlands District. [100 yr. elev. = 9 ft. NGVD; 500 yr. elev. = 13 ft.; Maximum SLOSH surge elevations (with high astronomical tide) : Cat. 1 = 8.2 ft.; Cat. 2 = 9.1 ft.; Cat. 3 = 10.2 ft.; Cat. 4 = 12.8 ft.

TABLE 3-14
BERGEN COUNTY
INSTITUTIONS/MEDICAL FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	TYPE	FLOOD POTENTIAL
1	Englewood	Actor's Fund Home	Nurs.	None[3]
2	Englewood	Englewood Hospital	Hosp.	"
3	Englewood	Inglemoor Inc.	Nurs.	"
4	Englewood Cliffs	Cliff House	Nurs.	"
5	Hackensack	Bergen County Jail	Corr.	See Note[4]
6	Hackensack	Bergen County Jail Annex	Corr.	See Note[4]
7	Hackensack	Hackensack Medical Center	Hosp.	None[3]
8	Hasbrouck Hts.	South Bergen Hospital	Hosp.	"
9	Teaneck	Brightside	Nurs.	"
10	Teaneck	Holy Name Hospital	Hosp.	"
11	Tenafly	County Manor	Nurs.	"
12	Tenafly	Mary Fisher Home	Nurs.	"

NOTES

[1] Only those medical facilities and institutions in the general vicinity of storm surge vulnerable areas are listed.

[2] See Plate 5-14, (following p. 5-30) for approximate locations of facilities.

[3] "None" indicates facility is not in an identified tidal or riverine flood hazard area.

[4] County Jail and Annex are in an area subject to tidal inundation from hurricanes of Category and higher intensity. Facility ground elevations should be compared to the following maximum SLOSH Model surge elevations for a more precise determination of flood vulnerability (worst case scenario including high astronomical tide): 8.2 (Cat. 1), 9.1(Cat. 2), 10.2 (Cat. 3), 13.9(Cat. 4).

Chapter Four

BEHAVIORAL ANALYSIS

4.1 PURPOSE

The behavioral analysis is intended to provide reliable estimates of how the public in the Study Area will respond to a variety of hurricane threats. These estimates are utilized in establishing assumptions to be used in other Study analyses 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 evacuation advisories. The term "affected population" refers to those persons residing near the coastline, the shorelines of estuaries, or in areas of low elevation near those locations that are subject to the hazards of flooding. The affected population also includes those persons residing in mobile homes or substandard housing which may be at risk from the winds associated with a hurricane. The term "non-affected population" refers to those individuals who are not threatened by storm surge or freshwater flooding and have substantial housing affording protection against winds expected to occur during a hurricane. It is known that a number of these individuals evacuate along with the affected population and contribute to the evacuating traffic and shelter demand during a hurricane threat.

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

c. The number of vehicles that the evacuating population will use during a hurricane evacuation.

d. The percentage of the total number of evacuating vehicles which may be towing boats, camper trailers, or other vehicular equipment.

e. The probable destinations of evacuating households. These data consist of percentages of the total number of evacuees going to local public shelters, staying locally with friends or relatives, staying locally in a hotel/motel, or leaving the county for out-of-region destinations.

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

g. The evacuation responses of tourists.

4.2 METHODOLOGY-HURRICANE GLORIA BEHAVIORAL RESPONSE

The primary data source utilized for the New Jersey behavioral analysis was a report entitled **Behavioral Assumptions for Hurricane Planning in New Jersey**. This document is an appendix of a comprehensive analysis entitled **Hurricane Evacuation Behavior in the Middle Atlantic and Northeast States**[1] commissioned for use in Hurricane Evacuation Studies of eight states: Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island and Massachusetts. A major feature of this effort was a survey of the response of threatened populations of these states to Hurricane Gloria in 1985. The analysis of residents' behavior consisted of the following steps:

a. A sample survey to document response to Gloria and to assess intended responses in hypothetical evacuations;

b. Comparison of response to Gloria of residents of the eight states, and specifically New Jersey, to a "general response model" i.e. patterns observed in a large number of evacuations documented over several decades in a variety of locations.

c. Comparison of intended response data to the general response model.

d. Formulation of behavioral assumptions from the general response model after calibration based on the data assembled in the report.

4.2.1 Sample Survey

Both "beach" and "mainland" surveys were conducted in all eight states. Criteria for selection varied from state to state, but in most instances the locations were representative of other areas. A total of approximately 2,000 samples were taken across the eight states.

The New Jersey portion of the sample survey was conducted by telephone. After consultation with State and county emergency management officials in New Jersey, a telephone survey of 200 coastal residents was designed. Half the sample was targeted in the Ocean City area of Cape May County and half in the Ocean Grove, Bradley Beach and Avon areas of Monmouth County.

4.2.2 Comparison of Response

Overall results of the eight-state Gloria survey and specific results of the New Jersey portion were compared to the "general response model." The general response model is based on data derived from an extensive list of post-hurricane response studies. These data are considered to be the most reliable indication of what people are most likely to do in future hurricane threats.

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[1]Copies of these documents may be obtained through the U.S. Army Corps of Engineers, Philadelphia District.

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.

Public response to Hurricane Gloria throughout the eight state report area, and specifically in New Jersey, was consistent with patterns observed in evacuations elsewhere. Evacuation rates, evacuation timing, patterns of refuge use, evacuation destinations, and vehicle use were all within the range that would be expected based on response data amassed from previous hurricane evacuations.

4.2.3 Intended Response

Many respondents to the overall Gloria survey did not evacuate in response to the threat. That information is useful in assessing evacuation rates forecast by the general response model, but provides no information concerning other behaviors such as shelter use by those respondents. Therefore residents who did not evacuate during Gloria were asked hypothetical questions about what they believe they would do in future hurricane threats or what they would have done if they had evacuated in Gloria. The hypothetical responses were compared to intended response data collected elsewhere and to actual response by other respondents in Gloria.

4.3 ANALYSIS RESULTS

It is important to recognize that no single set of behavioral assumptions is appropriate throughout the entire coastal area of New Jersey. As evidenced by the Hurricane Gloria Survey, response may vary even within relatively small geographical areas. Moreover, response in the next hurricane threat might well be quite different than that observed in Gloria. Fortunately, such variations are predictable. Response patterns observed in lower New Jersey in Gloria were very consistent with the general response model developed after studying public response in many hurricane evacuations throughout the United States over the past three decades.

The following paragraphs address each of the specific objectives established for the behavioral analysis and present generalized results for each objective. They have provided guidelines for the establishment of appropriate behavioral assumptions for use in the Transportation Analysis and Decision Arc Chapters of this Report. More detailed results are contained in **Behavioral Assumptions for Hurricane Planning in New Jersey**.

4.3.1 Evacuation Rates

There are two overriding factors influencing whether residents evacuate: actions by public officials and degree of hazard of the location. **In floodprone areas near the open coast, 90% or more of the residents will evacuate if public officials take aggressive action urging or ordering evacuation and are successful in communicating the urgency of that message.** The only way to ensure that the message reaches the intended audience is to supplement television and radio announcements with police or other officials going into neighborhoods door-to-door or at least with loudspeakers. Less aggressive or less successful dissemination of evacuation notices will result in evacuation rates closer to 80% in the more dangerous locations.

In floodprone areas on the mainland ("protected coast"), response will usually be somewhat lower. If officials take aggressive action, a rate of 80% can be expected. If actions are less aggressive or are not disseminated door-to-door, rates will be around 60%. Outside of floodprone areas, but nearby, a small percentage of the residents will leave, even though they are not told to evacuate.

Two other factors should also be noted. **Mobile home residents, wherever they reside, are more likely to evacuate than their neighbors. This is particularly true if officials specifically encourage their evacuation.** Severe storms will elicit somewhat greater response than lesser storms, particularly in the absence of aggressive action by officials.

Tourists tend to evacuate in numbers at least as high as residents in the same risk area. **Because most vacationers are at beachfront or nearby locations, 95% will evacuate if officials urge them to. However, many vacationers do not monitor television and radio regularly, and it is especially important that officials get word directly to hotels and motels that an evacuation has been ordered or recommended.** Vacationers, particularly campers with travel trailers, tend to rely upon hotel/motel or campground managers for advice. Concerns about losing deposits do not deter tourists from evacuating. It is important that emergency management officials have the cooperation of accommodation managers in order to ensure that guests receive the appropriate advice. Officials also need to be aware that there could be vacationers just arriving in the area during the evacuation, unaware that their destination is being evacuated. At the least, accommodation managers should know to stop taking reservations and, if possible, call to head off guests planning to arrive.

After consultation with State and county emergency officials at the outset of the Transportation Analysis, it was decided to assume a 100 percent evacuation of surge vulnerable areas for all scenarios, a 5 percent evacuation of nearby non-vulnerable areas for all scenarios and a 100 percent evacuation of mobile homes for all scenarios.

4.3.2 Evacuation Timing

The Hurricane Gloria response survey indicated that evacuation timing in Gloria was well within what would be expected from experience in other parts of the country. The behavioral response curves shown in Figure 4-1 (p. 4-6) represent four public response possibilities. They have been used in the Transportation Analysis and are reflected in the clearance times presented in Tables 6-7 through 6-20 (pp. 6-28 to 6-41) of the Transportation Analysis Chapter.

The curves range from immediate response to slow response and are intended to include the most probable range of possible mobilization times that might be experienced in a future hurricane evacuation situation. The "rapid response" curve is an early response curve in which most evacuees leave well before arrival of the storm. The "medium response" and "slow response" curves assume fairly rapid and more gradual responses respectively and could be expected to apply to an evacuation prompted by a well publicized, steadily moving hurricane. Finally, the "immediate response" curve represents a "last-minute" evacuation. This curve will occur when a storm increases speed, changes course, or gains strength dramatically and unexpectedly. Officials will have to hurriedly issue evacuation notices and make residents understand the urgency of rapid response.

People prefer not to evacuate at night if they have the luxury of waiting until morning or are able to leave before dark. They will, however, leave during the night if necessary. This factor is more relevant to operational guidance than to long-range planning. Beachfront residents usually leave earlier than residents in moderate-risk and low-risk locations.

Vacationers will evacuate at approximately the same time as residents, perhaps earlier, especially if the weather is unpleasant.

Operationally, two aspects of evacuation timing are very important: 1) people will not begin to leave in significant numbers until someone in a position of authority tells them to, and 2) timing will vary greatly from storm to storm. As in evacuation rates, actions by public officials are extremely important in influencing evacuation timing.

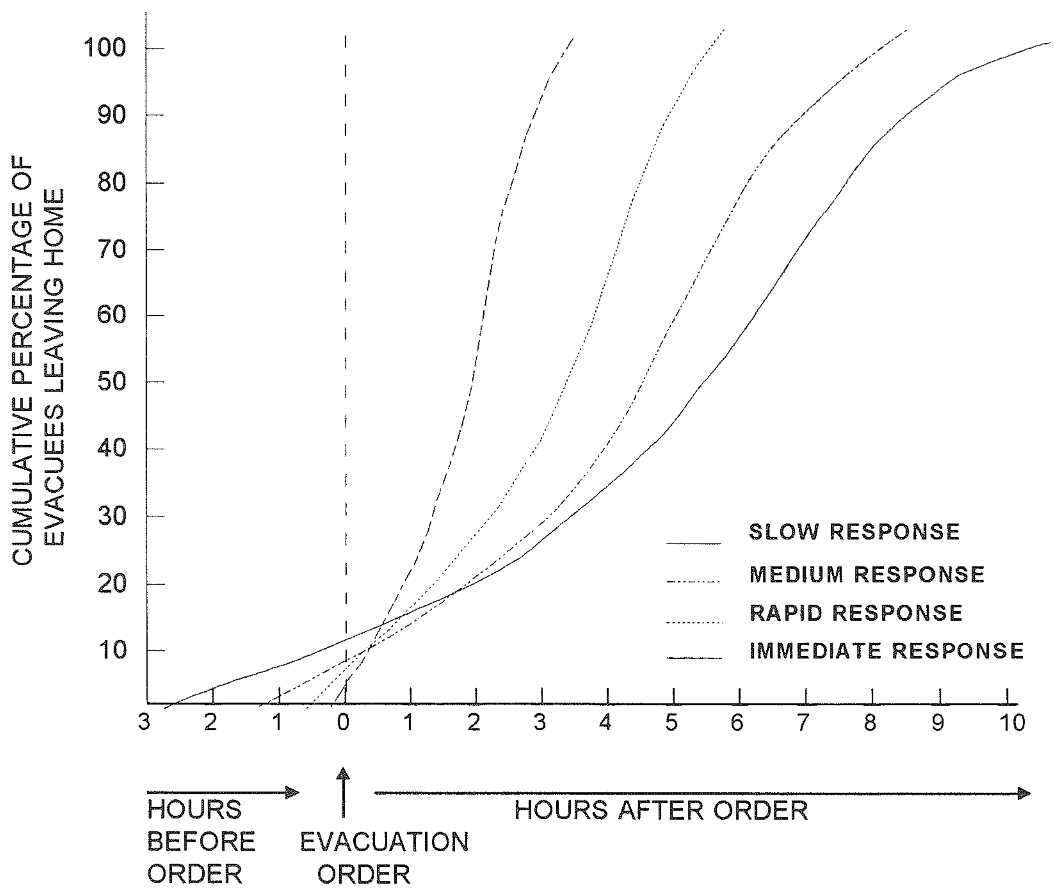

FIGURE 4-1
CUMULATIVE EVACUATION CURVES

4.3.3 Type of Refuge/Evacuation Destinations

Two factors usually influence type of refuge used more than others: income and degree of hazard of the area being evacuated. Lower income residents will be more likely than others to use public shelter and will be least likely to stay in hotels or motels.

Less than 10% of the evacuees from beach and open coast areas normally use public shelters. (An exception is in last-minute evacuations when there is insufficient time to travel to preferred destinations.) In New Jersey a very generous figure for public shelter use by beach residents would be 15%. Seldom will more than 25% of the mainland residents near the coast go to public shelters. Inland, however, (that is, in areas safe from flooding) 30% is a realistic value for shelter use, **if shelters are available locally.**

The actions of local officials can greatly influence the sheltering rates within a county. If, for example, public shelters are opened early and advertised, the public shelter use rates will most likely be significantly higher than for areas where the public is strongly advised to leave the county or where shelter locations and availability are not widely advertised.

Vacationers almost always intend to return to their homes when they evacuate, and they usually will. The great majority of vacationers in New Jersey live near enough to reach their homes in less than a day and have their own cars in which to travel. However, if the threat is extremely uncertain and officials have not made it clear that evacuation is definitely needed, vacationers who evacuate will tend to not go home, wanting to "wait-and-see" if they can return to their vacation place. That leads them to seek refuge either locally or in a nearby town, sometimes staying at public shelters if they are available, but usually seeking motels.

The day of the week can also influence whether vacationers return home. A Tuesday evacuation, for example, with vacationers having just arrived for a few days, will tempt evacuees to wait and see if they can return. A Friday evacuation is near the end of more people's planned stay, and more of them will return home when leaving.

It can be assumed that in evacuations clearly ordered or strongly recommended by government officials less than 10% of the evacuating vacationers will seek refuge in public shelters. Another 10% to 15% will seek motels farther inland, and the rest will either return home or stay with friends and relatives. In evacuations less aggressively ordered or recommended, 15% to 20% of the tourists will go to public shelters, and another 15% to 20% will look for motels farther inland. Only a last minute, urgent evacuation is likely to lead to higher shelter use figures than these.

People in vehicles towing travel trailers will usually go inland but not in all cases all the way home. Up to 20% to 25% might look for public shelters, but not in the local area. Again, it is important that emergency management officials apprise campground operators of the instructions they wish campers to receive.

The distribution of destinations of New Jersey evacuees observed in Gloria in southern New Jersey was consistent with those in other hurricane evacuations. It is typical for evacuees leaving from areas closest to the shore to evacuate greater distances than those further inland. "Late" evacuations will result in far fewer evacuees leaving the local area. Had Gloria eventually struck lower Delaware, the additional evacuees leaving late would probably have been less likely than early evacuees to go outside the local area.

After consultation with New Jersey State and County emergency planning and operation staffs, ranges of evacuation destination percentages were assumed for use in the Transportation Analysis (Table 4-1, p. 4-9). These percentages were varied for each evacuation zone in each county depending on category of risk (distance from Coastline) or special characteristics of a zone, such as high number of substandard housing units or low income residents, mobile homes or seasonal units, and seasonal occupancy. Specific assumptions for each scenario and evacuation zone are provided in the Transportation Model Support Document. It should be noted that these destination percentages refer to destination desires. Where destination desires could not be satisfied with in-county capacities, the transportation analysis assumed that some evacuees would have to leave the county to find acceptable shelter.

Evacuees from neighboring states will probably have little or no impact on sheltering in New Jersey and little or no impact on evacuation except in the New York Metropolitan area where, at certain periods of weekdays, commuter traffic from the direction of New York City will be significant.

Very little information on the home states of vacationers was discovered in the course of the behavioral analyses conducted for Middle Atlantic and New England States hurricane evacuation studies. A 1987 Report on the Economic Impact of Tourism[2] projected tourists state of residence in the proportions indicated by Figure 4-2 (p. 4-10). Information on the origins of tourists is useful in establishing assumptions regarding the desired destinations of evacuees, which in turn are used to estimate anticipated traffic volumes on evacuation routes. In the New Jersey Study it was decided that "normal" (i.e. summer Sunday evening) peak period traffic volumes were a valid indicator of the relative volumes of traffic that attempt to use various evacuation routes during a hurricane evacuation. The 1987 tourism report was not inconsistent with the highway traffic volume assignments used in this Study's transportation modeling.

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[2]R.L. Associates, Princeton, NJ, and the United States Travel Data Center, Washington, DC, Economic Impact of Tourism to the New Jersey Shore in 1987 Final Report Conducted for the State of New Jersey Department of Commerce and Economic Development, Division of Travel and Tourism, December 1987.

TABLE 4-1
EVACUATION DESTINATIONS

COUNTY	PUBLIC SHELTER[1]	FRIEND/ RELATIVE	HOTEL/ MOTEL[1]	OUT OF COUNTY[2]
SOUTHERN COUNTIES				
ATLANTIC	5-20%	20-55%	0-5%	25-85%
BURLINGTON	10-20%	35-55%	0-5%	25-50%
CAMDEN	10-20%	45-50%	0-5%	30-40%
CAPE MAY	10-30%	15-50%	0-5%	25-80%
CUMBERLAND	10-20%	35-55%	0-5%	25-50%
GLOUCESTER	15-20%	45-50%	0-5%	30-35%
MONMOUTH	15-20%	50-60%	0-5%	20-75%
OCEAN	15-30%	55-60%	0-5%	10-70%
SALEM	10-20%	45-55%	0-5%	35%
NORTHERN COUNTIES				
BERGEN	15%	50%	5%	30%[3]
ESSEX	30-40%	40-50%	0-5%	20%[3]
HUDSON	15-40%	40-50%	0-5%	20-30%
MIDDLESEX	10-40%	40-50%	0-10%	20-40%[3]
UNION	10-40%	40-50%	0-10%	20-40%[3]

[1] Percentages in this table refer to preferred destinations of evacuees; where there is insufficient public shelter or hotel/motel capacity, the traffic modeling assumes affected evacuees will go out of county.
[2] Out of county percentages include tourists leaving coastal counties for home as well as permanent residents in all counties travelling to any destination outside their county.
[3] Traffic modeling was conducted for only a limited portion of this county; "OUT OF COUNTY" destinations include destinations in this county but outside of the portion for which modeling was performed.

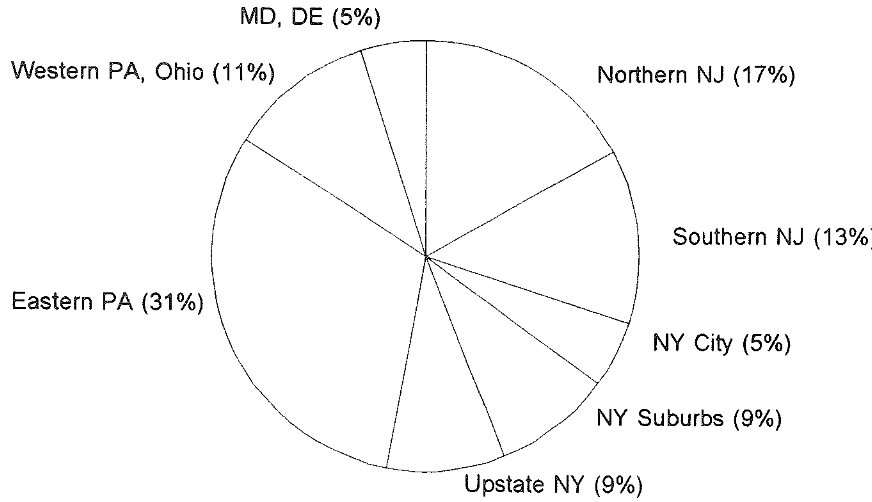


FIGURE 4-2
TOURIST STATES OF RESIDENCE

4.3.4 Vehicle Use and Transportation Assistance

Not all available vehicles are used in evacuations for fear of families being separated. For the Transportation Analysis the assumption was made that in areas nearest the coast 80 to 85% of the vehicles will be taken, and that in less hazardous areas 65 to 70% will be used. These figures were applied only to the households assumed to be evacuating, not to all registered vehicles.

In the Hurricane Gloria Survey area, very few of the households contain people who will need assistance from a social service agency to evacuate. This can, of course, be highly variable from one community to the next. **To operationally respond to this need, lists of names and addresses of all people needing special assistance should be developed and maintained at the local level.**

A variety of public and private rail and bus lines service New Jersey coastal tourist areas with Atlantic City the most dependent on bus transportation.

The majority of vacationers at the New Jersey Coast will have their own automobiles or recreational vehicles and these will be used in the evacuation. Some tourists will choose to leave the trailer at the campground if it is not floodprone and drive to a nearby public shelter. This varies greatly even among campgrounds at equal risk, and is probably a function of advice offered by management.

Chapter Five

SHELTER ANALYSIS

5.1 PURPOSE

The shelter analysis serves two primary purposes. The most apparent use of analysis data is to develop the number of evacuees who will seek public shelter (shelter demand) within each county and to determine the number of spaces available for those evacuees. This is the public shelter demand/capacity analysis. Total shelter capacity for each county is subject to change with the availability of suitable facilities.

The second purpose of the shelter analysis is, through establishing the locations of shelters, to provide part of the information needed to determine evacuation clearance times in the Transportation analysis. A thorough discussion of the methodology involved in those determinations may be found in Chapter Six.

This shelter analysis presents inventories, capacities, shelter demand, and potential flood vulnerability of public shelters. Data developed in the hazards, vulnerability and behavioral analyses were used in this shelter analysis.

It is important to note that a listing in this report does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision. Shelters will be opened by county and municipal authorities based on a variety of circumstances including season, intensity and direction of the threatening hurricane, and availability of qualified people, including American Red Cross (ARC) personnel, to manage facilities. Additionally, available public shelter space will change as buildings are constructed or demolished, as ownership changes and as agreements are reached or cancelled with building owners and with the ARC. The recent (July 1992) publication of hurricane shelter selection guidelines by the Red Cross may precipitate revisions of shelter lists in some counties in the near future.

5.2 SHELTER INVENTORIES, CAPACITIES AND VULNERABILITY

Eight of the counties included in the New Jersey Hurricane Evacuation Study list pre-designated hurricane shelters. In New Jersey public shelters may be pre-designated and operated by the American Red Cross (ARC) or opened and operated by the local governments in each county. Public shelters are listed for Atlantic, Cape May, Cumberland, Gloucester, Monmouth, Ocean, Salem and Union Counties in Tables 5-1 through 5-14 (pp. 5-7 to 5-28). These tables reflect lists of facilities provided by County emergency management coordinators to the Philadelphia District and, therefore, may not include all municipally designated shelters. The tables indicate whether an agreement for operation of each shelter has been reached with the ARC (at the time of publication of this report) and the potential vulnerability to storm surge for the four categories of hurricane intensity. The locations of shelters listed are shown on Plates 5-1 through 5-14 (following p. 5-30).

Determinations of tidal or riverine flood vulnerability were made by the Philadelphia District. Elevation surveys were conducted where necessary. **Only those shelters listed in Tables 5-1 through 5-14 have been checked for flood vulnerability. If additional facilities are selected for use as hurricane shelters, flood vulnerability surveys should be included in determinations of suitability. No attempt has been made to assess the vulnerability of any public shelter to effects of winds from hurricanes.**

5.3 PUBLIC SHELTER SELECTION GUIDELINES

As noted in Section 5.2, not all counties in the Study area have pre-designated facilities to be used as public shelter in hurricanes. Additional counties may choose to pre-designate shelters in the future. For those jurisdictions that have pre-designated shelters it can be expected that shelters lists will change from year to year. In either case it is vitally important that care be taken in shelter selection.

The American Red Cross recently (July 1992) established guidelines for selecting shelters (ARC 4496). The guidelines, which were prepared by an interagency group, reflect the application of technical data compiled in Hurricane Evacuation Studies, other hazard information, and research findings related to wind loads and structural problems. They are intended to supplement information contained in ***ARC 3031, Mass Care: Preparedness and Operations.*** These guidelines, which are reprinted on the following three pages, are also appropriate for use by municipalities operating their own shelters.

Planning considerations for hurricane evacuation shelters involve a number of factors and require close coordination with local officials responsible for public safety. Technical information contained in Hurricane Evacuation Studies, storm surge and flood mapping, and other data can now be used to make informed decisions about the suitability of shelters.

In the experience of the American Red Cross, the majority of people evacuating because of a hurricane threat generally provide for themselves or stay with friends and relatives. However, for those who do seek public shelter, **safety from the hazards associated with hurricanes must be assured.** These hazards include-

- Surge inundation.
- Rainfall flooding.
- High winds.
- Hazardous materials.

Recommended guidelines follow for each of these hurricane-associated hazards.

Surge Inundation Areas

In general, hurricane evacuation shelters should not be located in areas vulnerable to hurricane surge inundation. The National Weather Service has developed mathematical models, such as Sea, Lake, and Overland Surges from Hurricanes (SLOSH) and Special Program to List Amplitudes of Surges from Hurricanes (SPLASH), that are critical in determining the potential level of surge inundation in a given area.

- Carefully review inundation maps in order to locate all hurricane evacuation shelters outside Category 4 storm surge inundation zones.
- Avoid buildings subject to isolation by surge inundation in favor of equally suitable buildings not subject to isolation. Confirm that ground elevations for all potential shelter facilities and access routes obtained from topographic maps are accurate.
- Do not locate hurricane evacuation shelters on barrier islands.

Rainfall Flooding

Rainfall flooding must be considered in the hurricane evacuation shelter selection process. Riverine inundation areas shown on Flood Insurance Rate Maps (FIRMSs), as prepared by the National Flood Insurance Program, should be reviewed. FIRMs should also be reviewed in locating shelters in inland counties.

- Locate hurricane evacuation shelters outside the 100-year floodplain.
- Avoid selecting hurricane evacuation shelters located within the 500-year floodplain.
- Do not locate hurricane evacuation shelters in areas likely to be isolated due to riverine inundation of roadways.
- Make sure a hurricane evacuation shelter's first floor elevation is on an equal or higher elevation than that of the base flood elevation level for the FIRM area.
- Consider the proximity of shelters to any dams and reservoirs to assess flow upon failure of containment following hurricane-related flooding.

Wind Hazards

Consideration of any facility for use as a hurricane evacuation shelter must take into account wind hazards. Both design and construction problems may preclude a facility from being used as a shelter. Local building codes are frequently inadequate for higher wind speeds.

Structural Considerations

- If possible, select buildings that a structural engineer has certified as being capable of withstanding wind loads according to ASCE (American Society of Engineers) 7-88 or ANSI (American National Standards Institute) A58 (1982) structural design criteria. Buildings must be in compliance with all local building and fire codes.
- Failing a certification (see above), request a structural engineer to rank the proposed hurricane evacuation shelters based on his or her knowledge and the criteria contained in these guidelines.
- Avoid uncertified buildings of the following types:
  - Buildings with long or open roof spans
  - Un-reinforced masonry buildings
  - Pre-engineered (steel pre-fabricated) buildings built before the mid 1980s
  - Buildings that will be exposed to the full force of hurricane winds
  - Buildings with flat or lightweight roofs
- Give preference to the following:
  - Buildings with steep-pitched, hipped roofs; or with heavy concrete roofs

- Buildings more than one story high (if lower stories are used for shelter)
- Buildings in sheltered areas
- Buildings whose access routes are not tree-lined

Interior Building Safety Criteria During Hurricane Conditions

Based on storm data (e.g., arrival of gale-force winds), determine a notification procedure with local emergency managers regarding when to move the shelter population to pre-determined safer areas within the facility. Consider the following guidelines:

- Do not use rooms attached to, or immediately adjacent to, un-reinforced masonry walls or buildings.
- Do not use gymnasiums, auditoriums, or other large open areas with long roof spans during hurricane conditions.
- Avoid areas near glass, unless the glass surface is protected by an adequate shutter. Assume that windows and roof will be damaged and plan accordingly.
- Use interior corridors or rooms.
- In multi-story buildings, use only the lower floors and avoid corner rooms.
- Avoid any wall section that has portable or modular classrooms in close proximity, if these are used in your community.
- Avoid basements if there is any chance of flooding.

Hazardous Materials

The possible impact from a spill or release of hazardous materials should be taken into account when considering any potential hurricane evacuation shelter.

All facilities manufacturing, using, or storing hazardous materials (in reportable quantities) are required to submit Material Safety Data Sheets (emergency and hazardous chemical inventory forms) to the Local Emergency Planning Committee (LEPC) and the local fire department. These sources can assist you in determining the suitability of a potential hurricane evacuation shelter or determining precautionary zones (safe distances) for facilities near potential shelters that manufacture, use, or store hazardous materials.

- Facilities that store certain types or quantities of hazardous materials may be inappropriate for use as hurricane evacuation shelters.
- Hurricane evacuation shelters should not be located within the ten-mile emergency planning zone (EPZ) of a nuclear power plant.
- Service delivery units must work with local emergency management officials to determine if hazardous materials present a concern for potential hurricane evacuation shelters.

Hurricane Evacuation Shelter Selection Process

General procedures for investigating the suitability of a building or facility for use as a hurricane evacuation shelter are as follows:

- Identify potential sites. Evacuation and transportation route models must be considered.
- Complete a risk assessment on each potential site. Gather all pertinent data from SLOSH and/or SPLASH (storm surge), FIRM (flood hazard), facility base elevation, hazardous materials information, and previous studies concerning each building's suitability.
- Inspect the facility and complete a *Red Cross Facility Survey Form and a Self-Inspection Work Sheet/Off-Premises Liability Checklist*, in accordance with ARC 3031. Note all potential liabilities and the type of construction. Consider the facility as a whole—one weak section may seriously jeopardize the integrity of the building.
- Have the building certified as being capable of withstanding the wind loads according to ASCE 7-88 or ANSI A58 (1982) structural design criteria. In the absence of certification, have a structural engineer review the facility and rate its suitability to the best of his or her ability.
- Ensure that an exhaustive search for shelter space has been completed. Work with local emergency management officials and others to identify additional potential sites.
- Review, on a regular basis, all approved hurricane evacuation shelters. Facility improvements, additions, or deterioration may change the suitability of a selected facility as a hurricane evacuation shelter. Facility enhancements may also enable previously rejected facilities to be used as hurricane evacuation shelters.
- If possible, work with officials, facility managers, and school districts on mitigation opportunities. Continue to advocate that the building program for new public buildings, such

as schools, should include provisions to make them more resilient to possible wind damage. It may also be possible to suggest a minor modification of a municipal, community, or school building in the planning stages to make for a more useful hurricane evacuation shelter site, such as the addition of hurricane shutters.

Least-Risk Decision Making

Safety is the primary consideration for the American Red Cross in providing hurricane evacuation shelters. When anticipated demands for hurricane evacuation shelter spaces exceed suitable capacity as defined by the preceding criteria, there may be a need to utilize marginal facilities. It is therefore critical that these decisions be made carefully and in consultation with local emergency management and public safety officials. Guidance should be obtained from Disaster Services at national headquarters, in consultation with the Risk Management Division.

This process should include the following considerations:

- No hurricane evacuation shelter should be located in an evacuation zone for obvious safety reasons. All hurricane evacuation shelters should be located outside of Category 4 storm surge inundation zones. **Certain exceptions may be necessary, but only if there is a high degree of confidence that the level of wind, rain, and surge activities will not surpass established shelter safety margins.**
- When a potential hurricane evacuation shelter is located in a flood zone, it is important to consider its viability. By comparing elevations of sites with FIRMs, one can determine if the shelter and a major means of egress are in any danger of flooding. Zone AH (within the 100-year flood plain and puddling of 1-3 feet expected) necessitates a closer look at the use of a particular facility as a sheltering location. Zones B, C, and D may allow some flexibility. **It is essential that elevations be carefully checked to avoid unnecessary problems.**
- In the absence of certification by a structural engineer, any building selected for use as a hurricane evacuation shelter must be in compliance with all local building and fire codes. Certain exceptions may be necessary, but only after evaluation of each facility, using the aforementioned building safety criteria.
- The Red Cross uses the planning guideline of 40 square feet of space per shelter resident. During hurricane conditions, on a short-term basis, shelter space requirements may be reduced. Ideally, this requirement should be determined using no less than 20 square feet per person. Adequate space must be set aside for registration, health services, and safety and fire considerations. Disaster Health Services areas should still be planned using a 40 square feet per person calculation. On a **long-term recovery basis, shelter space requirements should follow guidelines established in ARC 2021,** *Mass Care: Preparedness and Operations.*

5.4 PUBLIC SHELTER DEMAND/CAPACITY

The results of the behavioral analysis conducted for the New Jersey Hurricane Evacuation Study were in determining the shelter demand for a variety of hurricane scenarios. The shelter capacities used in the analysis were developed by State and county officials, Red Cross officials and the Corps of Engineers.

Tables 5-15(A) and 5-15(B) (pp. 5-29 & 5-30) shows the public shelter demand (number of evacuees seeking public shelter) resulting from each evacuation scenario. Evacuation scenarios are defined for each county in Chapter 6, Table 6-2 (p. 6-7). For those counties where seasonal occupancy varies appreciably, shelter demand is given as a range based on that variation. The analysis assumes 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:

a. One hundred percent of the affected population will evacuate. (This assumption is incorporated into the Shelter Analysis and the Transportation Analysis even though the Behavioral Analysis indicates that participation rates in most hurricanes will be somewhat less than 100 percent.)

b. One to five percent (depending on storm intensity) of nearby non-affected population will evacuate.

c. Persons living in highly vulnerable locations, especially on the shoreline, will utilize public shelter facilities at rates of 10 to 15 percent of the total number of evacuees from those locations.

d. Persons living in moderately vulnerable locations will utilize public shelter facilities at a rate of 25 percent of the total number of evacuees from those locations.

e. Thirty to forty percent of the mobile home residents and persons evacuating from areas of low vulnerability will utilize public shelter facilities.

f. Less than five percent of vacationers will seek public shelter.

Tables 5-15(A) and 5-15(B) (pp. 5-29 & 5-30) also provide the total identified public shelter derived from Tables 5-1 through 5-14 (pp. 5-7 to 5-28).

TABLE 5-1
BURLINGTON COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Bordentown	Bordentown Regional H.S.	125	None[4]	Yes
2	Bordentown	Peter Muschal School	75	"	Yes
3	Burlington	Township High School	200	"	Yes
4	Chesterfield Twp.	Chesterfield Twp. School	75	"	Yes
5	Chesterfield Twp.	Crosswicks Community House	35	"	Yes
6	Chesterfield Twp.	Crosswicks Methodist Church	100	"	Yes
7	Chesterfield Twp.	Crosswicks Union Fire Co.	70	"	Yes
8	Chesterfield Twp.	Seventh Day Adventist School	50	"	Yes
9	Delanco Twp.	Delanco Township Public Schools	100	"	Yes
10	Delanco Twp.	Dobbins United Methodist Church	50	"	Yes
11	Evesham Twp.	Florence V. Evans School	85	"	Yes
12	Evesham Twp.	Helen L. Beeler School	75	"	Yes
13	Evesham Twp.	J. Harold Van Zant School	80	"	Yes
14	Evesham Twp.	Merlton Middle School	150	"	Yes
15	Evesham Twp.	Robert B. Jaggard School	90	"	Yes
16	Moorestown Twp.	Moorestown Bible Church	40	"	Yes
17	Moorestown Twp.	Moorestown Field Club	50	"	Yes
18	Moorestown Twp.	Moorestown Senior High School	1250	"	Yes
19	Moorestown Twp.	North Church St. Recreation Ctr.	50	"	Yes
20	Moorestown Twp.	Our Lady of Good Counsel School	185	"	Yes
21	Moorestown Twp.	Trinity Church	30	"	Yes
22	Moorestown Twp.	William S. Allen	50	"	Yes
23	North Hanover Twp.	C.B. Lamb School	125	"	Yes
24	Plumstead Twp. (Ocean Co.)	Church of the Assumption	50	"	Yes
		TOTAL	**3,190**		

NOTES
[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.
[2] See Plate 5-1, following p. 5-30 for approximate locations of shelters.
[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.
[4] Because of late Burlington County/ARC revisions to the County shelter list, there was insufficient time for a field check of this facility for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from tidal or riverine sources

TABLE 5-2
CAMDEN COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Audubon	Audubon H.S.	175	None[4]	
2	Camden City	Camden H.S.	175	"	
3	Camden City	Woodrow Wilson H.S.	160	"	
4	Cherry Hill Twp.	Camden Catholic H.S.	300	"	
5	Cherry Hill Twp.	Cherry Hill East H.S.	450	"	Yes
6	Cherry Hill Twp.	Cherry Hill West H.S.	450	"	
7	Gloucester Twp.	Camden County Vocational School	250	"	Yes
8	Gloucester City	Gloucester Catholic H.S.	400	500 yr[5]	
9	Gloucester Twp.	Highland H.S.	250	None	
10	Haddon Twp.	Haddon Township H.S.	200	"	Yes
11	Haddon Heights	Haddon Heights H.S.	175	"	
12	Haddon Twp.	Paul VI H.S.	250	"	
13	Haddonfield	Haddonfield H.S.	200	"	Yes
14	Pennsauken Twp.	Bishop Eustace H.S.	250	"	
15	Pennsauken Twp.	Camden County Vocational H.S.	450	"	
16	Pennsauken Twp.	Pennsauken H.S.	200	"	Yes
17	Pine Hill	Overbrook H.S.	225	"	
18	Runnemede	Triton H.S.	250	"	
19	Somerdale	Sterling H.S.	200	"	
20	Voorhees Twp.	Eastern H.S.	350	"	
21	Winslow Twp.	Edgewood H.S.	400	"	
		TOTAL	**5,760**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-2, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] "None" indicates facility is not in a riverine or tidal flood hazard area.

[5] This school is within the 500 year floodplain as mapped on the Flood Insurance Rate Map for Gloucester City.

TABLE 5-3
GLOUCESTER COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Clayton	Clayton H.S.	280	None[4]	Yes
2	Deptford	Deptford H.S.	200	"	Yes
3	Franklin Twp.	American Legion Post #179	175	Yes	Yes
4	Harrison Twp.	Harrison Twp. Elementary School	270	"	Yes
5	Monroe Twp.	Williamstown H.S.	460	"	Yes
6	Monroe Twp.	Oak Knoll School	180	"	Yes
7	Paulsboro	Paulsboro H.S.	300	See Note[5]	Yes
8	Pitman	Pitman H.S.	200	None[4]	Yes
9	Pitman	Pitman Elementary School	150	"	Yes
10	Washington Twp.	Bells School	200	"	Yes
11	Washington Twp.	Birches School	300	"	Yes
12	Washington Twp.	Huffville School	150	"	Yes
13	Washington Twp.	Thomas Jefferson School	500	"	Yes
14	Washington Twp.	Wedgewood School	200	"	Yes
15	Washington Twp.	Whitman School	350	"	Yes
16	Washington Twp.	Chestnut Ridge Middle School	500	"	Yes
17	Washington Twp.	Orchard Valley Middle School	500	"	Yes
18	Washington Twp.	9-10 H.S. Building	500	"	Yes
19	Washington Twp.	11-12 H.S. Building	500	"	Yes
20	West Deptford	West Deptford Middle School	275	"	Yes
21	West Deptford	West Deptford H.S.	300	See Note[6]	Yes
22	Woodbury	NJ National Guard Armory	290	None[4]	Yes
23	Woodbury	West End Memorial School	200	"	Yes
24	Woodbury	Woodbury H.S.	200	"	Yes
		TOTAL	**7,180**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-3, following p. 5-30 for approximate locations of shelters..

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] "None" indicates facility is not in a riverine or tidal flood hazard area.

[5] This school is at the perimeter of an area subject to flooding from a "worst-case" Category 4 hurricane. The ground elevation adjacent to the school is approximately 13.5 ft NGVD. [Category 4 surge elevation = 14.4 ft.]. The school's lowest floor, however, is several feet below grade. The school could be isolated by surrounding flood waters in a hurricane of lesser intensity.

[6] This facility is located near, but not in, a potential tidal flooding area. [No elevation survey].

TABLE 5-4
SALEM COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Penns Grove	Field Street School	325	See Note[4]	Yes
2	Penns Grove	Penns Grove High School	550	See Note[5]	Yes
3	Pittsgrove Twp.	Arthur P. Schalick School	525	None[6]	Yes
4	Pittsgrove Twp.	Pittsgrove Middle School	325	"	Yes
5	Woodstown	Shoemaker Elem. School	275	"	Yes
6	Woodstown	Woodstown Middle School	325	"	Yes
7	Woodstown	Woodstown High School	525	"	Yes
		TOTAL	**2,850**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-4, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] This facility is close to, but out of, an area subject to tidal flooding from major hurricanes [No elevation survey].

