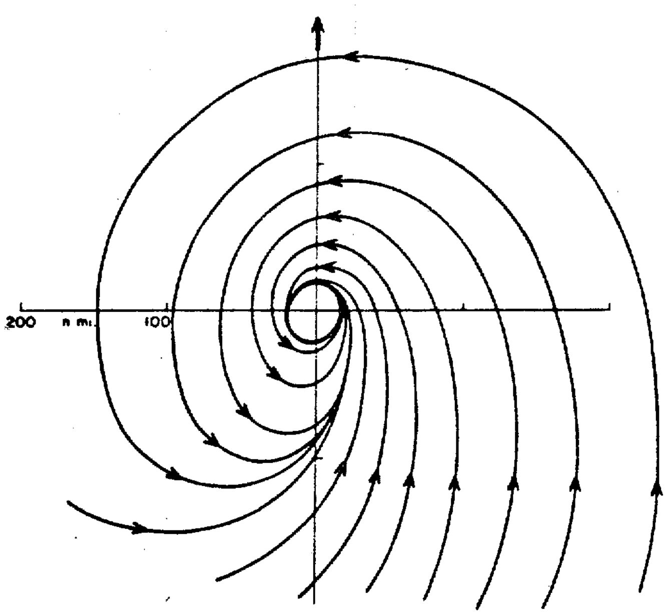
HURRICANE EVACUATION PLAN

Phase One - An Analysis of Evacuation Capability and Vulnerability to Hurricanes in New Hanover County

JUNE 1984

Prepared by the New Hanover County Planning Department



Hurricane Wind Direction

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-Figure on cover from Simpson, R., and H. Riehl, 1981, The Hurricane and It's Impact, Baton Rouge, LA, Louisiana State University Press.

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HURRICANE EVACUATION PLAN

I. PURPOSE AND SCOPE

This Hurricane Evacuation Plan analyzes the capability of expected evacuation routes and shelters to safely accommodate the evacuation of County residents from hurricane-vulnerable areas. This Plan represents the major product of the first year of a two-year comprehensive, Countywide planning effort that will result in an overall "Hurricane Hazard Mitigation and Post Disaster Plan". This plan is being funded by a grant from the North Carolina Office of Coastal Management under authority of the Coastal Area Management Act (CAMA).

The products of this two-year planning study will be:

1. Hurricane Evacuation Plan (year one)
   a. hazard area map
   b. analysis of expected evacuation routes
   c. assessment of existing evacuation routes and sites
   d. proposed mitigation policies if sites and routes are assessed to be inadequate
   e. up-dating of the operational elements of the existing "Hurricane Evacuation Plan", prepared by the New Hanover County Civil Preparedness Agency.

2. Preparation, printing and distribution of evacuation instructions and hurricane season warning poster (year one)

3. Storm Hazard Mitigating Plan (year two)
   a. Inventory and analysis of existing land uses and structures in the hazard areas
   b. Economic risk assessment
   c. Hazard Mitigation policies based on 3a and 3c.

4. Post Disaster Reconstruction Plan (year two)
   a. Guidelines for post disaster reconstruction including the phasing of damage assessment, temporary moratorium, and post disaster development standards
   b. Establishment of damage assessment teams and standards.

II. THE HURRICANE THREAT

A. BACKGROUND

A hurricane resembles a large, shallow funnel with air flowing in a counter clockwise direction from high pressure areas along the storm's periphery to a concentrated center of extremely low pressure. Winds may reach 200 miles per hour near the center of the hurricane, even though the center, or the "eye", is an area of relative calm.

Atlantic hurricanes generally begin as low intensity storm systems in the Carribean Sea or the Western Atlantic