[5] Penns Grove High School is in an area that has a potential for inundation from a Category 3 or higher hurricane. It would be suitable for use as a public shelter in a Category 1 or 2 hurricane. SLOSH Model surge elevations (worst case scenario including high astronomical tide) are 8.1 (Cat. 1), 10.2 Cat. 2), 14.7(Cat. 3), 21.7(Cat. 4). [No elevation survey was conducted by the Philadelphia District for this facility.]

[6] "None" indicates facility is not subject to tidal or riverine flooding.

TABLE 5-5
CUMBERLAND COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Bridgeton	Bridgeton H.S.	270	None[4]	Yes
2	Bridgeton	Bridgeton Middle School	209	"	Yes
3	Bridgeton	Cumberland County Voc-Tech	187	"	Yes
4	Millville	Holly Heights School	282	"	Yes
5	Millville	Memorial H.S.	270	"	Yes
6	Millville	Millville Senior H.S.	375	"	Yes
7	Millville	Rieck Avenue School	175	"	Yes
8	U. Deerfield Twp.	Cumberland Regional H.S.	323	"	Yes
9	U. Deerfield Twp.	Woodruff School	175	"	Yes
10	Vineland	Landis Intermediate School	116	"	Yes
11	Vineland	Vineland H.S. - North	285	"	Yes
12	Vineland	Vineland H.S. - South	340	"	Yes
		TOTAL	**3007**		

NOTES
[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.
[2] See Plate 5-5, following p. 5-30 for approximate locations of shelters.
[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.
[4] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-6
CAPE MAY COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Dennis Twp.	Belleplain Fire Hall		None[4]	
2	Dennis Twp.	Belleplain VFW Post 6257		"	
3	Dennis Twp.	Dennisville Fire Hall		Cat. 3/4[5]	
4	Dennis Twp.	Elementary School		"	
5	Dennis Twp.	Masonic Cannon Lodge		None[4]	
6	Dennis Twp.	Ocean View Fire Hall		"	
7	Lower Twp.	Carl Mitnick School		Cat. 3/4[5]	
8	Lower Twp.	Knights of Columbus Hall		"	
9	Lower Twp.	Lower Cape May Regional H.S.		"	
10	Lower Twp.	Sandman Consolidated School		"	
11	Lower Twp.	Memorial Elementary School		"	
12	Lower Twp.	Lower Twp. Democratic Club		"	
13	Lower Twp.	Maude Abrams School		"	
14	Lower Twp.	Nazarene Church		"	
15	Lower Twp.	Nazarene Hall		"	
16	Lower Twp.	Optimist Club		"	
17	Lower Twp.	St. John of God Catholic Church		"	
18	Lower Twp.	Tabernacle Methodist Church		"	
19	Lower Twp.	Titleman Junior H.S.		"	
20	Middle Twp.	4-H Building		None[4]	
21	Middle Twp.	American Legion		"	
22	Middle Twp.	First Methodist Church & Hall		Cat. 3/4[5]	
23	Middle Twp.	Middle Twp. Elementary School #1		"	
24	Middle Twp.	Middle Twp. Elementary School #3		"	

(TABLE CONTINUED)

NOTES

[1] **Current Cape May County Emergency Management plans do not include in-county public sheltering for hurricane threats. A large percentage of the county is potentially vulnerable to tidal flooding from hurricanes. No buildings in the county which might otherwise be suitable for use as public shelters have been found to be in conformance with the American Red Cross hurricane shelter selection guidelines regarding susceptibility to flooding or damage from high winds (see pp. 5-2 to 5-5 above). The Cape May County Office of Emergency Management may, in some circumstances, use the listed facilities as evacuation staging areas.**

[2] See Plate 5-6, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. No ARC hurricane shelter management agreements in Cape May County.

[4] "None" indicates facility is not subject to tidal or riverine flooding.

[5] "Cat. 3/4" indicates facility is in an area subject to possible inundation from a hurricane of Category 3 or higher intensity. Those facilities not listed as having a flood potential may be susceptible to wind damage and are therefore not considered to be in conformance with ARC hurricane shelter selection guidelines.

TABLE 5-6 (CONTINUED)
CAPE MAY COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
25	Middle Twp.	Middle Twp. Elementary School #4		Cat. 3/4[4]	
26	Middle Twp.	Middle Twp. High School			
27	Middle Twp.	Middle Twp. Fire Hall		"	
28	Middle Twp.	Rio Grande Rescue Squad & Hall		"	
29	Upper Twp.	Upper Twp. Elementary School		"	
30	Upper Twp.	Upper Twp. Primary School		None[5]	
31	Upper Twp.	Upper Twp. Middle School		"	
32	Woodbine Bor.	Borough Hall		"	
33	Woodbine Bor.	Kingdom Hall Jehovah's Witnesses		"	
34	Woodbine Bor.	Woodbine Day Care Center		"	
35	Woodbine Bor.	St. Casimir's Church		"	
36	Woodbine Bor.	Woodbine Ambulance Corps		"	
37	Woodbine Bor.	Woodbine American Legion		"	
38	Woodbine Bor.	Woodbine Brotherhood Synagogue		"	
39	Woodbine Bor.	Woodbine Elementary School		"	

NOTES

[1] **Current Cape May County Emergency Management plans do not include in-county public sheltering for hurricane threats. A large percentage of the county is potentially vulnerable to tidal flooding from hurricanes. No buildings in the county which might otherwise be suitable for use as public shelters have been found to be in conformance with the American Red Cross hurricane shelter selection guidelines regarding susceptibility to flooding or damage from high winds (see pp. 5-2 to 5-5 above). The Cape May County Office of Emergency Management may, in some circumstances, use the listed facilities as evacuation staging areas.**

[2] See Plate 5-6, following p. 5-30 for approximate locations of these facilities.

[3] American Red Cross. No ARC hurricane shelter management agreements in Cape May County.

[4] "Cat. 3/4" indicates facility is in an area subject to possible inundation from a hurricane of Category 3 or higher intensity. Those facilities not listed as having a flood potential may be susceptible to wind damage and are therefore not considered to be in conformance with ARC hurricane shelter selection guidelines.

[5] "None" indicates facility is not subject to tidal or riverine flooding.

TABLE 5-7
ATLANTIC COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Absecon	Absecon Community Complex	750	None[4]	Yes
2	Absecon	Holy Spirit School	1180	See Note[5]	
3	Buena Borough	Cleary Junior H.S.	500	None[4]	Yes
4	Buena Borough	Donini School	261	"	Yes
5	Buena Borough	Our Lady of Victory	411	"	Yes
6	Buena Vista Twp	Buena Regional H.S.	650	"	Yes
7	Buena Vista Twp	Collings Lake Elementary School	420	"	Yes
8	Buena Vista Twp	Milanesi Elementary School	310	"	Yes
9	Buena Vista Twp	St. Augustine Prep School	500	"	Yes
10	Corbin City	Regional Day School	270	"	Yes
11	Egg Harbor City	Philadelphia School	250	"	Yes
12	Egg Harbor City	Spragg School	315	"	Yes
13	Egg Harbor City	St. Nicholas School	250	"	Yes
14	Egg Harbor Twp.	Davenport Elementary School	1904	"	Yes
15	Egg Harbor Twp.	Egg Harbor Twp. H.S.	1800	"	Yes
16	Egg Harbor Twp.	Russel Swift School	600	"	Yes
17	Egg Harbor Twp.	Slaybaugh School	1320	"	Yes
18	Folsom Borough	Folsom School	650	"	Yes
19	Galloway Twp.	Absegami H.S.	2040	"	Yes
20	Galloway Twp.	Arthur Rann School	1000	"	Yes
21	Galloway Twp.	Assumption Church	867	"	Yes
22	Galloway Twp.	Pilgrim Academy	791	"	Yes
23	Galloway Twp.	Reed's Road School	300	"	Yes
		SUB-TOTAL (TABLE CONTINUED)	17,339		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-7, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] "None" indicates facility is not in a tidal or riverine flood hazard area.

[5] This facility is not in a tidal or riverine flood hazard area; there are, however, potential access problems from flooding on Route 9 just north of the high school (vicinity of Absecon Creek).

TABLE 5-7 (CONTINUED)
ATLANTIC COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
24	Hamilton Twp.	Atlantic Community College	2500	None[4]	Yes
25	Hamilton Twp.	Davies School	250	"	Yes
26	Hamilton Twp.	Oakrest H.S.	2500	"	Yes
27	Hammonton	Hammonton Twp. Middle School	1248	"	Yes
28	Hammonton	Hammonton Twp. Elem. School	1000	"	Yes
29	Hammonton	Hammonton Twp. H.S.	1999	"	Yes
30	Linwood	Mainland High	450	See Note[5]	Yes
31	Pleasantville	Leeds Avenue School	635	See Note[6]	Yes
32	Pleasantville	Pleasantville Jr. H.S.	500	None[4]	Yes
33	Pleasantville	South Main School	200	"	Yes
34	Somers Point	Jordan Road School	997	See Note[7]	Yes
35	Somers Point	St. Joseph School	376	None[4]	Yes
36	Somers Point	Dawes Ave. School	300	See Note[7]	Yes
37	Weymouth Twp.	Weymouth Twp. Elem. School	500	None[4]	Yes
		SUB-TOTAL	13,455		
		TOTAL	**30,794**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-7, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] "None" indicates facility is not in a tidal or riverine flood hazard area.

[5] Mainland High School is in an area subject to inundation from hurricanes of Category 3 or higher intensity. Ground elevations adjacent to the school (sidewalks at south entrance) are between 14 and 15 ft. (NGVD); driveway elevation at SW corner of school (toward tributary of Patcong Creek) is approximately 12 ft. SLOSH Model surge elevations (worst case scenario including high astronomical tide) are 9.5 (Cat. 1), 13.6(Cat. 2), 18.1(Cat. 3), 21.7(Cat. 4).

[6] School is sated above maximum hurricane surge elevations. However, Leeds Avenue immediately west of the school is potentially subject to inundation from Category 2 and higher hurricanes.

[7] School is sited above maximum hurricane surge elevations. However, many streets in the vicinity are potentially vulnerable to tidal surge flooding.

TABLE 5-8
OCEAN COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Barnegat Twp.	Cecil S. Collins School	640	See Note[4]	Yes
2	Barnegat Twp.	Elizabeth V. Edwards School	260	See Note[4,5]	Yes
3	Barnegat Twp.	Lillian M. Dunfee School	490	See Note[4]	Yes
4	Barnegat Twp.	Russell O. Brackman Middle School	1000	"	Yes
5	Beachwood Bor.	Beachwood Elementary School	550	None[6]	Yes
6	Berkeley Twp.	Bayville School	490	See Note[3]	Yes
7	Berkeley Twp.	Central Regional H.S.	2000	None[6]	Yes
8	Berkeley Twp.	Central Regional Middle School	1000	"	Yes
9	Berkeley Twp.	Clara B. Worth School	645	See Note[4]	Yes
10	Brick Twp.	Brick Twp. H.S.	700	None[6]	Yes
11	Brick Twp.	Brick Twp. Memorial H.S.	700	"	Yes
12	Brick Twp.	Drum Point Road School	500	See Note[4,5]	Yes
13	Brick Twp.	Emma Havens Young School	950	"	Yes
14	Brick Twp.	Herbertsville School	188	See Note[4]	Yes
15	Brick Twp.	Lake Riviera Middle School	500	None[6]	Yes
16	Brick Twp.	Lanes Mill School	1300	See Note[4]	Yes
17	Brick Twp.	Laurelton School	100	"	Yes
18	Brick Twp.	Midstream School	400	See Note[4,5]	Yes
19	Brick Twp.	Osbornville School	240	See Note[4]	Yes
20	Brick Twp.	St. Pauls United Methodist Church	170	"	Yes
21	Brick Twp.	Veterans Memorial Middle School	500	None[6]	Yes
22	Brick Twp.	Veterans Memorial School	350	"	Yes
23	Dover Twp.	Cedar Grove Elementary School	750	See Note[4]	Yes
24	Dover Twp.	East Dover Elementary School	1150	See Note[4,5]	Yes
25	Dover Twp.	Hooper Avenue Elementary School	900	"	Yes
26	Dover Twp.	Intermediate School East	1600	"	Yes
27	Dover Twp.	Intermediate School West	200	See Note[4]	Yes
28	Dover Twp.	North Dover Elementary School	100	"	Yes
		SUB-TOTAL (TABLE CONTINUED)	18,337		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-8, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] Because of late Ocean County/ARC revisions to the County shelter list, there was insufficient time for a field check of this facility for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from tidal or riverine sources

[5] This facility is located near, but not in, a potential tidal flooding area. [No elevation survey].

[6] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-8 (CONTINUED)
OCEAN COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
29	Dover Twp.	Toms River H.S. East	4116	None[6]	Yes
30	Dover Twp.	Toms River H.S. North	3750	"	Yes
31	Dover Twp.	Toms River H.S. South	1675	"	Yes
32	Dover Twp.	Walnut Street Elementary School	100	See Note[4]	Yes
33	Dover Twp.	Washington Street School	475	"	Yes
34	Dover Twp.	West Dover Elementary School	550	"	Yes
35	Eagleswood Twp.	Eagleswood Twp. Elementary School	250	See Note[4,5]	Yes
36	Island Hts. Bor.	Island Heights Fire Company	300	"	Yes
37	Island Hts. Bor.	Island Heights School	160	See Note[4]	Yes
38	Jackson Twp.	Carl W. Goetz Intermed. School	1200	None[6]	Yes
39	Jackson Twp.	H.C. Johnson	540	See Note[4]	Yes
40	Jackson Twp.	Lucy Holman School	570	"	Yes
41	Lacey Twp.	Cedar Creek Elementary School	1000	"	Yes
42	Lacey Twp.	Forked River Elementary School	500	"	Yes
43	Lacey Twp.	Lacey Twp. H.S.	2443	None[6]	Yes
44	Lacey Twp.	Lacey Twp. Middle School	1734	"	Yes
45	Lacey Twp.	Lanoka Harbor Elementary School	600	See Note[4]	Yes
46	Lacey Twp.	St. Pius X R.C. Church	280	"	Yes
47	L. Egg Harbor Twp.	Pinelands Middle School	400	See Note[4,5]	Yes
48	L. Egg Harbor Twp.	Pinelands Regional H.S.	2000	See Note[5]	Yes
49	Lakehurst	Lakehurst Elementary School	500	None[6]	Yes
50	Lakewood Twp.	Clifton Ave. School	830	"	Yes
51	Lakewood Twp.	Ella Clarke School	1360	"	Yes
52	Lakewood Twp.	Lakewood H.S.	3400	"	Yes
53	Lakewood Twp.	Lakewood Middle School	2000	"	Yes
54	Lakewood Twp.	Oak Street School	900	See Note[4]	Yes
55	Lakewood Twp.	Spruce Street School	435	None[6]	Yes
56	Manchester Twp.	Community Reformed Church	200	See Note[4]	Yes
		SUB-TOTAL (TABLE CONTINUED)	32,268		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-8, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] Because of late Ocean County/ARC revisions to the County shelter list, there was insufficient time for a field check of this facility for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from tidal or riverine sources

[5] This facility is located near, but not in, a potential tidal flooding area. [No elevation survey].

[6] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-8 (CONTINUED)
OCEAN COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
57	Manchester Twp.	Manchester Twp. H.S.	1000	None[6]	Yes
58	Manchester Twp.	Manchester Twp. Middle School	500	"	Yes
59	Ocean Twp.	Frederic A. Priff Elementary School	300	See Note[4]	Yes
60	Ocean Twp.	Waretown Elementary School	200	See Note[4,5]	Yes
61	Plumstead Twp.	New Egypt School	250	None[6]	Yes
62	S. Toms River Bor.	South Toms River Elementary	240	See Note[4]	Yes
63	Stafford Twp.	McKinley Elementary School	990	"	Yes
64	Stafford Twp.	Southern Regional H.S.	1640	See Note[4,5]	Yes
65	Stafford Twp.	Southern Regional Middle School	1540	"	Yes
66	Stafford Twp.	Stafford Elementary School	950	See Note[4]	Yes
		SUB-TOTAL	7,610		
		TOTAL	**58,251**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-8, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] Because of late Ocean County/ARC revisions to the County shelter list, there was insufficient time for a field check of this facility for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from tidal or riverine sources

[5] This facility is located near, but not in, a potential tidal flooding area. [No elevation survey].

[6] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-9
MONMOUTH COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	Allentown	Allentown High School	800	See Note[4]	Yes
2	Eatontown	Meadowbrook Elementary School	100	"	Yes
3	Freehold	Freehold Borough H.S.	250	None[5]	Yes
4	Freehold	Freehold Intermediate School	400	See Note[4]	Yes
5	Freehold Twp.	Freehold Regional H.S.	455	None[5]	Yes
6	Hazlet Twp.	Raritan H.S.	420	"	Yes
7	Highlands	Henry Hudson High School	800	See Note[4]	Yes
8	Highlands	Highlands School	185	None[5]	Yes
9	Holmdel Twp.	Holmdel H.S.	330	"	Yes
10	Keyport	Keyport H.S.	250	See Note[6]	Yes
11	Little Silver	Red Bank Regional H.S.	500	See Note[4]	Yes
12	Marlboro	Central Elementary School	400	"	Yes
13	Marlboro	Frank Dugan Elementary School	500	"	Yes
14	Marlboro	Marlboro Elementary School	384	"	Yes
15	Marlboro	Marlboro Middle School	500	"	Yes
16	Marlboro	Robertsville Elementary School	348	"	Yes
17	Middletown Twp.	Middletown North H.S.	625	None[5]	Yes
18	Middletown Twp.	Thorne School	330	See Note[7]	Yes
19	Millstone	Millstone High School	400	See Note[4]	Yes
20	Neptune Twp.	Neptune Middle School	900	None[5]	Yes
21	Neptune Twp.	Neptune Senior Center	100	See Note[4]	Yes
22	Neptune Twp.	Neptune Senior H.S.	675	None[5]	Yes
		SUBTOTAL (TABLE CONTINUED)	9,652		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-9, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] Because of late Monmouth County/ARC revisions to the County shelter list, there was insufficient time for a field check of this facility for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from tidal or riverine sources.

[5] "None" indicates facility is not in a tidal or riverine flood hazard area.

[6] Ground elevations in the vicinity of Keyport H.S. are approximately 25 ft. NGVD. The first floor elevation of the school is approximately 28 ft. Additional classrooms are on the basement level below the first floor. Mapped surge elevations are as follows: Category 1: 11 ft., Category 2: 17.5 ft., Category 3: 23.4 ft., Category 4: 27.7 ft.

[7] Ground elevations in the immediate vicinity of the Thorne School are above the mapped maximum Category 4 surge elevation of 26.3 ft. The first floor elevation of the school is approximately 32 ft.

TABLE 5-9 (CONTINUED)
MONMOUTH COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
23	Ocean Twp.	Ocean Township Elem. School	750	See Note[4]	Yes
24	Ocean Twp.	Ocean Township H.S.	280	None[5]	Yes
25	Ocean Twp.	Wanamassa Elementary School	375	See Note[4]	Yes
26	Ocean Twp.	Wayside Elementary School	580	"	Yes
27	Red Bank	Red Bank Elementary School	800	"	Yes
28	Red Bank	Red Bank Middle School	677	"	Yes
29	Roosevelt	Roosevelt Elementary School	262	"	Yes
30	Rumson	Forrestal Elementary School	600	"	Yes
31	Rumson	Rumson H.S.	355	None[5]	Yes
32	Tinton Falls	Atchison Elementary School	600	See Note[4]	Yes
33	Tinton Falls	Monmouth Regional H.S.	390	"	Yes
34	Tinton Falls	Swimming River Elem. School	300	"	Yes
35	Tinton Falls	Tinton Falls Elementary School	543	"	Yes
36	Wall Twp.	Wall Intermediate School	333	"	Yes
37	W. Long Branch	Shore Regional H.S.	690	"	Yes
		SUBTOTAL	7535		
		TOTAL	**17,187**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-9, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] Because of late Monmouth County/ARC revisions to the County shelter list, there was insufficient time for a field check of this facility for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from tidal or riverine sources.

[5] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-10
MIDDLESEX COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	East Brunswick	East Brunswick Vocational H. S.	200	See Note[4]	
2	East Brunswick	East Brunswick H. S.	550	"	
3	East Brunswick	Churchill School	350	"	
4	Edison	Woodrow Wilson Middle School	170	"	
5	Edison	John Adams Middle School	200	"	
6	Edison	Edison H. S.	500	"	
7	Edison	J. P. Stevens H. S.	500	"	
8	Highland Park	Irving School	115	"	
9	Highland Park	Highland Park H. S.	230	"	
10	Highland Park	The Bartle School	115	"	
11	Metuchen	Campbell School	110	"	
12	Metuchen	Metuchen H. S.	200	"	
13	New Brunswick	New Brunswick H. S.	225	"	
14	New Brunswick	New Brunswick Vocational H. S.	50	"	
15	New Brunswick	Paul Robeson Community School	125	"	
16	Old Bridge	Cedar Ridge H. S.	375	"	
17	Old Bridge	Sandburg Middle School	310	"	
18	Old Bridge	Cheesequake School	110	"	
19	Old Bridge	Madison Central H. S.	400	"	
20	Old Bridge	Salk Middle School	310	"	
21	Perth Amboy	James J. Flynn School	150	"	
22	Perth Amboy	Perth Amboy H. S.	500	"	
23	Perth Amboy	Perth Amboy Vocational H. S.	70	"	
		SUBTOTAL (TABLE CONTINUED)	5,865		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-10, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. No ARC hurricane shelter management agreements have been concluded in Middlesex County.

[4] This facility is not subject to tidal flooding. The Middlesex County list of shelters was not received in time to permit field checks for exact location and riverine flooding potential; the facility does not, however, appear to be subject to flooding from riverine sources.

TABLE 5-10 (CONTINUED)
MIDDLESEX COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[4]
24	Piscataway	Piscataway Vocational H. S.	150	See Note[5]	
25	Piscataway	Conackamack Middle School	150	"	
26	Piscataway	Schor Middle School	150	"	
27	Piscataway	Piscataway H. S.	550	"	
28	Sayreville	Enuna L. Arleth School	130	"	
29	Sayreville	Sayreville Middle School	425	"	
30	Sayreville	Wilson School	110	"	
31	Sayreville	Sayreville War Memorial H. S.	430	"	
32	South Amboy	Marold G. Hoffman H. S.	65	"	
33	South River	South River H. S.	140	"	
34	South River	Campbell School	100	"	
35	Spotswood	Spotswood H. S.	175	"	
36	Spotswood	G. Austin Schoenly School	60	"	
37	Spotswood	Raymond Appleby School	150	"	
38	Woodbridge	Woodbridge Vocational H. S.	60	"	
39	Woodbridge	Woodbridge H. S.	425	"	
40	Woodbridge	Iselin Middle School	175	"	
41	Woodbridge	Kennedy Memorial H. S.	250	"	
42	Woodbridge	Avenel Middle School	150	"	
43	Woodbridge	Fords Middle School	150	"	
		SUBTOTAL	3,995		
			9,960		

NOTES

1 Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

2 See Plate 5-10, following p. 5-30 for approximate locations of shelters.

3 American Red Cross. No ARC hurricane shelter management agreements have been concluded in Middlesex County.

4 This facility is not subject to tidal flooding. The Middlesex County list of shelters was not received in time to permit location/field checks for riverine flooding; the facility does not, however, appear to be subject to flooding from riverine sources.

TABLE 5-11
UNION COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY[3]	FLOOD POTENTIAL	ARC[4]
1	Clark Township	Carl Kumpf School		"	Yes
2	Clark Township	Charles Brewer School		"	Yes
3	Clark Township	Johnson Regional H.S.		"	Yes
4	Clark Township	Valley Road School		"	Yes
5	Elizabeth	Hamilton Junior H.S.		None[5]	Yes
6	Elizabeth	P.S. # 6		"	Yes
7	Elizabeth	P.S. # 12		"	Yes
8	Elizabeth	P.S. # 14		"	Yes
9	Elizabeth	P.S. # 16		"	Yes
10	Elizabeth	P.S. # 18		"	Yes
11	Elizabeth	P.S. # 21		"	Yes
12	Elizabeth	P.S. # 23		"	Yes
13	Linden	Linden H.S.		"	Yes
14	Linden	P.S. # 1		"	Yes
15	Linden	P.S. # 5		"	Yes
16	Linden	P.S. # 6		"	Yes
17	Linden	P.S. # 8		"	Yes
18	Linden	P.S. # 9		"	Yes
19	Linden	P.S. # 10		"	Yes
20	Rahway	Rahway H.S.		"	Yes
21	Rahway	Rahway Junior High		"	Yes

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-11, following p. 5-30 for approximate locations of shelters.

[3] Exact capacities not available; however, this Study calculates the maximum number of Union County evacuees who would seek public shelter at under 4,000. With a very conservative assumption of 200 evacuees per shelter, Union County has more than adequate shelter space.

[4] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[5] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-12
ESSEX COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY[3]	FLOOD POTENTIAL	ARC[4]
1	Bloomfield	Essex County Vo-Tech School		None[5]	Yes
2	Cedar Grove	Essex County Vo-Tech School		"	Yes
3	E. Orange	American Red Cross		"	Yes
4	E. Orange	Clark School		"	Yes
5	E. Orange	Clifford J. Scott High School		"	Yes
6	E. Orange	Columbian School		"	Yes
7	E. Orange	Community Education Center		"	Yes
8	E. Orange	Department of Public Welfare		"	Yes
9	E. Orange	E. Orange Community		"	Yes
		Development Corp.		"	
10	E. Orange	E. Orange Division		"	Yes
		of Neighborhood Facilities			
11	E. Orange	E. Orange High School		"	Yes
12	E. Orange	Elmwood School		"	Yes
13	E. Orange	Essex Catholic Boys School		"	Yes
14	E. Orange	Franklin School		"	Yes
15	E. Orange	Henry E. Kentopp School		"	Yes
16	E. Orange	Holy Name of Jesus School		"	Yes
17	E. Orange	J. Garfield Jackson Sr. School		"	Yes
18	E. Orange	John L. Costly School		"	Yes
19	E. Orange	Lincoln School		"	Yes
20	E. Orange	Nassau School		"	Yes
21	E. Orange	Our Lady of the Most		"	Yes
		Blessed Sacrament School			Yes

(TABLE CONTINUED)

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-12, following p. 5-30 for approximate locations of shelters.

[3] Exact capacities not available; however, this Study calculates the maximum number of Essex County evacuees who would seek public shelter at approximately 7,000. With a very conservative assumption of 200 evacuees per shelter, Essex County has more than adequate shelter space.

[4] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[5] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-12 (CONTINUED)
ESSEX COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY[3]	FLOOD POTENTIAL	ARC[4]
22	E. Orange	Our Lady Help Of Christians School		None[5]	Yes
					Yes
23	E. Orange	Our Lady of All Souls School		"	Yes
24	E. Orange	Patrick Francis Healy School		"	Yes
25	E. Orange	Salvation Army		"	Yes
26	E. Orange	Sojourner Truth School		"	Yes
27	E. Orange	St. Joseph's School		"	Yes
28	E. Orange	Stockton School		"	Yes
29	E. Orange	Upsala College		"	Yes
30	E. Orange	Vernon L. Davey, Jr. School		"	Yes
31	E. Orange	Washington School		"	Yes
32	E. Orange	William S. Hart Education Center		"	Yes
33	Newark	Barringer High		"	Yes
34	Newark	Central High		"	Yes
35	Newark	Essex County Vo-Tech School		"	Yes
36	Newark	Weequahic High		"	Yes
37	Newark	West Side High		"	Yes
38	West Caldwell	Essex County Vo-Tech School		"	Yes

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-12, following p. 5-30 for approximate locations of shelters.

[3] Exact capacities not available; however, this Study calculates the maximum number of Essex County evacuees who would seek public shelter at approximately 7,000. With a very conservative assumption of 200 evacuees per shelter, Essex County has more than adequate shelter space.

[4] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[5] "None" indicates facility is not in a riverine or tidal flood hazard area.

TABLE 5-13
HUDSON COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY[3]	FLOOD POTENTIAL	ARC[4]
1	Bayonne	Bayonne High School		None[5]	Yes
2	Bayonne	Bayonne Vocational School		"	Yes
3	Bayonne	Horace Mann School		"	Yes
4	Bayonne	Public School #12		"	Yes
5	Bayonne	Public School #3		"	Yes
6	Bayonne	Public School #4		"	Yes
7	Bayonne	Philip Vroom School		"	Yes
8	Bayonne	Washington School		"	Yes
9	Bayonne	Woodrow Wilson School		"	Yes
10	East Newark	East Newark Recreational Ctr		"	Yes
11	East Newark	St Anthony's Social Ctr		"	Yes
12	Jersey City	Academic High School		"	Yes
13	Jersey City	Dickenson High School		"	Yes
14	Jersey City	Lincoln High School		"	Yes
15	Jersey City	Public School No. 05		"	Yes
16	Jersey City	Public School No. 08		"	Yes
17	Jersey City	Public School No. 11		"	Yes
18	Jersey City	Public School No. 12		"	Yes
19	Jersey City	Public School No. 14		"	Yes
20	Jersey City	Public School No. 15		"	Yes
21	Jersey City	Public School No. 17		"	Yes
22	Jersey City	Public School No. 18		"	Yes
23	Jersey City	Public School No. 20		"	Yes
24	Jersey City	Public School No. 23		"	Yes
25	Jersey City	Public School No. 24		"	Yes
26	Jersey City	Public School No. 25		"	Yes
27	Jersey City	Public School No. 27		"	Yes
28	Jersey City	Public School No. 28		"	Yes
29	Jersey City	Public School No. 29		"	Yes
30	Jersey City	Public School No. 30		"	Yes

(TABLE CONTINUED)

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-13, following p. 5-30 for approximate locations of shelters.

[3] Exact capacities not available; however, this Study calculates the maximum number of Hudson County evacuees who would seek public shelter at approximately 14000. With a very conservative assumption of 250 evacuees per shelter, Hudson County has more than adequate shelter space.

[4] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[5] "None" indicates facility is not in a tidal or riverine flood hazard area.

TABLE 5-13
HUDSON COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY[3]	FLOOD POTENTIAL	ARC[4]
31	Jersey City	Public School No. 31		None[5]	Yes
32	Jersey City	Public School No. 33		"	Yes
33	Jersey City	Public School No. 34		"	Yes
34	Jersey City	Public School No. 35		"	Yes
35	Jersey City	Public School No. 38		"	Yes
36	Jersey City	Public School No. 40		"	Yes
37	Jersey City	Public School No. 41		"	Yes
38	Jersey City	Public School No. 42		"	Yes
39	Jersey City	Snider High School		"	Yes
40	Kearney	Franklin School		"	Yes
41	Kearney	Garfield School		"	Yes
42	Kearney	Kearney High School		"	Yes
43	Kearney	Lincoln School		"	Yes
44	Kearney	Roosevelt School		"	Yes
45	Kearney	Schuyler School		"	Yes
46	Kearney	Washington School		"	Yes
47	North Bergen	Franklin Grammar School		"	Yes
48	North Bergen	Horace Mann Grammar School		"	Yes
49	North Bergen	IHM (Head Start)		"	Yes
50	North Bergen	Kennedy Grammar School		"	Yes
51	North Bergen	Lincoln Grammar School		"	Yes
52	North Bergen	North Bergen High School		"	Yes
53	North Bergen	Robert Fulton Grammar School		"	Yes
54	North Bergen	Sacred Heart Catholic School		"	Yes
55	North Bergen	St. John's Catholic School		"	Yes
56	Weehawken	Weehawken High School		"	Yes
57	Weehawken	Weehawken Senior Citizen Bldg		"	Yes
58	Weehawken	Weehawken Senior Nutrition Ctr		"	Yes
59	Weehawken	Woodrow Wilson		"	Yes
60	West New York	West New York Rec. Ctr		"	Yes

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-13, following p. 5-30 for approximate locations of shelters.

[3] Exact capacities not available; however, this Study calculates the maximum number of Hudson County evacuees who would seek public shelter at approximately 14000. With a very conservative assumption of 250 evacuees per shelter, Hudson County has more than adequate shelter space.

[4] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[5] "None" indicates facility is not in a tidal or riverine flood hazard area.

TABLE 5-14
BERGEN COUNTY
PUBLIC SHELTER FACILITIES[1]

MAP KEY[2]	LOCATION	FACILITY	CAPACITY	FLOOD POTENTIAL	ARC[3]
1	East Rutherford	Becton Regional H.S.	1000	See Note[4]	Yes
2	Hackensack	Bergen Co. Vocational and Technical H.S.	1000	See Note[4]	Yes
		TOTAL	**2000**		

NOTES

[1] Inclusion on this list does not indicate that a facility will be used in a given hurricane evacuation. The choice of public shelters for a specific evacuation is an operational decision made by local emergency management officials.

[2] See Plate 5-14, following p. 5-30 for approximate locations of shelters.

[3] American Red Cross. "Yes" indicates that the ARC has agreed to operate the facility as a hurricane shelter.

[4] This facility is close to the perimeter of an area subject to tidal flooding from major hurricanes [No elevation survey performed by Philadelphia District]. County emergency management should compare lowest floor elevations of shelter space and access road elevations to the maximum surge elevations found on County Storm Surge Inundation Areas and Evacuation Network Maps in order to ascertain suitability.

TABLE 5-15(A)
SOUTHERN COUNTIES
PUBLIC SHELTER DEMAND/CAPACITY[1]

COUNTY	STORM SCENARIO	SEASONAL OCCUPANCY	MAXIMUM SHELTER DEMAND	MAXIMUM SHELTER CAPACITY
BURLINGTON	CATEGORY 1	N.A.	1,461	3,190
	CATEGORY 2-4		4,102	
CAMDEN	CATEGORY 1-4	N.A.	4,498	5,760
GLOUCESTER	CATEGORY 1-4	N.A.	4,249	7,180
SALEM	CATEGORY 1-2	N.A.	3,308	2,850
	CATEGORY 3-4		4,187	
CUMBERLAND	CATEGORY 1-4	N.A.	2,404	3,007
CAPE MAY	CATEGORY 1-2	LOW	8,942	SEE NOTE[2]
		MEDIUM	14,260	
		HIGH	30,218	
	CATEGORY 3-4	LOW	12,787	
		MEDIUM	18,105	
		HIGH	34,063	
ATLANTIC	CATEGORY 1-2	LOW	20,297	30,794
		MEDIUM	24,313	
		HIGH	27,599	
	CATEGORY 3-4	LOW	26,239	
		MEDIUM	30,255	
		HIGH	33,541	
OCEAN	CATEGORY 1-2	LOW	18,053	58,251
		HIGH	21,631	
	CATEGORY 3-4	LOW	34,783	
		HIGH	38,361	
MONMOUTH	CATEGORY 1-2	LOW	16,551	17,187
		HIGH	23,021	
	CATEGORY 3-4	LOW	28,228	
		HIGH	34,698	

NOTES

[1] The percentages of evacuees assumed to go to various destination types, including public shelter, were developed after careful review of information available in past behavioral research. Where destination desires could not be satisfied with in-county capacities, the transportation analysis assumed that evacuees would have to leave the county to find acceptable shelter.

[2] Current Cape May County Emergency Management plans do not include in-county public sheltering for hurricane threats (See Table 5-6, Note 1).

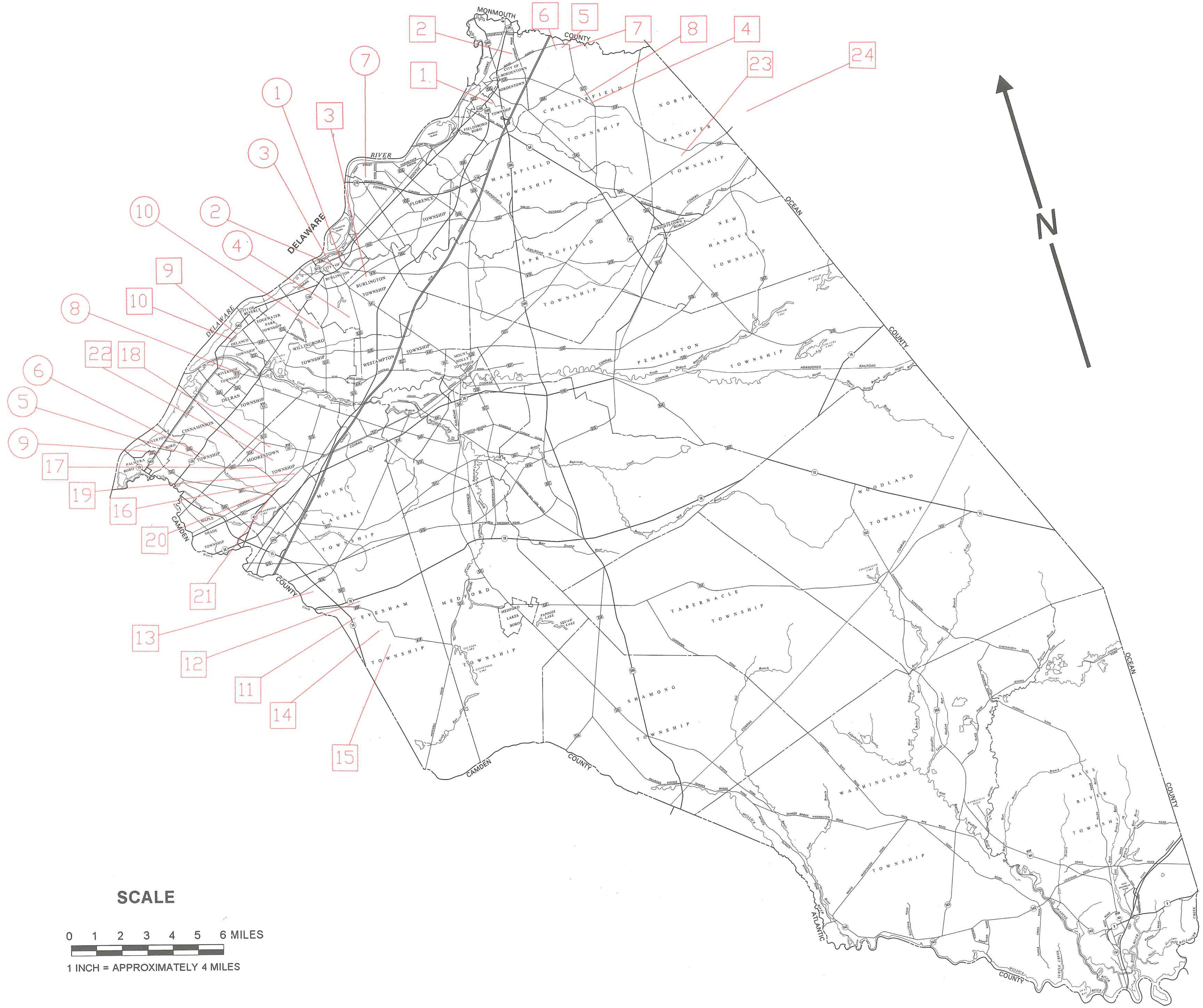
TABLE 5-15(B)
METROPOLITAN NEW YORK AREA COUNTIES
ESTIMATED PUBLIC SHELTER DEMAND/CAPACITY[1]

COUNTY	STORM SCENARIO	SEASONAL OCCUPANCY	MAXIMUM SHELTER DEMAND	MAXIMUM SHELTER CAPACITY
MIDDLESEX	CATEGORY 1-2	N.A.	610	9,960
	CATEGORY 3-4		2,070	
UNION	CATEGORY 1	N.A.	100	SEE NOTE[2]
	CATEGORY 2-4		1,710	
ESSEX	CATEGORY 1	N.A.	940	SEE NOTE[2]
	CATEGORY 2-4		5,260	
HUDSON	CATEGORY 1	N.A.	3,250	SEE NOTE[2]
	CATEGORY 2-4		8,262	
BERGEN	CATEGORY 1-4	N.A.	1,090	2,000

NOTES

[1] The percentages of evacuees assumed to go to various destination types, including public shelter, were developed after careful review of information available in past behavioral research. Where destination desires could not be satisfied with in-county capacities, the transportation analysis assumed that evacuees would have to leave the county to find acceptable shelter.

[2] Exact capacities were not available for Union, Essex or Hudson Counties. However, using very conservative assumptions regarding capacities per available shelter, all three counties appear to have more than adequate shelter space.



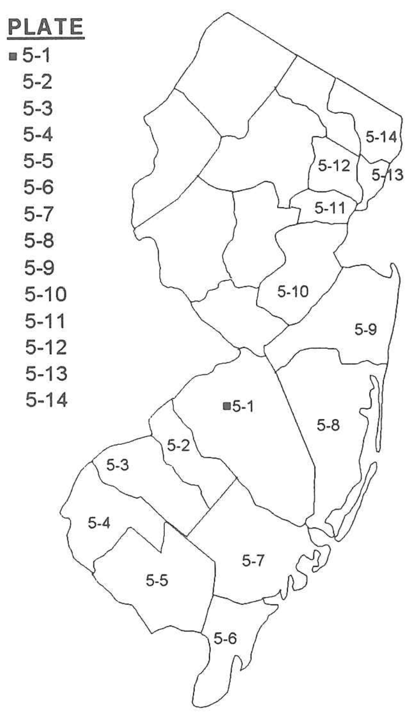
LEGEND

MEDICAL FACILITY/ INSTITUTIONAL LOCATION
See Table 3-1 for List of Facilities Mapped

PUBLIC SHELTER LOCATION
See Table 5-1 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	■5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14



SCALE

0 1 2 3 4 5 6 MILES

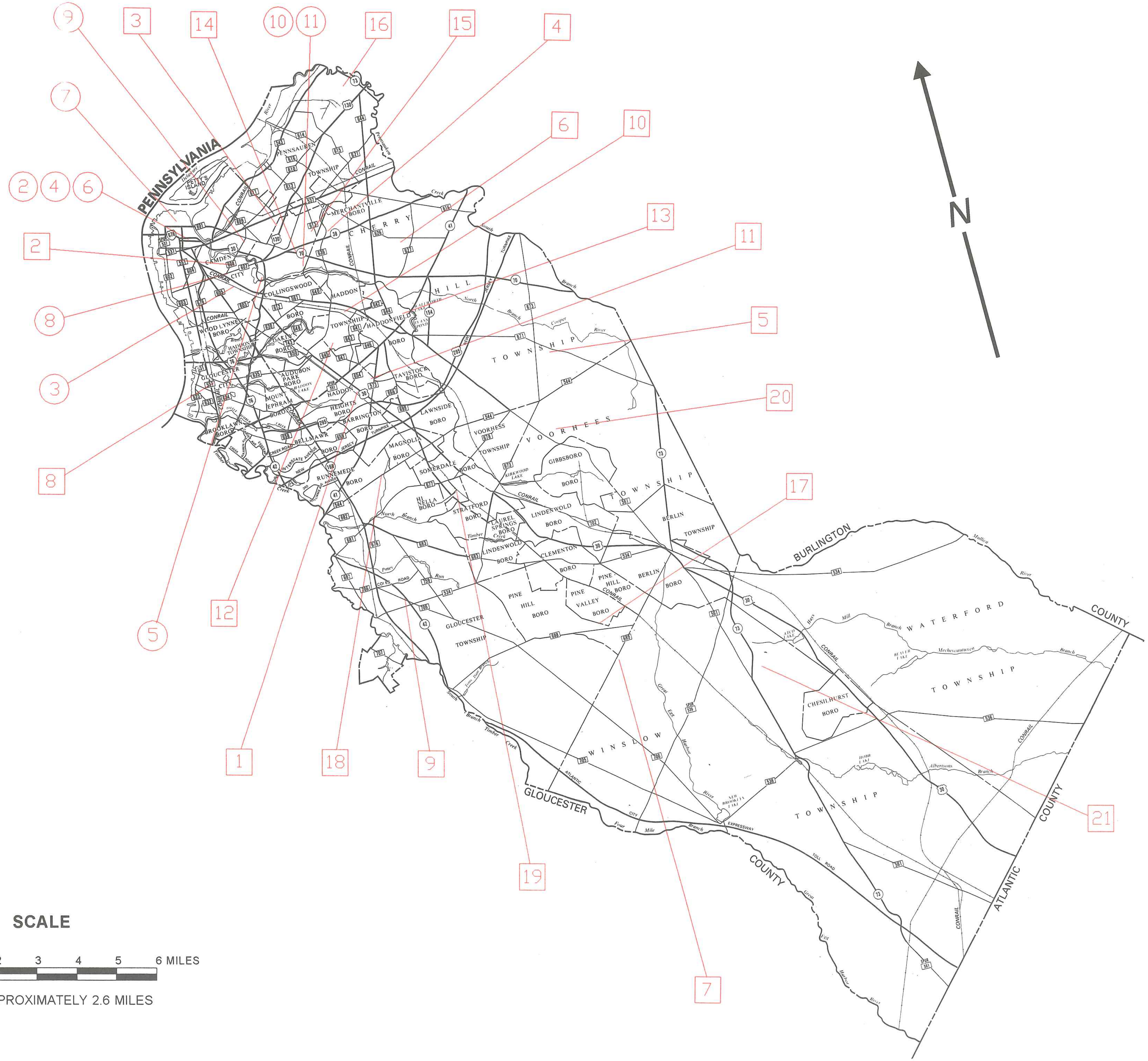
1 INCH = APPROXIMATELY 4 MILES

NEW JERSEY HURRICANE EVACUATION STUDY

BURLINGTON COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-1

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



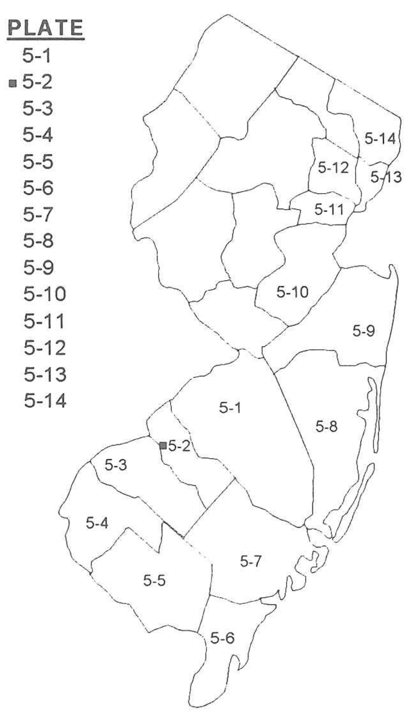
LEGEND

MEDICAL FACILITY/ INSTITUTIONAL LOCATION
See Table 3-2 for List of Facilities Mapped

PUBLIC SHELTER LOCATION
See Table 5-2 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	▪ 5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

CAMDEN COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-2

Prepared by the U.S. Army Corps of Engineers, Philadelphia District,
in cooperation with the Federal Emergency Management Agency Region II
for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2.6 MILES

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

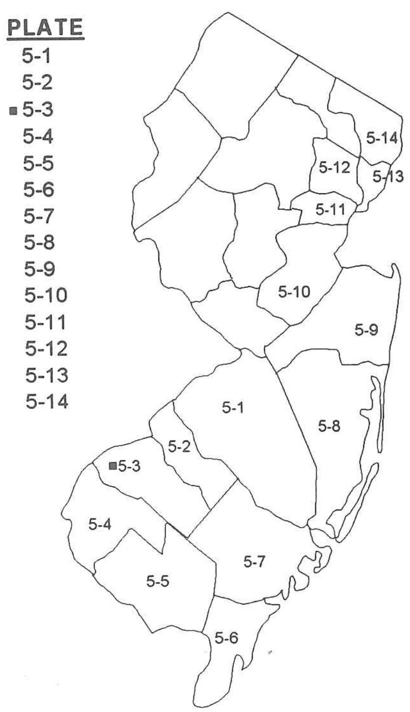
LEGEND

(3) **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-3 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-3 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	▪5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14

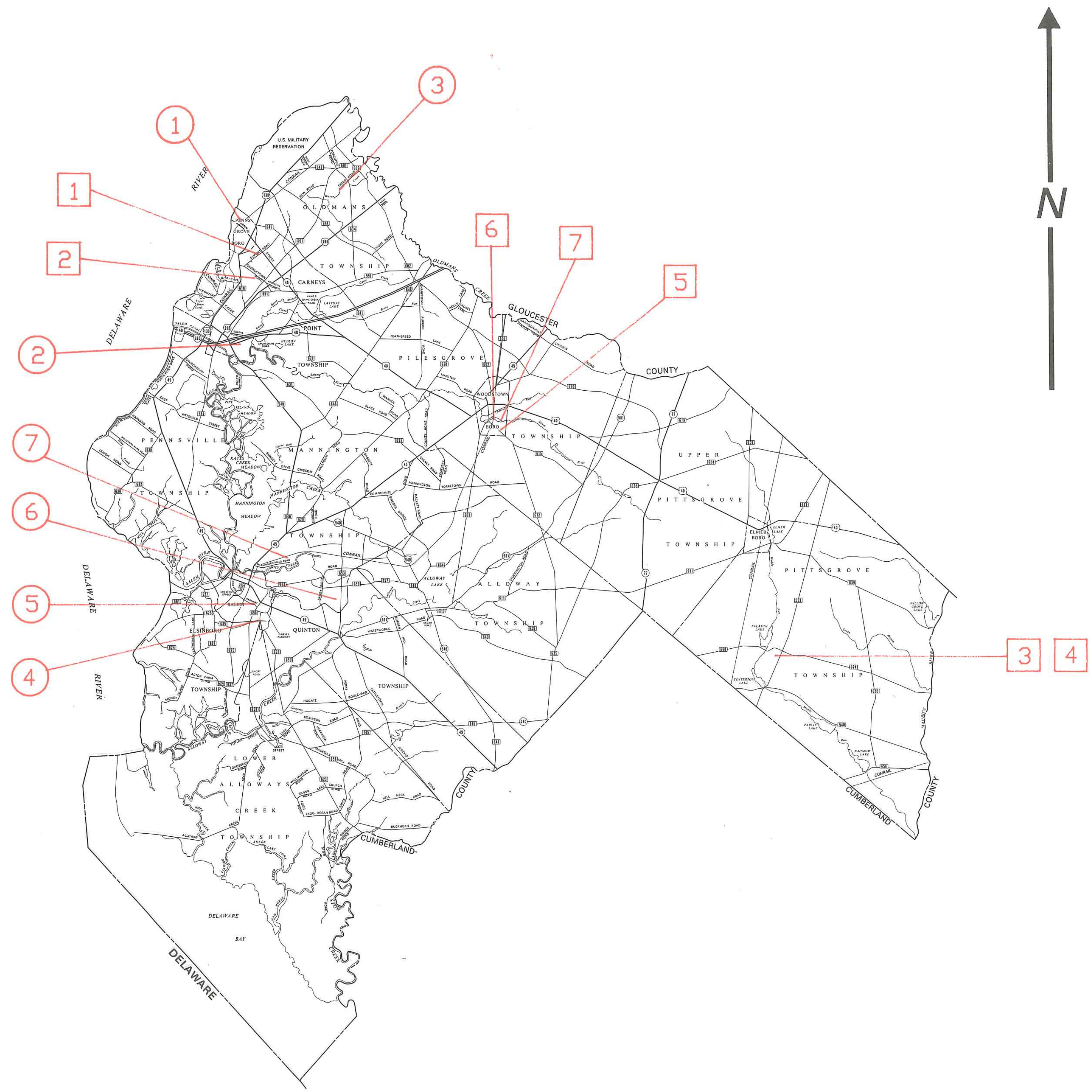


NEW JERSEY
HURRICANE EVACUATION STUDY

GLOUCESTER COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-3

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



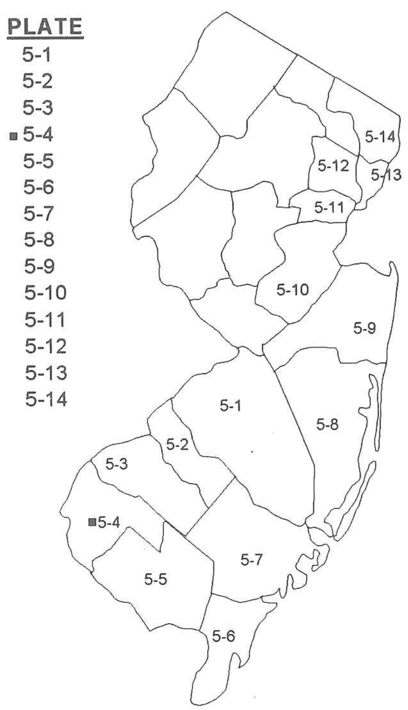
LEGEND

(3) **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-4 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-4 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	■5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

SALEM COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-4

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

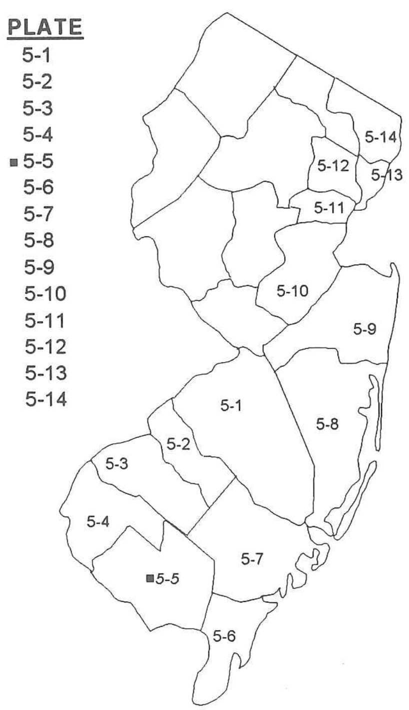
LEGEND

(3) **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-5 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-5 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	■5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14

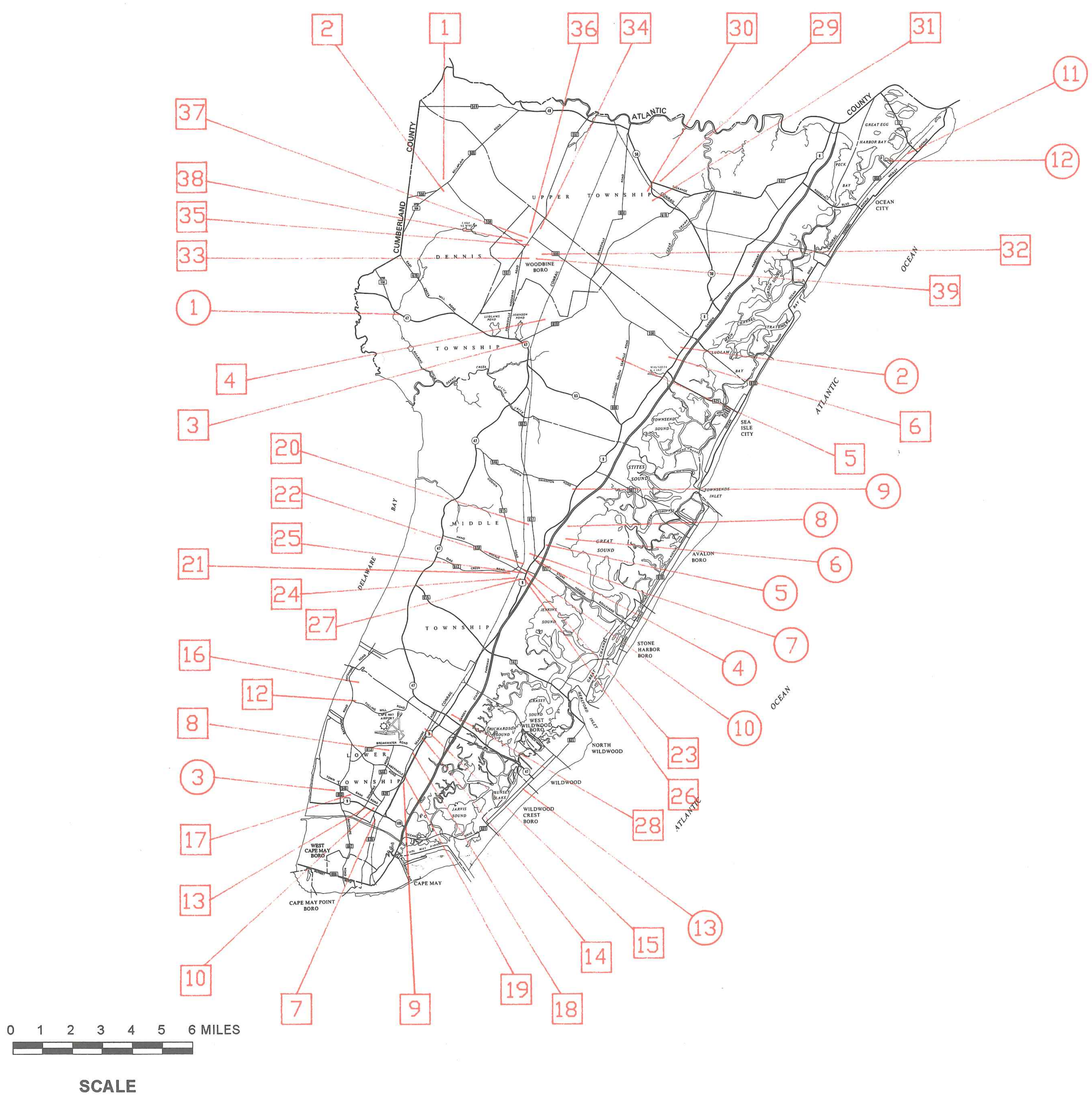


NEW JERSEY
HURRICANE EVACUATION STUDY

CUMBERLAND COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-5

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



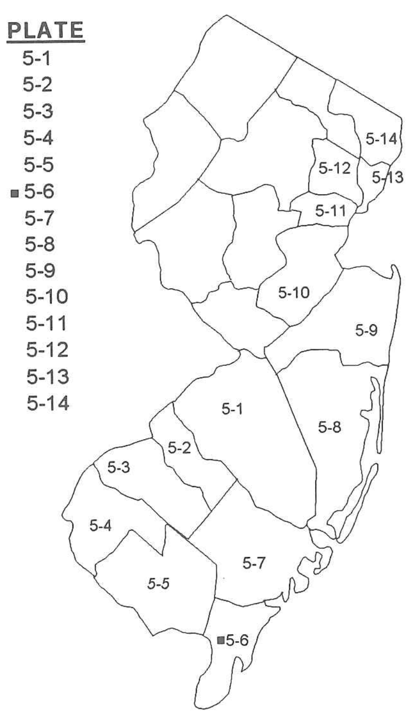
LEGEND

MEDICAL FACILITY/ INSTITUTIONAL LOCATION
See Table 3-6 for List of Facilities Mapped

PUBLIC SHELTER LOCATION *Current Cape May County evacuation plans do not include in-county public sheltering for hurricane threats. See Note (1), Table 5-6.*

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	▪5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14

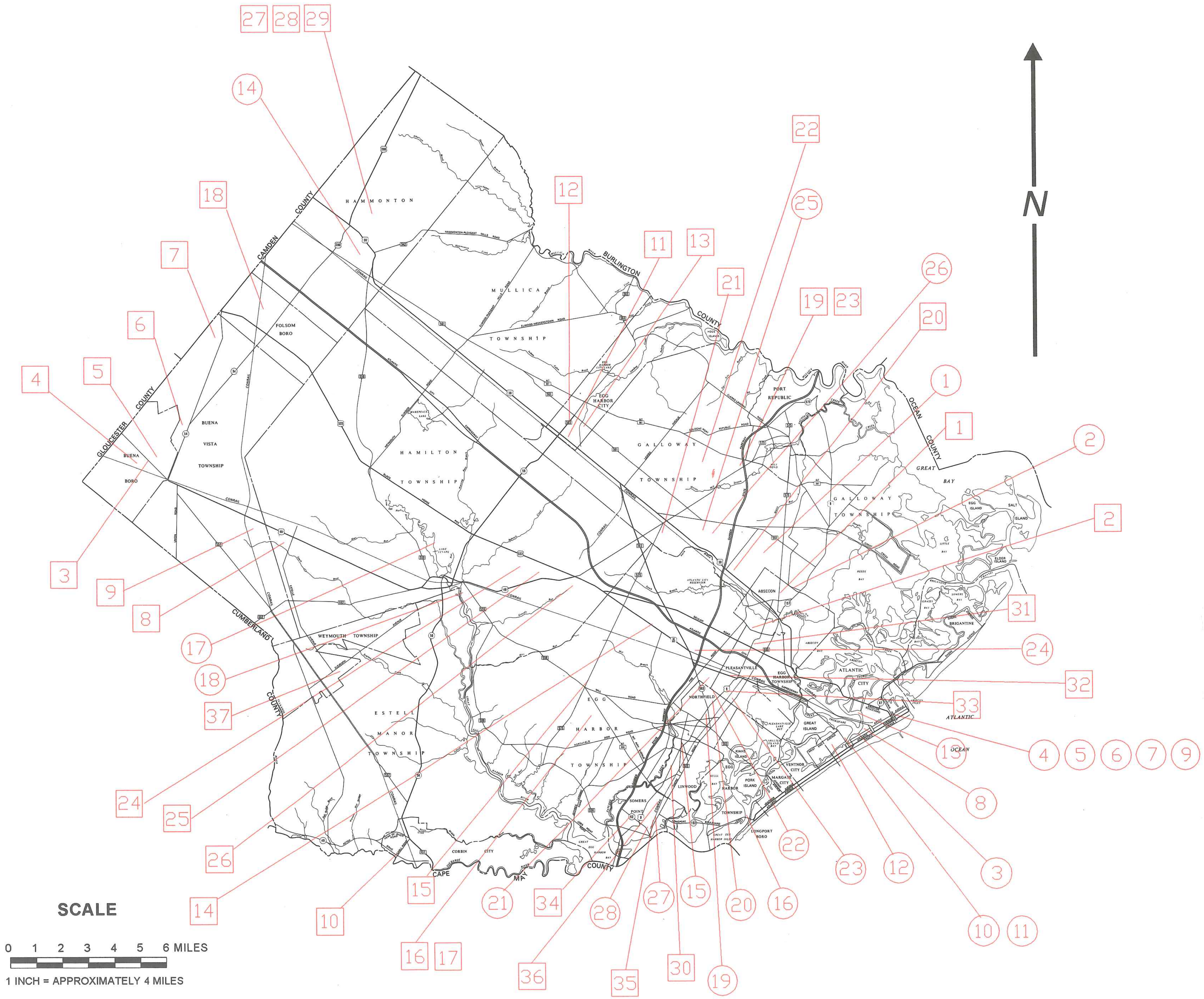


NEW JERSEY
HURRICANE EVACUATION STUDY

CAPE MAY COUNTY
PUBLIC SHELTERS
MEDICAL FACILITIES/
INSTITUTIONS

PLATE 5-6

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



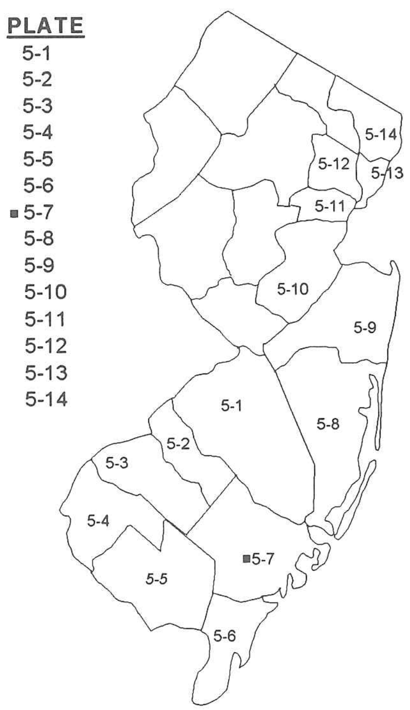
LEGEND

(3) **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-7 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-7 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	▪5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14

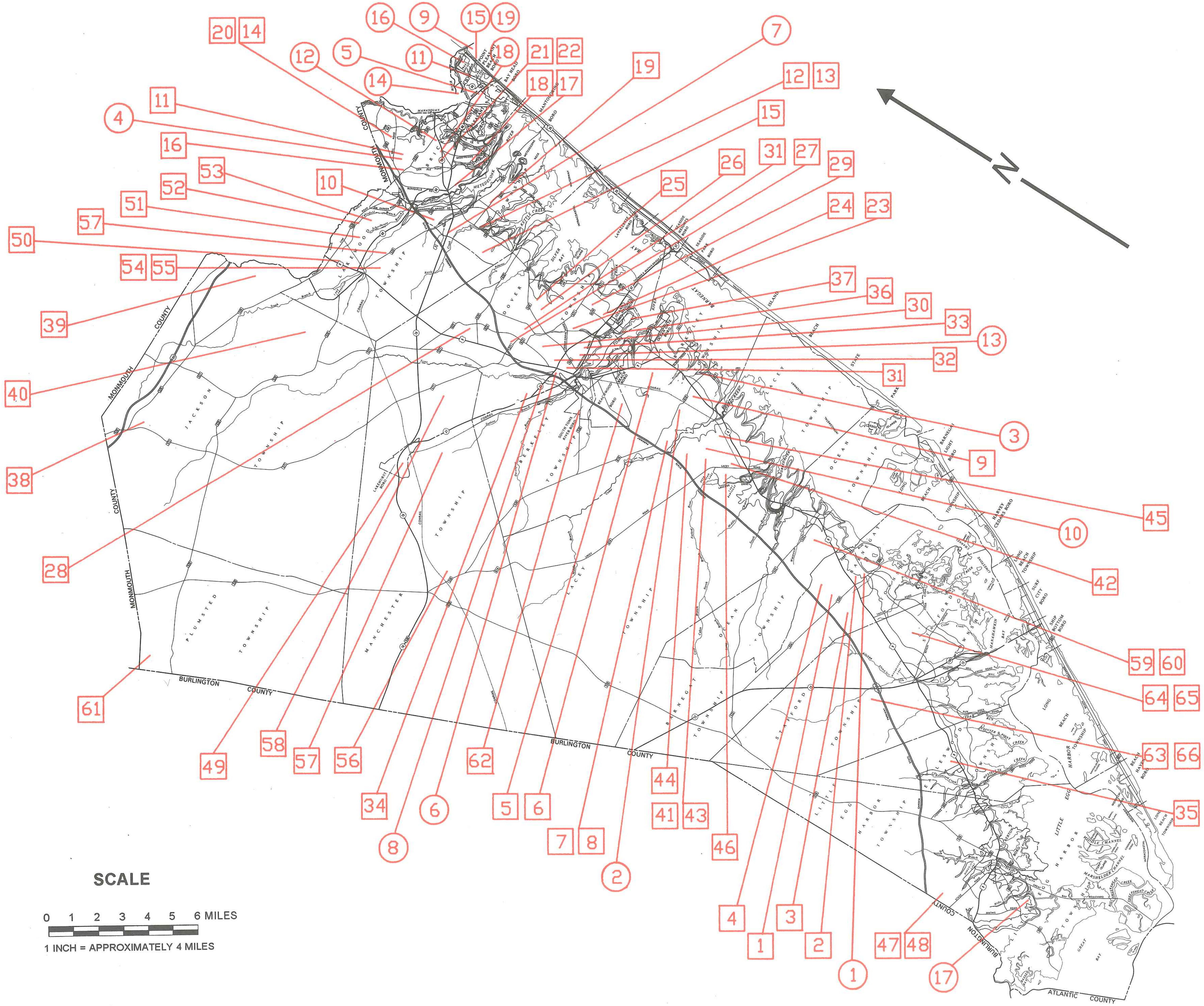


NEW JERSEY
HURRICANE EVACUATION STUDY

ATLANTIC COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-7

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



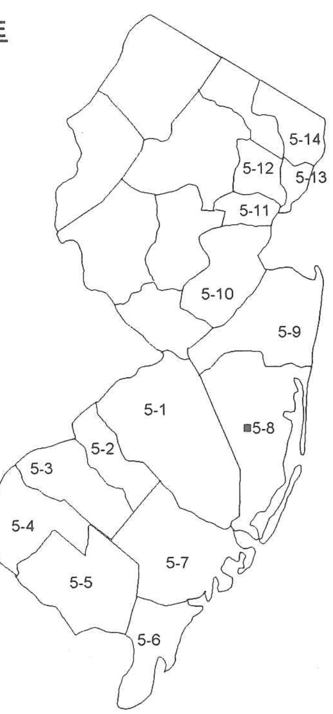
LEGEND

3 (circle) — **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-8 for List of Facilities Mapped

3 (square) — **PUBLIC SHELTER LOCATION**
See Table 5-8 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	■5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

OCEAN COUNTY
PUBLIC SHELTERS
MEDICAL FACILITIES/
INSTITUTIONS

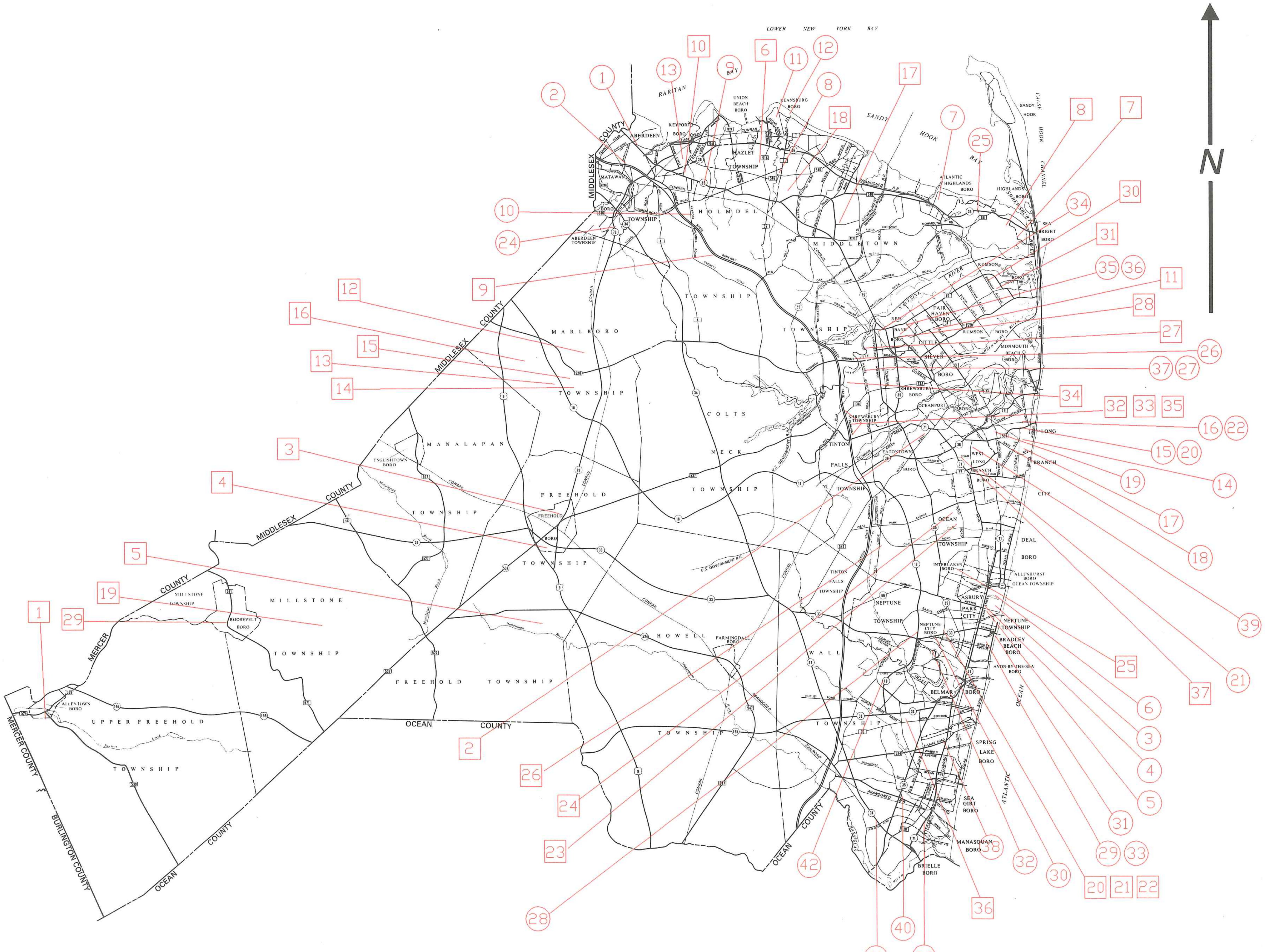
PLATE 5-8

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 3.4 MILES

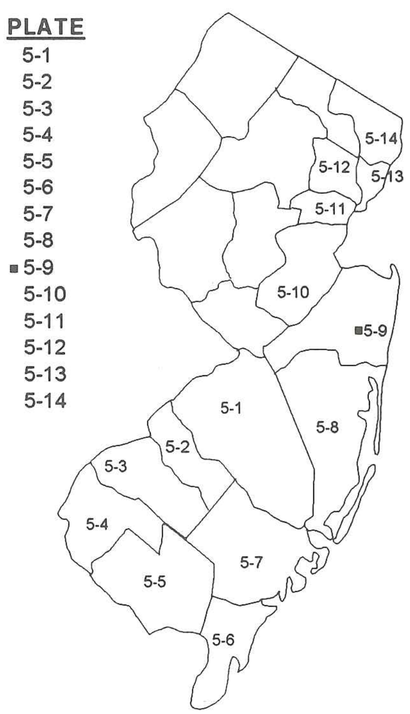
LEGEND

③ **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-9 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-9 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	▪5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14

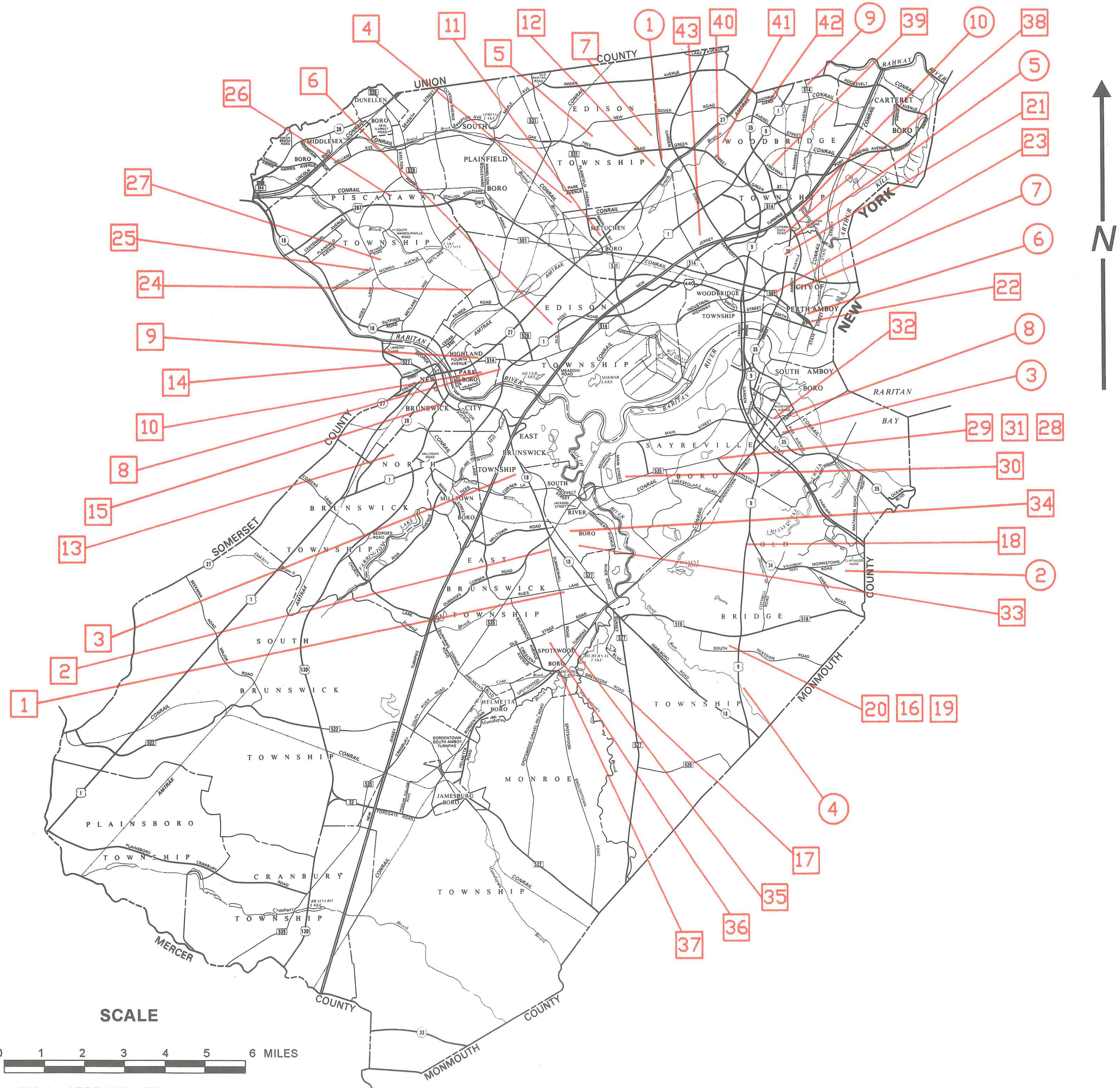


NEW JERSEY HURRICANE EVACUATION STUDY

MONMOUTH COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-9

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2.6 MILES

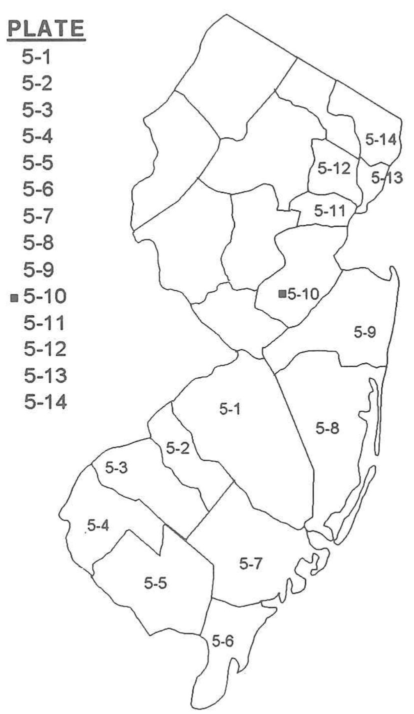
LEGEND

MEDICAL FACILITY/ INSTITUTIONAL LOCATION
See Table 3-10 for List of Facilities Mapped

PUBLIC SHELTER LOCATION
See Table 5-10 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	▪5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14

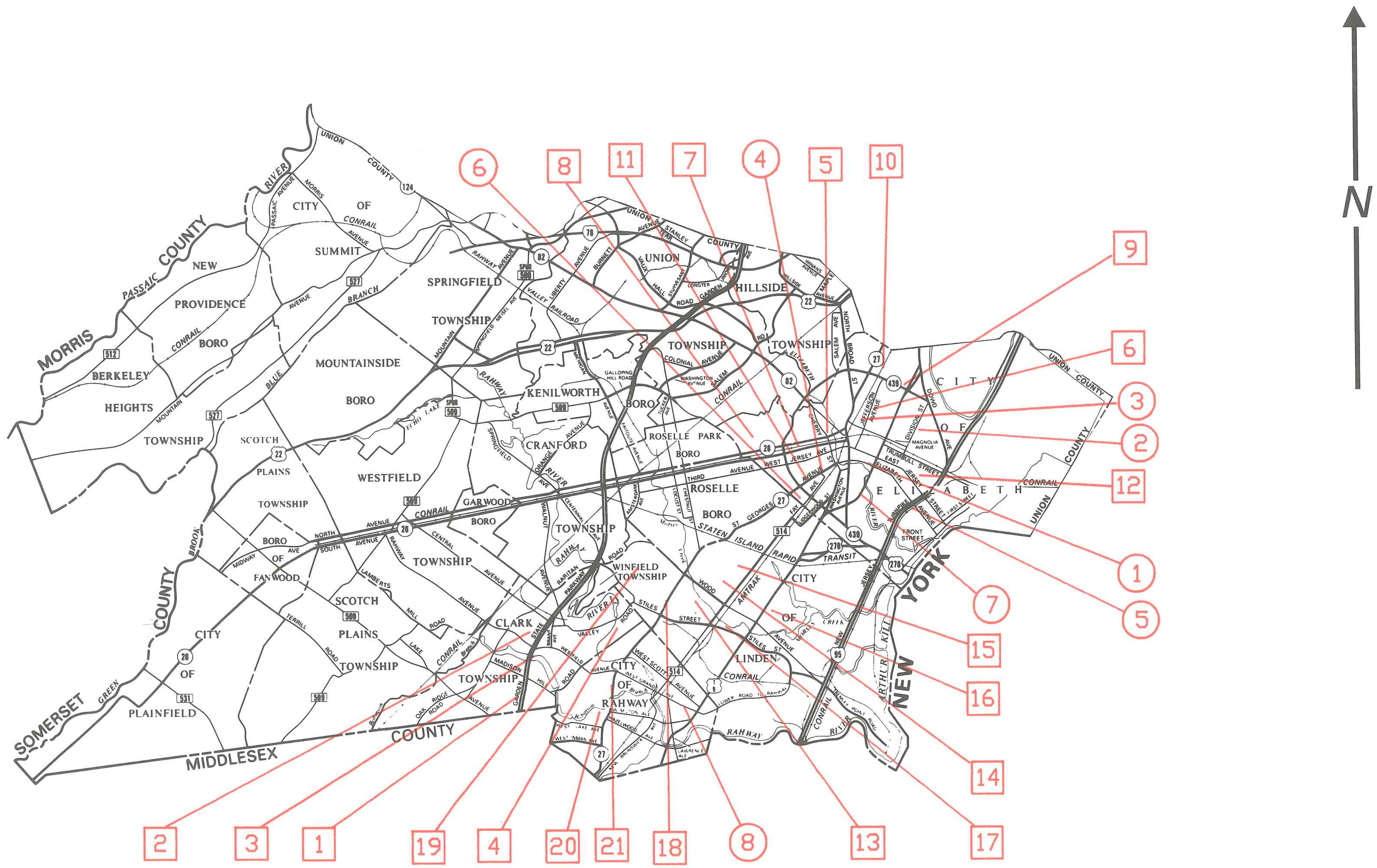


NEW JERSEY
HURRICANE EVACUATION STUDY

MIDDLESEX COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-10

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

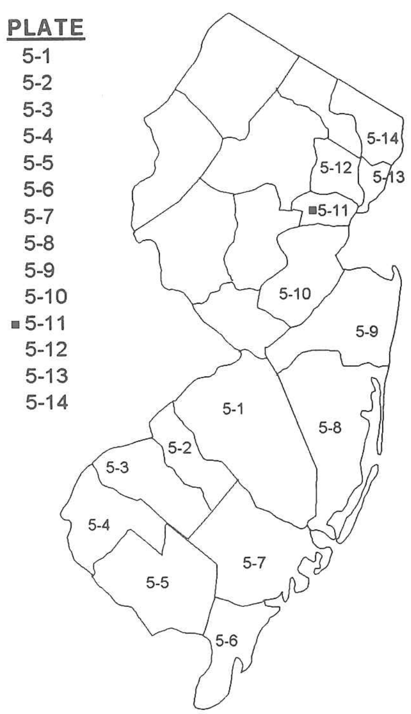
LEGEND

③ **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-11 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-11 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	▪5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

UNION COUNTY
PUBLIC SHELTERS
MEDICAL FACILITIES/
INSTITUTIONS

PLATE 5-11

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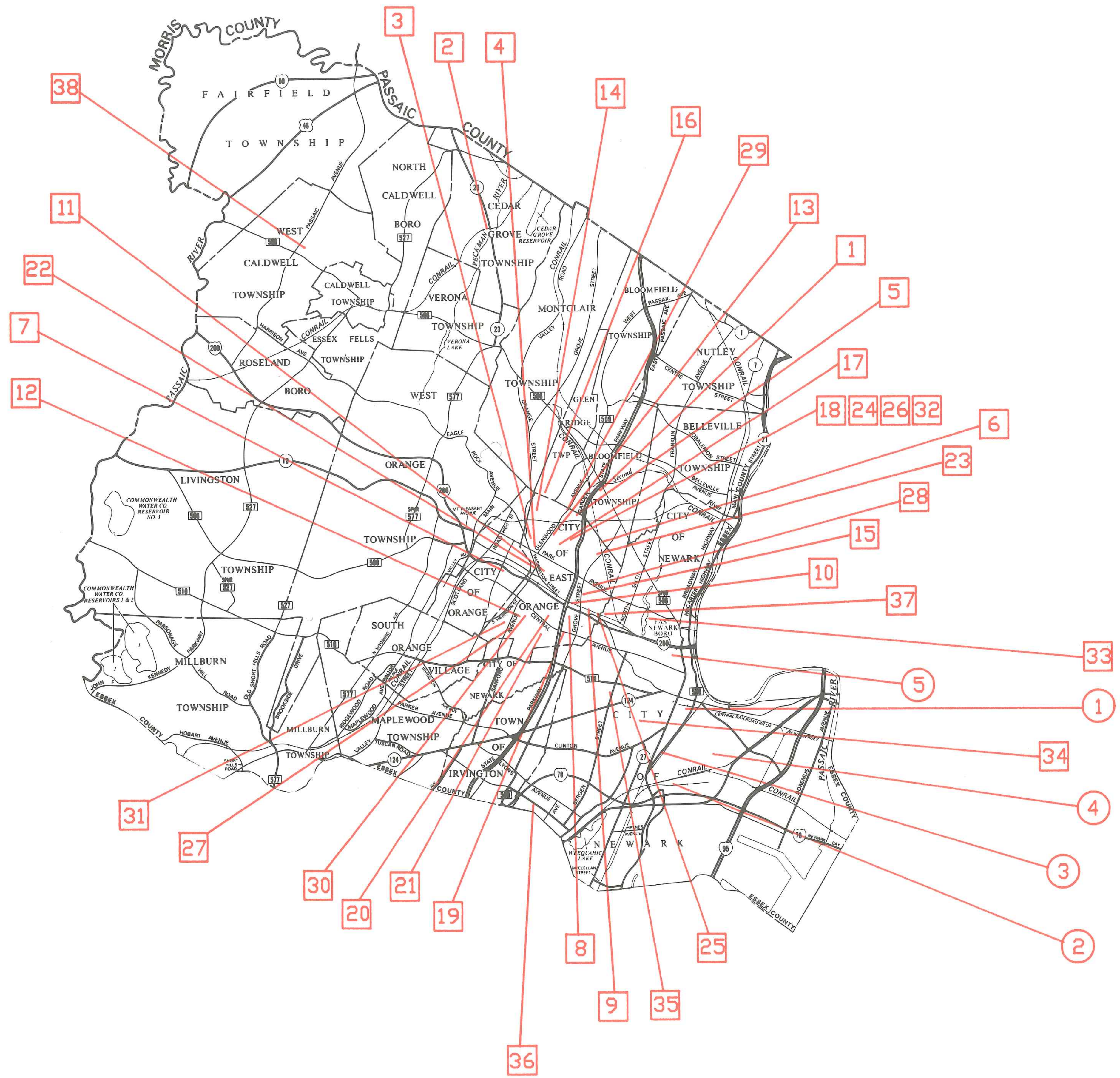
for the New Jersey State Police Office of Emergency Management



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

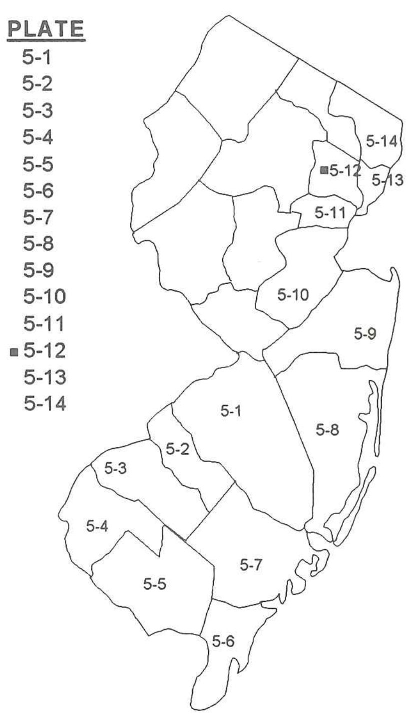
LEGEND

(3) **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-12 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-12 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	■ 5-12
HUDSON	5-13
BERGEN	5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

ESSEX COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-12

Prepared by the U.S. Army Corps of Engineers, Philadelphia District,
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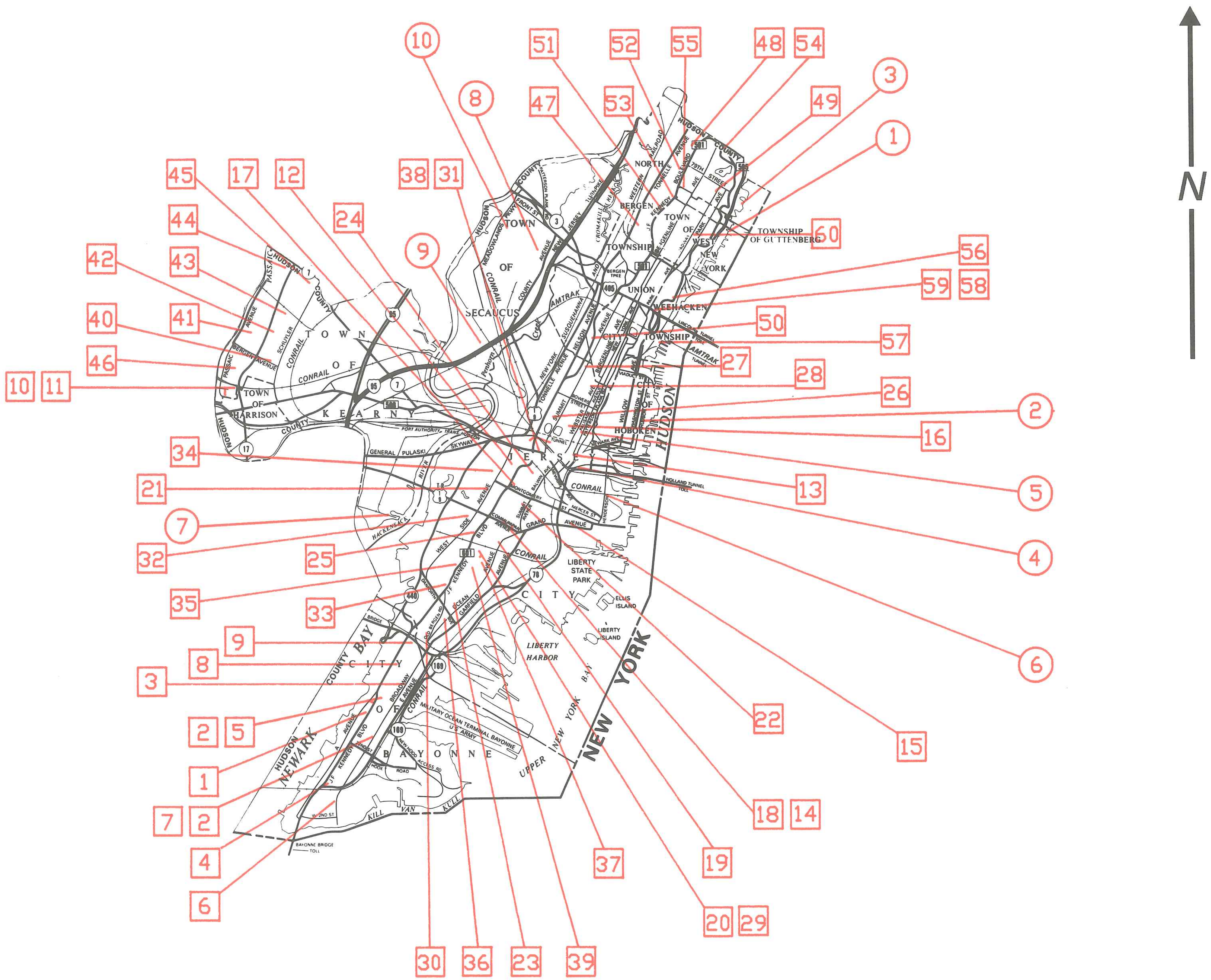
for the New Jersey State Police Office of Emergency Management



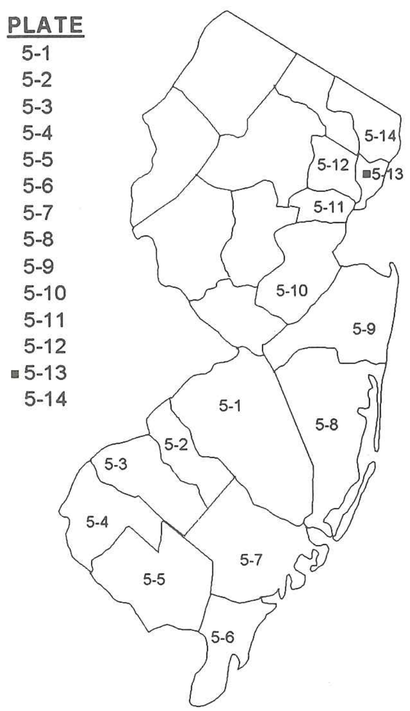
LEGEND

MEDICAL FACILITY/ INSTITUTIONAL LOCATION
See Table 3-13 for List of Facilities Mapped

PUBLIC SHELTER LOCATION
See Table 5-13 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	▪5-13
BERGEN	5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

**HUDSON COUNTY
PUBLIC SHELTERS
MEDICAL FACILITIES/
INSTITUTIONS**

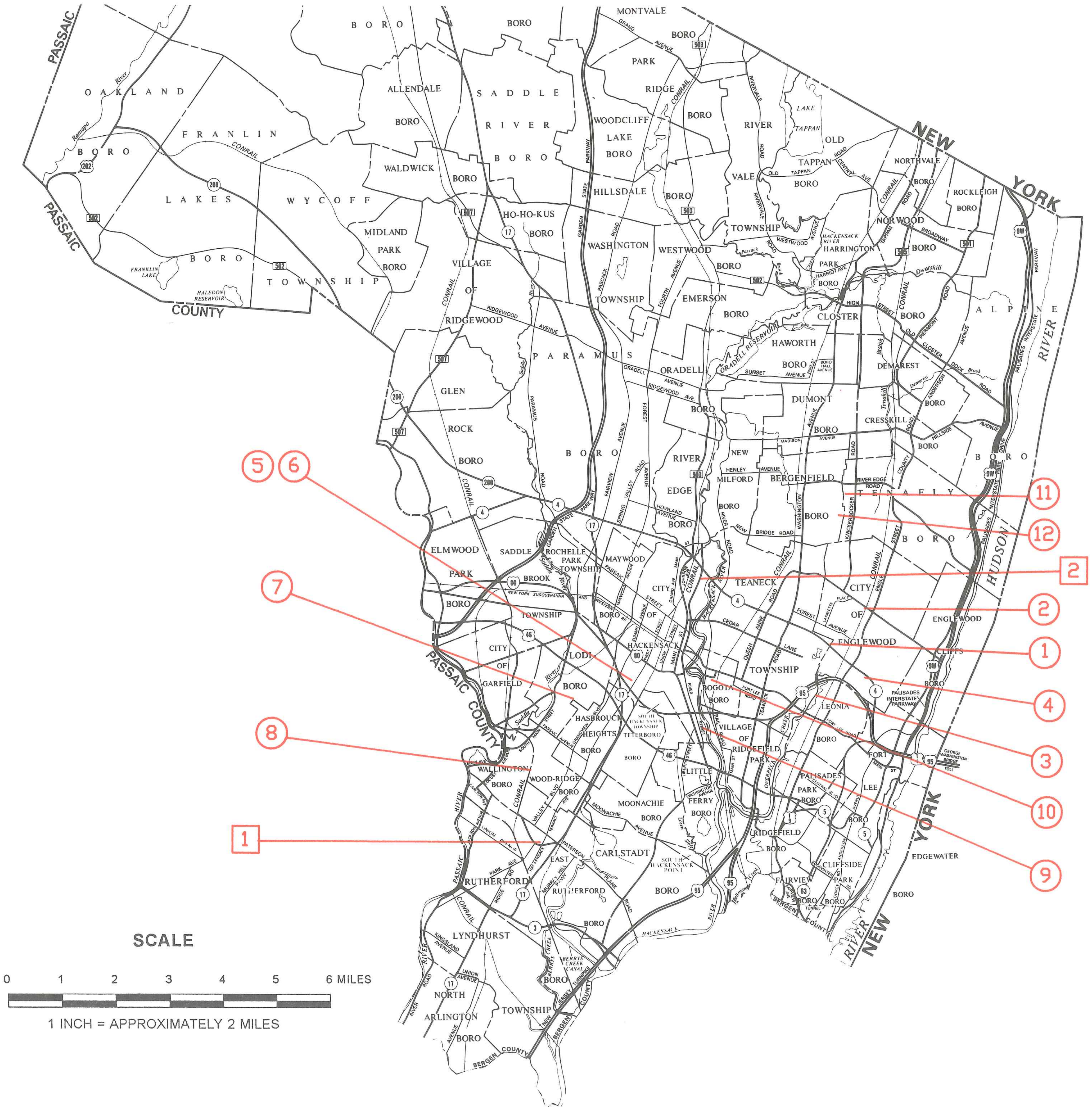
PLATE 5-13

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

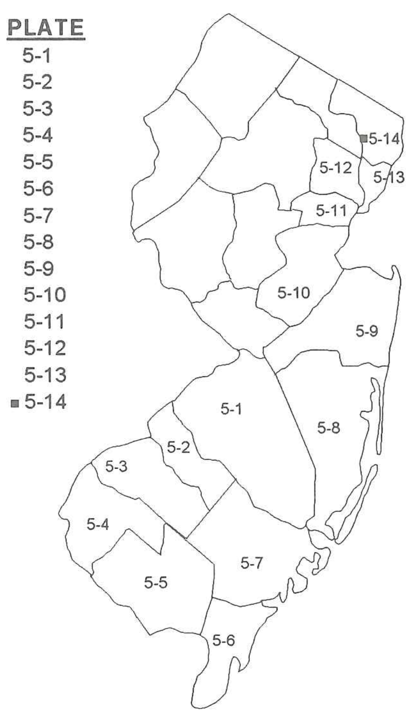
LEGEND

③ **MEDICAL FACILITY/ INSTITUTIONAL LOCATION**
See Table 3-14 for List of Facilities Mapped

[3] **PUBLIC SHELTER LOCATION**
See Table 5-14 for List of Shelters

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	5-1
CAMDEN	5-2
GLOUCESTER	5-3
SALEM	5-4
CUMBERLAND	5-5
CAPE MAY	5-6
ATLANTIC	5-7
OCEAN	5-8
MONMOUTH	5-9
MIDDLESEX	5-10
UNION	5-11
ESSEX	5-12
HUDSON	5-13
BERGEN	▪5-14



NEW JERSEY
HURRICANE EVACUATION STUDY

BERGEN COUNTY PUBLIC SHELTERS MEDICAL FACILITIES/ INSTITUTIONS

PLATE 5-14

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

Chapter Six

TRANSPORTATION ANALYSIS

6.1 PURPOSE

During a hurricane evacuation a large number of vehicles have to move across a road network in a relatively short period of time. The number of vehicles and evacuees becomes particularly significant for an area such as the New Jersey coast, where many seasonal beach communities are located. The volume of evacuating vehicles varies depending upon the intensity of the hurricane, presence of tourists, and certain behavioral response characteristics of the vulnerable population. Vehicles enter the road network at different times depending on the timing of evacuees' response relative to an evacuation order or advisory. Conversely, vehicles leave the road 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 road network from trip origin to destination at a speed dependent on the traffic loadings and capacities of various roadway segments.

The overall goals of the transportation analysis performed for the New Jersey hurricane evacuation Study were to estimate clearance times (the time it takes to clear a county's roadways of all evacuating vehicles), to define the evacuation road network, and to look at general traffic control measures that could improve traffic flow along critical roadway segments. Results of the analysis must be combined with pre-landfall hazards data to determine when a strong evacuation advisory must be issued to allow all evacuees time to reach safe shelter before the arrival of sustained tropical storm winds. Factors that influence clearance time must be studied in detail to determine which factors have the strongest influence. Therefore, a sensitivity analysis was performed with approximately 24 clearance times calculated for each county by varying key input parameters.

6.2 EVACUATION TRAVEL PATTERNS

6.2.1 General

The transportation analysis task initially identified the kinds of traffic movements associated with a hurricane evacuation that must be considered in the development of clearance times. Basic assumptions for the transportation analysis were then developed related to storm scenarios, population-at-risk, behavioral and socioeconomic characteristics, the roadway system and traffic control. A transportation modeling methodology and a roadway system representation were developed for each county 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 chapter. A transportation model support document is available through the Philadelphia District Corps of Engineers and includes a detailed account of all transportation modeling activities and zone by zone data listings for each county.

6.2.2 Traffic Movements

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

A. In-County Origins to In-County Destinations

Trips made from storm surge vulnerable areas, mobile home units, and historically heavy rain flooded areas in an individual county to destinations within the same county, such as public shelters, hotel and motel units, and friends or relatives outside the storm surge vulnerable areas. *Example: Trip from the City of Margate (Absecon Island), Atlantic County, to Hammonton Township, Atlantic County.*

B. In-County Origins to Out-of-County Destinations

Trips made as in Pattern A that originate in an individual county, but have destinations in other counties of the Study area or outside the Study area entirely. *Example: Trip from the City of Margate to Philadelphia, PA.*

C. Out-of-County Origins to In-County Destinations

Trips made as in Pattern A that enter an individual county from other counties in the Study area. *Example: Trip from Ocean City, Cape May County to Hammonton Township, Atlantic County.*

D. Out-of-County Origins to Out-of-County Destinations

Trips passing through an individual county while traveling from another county in the Study area to either another county or outside the Study area entirely. *Example: Trip from Ocean City, Cape May County, through Atlantic County, to Philadelphia, PA.*

E. Background Traffic

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

Figure 6-1 (p. 6-4) graphically depicts these traffic movement patterns associated with hurricane evacuation situations in New Jersey. It is important to recognize that three of the five defined patterns involve traffic movement patterns generated outside of one county's boundaries. It is evident that, depending on the assumed storm track, these inter-county movements result in a number of regional traffic impacts. During the transportation analysis task, these movements were quantified to facilitate estimation of demand for roadway segments and resulting clearance times.

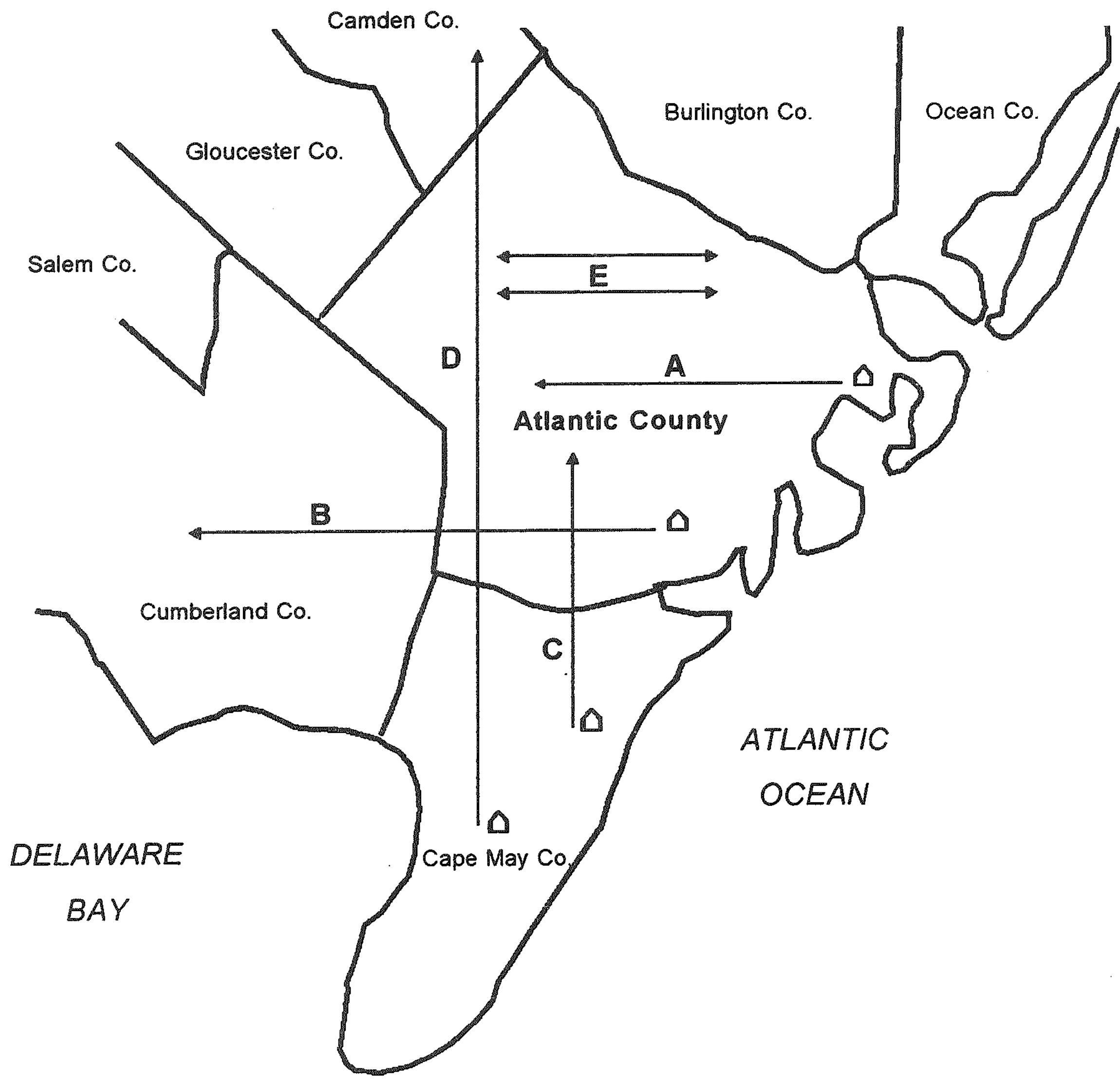
6.3 TRANSPORTATION ANALYSIS INPUT ASSUMPTIONS

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 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. Ranges of those variables having the greatest influence on clearance time were identified and then varied as input assumptions.

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

a. Permanent and Tourist Population Data
b. Storm Scenarios
c. Evacuation Zones
d. Behavioral Characteristics of the Evacuating Population
e. Roadway Network and Traffic Control Assumptions

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



A IN-COUNTY ORIGINS TO IN-COUNTY DESTINATIONS

B IN-COUNTY ORIGINS TO OUT-OF-COUNTY DESTINATIONS

C OUT-OF-COUNTY ORIGINS TO IN-COUNTY DESTINATIONS

D OUT-OF-COUNTY ORIGINS TO OUT-OF-COUNTY DESTINATIONS

E BACKGROUND TRAFFIC

FIGURE 6-1
EVACUATION TRAVEL PATTERNS
(SAMPLE: ATLANTIC COUNTY)

6.3.1 Permanent and Tourist Population Data

The data base for each county was initially developed using 1980 census complemented by New Jersey Department of Labor yearly estimates. This source of data provided a base for permanent population parameters on a sub-county basis. Since data are regularly updated for census units, their use provides a means to facilitate updating of the evacuation study in the future. Sources of seasonal and permanent dwelling unit data provided included:

a. 1990 Census preliminary data.

b. New Jersey Department of Labor - official 1988 permanent population estimates.

c. Various county planning departments, Chambers of Commerce, tax offices - seasonal estimates by sub-county areas.

d. James K. Mitchell, Rutgers University Department of Geography Discussion Paper No. 21: Hurricane Evacuation in Coastal New Jersey, July 1984.

Any future update of the transportation analysis should carefully examine any additional seasonal dwelling unit data that may become available in areas of each coastal county. Current permanent population estimates range from approximately 65,294 in Salem County to 553,124 in Monmouth County[1]. In Atlantic and Cape May Counties, peak season population can have a dramatic effect on the number of people residing in the surge vulnerable area. In the peak summer season, population in is more than doubled in Atlantic County and in Cape May County population is more than quadrupled. Table 6-1 (p. 6-6) lists the current estimated population and total number of permanent, mobile home, and seasonal/tourist dwelling units by county. In addition to number of dwelling units, data was obtained concerning the number of vehicles available by census tract. This data was crucial to translating hurricane vulnerable housing units to vehicle demand for roadways.

[1] 1990 Census preliminary data.

TABLE 6-1
ESTIMATED CURRENT POPULATION, PERMANENT AND TOURIST/SEASONAL DWELLING UNIT DATA

	POPULATION[1]		DWELLING UNITS[2]		
COUNTY	ESTIMATED CURRENT	ADDITIONAL PEAK SEASON	TOTAL PERMANENT	MOBILE HOME	TOURIST/ SEASONAL
SOUTHERN COUNTIES[3]					
BURLINGTON	395,066	-	120,165	2,279	-
CAMDEN	502,824	-	170,061	929	-
GLOUCESTER	230,082	-	68,647	1,594	-
SALEM	65,294	-	22,487	831	-
CUMBERLAND	138,053	-	45,483	2,257	-
CAPE MAY	95,089	532,000	36,246	938	177,320
ATLANTIC	224,327	292,500	78,171	2,124	97,392
OCEAN	433,203	119,170	157,284	3,637	39,722
MONMOUTH	553,124	172,500	184,445	2,154	57,501
METROPOLITAN NEW YORK AREA COUNTIES[4]					
MIDDLESEX	671,780	-	10,330	694	-
UNION	493,819	-	9,562	14	-
HUDSON	553,099	-	43,656	23	-
ESSEX	778,026	-	14,896	-	-
BERGEN	825,380	-	7,816	331	-

[1] Based on 1990 Census preliminary data.
[2] Dwelling Unit is based on the 1980 census and, for seasonal units, on estimates from various sources.
[3] Data for the nine southern New Jersey counties is county wide.
[4] Dwelling unit data for the five New York Metro area counties reflects only those portions of each county included in the transportation analysis. (See footnotes Table 3-B, p. 3-4).

6.3.2 Storm Scenarios

The hazards analysis identified those storm tracks causing the worst possible storm surge in each county of the Study area for each of four hurricane intensity categories (corresponding to the Saffir-Simpson scale). When four storm intensities are factored by several varying behavioral parameters, the number of hypothetical hurricane situations can quickly multiply. Calculation of clearance times for this many storm situations would be cumbersome for 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 storm scenarios (grouping by intensity) per county. Census tracts were overlaid with storm surge limits corresponding to the four 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. Table 6-2 provides the storm scenarios developed in the transportation analysis for each county.

TABLE 6-2

TRANSPORTATION ANALYSIS STORM SCENARIOS

COUNTY	STORM SCENARIO	SAFFIR-SIMPSON CATEGORY
ATLANTIC CAPE MAY OCEAN MONMOUTH SALEM	A B	CATEGORY 1-2 CATEGORY 3-4
CAMDEN CUMBERLAND GLOUCESTER BERGEN	A	CATEGORY 1-4
BURLINGTON UNION ESSEX HUDSON	A B	CATEGORY 1 CATEGORY 2-4
MIDDLESEX	A B	CATEGORY 2 CATEGORY 3-4

6.3.3 Evacuation Zones

Through the hazards analysis, those areas which are subject to hurricane storm surge were identified and mapped. This information became one of the key inputs to the transportation analysis. Those residents who must evacuate were defined. Within the transportation analysis it was assumed that all 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 seasonal housing units located in storm surge vulnerable areas. In addition, all mobile home residents living outside the hurricane flooded areas of each county were assumed to evacuate due to high wind vulnerability. [At the request of the emergency management directors in Ocean and Monmouth Counties, mobile home residents were not included in the Category 1-2 vulnerable population for that county.] 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 was established for each county based on the following factors:

a. Zones should relate to maximum potential surge flooding limits for each storm scenario.

b. Zones should relate well to census or other available data base unit.

c. Zones should be set up, where possible, for use in emergency management operations.

d. Zonal boundaries should include identifiable natural features, roadways, landmarks, etc.

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

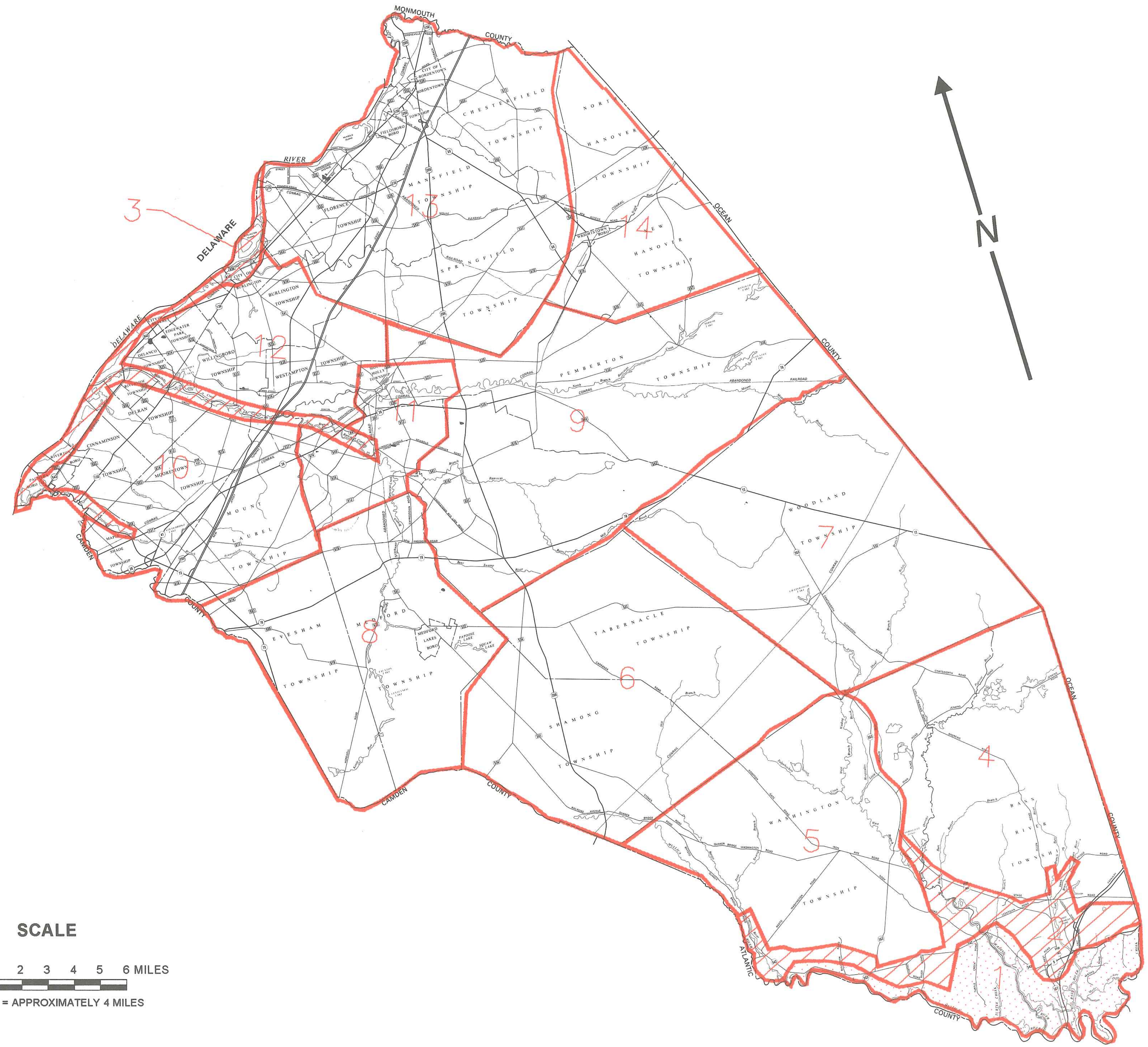
f. Zones should be able to be served by major evacuation routes.

g. Zones must allow for appropriate transportation modeling.

Table 6-3 (next page) provides the number of evacuation zones for the transportation analysis and assumed vulnerability of each zone for storm scenarios in each county. The number of zones ranges from 8 zones in Essex and Middlesex Counties to 37 zones in Ocean County. Plates 6-1 through 6-14 (following p. 6-9) illustrate the evacuation zones established in each county for the transportation analysis.

TABLE 6-3
TRANSPORTATION ANALYSIS EVACUATION ZONES
ASSUMED VULNERABILITY
BY STORM SCENARIO AND COUNTY

COUNTY	NUMBER OF ZONES	STORM SCENARIOS	SAFFIR-SIMPSON CATEGORY	ALL RESIDENTS IN ZONES	MOBILE HOME RESIDENTS IN ZONES
SOUTHERN COUNTIES					
BURLINGTON	14	A	1	1	2-14
		B	2-4	1-3	4-14
CAMDEN	13	A	1-4	1-6	7-13
GLOUCESTER	12	A	1-4	1-3	4-12
SALEM	16	A	1-2	1-7	8-16
		B	3-4	1-11	12-16
CUMBERLAND	15	A	1-4	1-7	8-15
CAPE MAY	25	A	1-2	1-16	17-25
		B	3-4	1-24	25
ATLANTIC	31	A	1-2	1-13	14-31
		B	3-4	1-22	23-31
OCEAN	37	A	1-2	1-16	
		B	3-4	1-26	27-37
MONMOUTH	28	A	1-2	1-8	
		B	3-4	1-13	14-28
METRO NEW YORK AREA COUNTIES					
MIDDLESEX	8	A	1-2	1-5	6-8
		B	3-4	1-8	-
UNION	12	A	1	1-5	6-12
		B		2-4	1-12
HUDSON	23	A	1	1-14	15-23
		B	2-4	1-19	20-23
ESSEX	8	A	1	1-3	4-8
		B	2-4	1-8	-
BERGEN	9	A	1-4	1-9	



LEGEND

STORM SCENARIO "A" EVACUATION ZONE

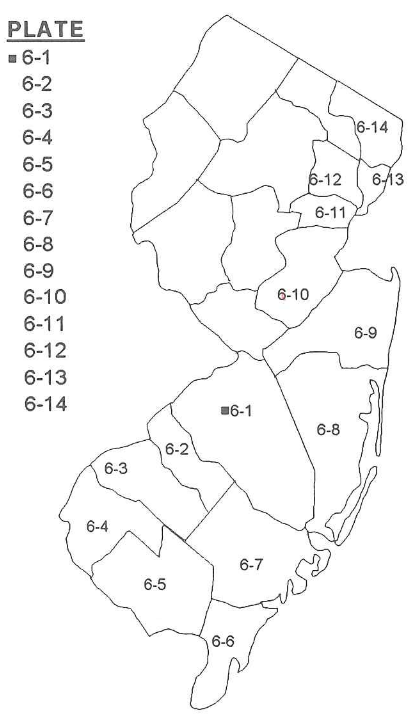
STORM SCENARIO"B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	▪6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



NEW JERSEY
HURRICANE EVACUATION STUDY

BURLINGTON COUNTY EVACUATION ZONE MAP

PLATE 6-1

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SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

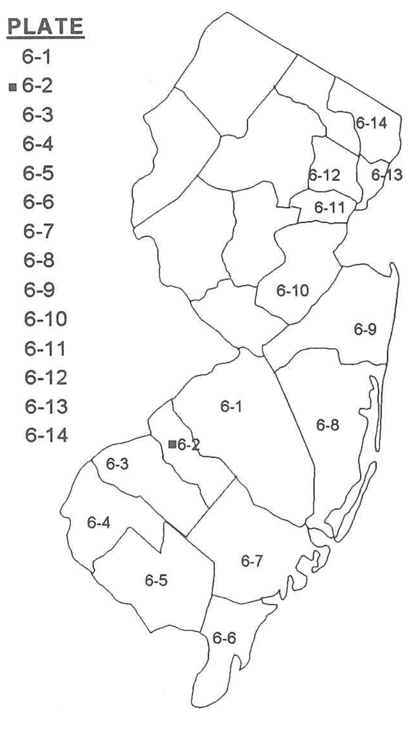
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	■ 6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



NEW JERSEY
HURRICANE EVACUATION STUDY

CAMDEN COUNTY EVACUATION ZONE MAP

PLATE 6-2

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SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2.6 MILES

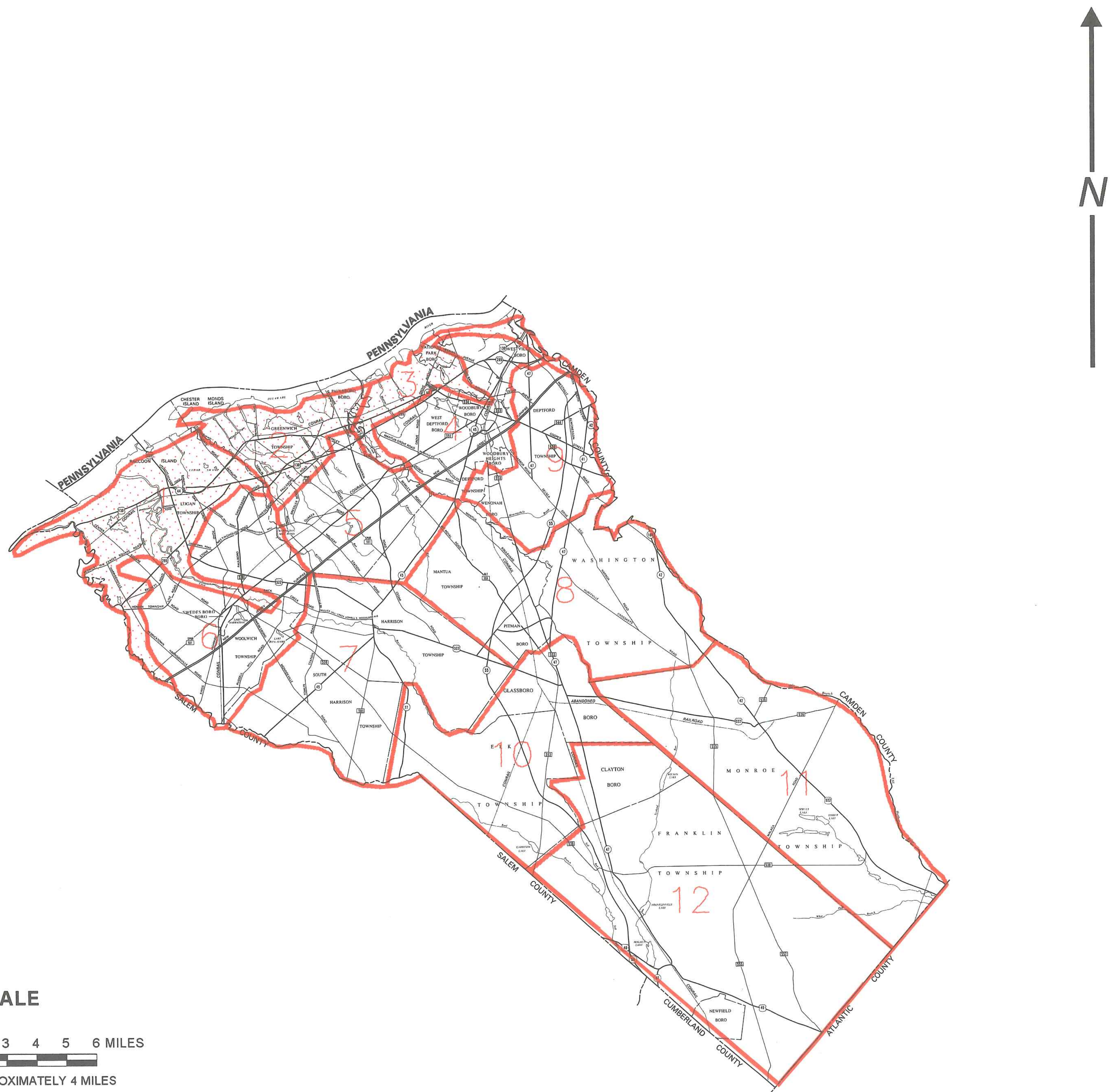
LEGEND

STORM SCENARIO "A" EVACUATION ZONE

STORM SCENARIO "B" EVACUATION ZONE

3 — EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.



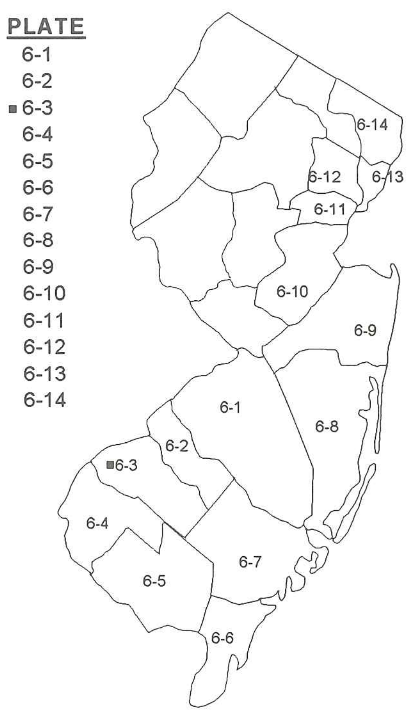
SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	■6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14

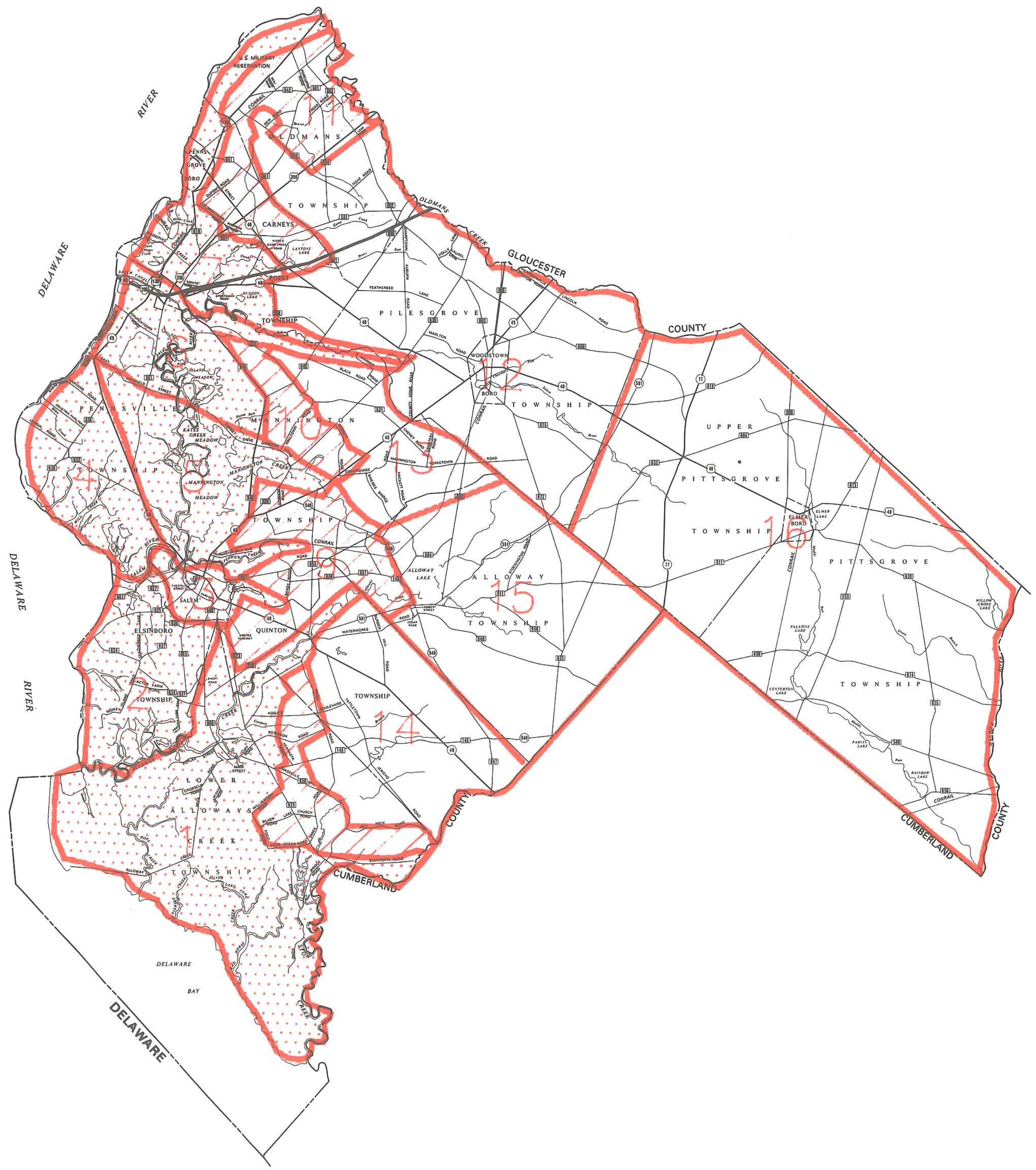


NEW JERSEY
HURRICANE EVACUATION STUDY

GLOUCESTER COUNTY EVACUATION ZONE MAP

PLATE 6-3

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



LEGEND

STORM SCENARIO "A" EVACUATION ZONE

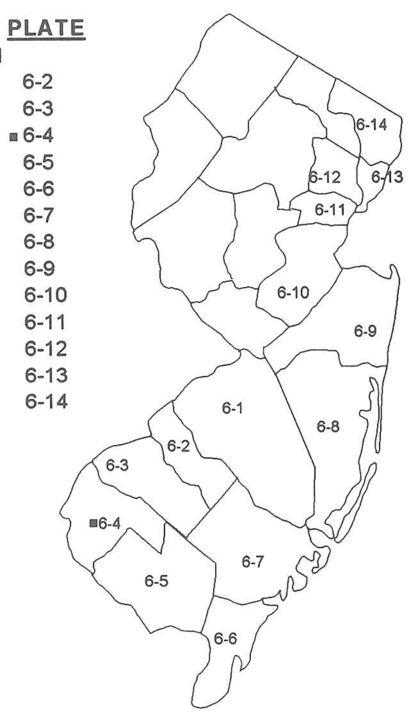
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	■ 6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



SCALE

0 1 2 3 4 5 6 MILES

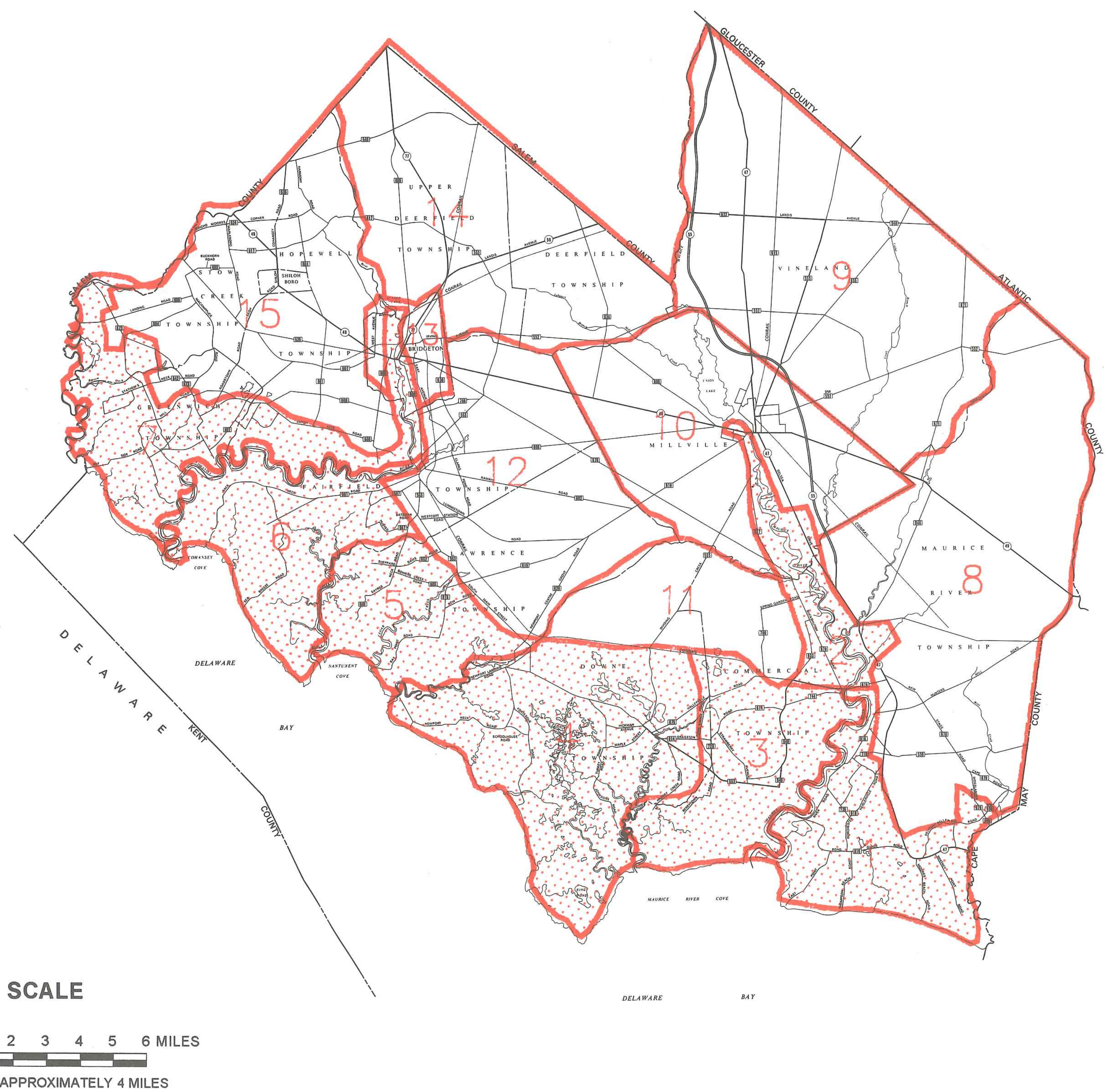
1 INCH = APPROXIMATELY 4 MILES

NEW JERSEY
HURRICANE EVACUATION STUDY

SALEM COUNTY EVACUATION ZONE MAP

PLATE 6-4

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



LEGEND

STORM SCENARIO "A" EVACUATION ZONE

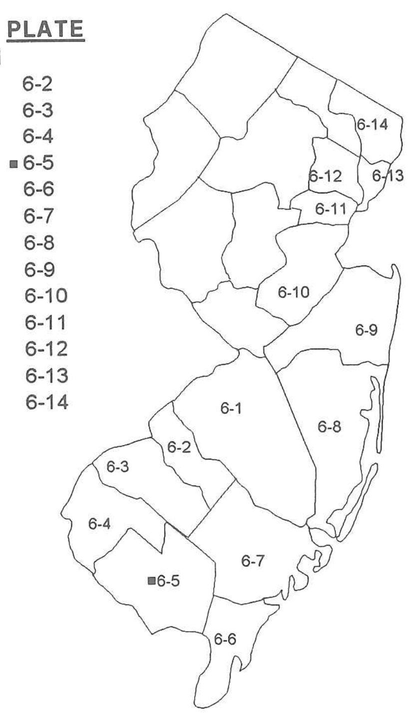
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	■ 6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14

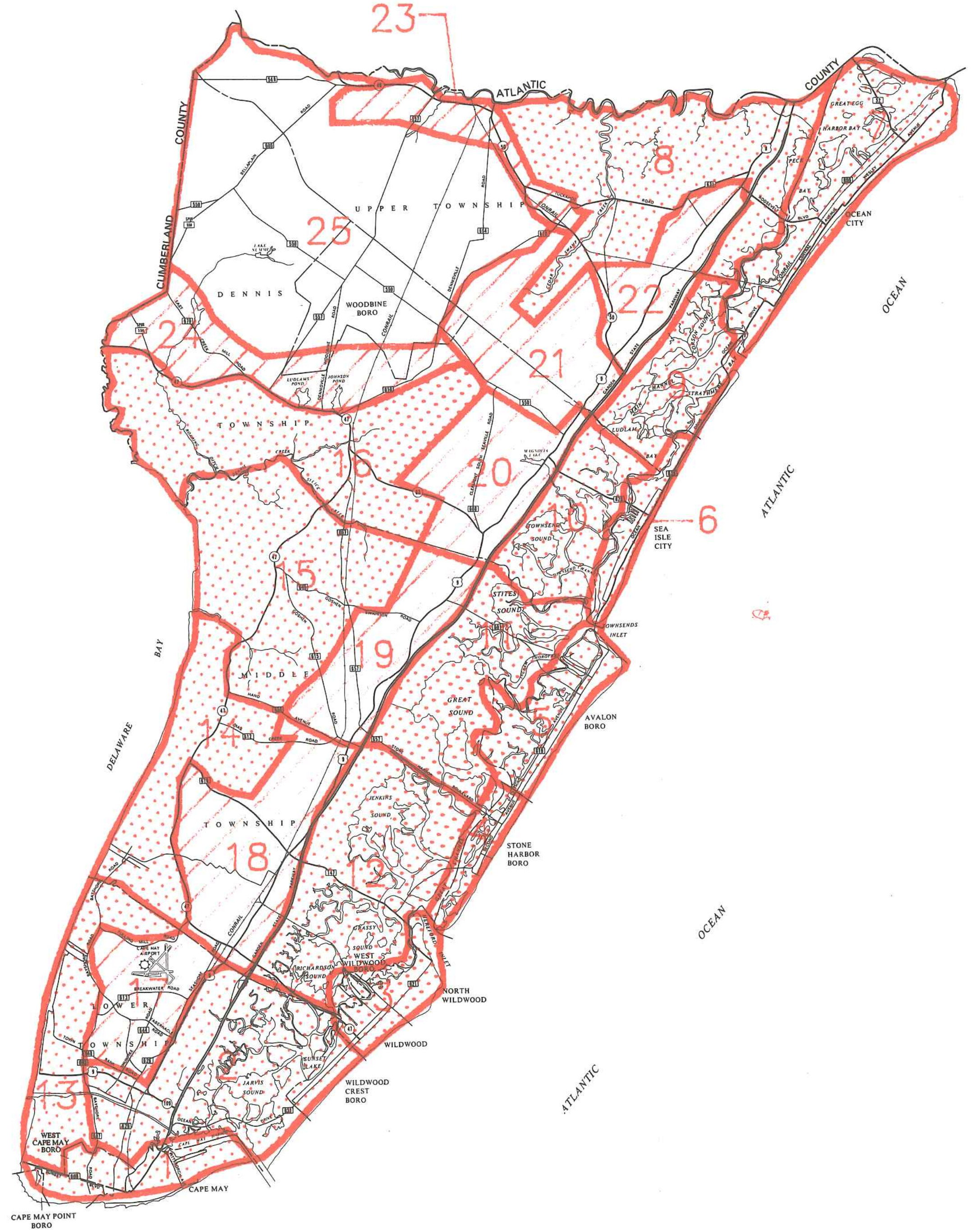


NEW JERSEY
HURRICANE EVACUATION STUDY

CUMBERLAND COUNTY EVACUATION ZONE MAP

PLATE 6-5

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



0 1 2 3 4 5 6 MILES

SCALE

N

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

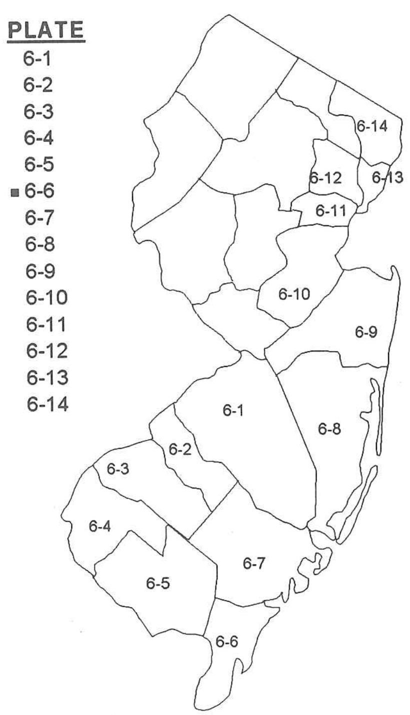
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	■ 6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14

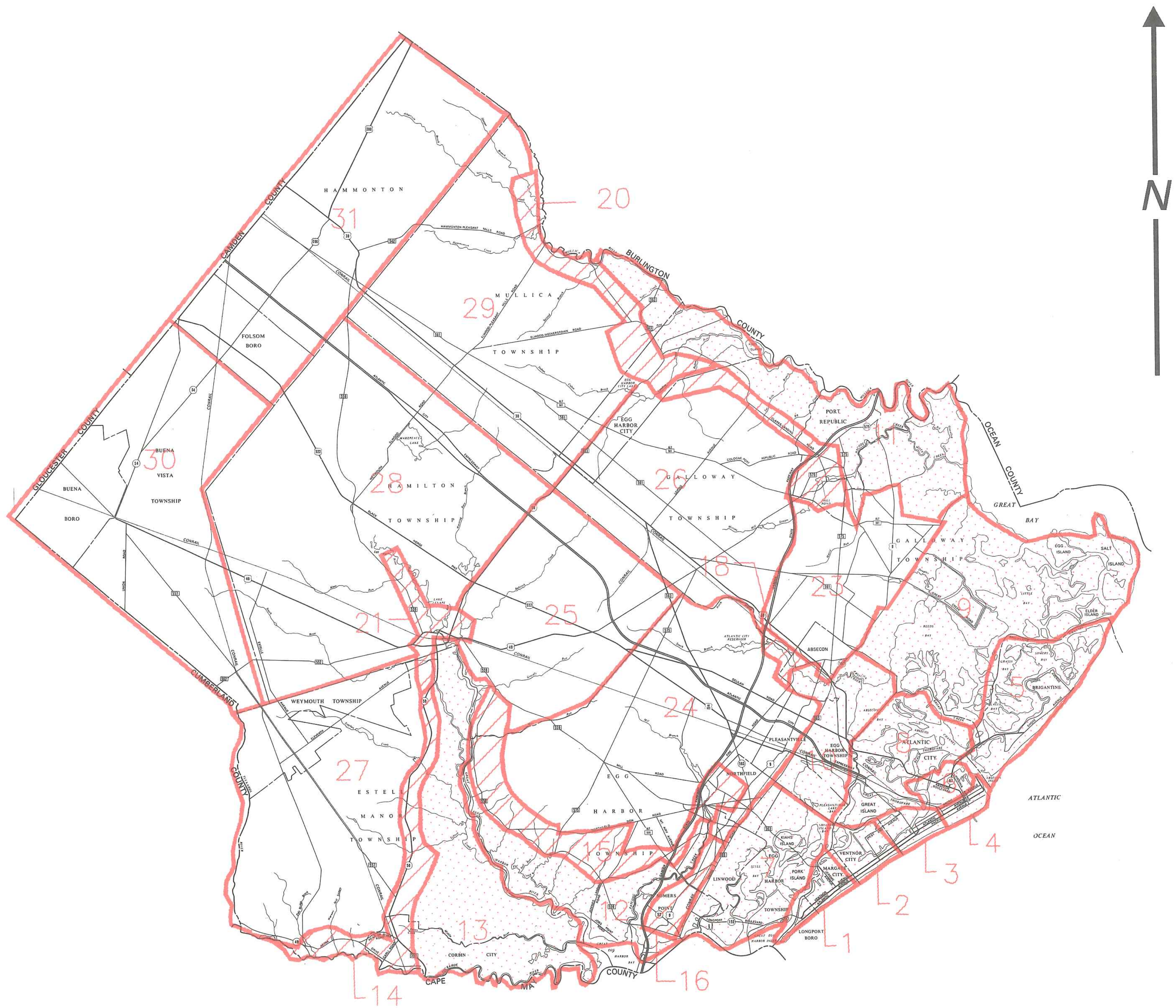


NEW JERSEY
HURRICANE EVACUATION STUDY

CAPE MAY COUNTY EVACUATION ZONE MAP

PLATE 6-6

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



LEGEND

STORM SCENARIO "A" EVACUATION ZONE

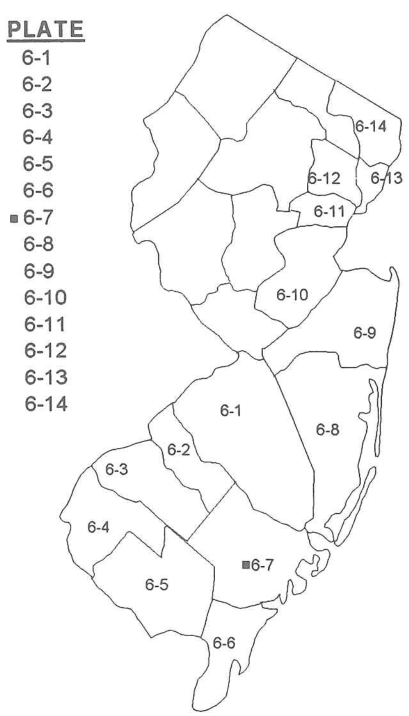
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	▪ 6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



SCALE

0 1 2 3 4 5 6 MILES

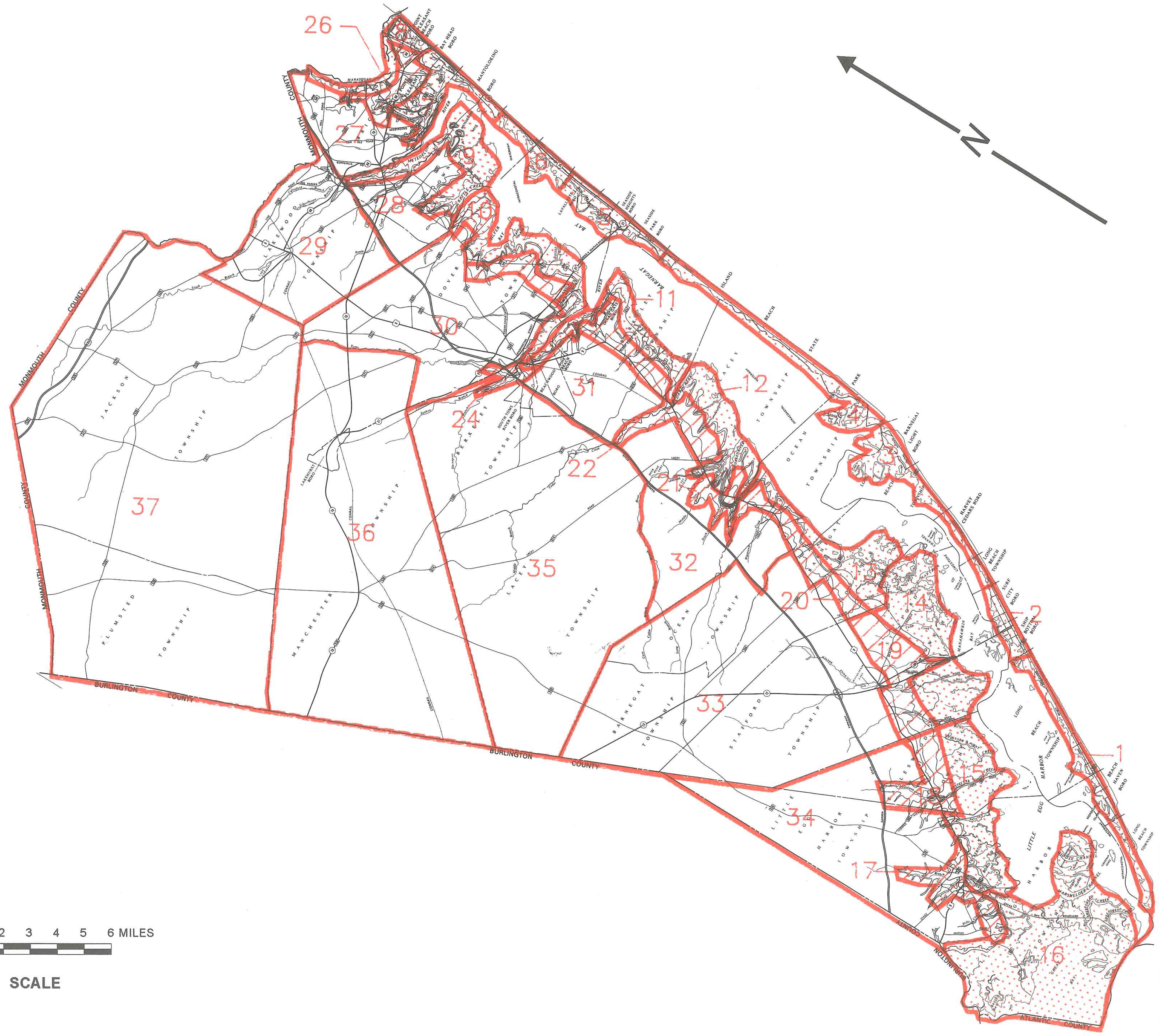
1 INCH = APPROXIMATELY 4 MILES

NEW JERSEY
HURRICANE EVACUATION STUDY

ATLANTIC COUNTY
EVACUATION ZONE MAP

PLATE 6-7

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



0 1 2 3 4 5 6 MILES

SCALE

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

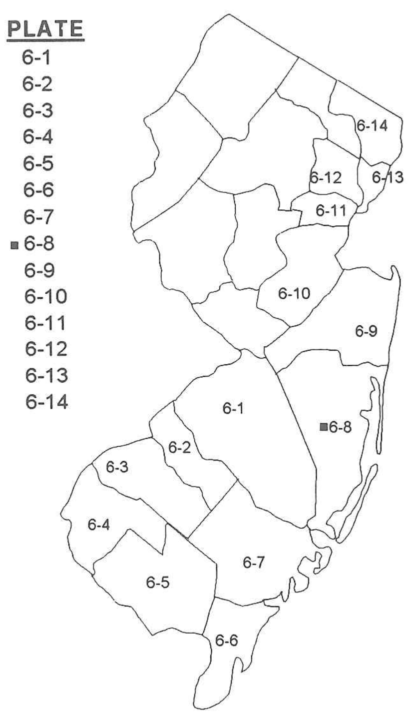
STORM SCENARIO "B" EVACUATION ZONE

3 — EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	■ 6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14

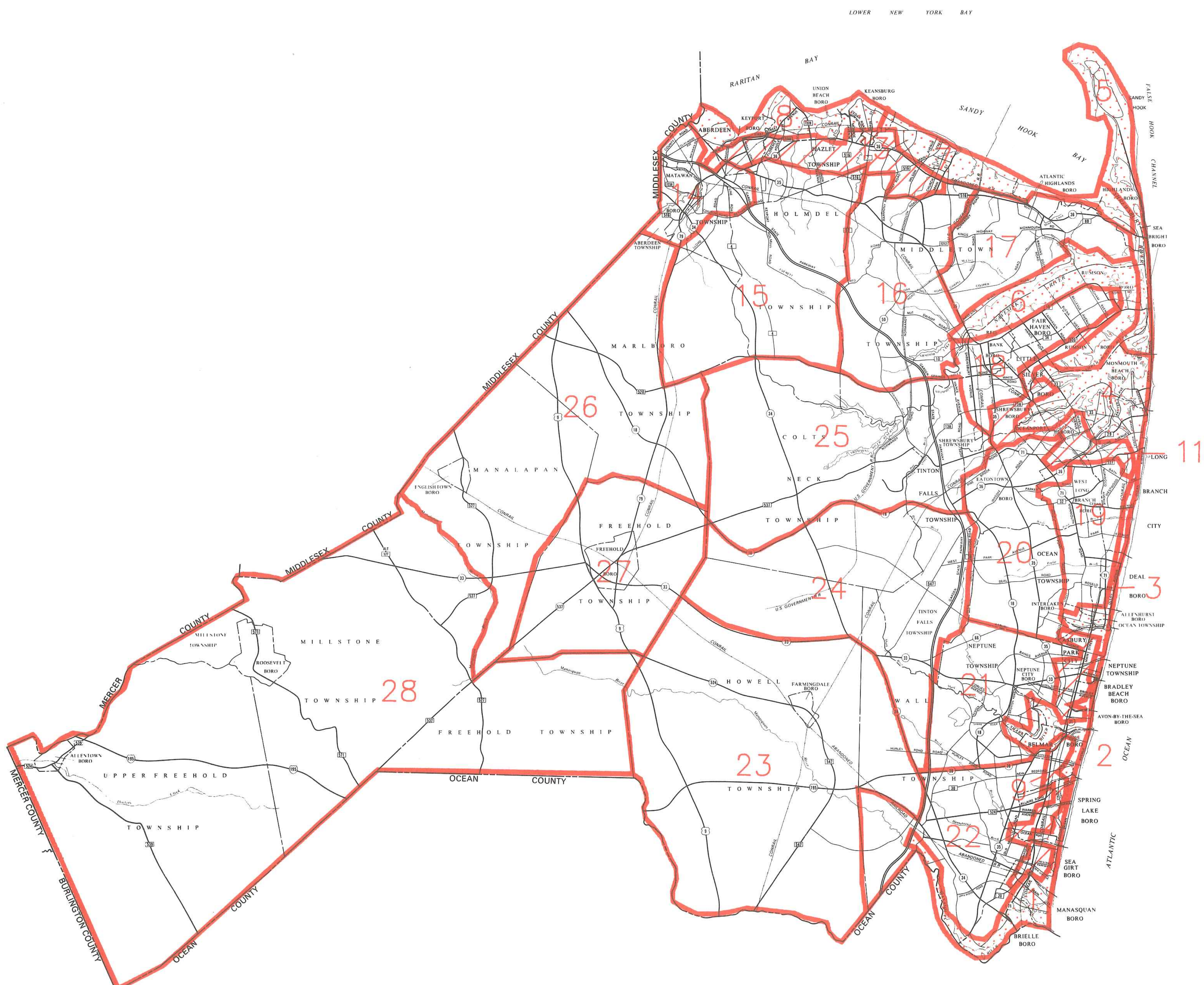


NEW JERSEY HURRICANE EVACUATION STUDY

OCEAN COUNTY EVACUATION ZONE MAP

PLATE 6-8

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



N

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

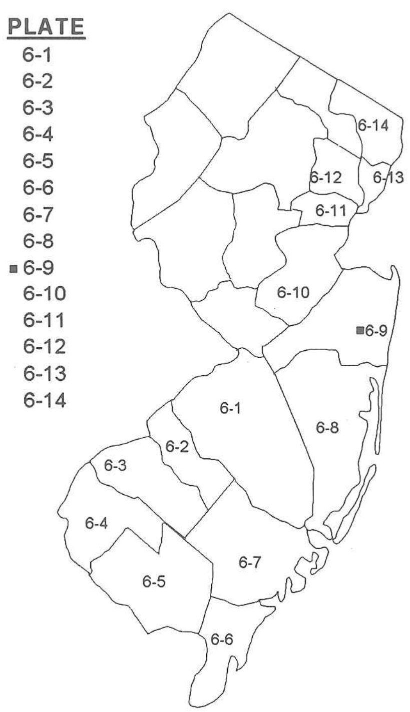
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	■ 6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 3.4 MILES

NEW JERSEY
HURRICANE EVACUATION STUDY

**MONMOUTH COUNTY
EVACUATION ZONE MAP**

PLATE 6-9

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

N

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

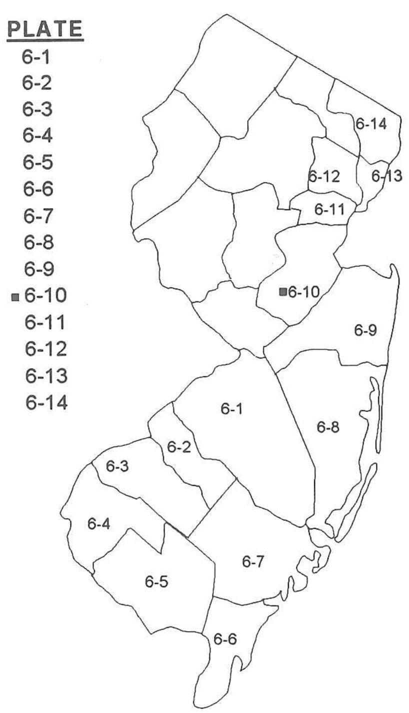
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	■ 6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



SCALE

0 1 2 3 4 5 6 MILES

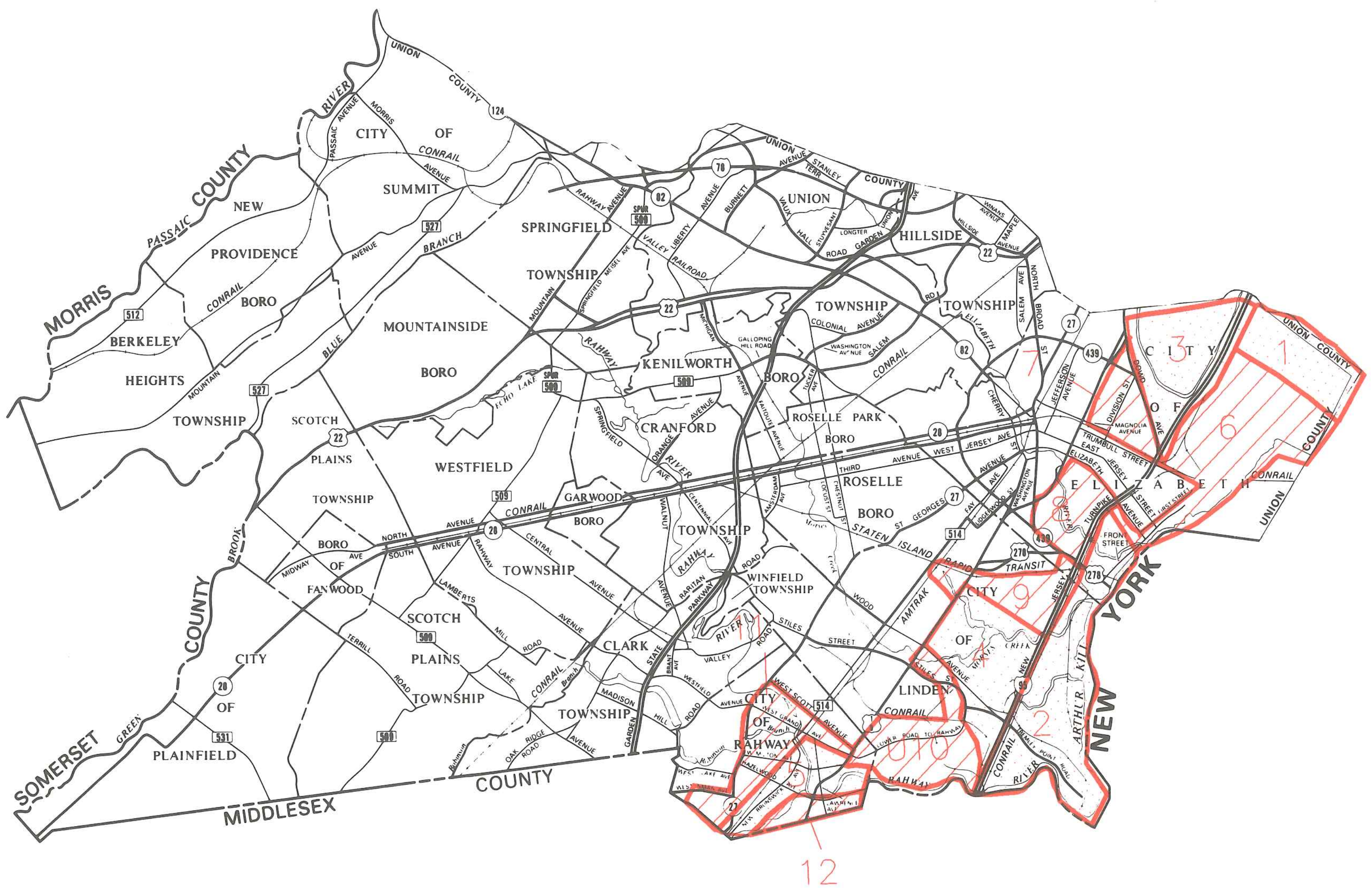
1 INCH = APPROXIMATELY 2.6 MILES

NEW JERSEY
HURRICANE EVACUATION STUDY

MIDDLESEX COUNTY
EVACUATION ZONE MAP

PLATE 6-10

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



N

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

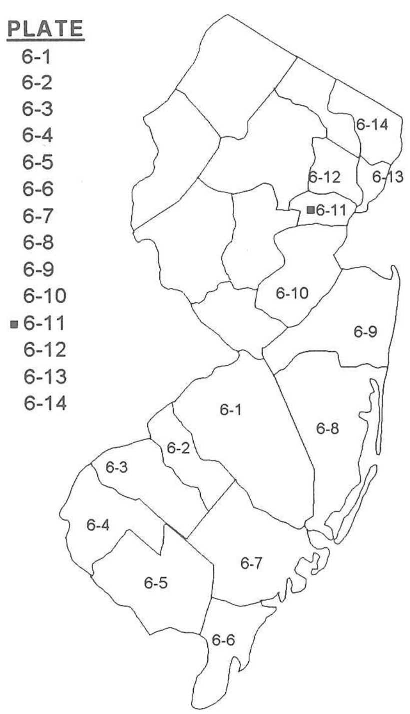
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	▪6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	6-14



SCALE

0 1 2 3 4 5 6 MILES

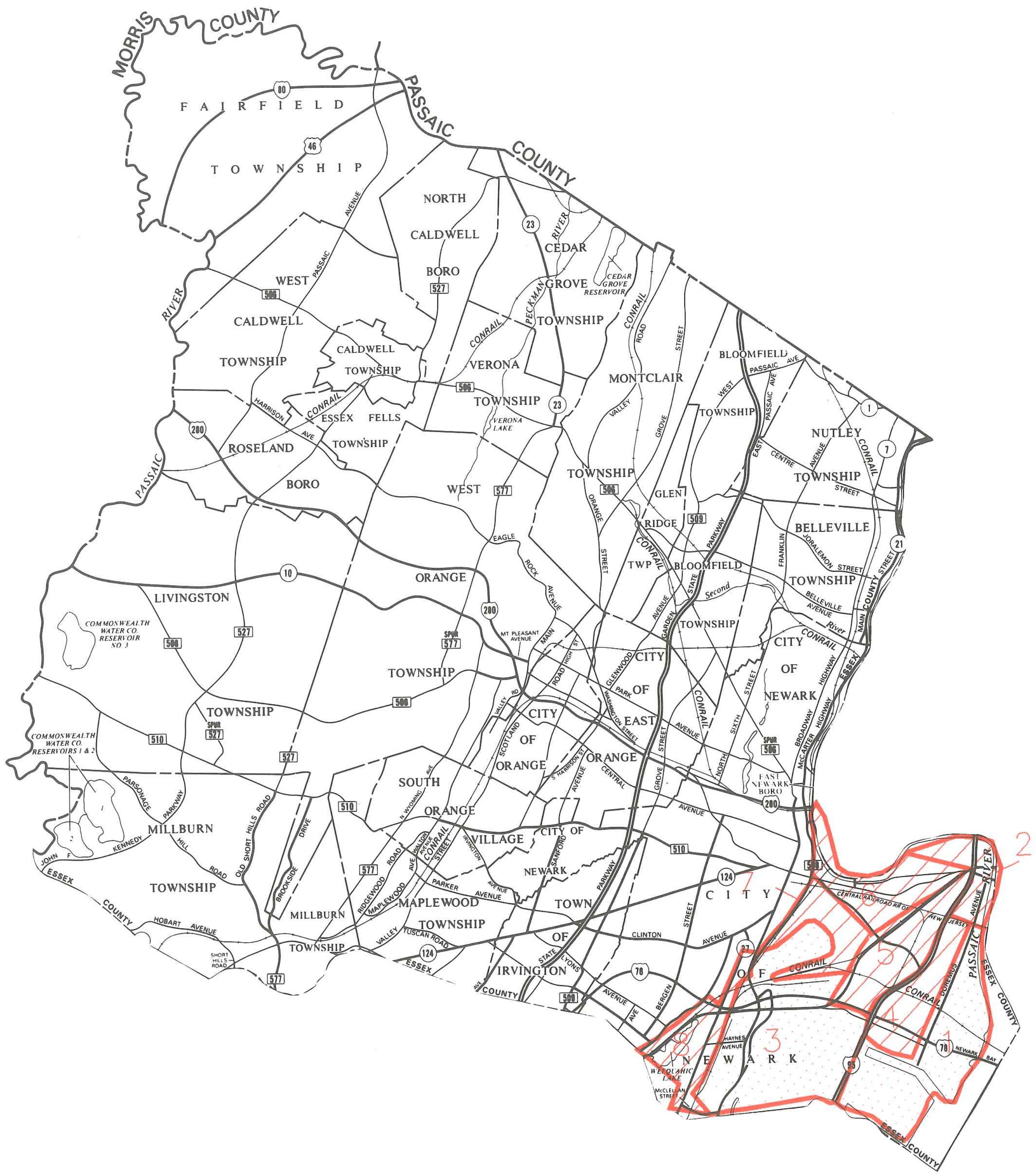
1 INCH = APPROXIMATELY 2 MILES

NEW JERSEY
HURRICANE EVACUATION STUDY

UNION COUNTY EVACUATION ZONE MAP

PLATE 6-11

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



LEGEND

STORM SCENARIO "A" EVACUATION ZONE

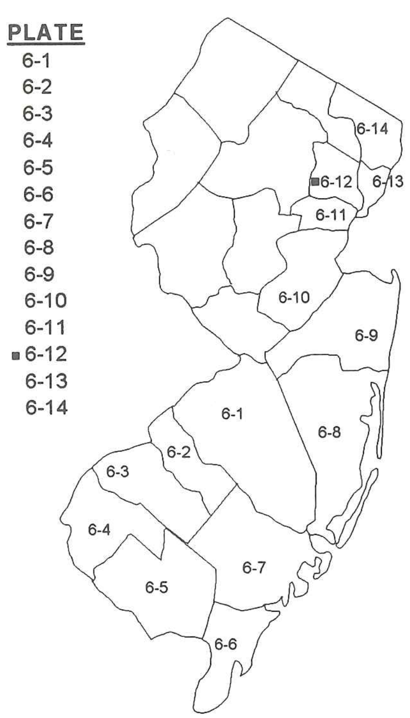
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	▪6-12
HUDSON	6-13
BERGEN	6-14



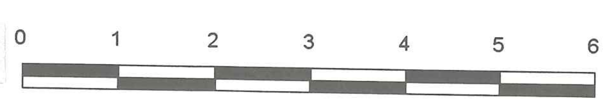
NEW JERSEY
HURRICANE EVACUATION STUDY

ESSEX COUNTY EVACUATION ZONE MAP

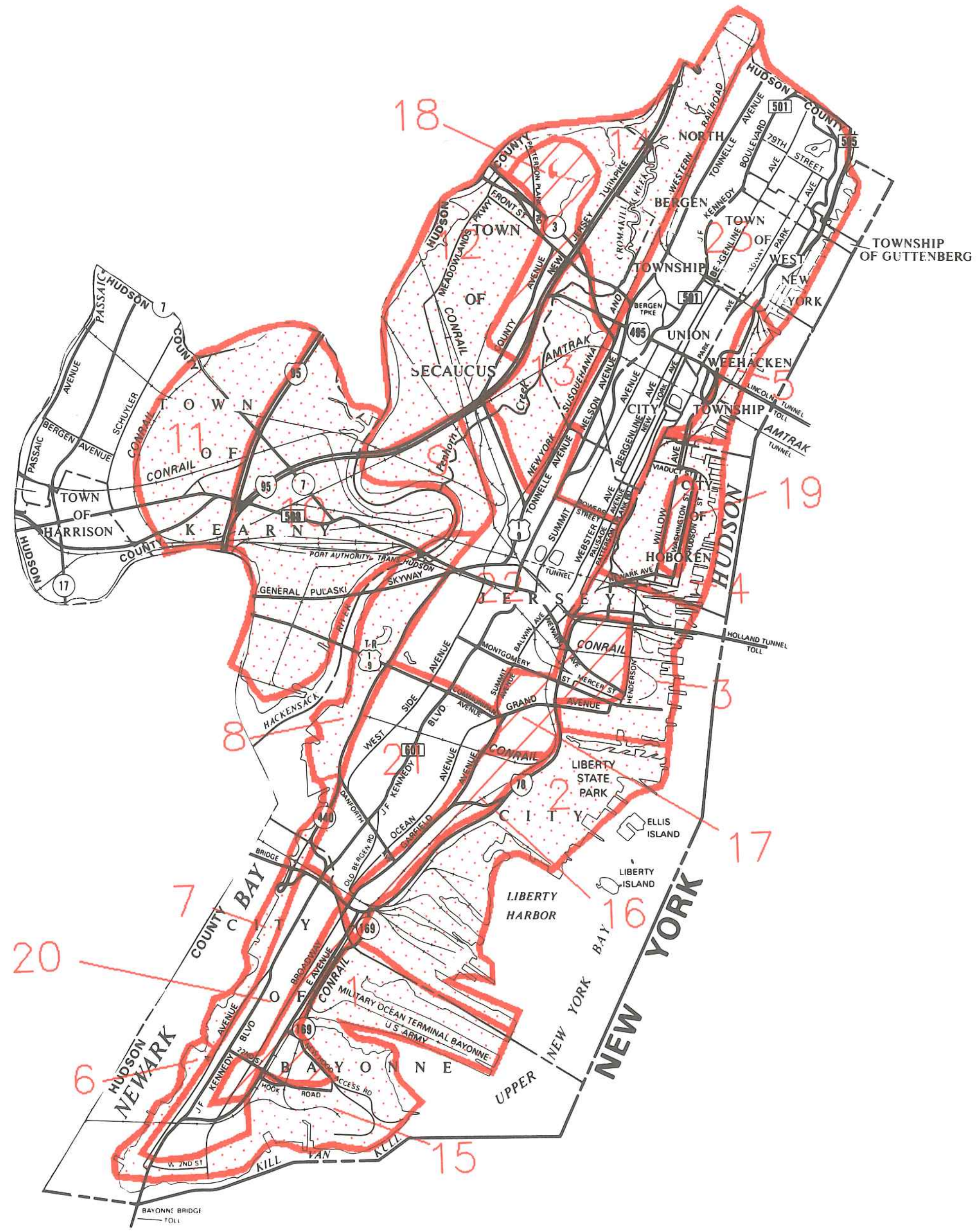
PLATE 6-12

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE



1 INCH = APPROXIMATELY 2 MILES



N

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

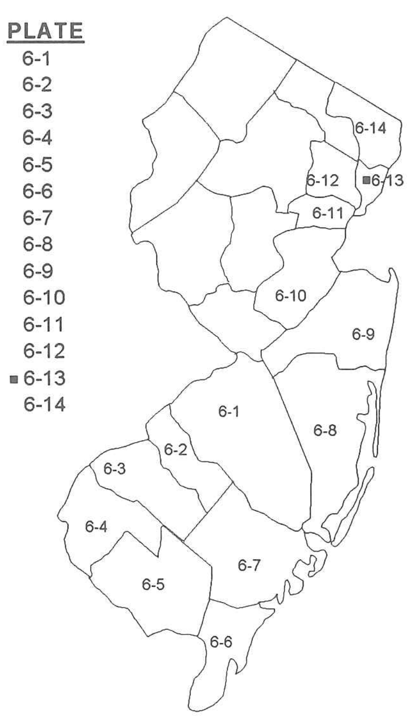
STORM SCENARIO"B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	▪ 6-13
BERGEN	6-14



NEW JERSEY
HURRICANE EVACUATION STUDY

HUDSON COUNTY EVACUATION ZONE MAP

PLATE 6-13

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

LEGEND

STORM SCENARIO "A" EVACUATION ZONE

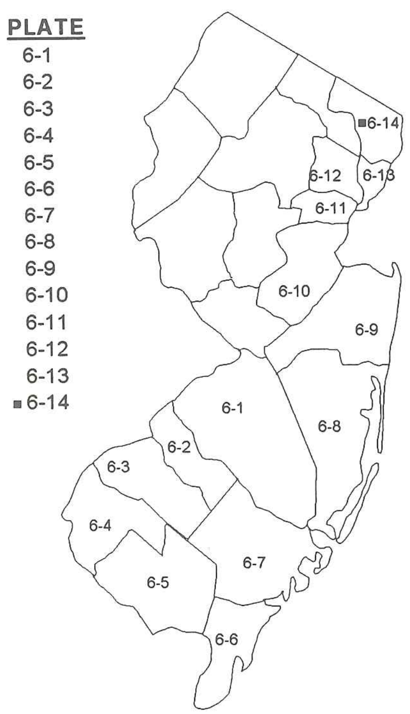
STORM SCENARIO "B" EVACUATION ZONE

3 EVACUATION ZONE NUMBER

NOTE: See Sections 3.2 and 3.3 for explanations of evacuation zones and storm scenarios.

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-1
CAMDEN	6-2
GLOUCESTER	6-3
SALEM	6-4
CUMBERLAND	6-5
CAPE MAY	6-6
ATLANTIC	6-7
OCEAN	6-8
MONMOUTH	6-9
MIDDLESEX	6-10
UNION	6-11
ESSEX	6-12
HUDSON	6-13
BERGEN	■6-14



NEW JERSEY HURRICANE EVACUATION STUDY

BERGEN COUNTY EVACUATION ZONE MAP

PLATE 6-14

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

6.3.4 Behavioral Assumptions

The following behavioral aspects were addressed:

a. Occupancy of tourist units
b. Participation rates
c. Evacuation rates
d. Destination desires
e. Vehicle usage

As a hurricane approaches the Study area, the number of tourists who may be required to evacuate along with the permanent residents could be significant. Discussions at workshop meetings with disaster preparedness officials along the eastern seaboard have revealed a number of varying opinions regarding this issue. Some individuals feel strongly that most tourists will leave prior to the start of an evacuation. Others feel that tourists might possibly take a "wait and see" attitude, resulting in a significant number of tourists present at the start of an evacuation. To address these differing opinions, a sensitivity analysis was performed. The specific occupancy parameters are listed below for counties where tourist occupancy was varied. These percentages were agreed upon by local officials as the appropriate maximum and minimum figures to use for tourist occupancy.

COUNTY	% OF SEASONAL UNITS OCCUPIED		
CAPE MAY	10%	30%	90%
ATLANTIC		45%	95%
OCEAN		30%	90%
MONMOUTH	15%		90%

Another important behavioral aspect is that of participation rates. Several elements were incorporated in the transportation analysis regarding participation in the evacuation. Generally, a 100 percent participation by those evacuees living in surge inundated areas and mobile homes outside the surge flooded areas was assumed. In addition, a small percentage (1 to 5% depending on storm intensity) of the non-vulnerable population was assumed to evacuate their dwelling units in the open coast counties (Cape May, Atlantic, Ocean and Monmouth). Behavioral research confirms this behavioral phenomenon. The transportation model support document provides a listing of all participation rates assumed by storm scenarios for each county in the Study area.

An important behavioral aspect that must be considered for the transportation analysis is the departure 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. For the New Jersey Study, clearance times were tested for three evacuation rates represented by three different behavioral response curves. Behavioral response curves describing mobilization by the vulnerable population define the rate at which evacuating vehicles load onto the evacuation street network for each hourly interval relative to an evacuation order or strong advisory. The percentage of evacuees leaving dwelling units is then available for the calculations relating to traffic loadings at critical links along the evacuation network.

The behavioral response curves shown in Figure 4-1 (p. 4-6) range from immediate response to slow response and are intended to include the most probable range of possible mobilization times that might be experienced in a future hurricane evacuation situation. For sensitivity analysis, the mobilization/traffic loading time was varied between four hours and nine hours.

The percentage of evacuees assumed to go to one of four general destination types was another important behavioral input to the transportation analysis. Evacuee destination percentages were developed with local officials in each area 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 county entirely. Destination percentages were varied for each evacuation zone in each county depending on category of risk (distance from coastline) or special characteristics of a zone such as 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. It should be noted that these destination percentages refer to destination desires. Where destination desires could not be satisfied with in-county capacities, the transportation analysis assumed that some evacuees would have to leave the county to find acceptable shelter.

A 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 review committees produced the needed parameters. Vehicle usage percentages refer to the percent of vehicles available at the home origin that are assumed to be used in the evacuation. Vehicle usage percentages were approximately 65% to 85% (depending on distance from the coastline) for the New Jersey Study transportation analysis. The percent of households expected to pull a boat, trailer or RV was approximately 1-5 percent in the immediate coastal area zones.

6.3.5 Roadway Network and Traffic Control Assumptions

A final group of assumptions used for input to the analysis related to the roadway system chosen for the evacuation network and traffic control measures selected for traffic movement. Although the assumptions developed for the transportation analysis are general, the efforts at county and municipal levels regarding traffic control and roadway selection must be quite detailed. Detailed manpower allocations to major intersections 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, an effort was made to include street facilities with sufficient elevations, little or no adjacent tree coverage, substantial shoulder width and surface, and roadways already contained in existing hurricane evacuation plans. 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. Plates 6-15 through 6-28 (following p. 6-14) show the roadway system representations (evacuation networks) for each county in the Study area. The legends included on these plates identify the following:

EVACUATION ZONE CENTER
ZONE NUMBER
EVACUATION ROAD SEGMENT
ROAD SEGMENT NAME
KEY INTERSECTION LOCATION

The evacuation zone centers (with identifying numbers) are connected by dotted lines to the key intersection locations (nodes) by which they are generally served. Road segments (links) are portions of the evacuation roadway network defined by intersection locations. The segments are identified by a letter designation. [The key intersection location symbol is also used at points in highways where road characteristics change significantly.] Once the links and nodes for the evacuation routes were identified, roadway characteristics such as number of travel lanes and type of facility (urban, rural, limited access, etc.) were specified for each link. These characteristics, as well as other data used in the modeling process is explained in the transportation model support document. Agencies needing detailed information on the traffic modeling process can obtain copies of this document from the Philadelphia District of the Corps of Engineers. [The Evacuation Road Network is also shown on the County Storm Surge Inundation Areas and Evacuation Network Maps.].

An important assumption for the transportation modeling was that all bridges would remain 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, request 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 great risk if bridges are not allowed to operate at 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 (local policemen, sheriffs, deputies, state police) will be assigned to critical intersections in the Study area. This would allow for smoother traffic flow and would allow evacuating traffic more intersection "green time." **The transportation modeling task also assumes that provisions would be made for removal of vehicles in distress during the evacuation and that the evacuation of all vehicles will occur prior to the arrival of sustained tropical storm winds (34 knot/39 mph) and/or storm surge inundation.**

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

a. Hazards Data
b. Socioeconomic Data
c. Behavioral Data
d. Roadway Network

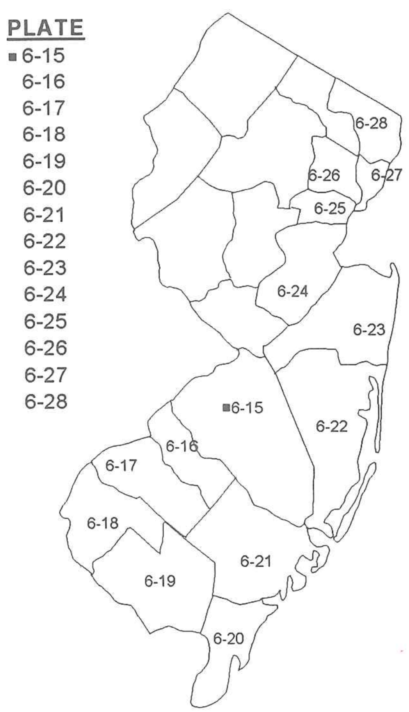
Table 6-4 (p. 6-14) provides a listing of each major data input for each of the four categories.

LEGEND

- ◯ EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- — EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- ● KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	▪6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

NEW JERSEY
HURRICANE EVACUATION STUDY

BURLINGTON COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-15

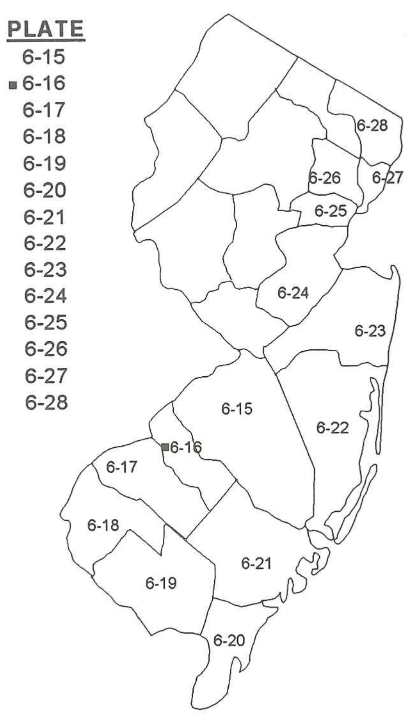
Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

LEGEND

- EVACUATION ZONE CENTER
- 3 — ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A — ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	▪ 6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



SCALE

0 1 2 3 4 5 6 MILES

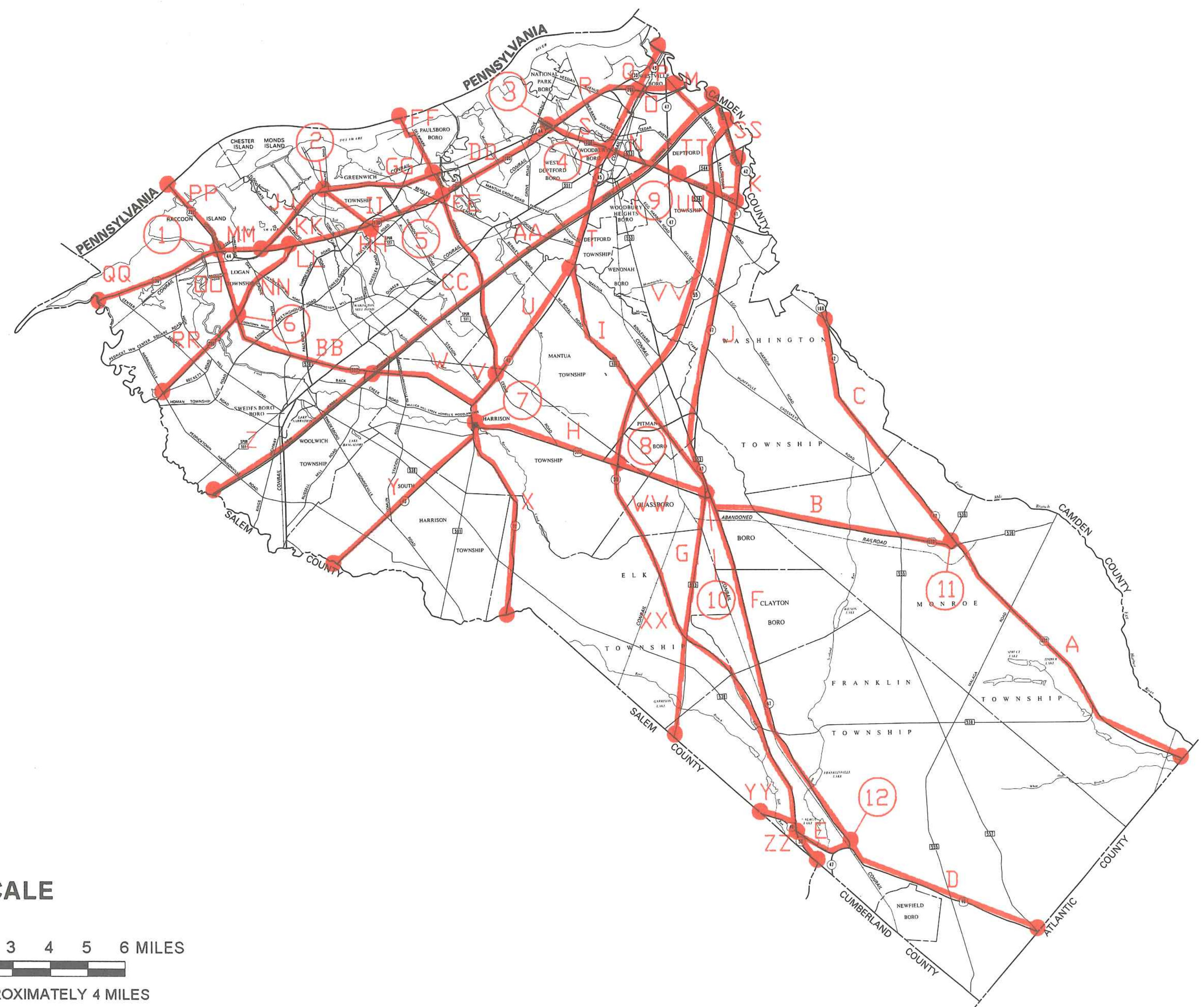
1 INCH = APPROXIMATELY 2.6 MILES

NEW JERSEY HURRICANE EVACUATION STUDY

CAMDEN COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-16

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



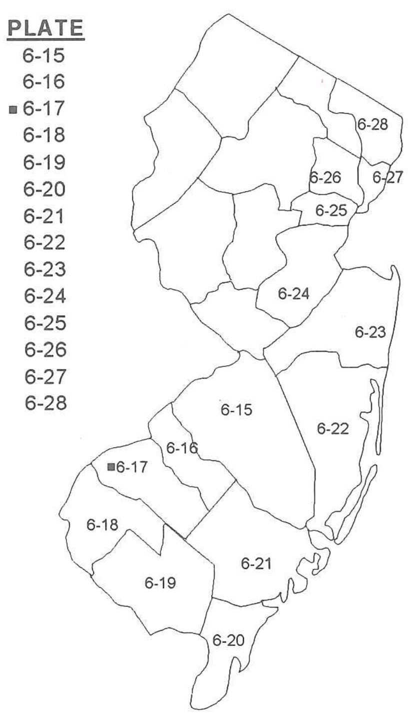
N

LEGEND

- EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	■ 6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

GLOUCESTER COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-17

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

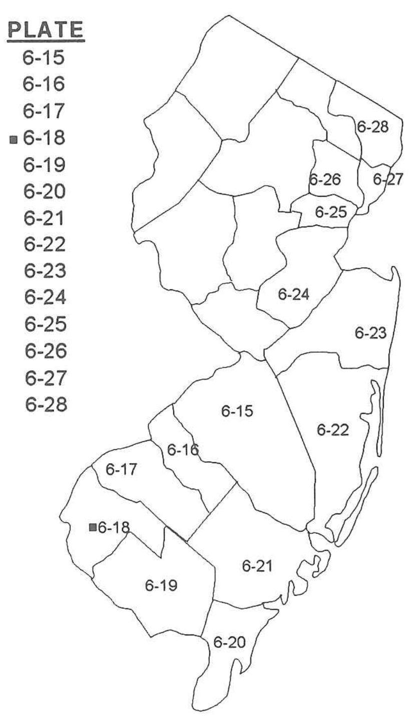
N

LEGEND

○	EVACUATION ZONE CENTER
3	ZONE NUMBER
—	EVACUATION ROAD SEGMENT
A	ROAD SEGMENT NAME
●	KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	■ 6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

SALEM COUNTY
EVACUATION ROAD NETWORK MAP

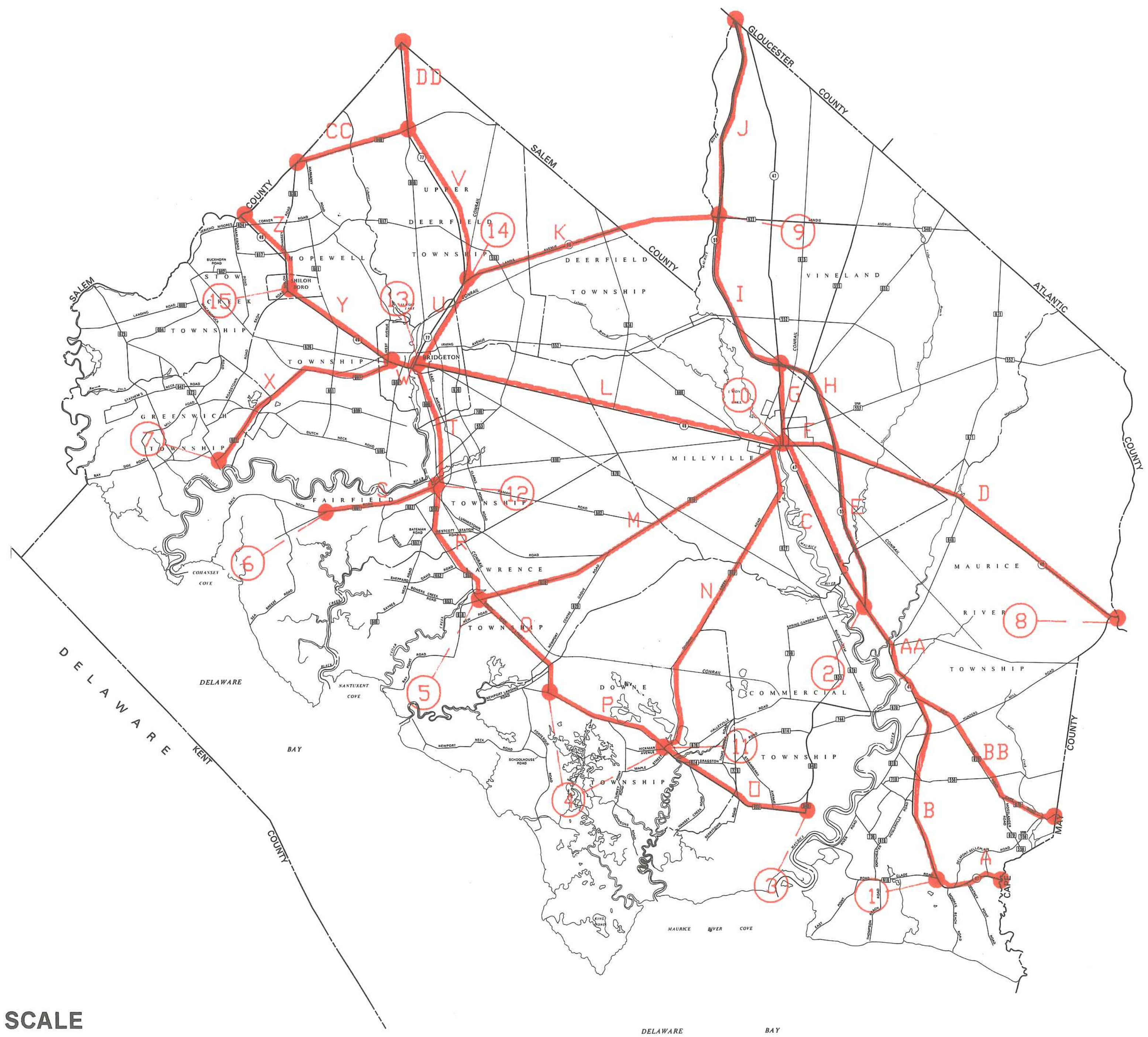
PLATE 6-18

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 4 MILES

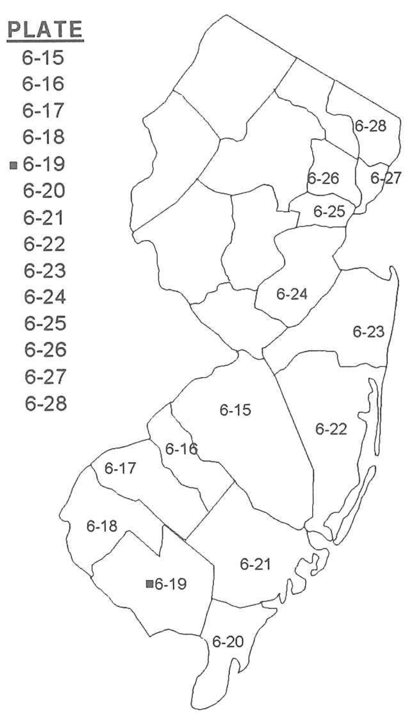
N

LEGEND

- EVACUATION ZONE CENTER
- 3 — ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A — ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	■ 6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28

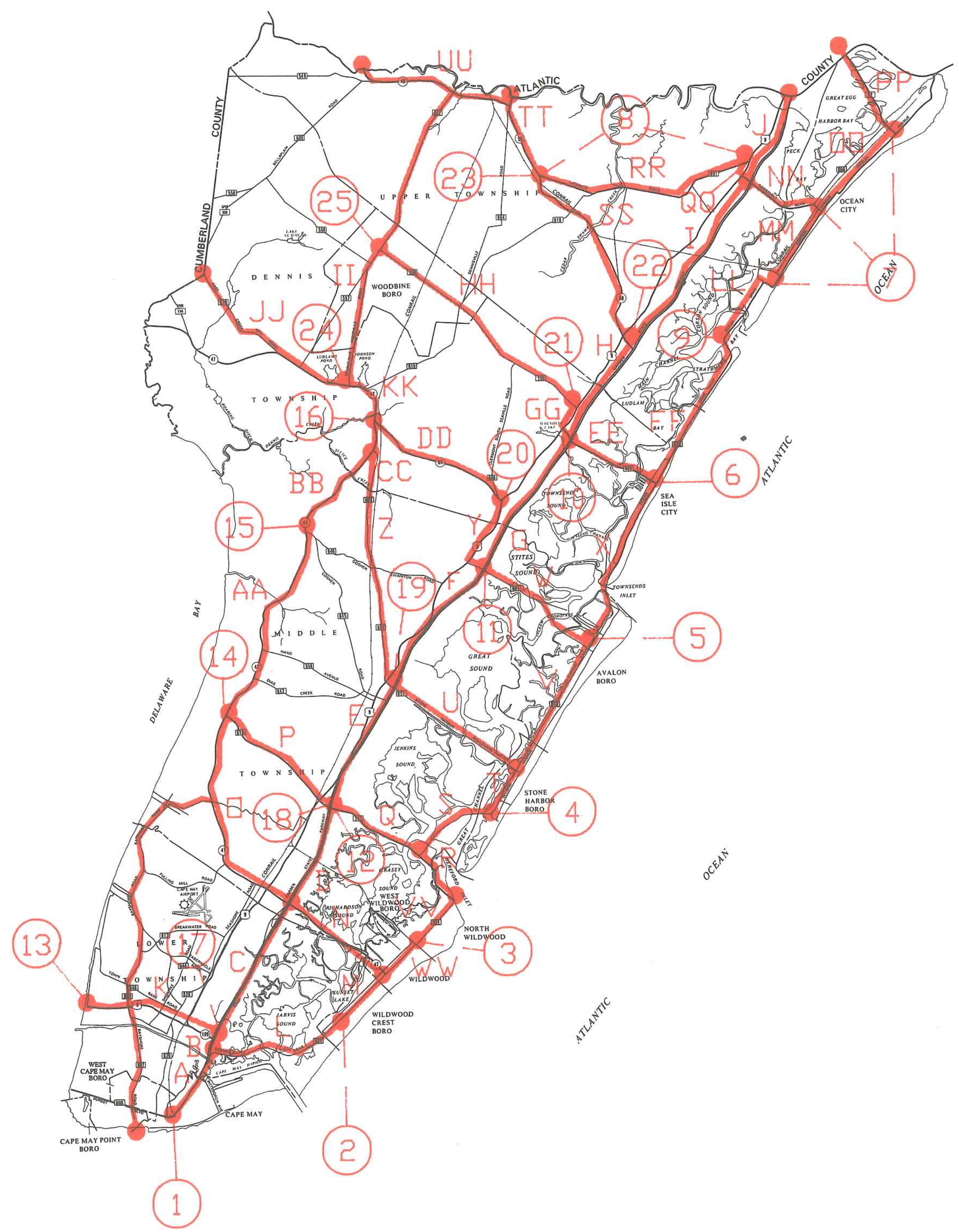


NEW JERSEY
HURRICANE EVACUATION STUDY

CUMBERLAND COUNTY
EVACUATION ROAD NETWORK MAP

PLATE 6-19

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



0 1 2 3 4 5 6 MILES

SCALE

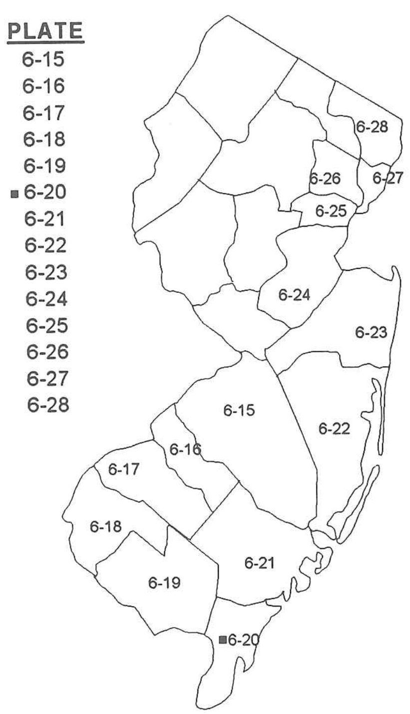
N

LEGEND

○	EVACUATION ZONE CENTER
3	ZONE NUMBER
—	EVACUATION ROAD SEGMENT
A	ROAD SEGMENT NAME
●	KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	■ 6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

CAPE MAY COUNTY
EVACUATION ROAD NETWORK MAP

PLATE 6-20

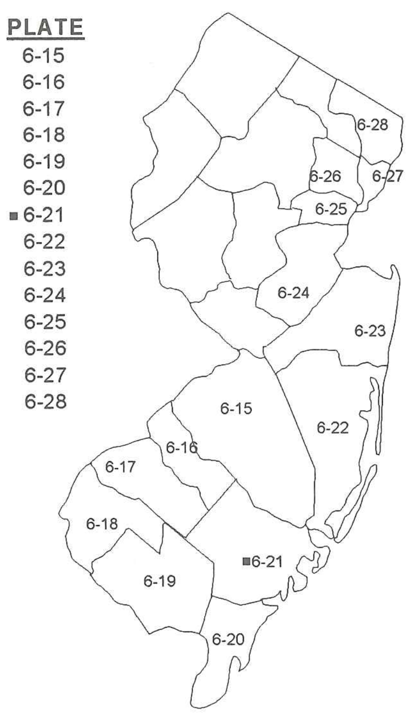
Prepared by the U.S. Army Corps of Engineers, Philadelphia District,
in cooperation with the Federal Emergency Management Agency Region II
for the New Jersey State Police Office of Emergency Management

LEGEND

- EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	■ 6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28

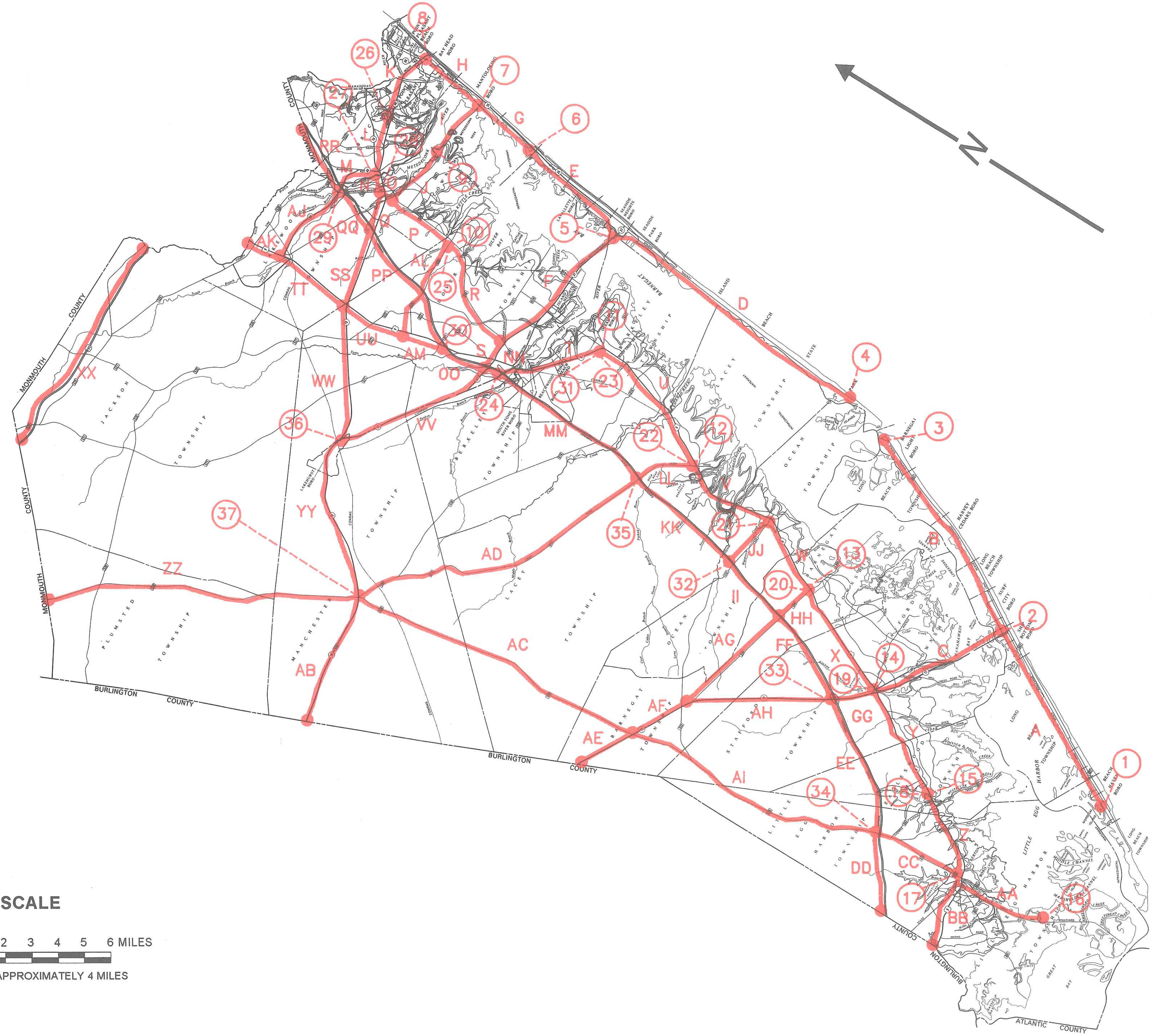


NEW JERSEY
HURRICANE EVACUATION STUDY

ATLANTIC COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-21

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



SCALE

0 1 2 3 4 5 6 MILES

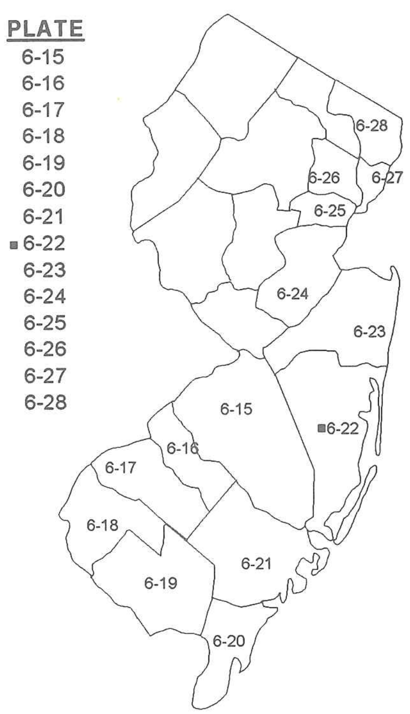
1 INCH = APPROXIMATELY 4 MILES

LEGEND

- EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	▪6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

OCEAN COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-22

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

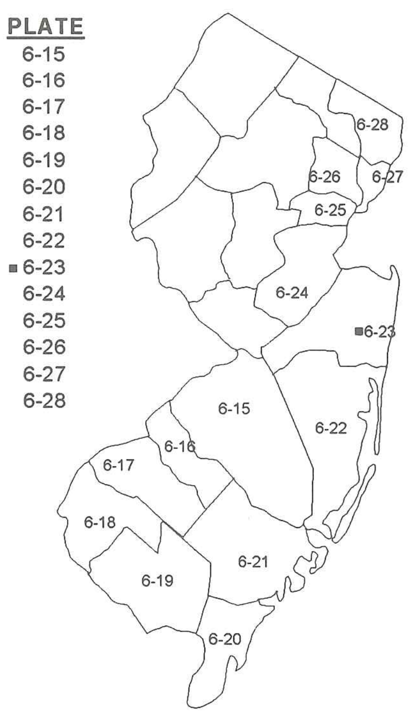
1 INCH = APPROXIMATELY 3.4 MILES

LEGEND

- ◯ EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- —— EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- ● KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	■ 6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28

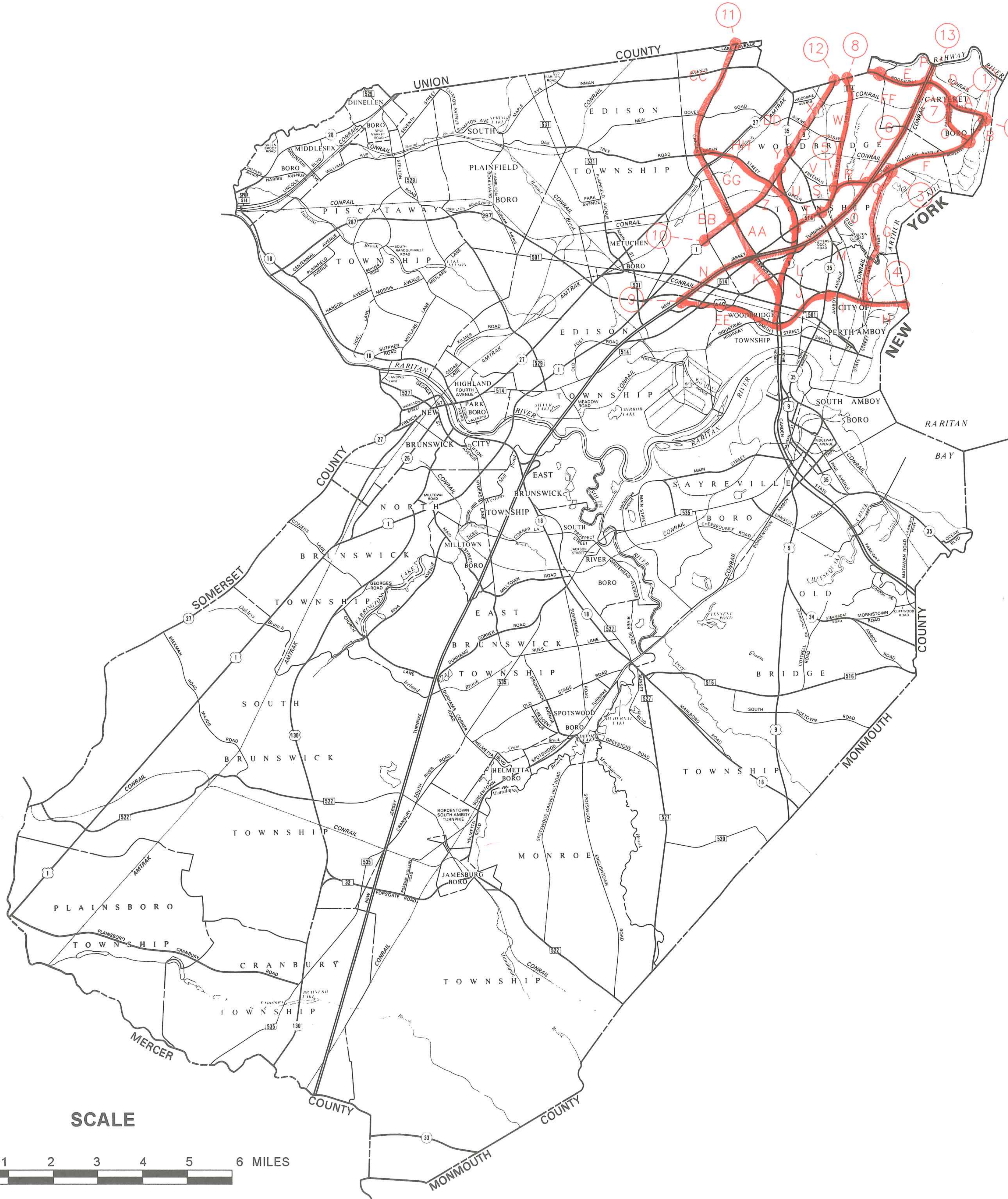


NEW JERSEY
HURRICANE EVACUATION STUDY

MONMOUTH COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-23

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management



SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2.6 MILES

N

LEGEND

EVACUATION ZONE CENTER

3 ZONE NUMBER

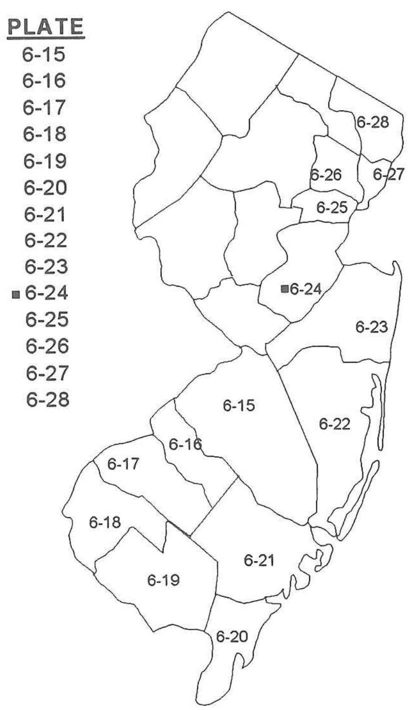
EVACUATION ROAD SEGMENT

A ROAD SEGMENT NAME

KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	▪6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28

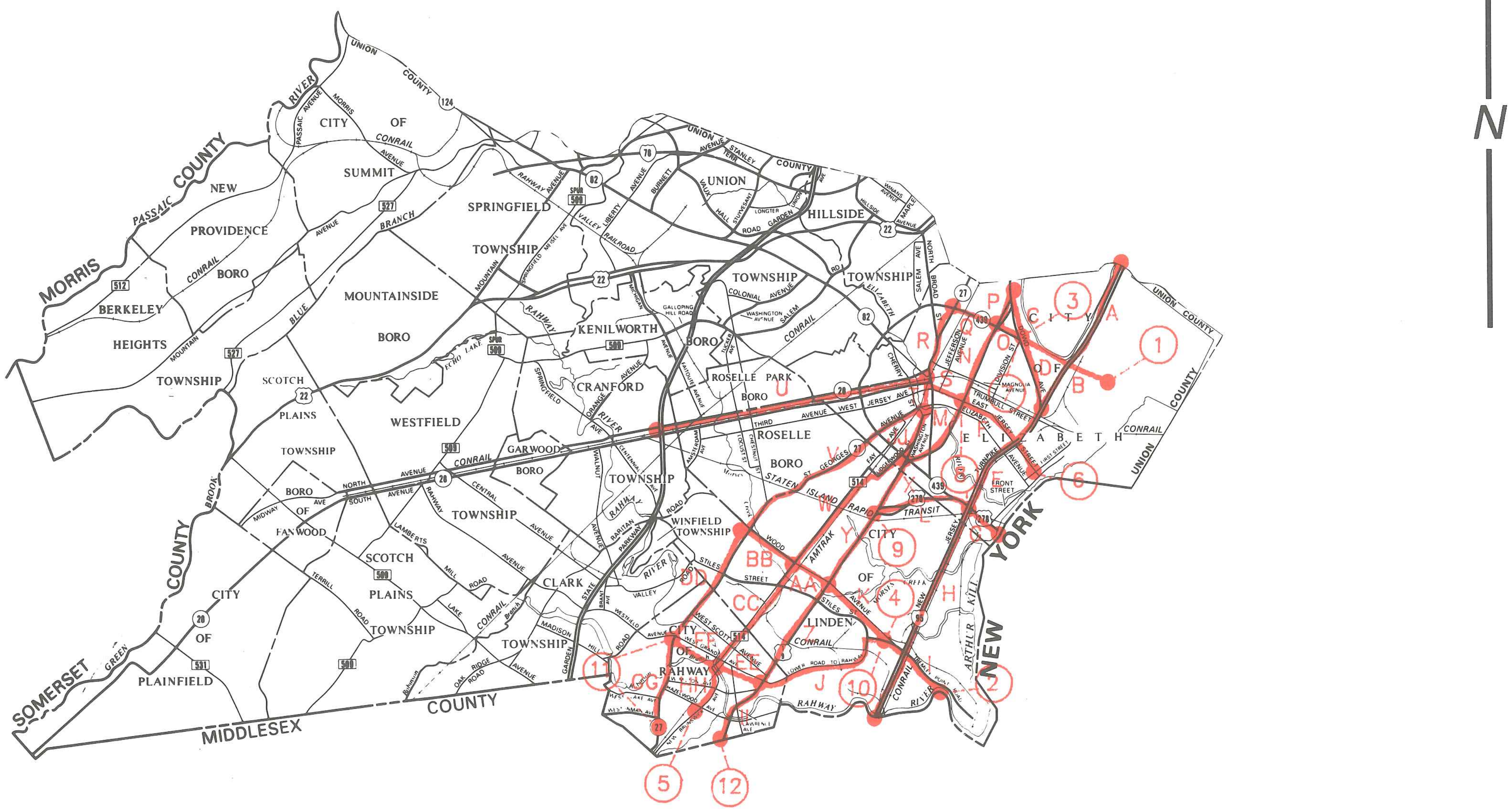


NEW JERSEY
HURRICANE EVACUATION STUDY

MIDDLESEX COUNTY
EVACUATION ROAD NETWORK MAP

PLATE 6-24

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

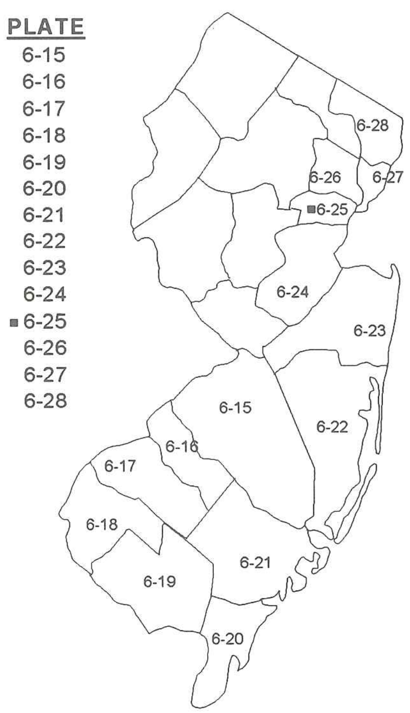


LEGEND

- EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	▪ 6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

UNION COUNTY
EVACUATION ROAD NETWORK MAP

PLATE 6-25

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

N

LEGEND

EVACUATION ZONE CENTER

3 ZONE NUMBER

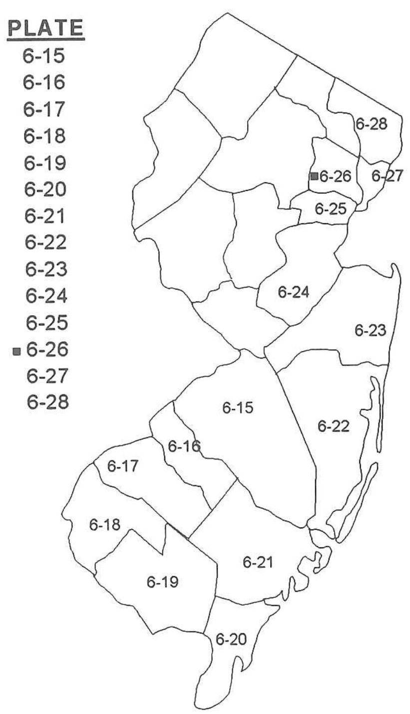
EVACUATION ROAD SEGMENT

A ROAD SEGMENT NAME

KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	6-28



NEW JERSEY HURRICANE EVACUATION STUDY

ESSEX COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-26

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

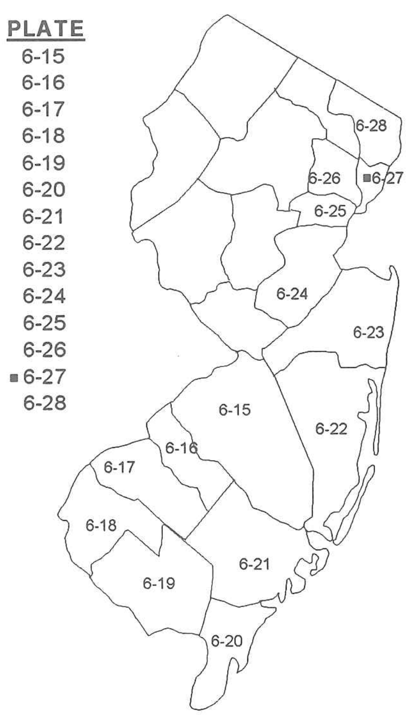
N

LEGEND

- EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	▪6-27
BERGEN	6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

HUDSON COUNTY
EVACUATION ROAD NETWORK MAP

PLATE 6-27

Prepared by the U.S. Army Corps of Engineers, Philadelphia District,
in cooperation with the Federal Emergency Management Agency Region II
for the New Jersey State Police Office of Emergency Management

SCALE

0 1 2 3 4 5 6 MILES

1 INCH = APPROXIMATELY 2 MILES

SCALE

0 1 2 3 4 5 6 MILES

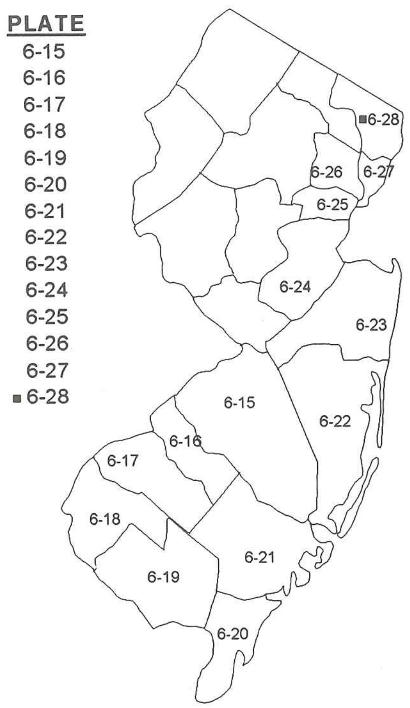
1 INCH = APPROXIMATELY 2 MILES

LEGEND

- EVACUATION ZONE CENTER
- 3 ZONE NUMBER
- EVACUATION ROAD SEGMENT
- A ROAD SEGMENT NAME
- KEY INTERSECTION LOCATION

MAP LOCATOR

COUNTY	PLATE
BURLINGTON	6-15
CAMDEN	6-16
GLOUCESTER	6-17
SALEM	6-18
CUMBERLAND	6-19
CAPE MAY	6-20
ATLANTIC	6-21
OCEAN	6-22
MONMOUTH	6-23
MIDDLESEX	6-24
UNION	6-25
ESSEX	6-26
HUDSON	6-27
BERGEN	■ 6-28



NEW JERSEY
HURRICANE EVACUATION STUDY

BERGEN COUNTY EVACUATION ROAD NETWORK MAP

PLATE 6-28

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency Region II for the New Jersey State Police Office of Emergency Management

TABLE 6-4
TRANSPORTATION ANALYSIS DATA INPUTS

HAZARDS DATA

Land Areas Flooded for each Category Hurricane
Public Shelter Usability 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
Elevation - "Low Spots"
Critical Links/Intersections Capacity Data

6.4 OVERVIEW OF TRANSPORTATION MODELING METHODOLOGY

The tasks involved in performing the transportation analysis are illustrated in the Transportation Analysis Work Flow Diagram (Figure 6-2, p. 6-17). In addition to the initial development of population data, evacuation zones, and scenarios, the diagram provides the transportation modeling steps in the upper right hand box. The transportation modeling methodology developed and employed for the New Jersey 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:

A. Evacuation Zonal Data Development

Data gathered by census tract/traffic analysis zone were stratified by evacuation zone. Numbers of permanent residential dwelling units, mobile homes, and tourist units were compiled by zone and formatted for input into trip generation.

B. Evacuation Road Network Preparation

This step involved developing information for those roadways selected for inclusion in the evacuation road 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.

C. Trip Generation

Specific dwelling unit variables were used in the trip generation calculations to produce total evacuating people 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.

D. Trip Distribution

This step concentrated only on those trips originating in a county and finding acceptable destinations within the same county. Productions from each zone were matched with available attractions in all zones. The end product of the 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.

E. 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.

F. Trip Assignment

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

G. Calculation of Clearance Times

Travel Time/Queuing Delay Analysis - This step involved a detailed look at the critical links and intersections identified for the counties in 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 an 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.

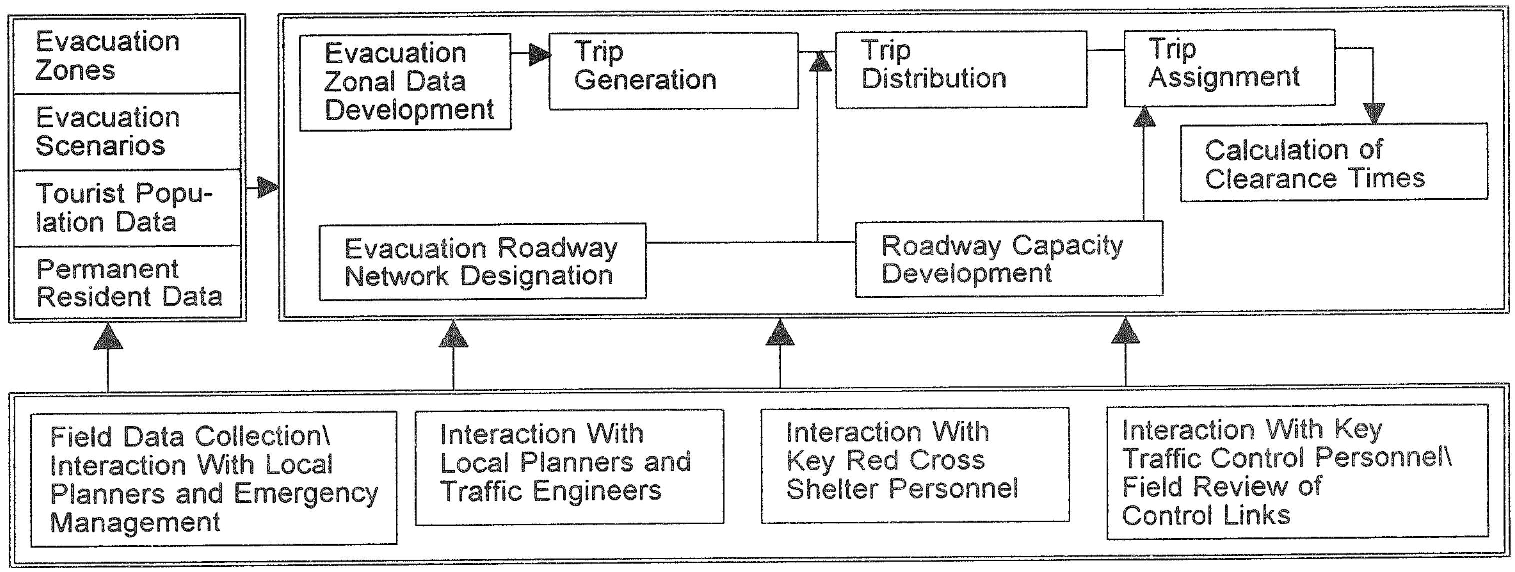


FIGURE 6-2

TRANSPORTATION ANALYSIS WORKFLOW DIAGRAM

6.4.1 Model Application

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:

a. Evacuating people and vehicle parameters
b. Shelter demand and capacity considerations
c. Traffic volumes and critical roadway segments
d. 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.

6.4.2 Evacuating People and Vehicle Parameters

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 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 zones of each county. Table 6-5 (next page) provides estimates of evacuating people and vehicles for each county within the Study area. The number of people evacuating and vehicles expected to be utilized in hurricane evacuations varies according to storm scenarios and tourist unit occupancies. Thus, the highest number relates to a high seasonal occupancy and the most severe hurricane storm category. Numbers are based on current population estimates and a range of evacuation participation rates vulnerable to tidal flooding from worst-case combinations of hurricane directions, forward speeds and landfall points. Evacuating people totals include mobile home residents as indicated by Table 6-3 (p. 6-9). Also included in the four open coast counties is a small percentage of persons who will evacuate although theoretically not vulnerable (See section 6.3.4, p. 6-10).

TABLE 6-5
EVACUATING PEOPLE AND VEHICLES
RANGES BY COUNTY

	NUMBER OF PEOPLE EVACUATING DWELLING UNITS	NUMBER OF VEHICLES EVACUATING DWELLING UNITS
SOUTHERN COUNTIES		
BURLINGTON	7,498 - 25,102	2,673 - 8,934
CAMDEN	42,892	14,995
GLOUCESTER	26,866	9,757
SALEM	31,566 - 40,360	12,418 - 15,866
CUMBERLAND	18,962	7,104
CAPE MAY	115,290 - 566,434	43,643 - 181,705
ATLANTIC	223,705 - 409,139	69,874 - 129,490
OCEAN	127,136 - 263,277	50,564 - 96,879
MONMOUTH	127,136 - 332,135	52,844 - 117,354
METRO NEW YORK AREA COUNTIES[1]		
MIDDLESEX	2,640 - 11,540	917 - 4,010
UNION	960 - 9,140	367 - 3,376
HUDSON	12,070 - 35,312	2,067 - 5,991
ESSEX	3,130 - 17,540	661 - 3,702
BERGEN	7,300	2,797

[1] See Table 3-15(B) (p. 3-4) footnotes for listing of portions of Metro New York counties included in traffic modeling. Plates 6-10 thru 6-14 (following p. 6-14) show these areas.

6.4.3 Shelter Demand/Capacity Considerations

The data presented above are most useful when matched with available sheltering (see Tables 5-15(A) & 5-15(B) (pp. 5-29 & 5-30) for listing of shelter capacities. It is important to note that evacuating people and vehicle statistics generated for each county, evacuation zone, and destination type reflect where evacuees would go assuming enough safe destinations were available. After matching the preferred destinations of evacuees with available shelters, the transportation analysis revealed that hotel/motel space will not be as widely available within the Study area as perceived by the evacuating population. For transportation modeling purposes, those evacuees unable to be accommodated by in-county and Study area hotel/motel space or public shelter space were assumed to leave the Study area.

6.4.4 Traffic Volumes and Critical Roadway Segments and Intersections

The Transportation Model Support Document provides the assigned number of evacuating vehicles for all roadway segments in each county's evacuation network. In addition, the Support Document provides the volume to capacity ratios calculated for each link. Those roadway segments with the highest volume to capacity ratios were identified as the critical links for each county. Table 6-6 (next page) lists the critical roadway segments and associated intersections for each county by order of severity. These constriction points control the flow of evacuation traffic during a hurricane evacuation and are key areas for special traffic control.

It should be noted that the most critical segments or intersections for Cape May and Atlantic Counties are on the mainland, most notably the Garden State Parkway/Atlantic City Expressway intersection, Route 47 in Cape May and Cumberland Counties, and the Route 42/Route 55 intersection in Camden County.

TABLE 6-6
CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS

BURLINGTON COUNTY

U.S. Route 206 and Route 70 intersection
Route 72 and Route 70 intersection
Route 70 through County
Route 73 through County

CAMDEN COUNTY

Route 42 Freeway/Route 55 connection
Atlantic City Expressway
I-76 (Route 42)
U.S. 70 through Cherry Hill
U.S. 30 through Camden

GLOUCESTER COUNTY

Route 42 in Camden County
Route 42 Freeway north of Route 55 connection
Route 55 throughout County
Delaware Avenue north of 1-295/U.S. 130
U.S. 322/Route 42 at Williamstown
U.S. 322/Route 47 intersection at Glassboro

SALEM COUNTY

U.S. 40 west of Woodstown
I-295/U.S. 40/New Jersey Turnpike interchange
Route 49 south of I-295
Route 45 at and north of Salem

CUMBERLAND COUNTY

Route 47 (Delsea Drive) at and south of Route 55
Route 55 throughout County
Route 49/77 intersection at Bridgeton
Delsea Drive/Route 49 intersection at Millville

(TABLE CONTINUED)

TABLE 6-6 (CONTINUED)
CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS

CAPE MAY COUNTY

Route 47, from Route 83 intersection to Route 55 intersection in Cumberland County
Garden State Parkway and Atlantic City Expressway Interchange
Route 147 from North Wildwood to Garden State Parkway
Garden State Parkway at Cape May Courthouse
Route 657 from Garden State Parkway to Route 47
Roosevelt Boulevard from Ocean City to Garden State Parkway
Route 47 at Wildwood
Route 52 from Ocean City to Garden State Parkway interchange in Atlantic County (including Somers Point traffic circle)
Route 50 and U.S. 322 intersection in Atlantic County
Sea Isle Boulevard
Avalon Boulevard
(All coastal drawbridge locations)

ATLANTIC COUNTY

Garden State Parkway/Atlantic City Expressway Interchange
Atlantic City Expressway west of Garden State Parkway
Route 563 at Northfield (Shore Road and U.S. 9 intersections)
Absecon Boulevard Causeway
U.S. 9 at Absecon
Jerome Avenue at Margate City
Route 87 Causeway from Brigantine and Absecon Boulevard intersection
Atlantic City Expressway Causeway
U.S. 40/322 Causeway - Pleasantville Boulevard
Longport Boulevard from Longport to Shore Road
Route 50/Atlantic City Expressway Interchange
Somers Point traffic circle
Shore Road and U.S. 30 intersection
Tilton Road and Garden State Parkway interchange
U.S. 9 at Somers Point

(TABLE CONTINUED)

TABLE 6-6 (CONTINUED)
CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS

ATLANTIC COUNTY

Garden State Parkway/Atlantic City Expressway Interchange
Atlantic City Expressway west of Garden State Parkway
Route 563 at Northfield (Shore Road and U.S. 9 intersections)
Absecon Boulevard Causeway
U.S. 9 at Absecon
Jerome Avenue at Margate City
Route 87 Causeway from Brigantine and Absecon Boulevard intersection
Atlantic City Expressway Causeway
U.S. 40/322 Causeway - Pleasantville Boulevard
Longport Boulevard from Longport to Shore Road
Route 50/Atlantic City Expressway Interchange
Somers Point traffic circle
Shore Road and U.S. 30 intersection
Tilton Road and Garden State Parkway interchange
U.S. 9 at Somers Point

OCEAN COUNTY

Route 528 (Cedar Bridge Road) and Route 70 intersection
Route 72 Causeway and Long Beach Boulevard intersection
Route 88 west of Point Pleasant
U.S. 9 from Toms River to 1-195 in Monmouth County
Route 528 and Ocean Avenue intersection
Mathis Bridge (Route 37) and Central Avenue intersection
Route 72 and U.S. 9 intersection
Route 72 and Garden State Parkway interchange
Route 539 and Route 72 intersection

MONMOUTH COUNTY

Route 36 from Ocean Avenue (at Long Branch) to Route 35/36 traffic circle at Eatontown
Route 36/Route 35 intersection south of Keyport
Route 71 through Manasquan
Route 36 intersection with Garden State Parkway east of Matawan
Route 520 west of Route 34
U.S. 9 south of I-195
Route 138 from Belmar to Garden State Parkway
Route 33 from Main Street (at Bradley Beach) to Garden State Parkway
Route 35 and 3rd Avenue intersection

(TABLE CONTINUED)

TABLE 6-6 (CONTINUED)
CRITICAL ROADWAY SEGMENTS AND INTERSECTIONS

MIDDLESEX COUNTY

I-95/New Jersey Turnpike
Garden State Parkway
Port Reading Avenue and Blair Rd. intersection
Roosevelt Avenue

UNION COUNTY

I-278 and I-95/New Jersey Turnpike interchange (toll plaza)
I-95/New Jersey Turnpike
West Grand Avenue and US 1 intersection
Tremley Point Road and Stiles Street intersection

HUDSON COUNTY

I-495/New Jersey turnpike interchange (toll plaza)
Holland tunnel exit/junction with I-78
Montgomery Street
Willow Avenue

ESSEX COUNTY

I-78 and I-95/New Jersey Turnpike interchange
I-95/New Jersey Turnpike

BERGEN COUNTY

Route 17 south of I-80
Route 3 and New Jersey Turnpike interchange (toll plaza)

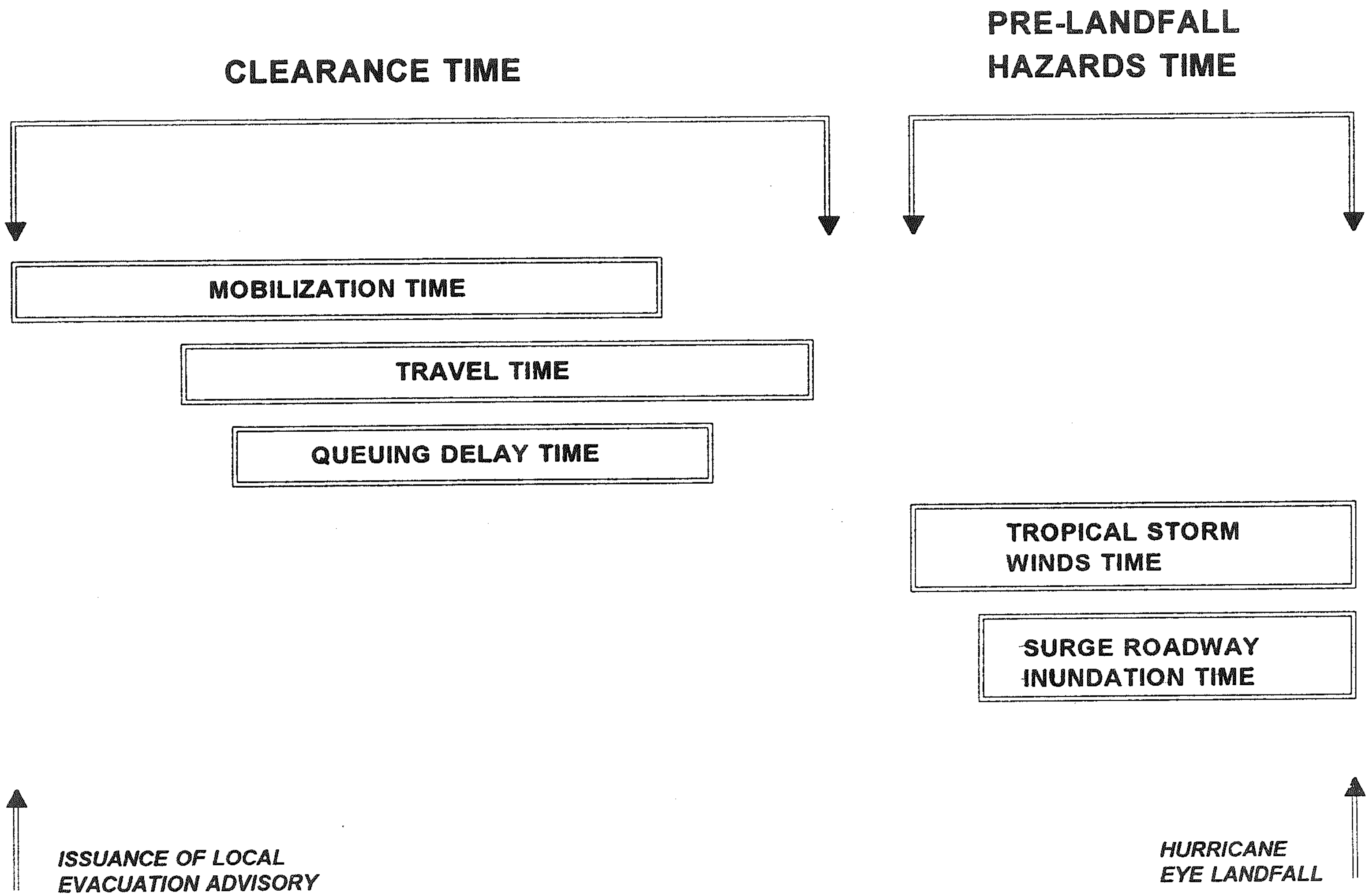


FIGURE 6-3
COMPONENTS OF EVACUATION TIME

6.5 ESTIMATED CLEARANCE TIMES

The most important products of the transportation analysis are the clearance times developed by storm scenario and evacuee response for each county. The clearance time is one of two major considerations in issuing an evacuation recommendation or advisory. Clearance time must be combined with pre-landfall hazards time in order to calculate the total time available for an evacuation. Figure 6-3 (p. 6-25) illustrates these components of evacuation time. Chapter 7 further explains the use of these components in the evacuation decision making process.

Clearance time is the time required to clear the roadways of all vehicles evacuating in response to a hurricane threat. Clearance time begins when the first evacuating vehicle enters the road network (as defined by a hurricane evacuation behavioral response curve) and ends when 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 (mobilization time), the time spent by evacuees traveling along the road network (travel time), and the time lost due to traffic congestion (queuing delay time). **Clearance time does not relate solely to the time any one vehicle spends traveling on the road network.**

Tables 6-7 through 6-20 (pp. 6-28 to 6-41) present the clearance times estimated for each county in the Study area. Times are stratified by intensity of hurricane (storm scenario); by rate of response on the part of the evacuating population; and by level of tourist occupancy. Tables are presented in counter-clockwise order beginning with Burlington County.

6.6 TRAFFIC CONTROL MEASURES

The movement of evacuating 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 involve local police, state police, emergency management personnel and where appropriate the U.S. Coast Guard. The following traffic control techniques/strategies were discussed with disaster preparedness Study review committee members:

A. In a high seasonal occupancy situation, it will be critical to use lane traffic control strategies on Route 47 between Dennisville and Eldora in Cape May County and between Bricksboro and Route 55 in Cumberland County. The clearance time calculations suggest a potential time savings of up to 16 hours with this reversal.

B. Ideally, two officers should be stationed at each critical intersection, one to move traffic, the other to assist disabled vehicles. Critical links and intersections discussed previously should be used as a starting point in developing manpower assignments. Due to the long evacuation times, personnel may be needed at some intersections for 18 to 24 hours. Since many municipalities may not have the resources to provide the required level of staffing, evacuation plans, mutual aid agreements, etc. should address this problem in detail.

C. All available tow trucks should be positioned along key travel corridors and critical links. At a minimum, tow trucks should be at major bridge crossings to remove disabled vehicles.

D. Where intersections will continue to have signalized control, signal patterns providing the most "green time" for the approach leading away from the coast should be actuated by the State Department of Transportation field office or local traffic engineer's office as appropriate.

E. All draw/swing bridges needed for evacuation should be locked in the "down" position during a hurricane warning. Boat owners must be made aware of flotilla plans and time requirements for securing vessels. Optimally, recreational vehicles should be moved to safe harbor before a hurricane watch.

F. Manual direction of traffic should be supplemented by physical barriers/cones that are adequately weighted down and which are placed to channel traffic and prevent unnecessary turning and merging conflicts. This could help at major interchanges such as Route 42/Route 55 and the Garden State Parkway/Atlantic City Expressway.

G. The movement of mobile homes and campers along evacuation routes should be minimized after a hurricane warning is issued. A disabled camper/RV could block the only escape route in some areas. Such vehicles are difficult to handle late in an evacuation due to sporadic wind gusts as the hurricane approaches.

H. Mechanisms should be established that would allow suspension of tolls on the Garden State Parkway and Atlantic City Expressway if and when their collection becomes a hindrance to a timely evacuation.

I. The junction of Route 55 and Route 42 in Gloucester County, although approximately 45 miles from the coast, will be a major bottleneck in the road network. Officers should be stationed there to facilitate traffic movements/ merging.

TABLE 6-7
BURLINGTON COUNTY CLEARANCE TIMES

	LOW COASTAL SEASONAL OCCUPANCY[1]		HIGH COASTAL SEASONAL OCCUPANCY	
CATEGORY 1-2 HURRICANE				
RAPID RESPONSE	4	[11][2,3]	4	[19]
MEDIUM RESPONSE	6	[13]	6	[21]
SLOW RESPONSE	9	[15]	9	[22]
CATEGORY 3-4 HURRICANE				
RAPID RESPONSE	4	[13]	4	[21]
MEDIUM RESPONSE	6	[15]	6	[22]
SLOW RESPONSE	9	[16]	9	[24]

NOTES

1 Coastal seasonal occupancy accounts for varying levels of evacuating traffic originating in Atlantic, Ocean and Monmouth counties.

2 Unbracketed times reflect local traffic only; numbers in brackets show time needed to clear roadways of all evacuation traffic, specifically that originating in other coastal counties.

3 All times have been rounded to the nearest whole hour.

TABLE 6-8
CAMDEN COUNTY CLEARANCE TIMES

	LOW COASTAL SEASONAL OCCUPANCY[1]	MEDIUM COASTAL SEASONAL OCCUPANCY	HIGH COASTAL SEASONAL OCCUPANCY
CATEGORY 1-4 HURRICANE LIGHT BACKGROUND TRAFFIC			
RAPID RESPONSE	4 [8] (7)[2,3]	4 [14] (10)	4 [22] (17)
MEDIUM RESPONSE	6 [9] (7)	6 [14] (11)	6 [22] (17)
SLOW RESPONSE	9 [10] (9)	9 [14] (12)	9 [24] (18)
CATEGORY 1-4 HURRICANE HEAVY BACKGROUND TRAFFIC			
RAPID RESPONSE	4 [10] (8)	4 [15] (12)	4 [24] (18)
MEDIUM RESPONSE	6 [11] (9)	6 [17] (13)	6 [25] (19)
SLOW RESPONSE	9 [14] (10)	9 [19] (14)	9 [28] (21)

NOTES

[1] Coastal seasonal occupancy accounts for varying levels of evacuating traffic from Cape May, Atlantic, Ocean and Monmouth Counties.

[2] Unbracketed times reflect local traffic only. Numbers in brackets show time needed to clear roadways of traffic originating in other coastal counties. Times in parentheses reflect the use of reverse lane traffic control strategies on Route 47 in Cape May and Cumberland Counties.

[3] All times have been rounded to the nearest whole hour.

TABLE 6-9
GLOUCESTER COUNTY CLEARANCE TIMES

	OFF-SEASON[1] WEEKDAY IN CAPE MAY CO.	OFF-SEASON WEEKEND IN CAPE MAY CO.	PEAK SEASON IN CAPE MAY CO.
CATEGORY 1-4 HURRICANE			
RAPID RESPONSE	4 [7][2,3]	4 [12]	4 [26]
MEDIUM RESPONSE	6 [8]	6 [12]	6 [27]
SLOW RESPONSE	9 [9]	9 [13]	9 [27]

NOTES

[1] Coastal seasonal occupancy accounts for varying levels of evacuating traffic from Cape May and Atlantic Counties. Seasonal occupancy rates tested for Cape May County ranged from 10% to 90% and for Atlantic County from 45% to 95%.

[2] Unbracketed times are for local traffic only. Numbers in brackets show time needed to clear roadways of all evacuating traffic, including that originating in Cape May and Atlantic Counties.

[3] All times have been rounded to the nearest whole hour.

TABLE 6-10
SALEM COUNTY CLEARANCE TIMES

	LOW COASTAL[1] SEASONAL OCCUPANCY	HIGH COASTAL SEASONAL OCCUPANCY
CATEGORY 1-2 HURRICANE		
RAPID RESPONSE	6 [9][2,3]	4 [16]
MEDIUM RESPONSE	6 [10]	6 [17]
SLOW RESPONSE	9 [11]	9 [19]
CATEGORY 3-4 HURRICANE		
RAPID RESPONSE	6 [12]	4 [19]
MEDIUM RESPONSE	7 [13]	6 [20]
SLOW RESPONSE	9 [14]	9 [22]

NOTES

1 Coastal seasonal occupancy accounts for varying levels of evacuating traffic from Cape May and Atlantic Counties. Seasonal occupancy rates tested for Cape May County ranged from 10% to 90% and for Atlantic County from 45% to 95%

2 Unbracketed times are for local traffic only; numbers in brackets show time needed to clear roadways of all evacuating traffic, including that originating in Cape May and Atlantic Counties.

3 All times have been rounded to the nearest whole hour.

TABLE 6-11
CUMBERLAND COUNTY CLEARANCE TIMES

	OFF-SEASON[1] WEEKDAY IN CAPE MAY CO.	OFF-SEASON WEEKEND IN CAPE MAY CO.	PEAK SEASON IN CAPE MAY CO.
CATEGORY 1-4 HURRICANE			
RAPID RESPONSE	4 [10] (6)[2,3]	4 [16] (10)	4 [37] (22)
MEDIUM RESPONSE	6 [10] (6)	6 [17] (10)	6 [37] (22)
SLOW RESPONSE	9 [11] (9)	9 [18] (11)	9 [38] (22)

NOTES

[1] Seasonal occupancy rates tested for Cape May County ranged from 10% to 90%

[2] Times not in brackets or parentheses are for local traffic only. Numbers in brackets show times needed to clear roadways of all evacuating traffic, including that originating in Cape May County. Times in parentheses reflect the use of reverse lane traffic control strategies for Cape May County traffic on Route 47 north to Route 55.

[3] All times have been rounded to the nearest whole hour.

TABLE 6-12
CAPE MAY COUNTY CLEARANCE TIMES[1]

	OFF-SEASON[2] WEEKDAY	OFF-SEASON WEEKEND	PEAK-SEASON
CATEGORY 1-2 HURRICANE			
RAPID RESPONSE	7 [4][3,4]	13 [7]	30 [16]
MEDIUM RESPONSE	9 [6]	13 [8]	30 [16]
SLOW RESPONSE	10 [9]	15 [9]	31 [16]
CATEGORY 3-4 HURRICANE			
RAPID RESPONSE	10 [6]	17 [9]	35 [19]
MEDIUM RESPONSE	11 [7]	17 [9]	35 [19]
SLOW RESPONSE	12 [9]	18 [10]	36 [20]

NOTES

1 This table reflects clearance of the Cape May County evacuation road network. Clearance times in Atlantic, Cumberland, Gloucester and Camden Counties involve Cape May County traffic; reference should be made to Table 6-11 (Cumberland County, p. 6-32) and 6-8 (Camden County, p. 6-29) for calculation of times needed for all Cape May County evacuees to reach destinations.

2 Seasonal occupancy rates tested for Cape May County ranged from 10% to 90%

3 Unbracketed times listed are for clearance of Cape May County roads. Bracketed times reflect reverse lane strategies on Route 47 north of Route 83 intersection.

4 All times have been rounded to the nearest whole hour.

TABLE 6-13
ATLANTIC COUNTY CLEARANCE TIMES[1,2]

	LOW SEASONAL[3] OCCUPANCY	MEDIUM SEASONAL OCCUPANCY	HIGH SEASONAL OCCUPANCY
CATEGORY 1-2 HURRICANE LIGHT BACKGROUND TRAFFIC[4]			
RAPID RESPONSE	9[5]	15	22
MEDIUM RESPONSE	10	16	22
SLOW RESPONSE	11	16	23
CATEGORY 1-2 HURRICANE HEAVY BACKGROUND TRAFFIC[4]			
RAPID RESPONSE	10	16	23
MEDIUM RESPONSE	10	17	23
SLOW RESPONSE	11	18	24
CATEGORY 3-4 HURRICANE LIGHT BACKGROUND TRAFFIC			
RAPID RESPONSE	11	17	23
MEDIUM RESPONSE	11	17	24
SLOW RESPONSE	12	18	24
CATEGORY 3-4 HURRICANE HEAVY BACKGROUND TRAFFIC			
RAPID RESPONSE	11	18	24
MEDIUM RESPONSE	12	18	25
SLOW RESPONSE	13	19	26

NOTES

1 Times allow for the clearance of traffic from all Atlantic County roads including through-traffic from Cape May County.

2 Reference should be made to Camden County (Table 6-8, p. 6-29) for calculation of times needed for traffic leaving Atlantic County to reach destinations.

3 Seasonal occupancy rates tested for Atlantic County ranged from 45% to 95%

4 Light background traffic clearance times apply to late evening through early morning weekdays and relatively quiet weekend periods. Heavy background traffic times apply to a.m. and p.m. rush hours as well as weekday and weekend busy retail periods.

5 All times have been rounded to the nearest whole hour.

TABLE 6-14
OCEAN COUNTY CLEARANCE TIMES[1]

	ROUTE 72[2]		ROUTE 37[1]		ROUTE 88/528[2]	
	OFF SEASON[3]	PEAK SEASON	OFF SEASON	PEAK SEASON	OFF SEASON	PEAK SEASON
CATEGORY 1-2 HURRICANE						
RAPID RESPONSE	7[4]	13	7	10	10	10
MEDIUM RESPONSE	8	14	8	11	11	11
SLOW RESPONSE	10	15	10	13	13	13
CATEGORY 3-4 HURRICANE						
RAPID RESPONSE	7	13	7	10	16	16
MEDIUM RESPONSE	8	14	8	11	17	18
SLOW RESPONSE	10	15	10	13	19	19

NOTES

1 Reference should be made to Table 6-7 (Burlington County, p. 6-28) for clearance times for coastal evacuees who are traveling towards Delaware River crossings.

2 Lower clearance times for roads leaving Long Beach Island (route 72) and the Seaside Park-Seaside Heights area (Route 37) reflect assumption by Ocean County Office of Emergency Preparedness that there will be significant voluntary reductions in vacation population (including an almost total absence of a "day-trip" population) in advance of government evacuation orders or recommendations. These areas have high proportions of seasonal vs. year-round housing in comparison to the vulnerable areas further north in Ocean County.

3 Seasonal occupancy rates tested for Ocean County ranged from 30% to 90%.

4 All times have been rounded to the nearest whole hour.

TABLE 6-15
MONMOUTH COUNTY CLEARANCE TIMES

	OFF-SEASON[1] OCCUPANCY	PEAK-SEASON OCCUPANCY
CATEGORY 1-2 HURRICANE		
RAPID RESPONSE	6[2]	7
MEDIUM RESPONSE	7	8
SLOW RESPONSE	10	10
CATEGORY 3-4 HURRICANE		
RAPID RESPONSE	7	7
MEDIUM RESPONSE	7	8
SLOW RESPONSE	10	10

NOTES

[1] Seasonal occupancy rates tested for Monmouth County ranged from 15% to 90%; reference should be made to Table 6-7 (Burlington County, p. 6-28) for clearance times for coastal evacuees who are traveling towards Delaware River crossings.

[2] All times have been rounded to the nearest whole hour.

TABLE 6-16
MIDDLESEX COUNTY CLEARANCE TIMES
(WOODBRIDGE-CARTERET AREA)[1]

	OFF-PEAK DAILY[2] TRAFFIC	PEAK DAILY TRAFFIC
CATEGORY 2 HURRICANE		
RAPID RESPONSE	4[3]	4
MEDIUM RESPONSE	6	6
SLOW RESPONSE	9	9
CATEGORY 3-4 HURRICANE		
RAPID RESPONSE	5	5
MEDIUM RESPONSE	6	7
SLOW RESPONSE	9	9

NOTES

[1] Plate 6-10 (following p. 6-9) shows portions of Middlesex County included in traffic modeling.

[2] Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as night time situations. New York evacuating vehicles that will use New Jersey regional roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a four-, six- and nine-hour period corresponding to a rapid, medium and slow behavioral response assumed for the evacuating population.

[3] All times have been rounded to the nearest whole hour.

TABLE 6-17
UNION COUNTY CLEARANCE TIMES
(RAHWAY-LINDEN-ELIZABETH AREA)[1]

	OFF-PEAK DAILY[2] TRAFFIC	PEAK DAILY TRAFFIC
CATEGORY 1 HURRICANE		
RAPID RESPONSE	4[3]	4
MEDIUM RESPONSE	6	6
SLOW RESPONSE	9	9
CATEGORY 2-4 HURRICANE		
RAPID RESPONSE	4	5
MEDIUM RESPONSE	6	7
SLOW RESPONSE	9	9

NOTES

[1] Plate 6-11 (following p. 6-9) shows portions of Union County included in traffic modeling.

[2] Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as night time situations. New York evacuating vehicles that will use New Jersey regional roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a four-, six- and nine-hour period corresponding to a rapid, medium and slow behavioral response assumed for the evacuating population.

[3] All times have been rounded to the nearest whole hour.

TABLE 6-18
ESSEX COUNTY CLEARANCE TIMES
(CITY OF NEWARK)[1]

	OFF-PEAK DAILY[2] TRAFFIC	PEAK DAILY TRAFFIC
CATEGORY 1 HURRICANE		
RAPID RESPONSE	4[3]	4
MEDIUM RESPONSE	6	6
SLOW RESPONSE	9	9
CATEGORY 2-4 HURRICANE		
RAPID RESPONSE	4	6
MEDIUM RESPONSE	6	8
SLOW RESPONSE	9	10

NOTES

[1] Plate 6-12 (following p. 6-9) shows portions of Essex County included in traffic modeling.

[2] Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as night time situations. New York evacuating vehicles that will use New Jersey regional roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a four-, six- and nine-hour period corresponding to a rapid, medium and slow behavioral response assumed for the evacuating population.

[3] All times have been rounded to the nearest whole hour.

TABLE 6-19
HUDSON COUNTY CLEARANCE TIMES

	OFF-PEAK DAILY[1] TRAFFIC	PEAK DAILY TRAFFIC
CATEGORY 1 HURRICANE		
RAPID RESPONSE	4[2]	5
MEDIUM RESPONSE	6	6
SLOW RESPONSE	9	9
CATEGORY 2-4 HURRICANE		
RAPID RESPONSE	6	8
MEDIUM RESPONSE	6	9
SLOW RESPONSE	9	11

NOTES

[1] Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as night time situations. New York evacuating vehicles that will use New Jersey regional roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a four-, six- and nine-hour period corresponding to a rapid, medium and slow behavioral response assumed for the evacuating population.

[2] All times have been rounded to the nearest whole hour.

TABLE 6-20
BERGEN COUNTY CLEARANCE TIMES
(SOUTHEAST AREA OF COUNTY)[1]

	OFF-PEAK DAILY[2] TRAFFIC	PEAK DAILY TRAFFIC
CATEGORY 1-4 HURRICANE		
RAPID RESPONSE	4[3]	4
MEDIUM RESPONSE	6	6
SLOW RESPONSE	9	9

NOTES

[1] Plate 6-14 (following p. 6-9) shows portions of Bergen County included in traffic modeling; Plate 6-28 (following p. 6-14) shows evacuation network modeled.

[2] Clearance times were calculated for evacuations including a normal AM or PM peak period and for evacuations in off-peak hours such as night time situations. New York evacuating vehicles that will use New Jersey regional roadways were included in the analysis. Evacuating vehicles were loaded onto the roadway system over a four-, six- and nine-hour period corresponding to a rapid, medium and slow behavioral response assumed for the evacuating population.

[3] All times have been rounded to the nearest whole hour.

Chapter Seven

DECISION ARC METHOD

7.1 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.

7.2 BACKGROUND

Along the Mid-Atlantic seaboard, hurricanes do not ordinarily approach landfall from a direction perpendicular to the coastline but are often recurving from the tropics and make landfall on a track more nearly parallel to shore. At a typical angle of approach to the shoreline, an error of 10 degrees in predicting the hurricane track can easily mean a 100 nautical mile difference in the point of landfall 24 hours later. Also, as hurricanes move out of the tropics toward the central Atlantic coast, they often lose their steering air currents and begin to behave somewhat erratically. In some cases, hurricanes have become totally unpredictable. Understandably, hurricane forecasting along the Atlantic coast has its uncertainties. The average error of 12 hour forecast landfall positions for Atlantic coast tropical cyclones (including storms of less than hurricane intensity) during 1970-79 was about 50 nautical miles and, for 24 hour forecasts, landfall position error was about 110 nautical miles.

When a hurricane approaches a coastline at an acute angle, which is the usual case along the Atlantic seaboard, an error in forecast landfall position will increase or decrease the distance to landfall, possibly resulting in a significant error in forecast time of landfall. The forward motion of hurricanes can also accelerate and decelerate, causing the time of landfall to be even more unpredictable.

The very large clearance times calculated for some New Jersey counties further complicate evacuation decision making. The National Hurricane Center's public advisories provide probabilities of a hurricane passing within 65 statute miles of given coastal locations. Clearance times for peak-season evacuation traffic out of Cape May County can exceed 24 or even 30 hours. However, the maximum probability that can be assigned 30 hours in advance for any location is 27 percent (See Table A-2, Maximum Public Advisory Probability Values, Appendix A, p. A-5). Thus, unless an evacuation order is given when the probability of being impacted is still quite low, it may be very difficult to initiate the evacuation in time to avoid exposure 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.

It is recommended that hurricane vulnerable jurisdictions investigate the various hurricane evacuation decision-making computer programs in use today. These programs incorporate Hurricane Evacuation Study data, including some version of the decision arc method presented in this chapter; they can be very useful in speeding needed calculations and automatically using checklists of factors that should be considered in deciding both if and when to evacuate. Even if a computer program(s) 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 ensure the ability to function in the event of power outages or computer failure.

7.3 DECISION ARC COMPONENTS

7.3.1 General

The Decision Arc Method employs two separate but related components which, when used together, depict the hurricane situation as it relates to each county. 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 the county considering evacuation.

7.3.2 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 New Jersey (following Appendix A). Superimposed on ordinary tracking charts are series of concentric arcs with their centers on three points: Cape May (Southern New Jersey Decision Arc Map), Barnegat Inlet (Central New Jersey Decision Arc Map) and Sandy Hook (Northern New Jersey Decision Arc Map). The arcs are spaced at 50 nautical mile intervals. These arcs are labeled both in nautical miles, measured from their center, and alphabetically.

7.3.3 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. These circles form a scale used to note the radius of 34 knot winds (gale force) reported by the National Hurricane Center in the Marine Advisory and Public Advisory (Sample Marine and Public Advisories are presented in Appendix A, beginning on p. A-6).

7.4 DECISION ARC METHOD

7.4.1 General

A hurricane evacuation should be completed prior to the arrival of sustained 34 knot (gale-force) winds or the onset of storm surge inundation, whichever occurs first. In the New Jersey Hurricane Evacuation Study area, the limiting factor for hurricane evacuation is the arrival of sustained 34 knot winds.

The clearance time is the time required to clear the roadways of all evacuating vehicles, or, the time necessary for a safe evacuation. Therefore, clearance time is measured in hours required prior to the arrival of sustained 34 knot winds. Clearance times are based primarily on three variables: (1) the Saffir/Simpson hurricane category, (2) the expected evacuee response rate, and (3) the tourist occupancy situation.

Decision Arcs are simply clearance times converted to distance 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 34 knot wind field will move while the evacuation is underway. For convenience, a Decision Arc table that converts an array of clearance times and forward speeds to respective Decision Arcs (Appendix A, Table A-3, p. A-10) is provided.

7.4.2 Should Evacuation Be Recommended?

Probability values shown in the National Hurricane Center's Public Advisory describe in percentages the chance that the center of a storm will pass within 65 nautical miles of the listed locations (A sample Public Advisory is presented in Appendix A, p. A-8). 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 Public Advisory, should be compared to other locations. A comparison should also be made with the possible maximums shown in Table A-2 the listing of maximum probability values included in Appendix A (p. A-5). There is no one threshold probability which should prompt an evacuation under any and every hurricane threat. The size and intensity of the storm, as well as its anticipated approach track will need to be considered. Decisions for or against evacuation should be coordinated with the New Jersey State Police Office Management and the National Weather Service.

7.4.3 When Evacuation Should Begin

As a hurricane approaches, the Decision Arc Method requires officials to make an evacuation decision prior to the time at which the radius of sustained 34 knot winds touches the appropriate hurricane forward speed of 25 knots, the evacuation should be initiated before the sustained 34 knot winds approach within 400 nautical miles (arc "H" on the Decision Arc Map). Once the sustained 34 knot winds move across the Decision Arc (within 400 miles of your location), there may not be sufficient time to safely evacuate the affected population.

As mobilization activities are proceeding prior to the Decision Point, consideration should also be given to the need for the traffic control measures discussed in Chapter 6 (p. 6-26), particularly the reversal of traffic on Route 47 in Cape May and Cumberland Counties. The decision to employ these strategies will have to be made simultaneously with the decision to evacuate and will itself influence the decision when to evacuate.

7.5 HURRICANE EVACUATION DECISION WORKSHEET

Appendix A contains a Decision Arc Method Worksheet designed to guide the decision-maker through the Decision Arc Method. Also included are the Decision Arc Table, sample National Hurricane Center marine and public advisories, a time conversion table and the three Decision Arc Maps.

APPENDIX A

HURRICANE EVACUATION

DECISION MAKING MATERIALS

DECISION ARC METHOD
EVACUATION DECISION WORKSHEET

The following procedure has been developed to provide assistance in determining, for a given jurisdiction, IF an evacuation should be initiated and WHEN an evacuation decision must be made. The National Weather Service (NWS) hurricane probability listing included in the Public Advisory is used to assist in this decision making process (see sample Public Advisory p. A-8 & A-9).

There are five basic "tools" needed in this evacuation decision procedure: (1) Decision Arc Map; (2) Decision Arc Table; (3) transparent STORM disk; (4) the NWS Marine Advisory (usually issued every 6 hours); (5) the NWS Public Advisory.

PROCEDURE

1. From the NWS Marine Advisory, plot the last reported position of the hurricane eye on the appropriate Decision Arc Map. [There are three decision arc maps: Southern New Jersey; Central New Jersey and Northern New Jersey. Use the one on which the center of the decision arcs is nearest your jurisdiction.] Notate position with date/time. ZULU time (Greenwich mean time or UTC [Universal Coordinated Time]) used in the advisory should be converted to eastern daylight time by subtracting four (4) hours (see Table A-4, p. A-11 for conversion of times). Plot and notate the five forecast positions of the hurricane from the advisory.

2. From the Marine Advisory, note the maximum radius of 34 knot winds (observed or forecast), the maximum sustained wind speed (observed or forecast), and the current forward speed. Plot the maximum radius of 34 knot winds onto the STORM disk.

3. Using the maximum sustained wind speed previously noted, enter the Saffir/Simpson hurricane scale table (Table A-1, p. A-4) and determine the category of the approaching hurricane.

4. Consult the clearance time table (Tables 6-7 to 6-20, pp. 6-28 to 6-41) for your county. Select the appropriate clearance time based on scenario, seasonal occupancy, background traffic, etc.

5. 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. If clearance times for a locality are very high the forecast forward speed should be determined by measuring the distance between the first forecast position and the forecast position nearest your locality and dividing by the number of hours between forecast positions, e.g. 24 or 36. This will provide the forecast speed for the entire progress of the hurricane toward your location.

6. With the appropriate clearance time, and the greater of the current or forecast forward speeds, enter the Decision Arc table (Table A-3, p. A-10) and select the recommended Decision Arc. Mark this arc on the county Decision Arc Map.

7. Using the center of the STORM as the hurricane eye, locate the STORM on the Decision Arc Map at the last reported hurricane position. Determine if the radius of 34 knot winds falls within the selected Decision Arc; i.e., past the Decision Point (the point at which the radius of 34 knot winds crosses into the selected Decision Arc). If so, available traffic control measures should be implemented and public advisories issued in order to ensure a prompt public response and completion of the evacuation prior to the arrival of sustained 34 knot winds.

8. Move the STORM to the first forecast position. Determine if the radius of 34 knot winds is past the Decision Point. If so, the Decision Point will be reached prior to the hurricane eye reaching the first forecast position.

9. Estimate the hours remaining before a decision must be made by dividing the number of nautical miles between the radius of 34 knot winds and the Decision Point by the forward speed used for the Decision Arc table. Determine if the next NWS Marine Advisory will be received prior to the Decision Point.

10. Compare probabilities shown in the Public Advisory to determine whether an evacuation is now necessary or is likely to become necessary (See Note [c.] next page). Determine how an evacuation of your county would affect the readiness of other counties, and when other counties should be notified. Check inundation maps to determine where flooding may occur, and evacuation zone maps for zones that should prepare to evacuate.

11. At the Decision Point, check the Public Advisory probability table for your location. There is no one threshold probability which should prompt an evacuation under any and every hurricane threat (See Note [c.] below). The size and intensity of the storm, as well as its approach track will need to be considered.

12. Steps 1 through 10 should be repeated after each NWS advisory until a decision is made by the county 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, 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 prior to the Decision Point.

b. Because information given in the Marine Advisory is in nautical miles and knots, the Decision Arc Maps and STORM have a nautical miles scale. 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 value by 1.15. Similarly, miles per hour can be converted to knots by dividing the miles per hour value by 1.15. Statute mile/nautical mile conversions and mile per hour/knot conversions are shown on page A-5.

c. Probability values shown in 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 Public 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 listed on Table A-1 (p. A-5). These comparisons will show the relative vulnerability of your location to adjacent locations and to the maximum possible probability.

d. Steps 3. and 4. above refer to the intensity of a threatening hurricane and to clearance times that are based, among other factors, on hurricane intensity. The Delaware Bay Basin SLOSH Model output indicates that Category 3 or 4 hurricanes approaching New Jersey on coast-paralleling tracks (north-northeast) produce maximum surge heights no higher than Category 2 hurricanes on coast-perpendicular tracks. Evacuation decision makers may wish to refer to these differences in potential inundation in designating areas that should be evacuated and in choosing clearance times. Note, however, that through-county clearance times will be dependent on scenarios utilized in other counties. These decisions should be coordinated between the counties and NJOEM.

TABLE A-1
SAFFIR/SIMPSON HURRICANE SCALE WITH CENTRAL BAROMETRIC PRESSURE RANGES

CATEGORY	CENTRAL PRESSURE MILLIBARS	CENTRAL PRESSURE INCHES	WIND SPEED MPH	WIND SPEED KNOTS	SURGE (FEET)	DAMAGE POTENTIAL
1	>980	>28.94	74-95	64-83	4-5	Minimal
2	965-979	28.5-28.9	96-110	84-96	6-8	Moderate
3	945-964	27.9-28.5	111-130	97-113	9-12	Extensive
4	920-944	27.2-27.9	131-155	114-135	13-18	Extreme
5	<920	<27.2	>155	>135	>18	Catastrophic

TABLE A-2

MAXIMUM PUBLIC ADVISORY PROBABILITY VALUES

FORECAST PERIOD	MAXIMUM PROBABILITY
72 Hours	10 %
60	11
48	13
36	20
30	27
24	35
18	45
12	60

Probabilities listed are the maximum assigned to any location in advance of predicted impact. To illustrate: the National Hurricane Center would not assign a higher than 35% probability that a hurricane would strike Cape May in 24 hours, or a higher than 20% probability that a hurricane would strike in 36 hours.

STATUTE MILES / NAUTICAL MILES

1 STATUTE MILE = .87 NAUTICAL MILES
1 NAUTICAL MILE = 1.15 STATUTE MILES

0 m | 50 m | 100 m | 150 m | 200 m | 250 m

57.5 m | 115 m | 172.5 m | 230 m

43.5 nm | 87 nm | 135 nm | 174 nm | 218 nm

0 nm | 50 nm | 100 nm | 150 nm | 200 nm

m = statute mile

nm = nautical mile

MILES PER HOUR / KNOTS

1 MILE PER HOUR = .87 KNOTS
1 KNOT = 1.15 MILES PER HOUR

0 mph | 50 mph | 100 mph | 150 mph | 200 mph

57.5 mph | 115 mph | 172.5 mph

43.5 kn | 87 kn | 135 kn | 174 kn

0 kn | 50 kn | 100 kn | 150 kn

mph = miles per hour

kn = knots

SAMPLE*
MARINE ADVISORY

MIATCMAT1
TTAA00 KNHC 200922
HURRICANE HUGO MARINE ADVISORY NUMBER 38
NATIONAL WEATHER SERVICE MIAMI FL
1000Z [6 AM] WED SEP 20 1989

TROPICAL STORM WARNINGS IN EFFECT FOR CENTRAL AND NORTHWESTERN BAHAMAS AND DISCONTINUED FOR SOUTHEASTERN BAHAMAS.

HURRICANE CENTER LOCATED NEAR 24.9N 70.5W AT 20/1000Z.
POSITION ACCURATE WITHIN 15 MILES BASED ON AIRCRAFT AND SATELLITE.

PRESENT MOVEMENT TOWARDS THE NORTHWEST OR 325 DEGREES AT 11 KT.

DIAMETER OF EYE 15 NM.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 64 KT WINDS 60NE 60SE 40SW 60NW.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.
RADIUS OF 12 FT SEAS OR HIGHER 150NE 125SE 100SW 175NW.

REPEAT CENTER LOCATED AT 24.9N 70.5W AT 20/1000Z.

FORECAST VALID 20/1800Z 26.0N 71.4W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.

FORECAST VALID 21/0600Z 27.8N 72.9W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.

RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.

(CONTINUED)

* This advisory was issued approximately 42 hours before Hurricane struck the South Carolina coast near midnight on September 21, 1989.

SAMPLE
MARINE ADVISORY
(CONTINUED)

FORECAST VALID 21/1800Z 29.2N 74.8W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.
RADIUS OF 34 KT WINDS 150NE 125SE 100SW 175NW.

REQUEST FOR 3 HOURLY SHIP REPORTS WITHIN 300 MILES OF
24.9N 70.5W.

EXTENDED OUTLOOK
THE FOLLOWING FORECASTS SHOULD BE USED ONLY FOR GUIDANCE
PURPOSES BECAUSE ERRORS MAY EXCEED A FEW HUNDRED MILES

OUTLOOK VALID 22/0600Z 30.5N 78.0W.
MAX SUSTAINED WINDS 90 KT WITH GUSTS TO 105 KT.
RADIUS OF 50 KT WINDS 100NE 100SE 50SW 100NW.

OUTLOOK VALID 23/0600Z 33.5N 81.0W.
MAX SUSTAINED WINDS 60 KT WITH GUSTS TO 75 KT.
RADIUS OF 50 KT WINDS 100SE .
NEXT ADVISORY AT 20/1600Z.

SAMPLE[*]
PUBLIC ADVISORY

88
MIATCPAT1
ETTAA00 KNHC 200925
BULLETIN
HURRICANE HUGO ADVISORY NUMBER 38
NATIONAL WEATHER SERVICE MIAMI FL
6 AM EDT WED SEP 20 1989

A TROPICAL STORM WARNING IS IN EFFECT FOR THE CENTRAL AND NORTHWESTERN BAHAMAS AND IS DISCONTINUED FOR THE SOUTHEASTERN BAHAMAS.

AT 6 AM EDT THE CENTER OF HUGO WAS LOCATED NEAR LATITUDE 24.9 NORTH LONGITUDE 70.5 WEST OR ABOUT 435 MILES EAST OF NASSAU IN THE BAHAMAS.

THE CENTER OF HUGO HAS BEEN MOVING TOWARD THE NORTHWEST AT 12 MPH AND THIS GENERAL MOTION IS EXPECTED TO CONTINUE FOR THE NEXT 24 HOURS.

MAXIMUM SUSTAINED WINDS ARE NEAR 105 MPH AND LITTLE CHANGE IN STRENGTH IS LIKELY TODAY. HURRICANE FORCE WINDS EXTEND OUTWARD UP TO 60 MILES FROM THE CENTER AND TROPICAL STORM FORCE WINDS EXTEND OUTWARD UP TO 200 MILES. THE LATEST MINIMUM PRESSURE REPORTED BY AN AIR FORCE RECONNAISSANCE PLANE IS 957 MILLIBARS...28.26 INCHES.

REPEATING THE 6 AM EDT POSITION...24.9N...70.5W. MOVEMENT... NORTHWESTWARD AT 12 MPH. MAXIMUM SUSTAINED WINDS...105 MPH. CENTRAL PRESSURE...957 MB.

THE NEXT ADVISORY WILL BE ISSUED BY THE NATIONAL HURRICANE CENTER AT NOON EDT WITH AN INTERMEDIATE ADVISORY AT 9 AM.

(CONTINUED)

[*] This advisory was issued approximately 42 hours before Hurricane Hugo struck the South Carolina coast near midnight on September 21, 1989.

SAMPLE
PUBLIC ADVISORY
(CONTINUED)

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

CHANCES OF CENTER OF HUGO PASSING WITHIN 65 MILES OF
LISTED LOCATIONS THROUGH 2 AM EDT SAT SEP 23 1989
CHANCES EXPRESSED IN PER CENT...TIMES EDT

COASTAL LOCATIONS	2 AM THU THRU 2 AM THU	ADDITIONAL PROBABILITIES 2 PM THU THRU 2 PM THU	2 AM FRI THRU 2 AM FRI	2 AM SAT	TOTAL THRU 2 AM SAT
MYSM 241N 745W	1	2	X	1	4
MYEG 235N 758W	X	1	1	X	2
MYAK 241N 776W	X	1	1	1	3
MYNN 251N 775W	X	3	2	1	6
MYGF 266N 787W	X	3	5	2	10
MARATHON FL	X	X	2	2	4
MIAMI FL	X	1	3	2	6
W PALM BEACH FL	X	1	5	2	8
FT PIERCE FL	X	1	6	3	10
COCOA BEACH FL	X	1	7	3	11
DAYTONA BEACH	X	1	6	4	11
JACKSONVILLE FL	X	X	6	5	11
SAVANNAH GA	X	X	5	6	11
CHARLESTON SC	X	X	6	6	12
MYRTLE BEACH	X	X	6	5	11
WILMINGTON NC	X	X	5	6	11
MOREHEAD CITY	X	X	5	5	10
CAPE HATTERAS	X	X	4	5	9
NORFOLK VA	X	X	1	6	7
OCEAN CITY MD	X	X	X	5	5
ATLANTIC CITY NJ	X	X	X	4	4
NEW YORK CITY	X	X	X	3	3
MONTAUK POINT	X	X	X	2	2
PROVIDENCE RI	X	X	X	2	2
NANTUCKET MA	X	X	X	2	2

"X" MEANS LESS THAN ONE PERCENT

TABLE A-3
DECISION ARCS[1]

ESTIMATED CLEARANCE TIME (HRS.)[2]	FORECAST HURRICANE FORWARD SPEED (KNOTS)[3]								
	10	15	20	25	30	35	40	45	50
	DECISION ARC[4]								
4	A	A	B	B	B	C	C	D	D
5	A	B	B	C	C	D	D	E	E
6	A	B	B	C	D	D	E	E	F
7	A	B	C	D	D	E	F	F	G
8	B	B	C	D	E	F	F	G	H
9	B	C	D	E	E	F	G	H	I
10	B	C	D	E	F	G	H	I	J
11	B	C	D	F	G	H	I	J	K
12	B	D	E	F	G	H	J	K	L
13	C	D	E	G	H	I	J	L	M
14	C	D	F	G	H	J	K	M	N
15	C	E	F	H	I	K	L	N	O
16	C	E	F	H	J	K	M	N	P
17	C	E	G	I	J	L	N	O	Q
18	D	E	G	I	K	M	N	P	R
19	D	F	H	J	K	M	O	Q	S
20	D	F	H	J	L	N	P	R	*[5]
21	D	F	H	K	M	O	Q	S	*
22	D	G	I	K	M	O	R	*[5]	*
23	E	G	I	L	N	P	R	*	*
24	E	G	J	L	N	Q	S	*	*
25	E	H	J	M	O	R	*[5]	*	*
26	E	H	J	M	P	R	*	*	*
27	E	H	K	N	P	*[5]	*	*	*
28	F	H	K	N	Q	*	*	*	*
29	F	I	L	O	Q	*	*	*	*
30	F	I	L	O	R	*	*	*	*

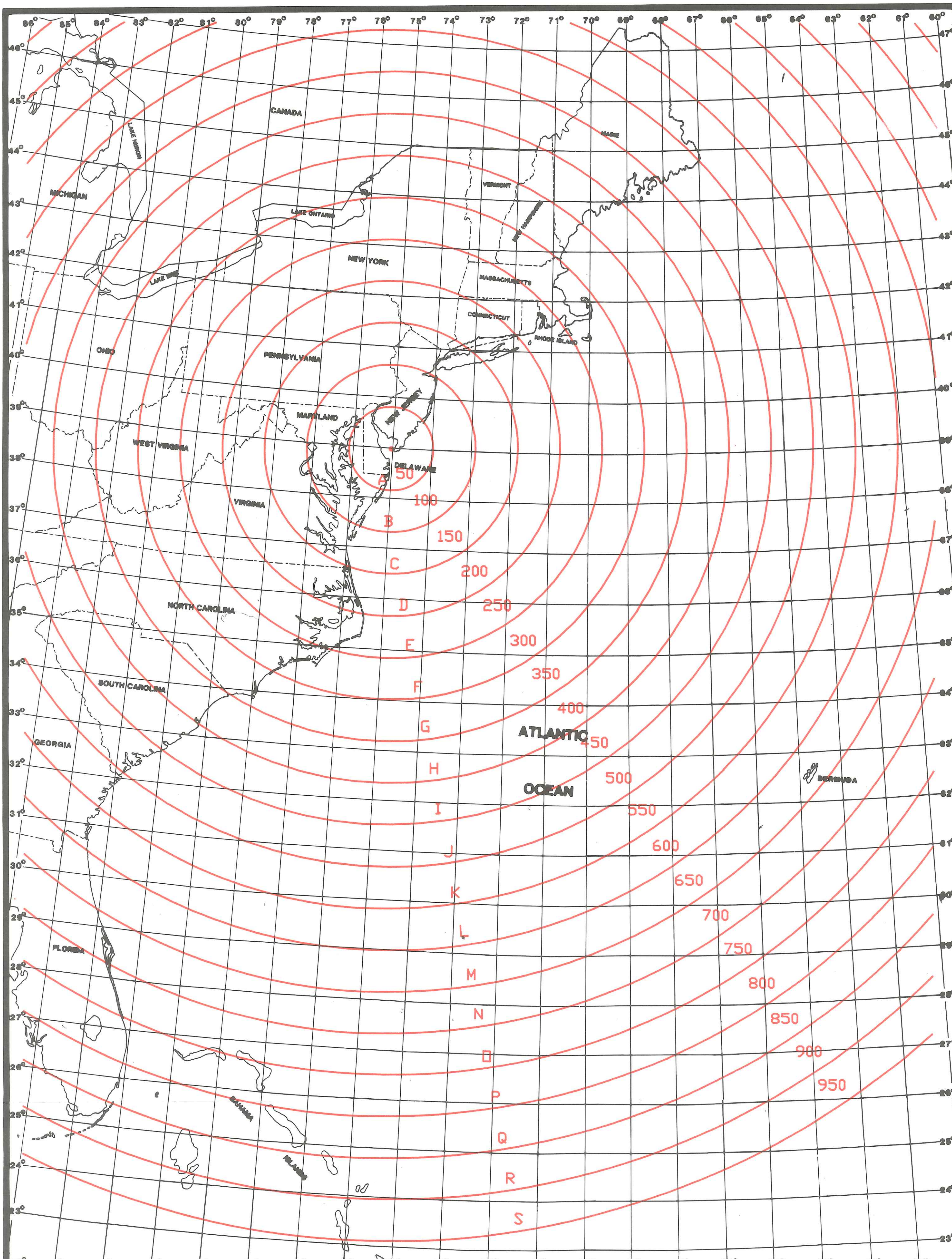
[1] This table can be used with any combination of clearance time and forward speed.
[2] See Tables 6-7 to 6-20 (pp. 6-28 to 6-41) for clearance times.
[3] See Procedure (5.) of Evacuation Decision Worksheet (p. A-2) for methods of determining forecast forward speed.
[4] "Arcs" refer to concentric circles on the New Jersey Decision Arc Map.
[5] * Decision Arc would be 1000 or more miles away from New Jersey.

TABLE A-4
TIME CONVERSIONS

UNIVERSAL COORDINATED TIME (UTC)[2]	EASTERN DAYLIGHT TIME[1] (24 HOUR TIME)	CIVIL-TIME
0500 MONDAY	0100 MONDAY	1 AM MONDAY
0600	0200	2 AM
0700	0300	3 AM
0800	0400	4 AM
0900	0500	5 AM
1000	0600	6 AM
1100	0700	7 AM
1200	0800	8 AM
1300	0900	9 AM
1400	1000	10 AM
1500	1100	11 AM
1600	1200	12 NOON
1700	1300	1 PM
1800	1400	2 PM
1900	1500	3 PM
2000	1600	4 PM
2100	1700	5 PM
2200	1800	6 PM
2300	1900	7 PM
2400 (0000)	2000	8 PM
0100 TUESDAY	2100	9 PM
0200	2200	10 PM
0300	2300	11 PM
0400	2400 (0000)	12 MIDNIGHT
0500	0100 TUESDAY	1 AM TUESDAY

[1] For late season hurricanes (Eastern Standard Time) subtract 5 hours from Universal Time.
[2] UTC = Greenwich Mean Time = ZULU Time; it is expected that future NWS advisories will reference "UTC."

☆ U.S. Government Printing Office: 1992—606-067



NEW JERSEY

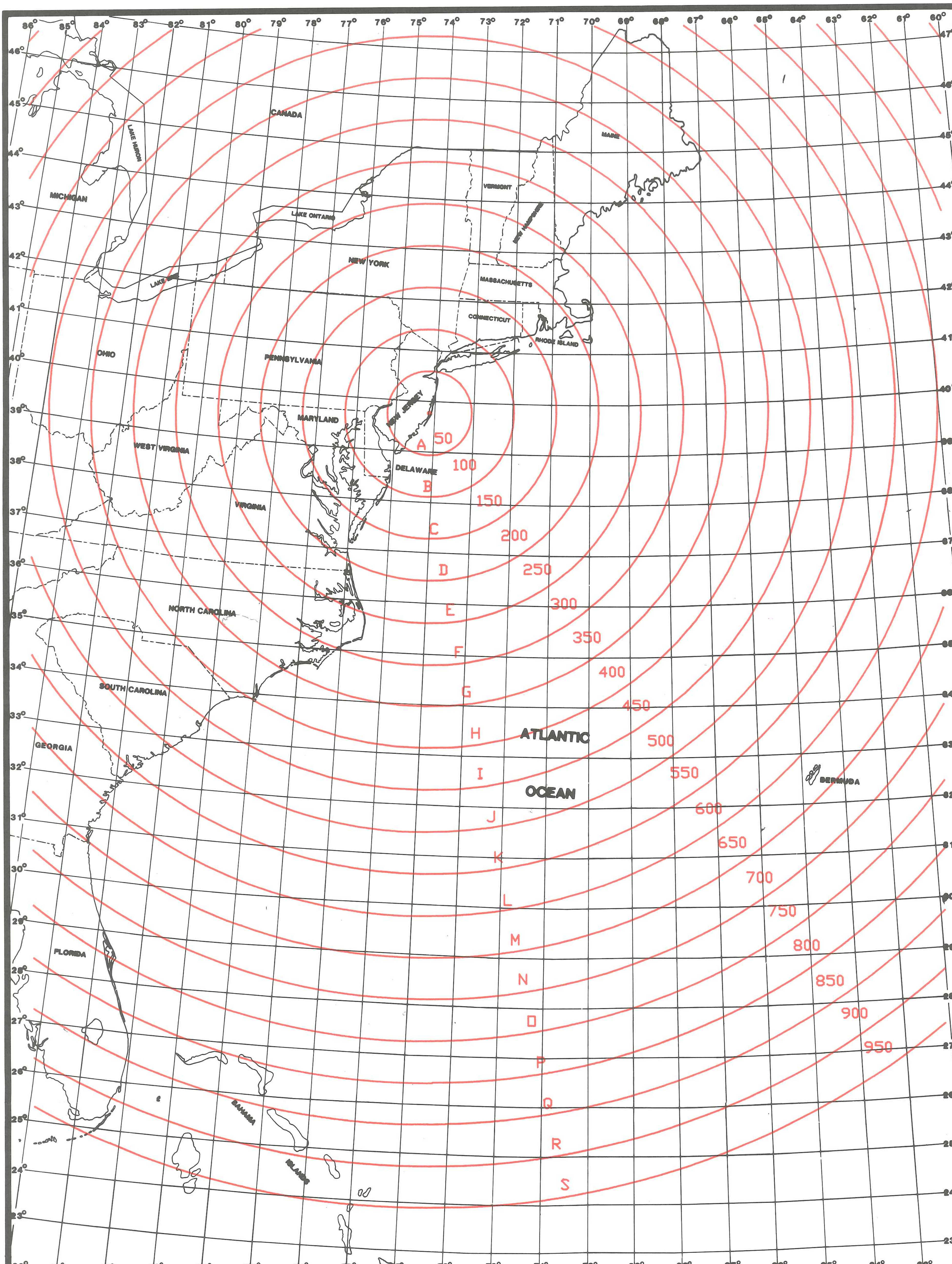
HURRICANE EVACUATION STUDY

SOUTHERN NEW JERSEY DECISION ARC MAP

SCALE: 50 25 00 50 100 150 200 250 NAUTICAL MILES

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency, Region II for the New Jersey State Police Office of Emergency Management.

☆ U.S. Government Printing Office: 1992—606-067

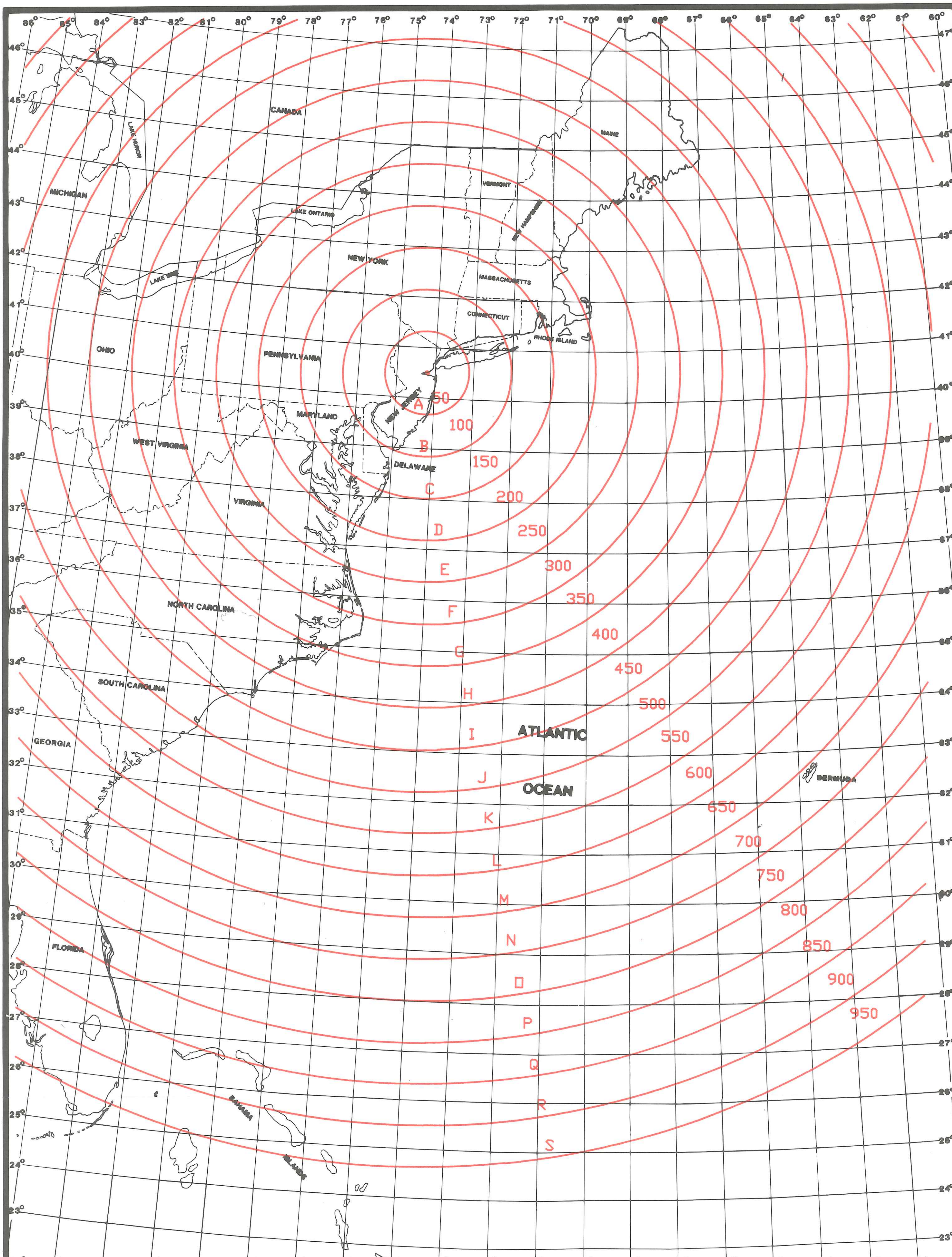


NEW JERSEY
HURRICANE EVACUATION STUDY

CENTRAL NEW JERSEY DECISION ARC MAP

SCALE: 50 25 00 50 100 150 200 250 NAUTICAL MILES

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency, Region II for the New Jersey State Police Office of Emergency Management.



SCALE: 50 25 00 50 100 150 200 250 NAUTICAL MILES

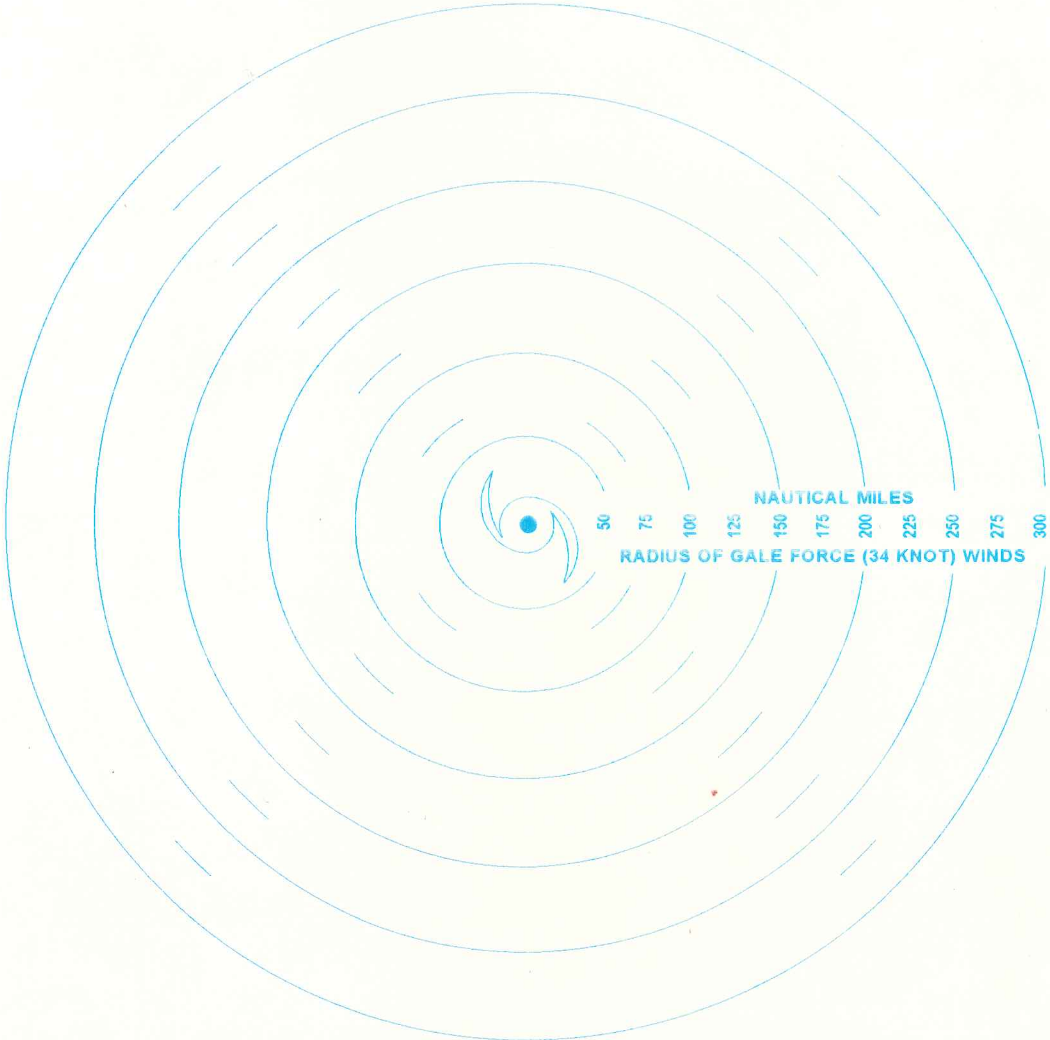
NEW JERSEY

HURRICANE EVACUATION STUDY

NORTHERN NEW JERSEY DECISION ARC MAP

Prepared by the U.S. Army Corps of Engineers, Philadelphia District, in cooperation with the Federal Emergency Management Agency, Region II for the New Jersey State Police Office of Emergency Management.

☆ U.S. Government Printing Office: 1992—606-067


NAUTICAL MILES
50 75 100 125 150 175 200 225 250 275 300
RADIUS OF GALE FORCE (34 KNOT) WINDS

STORM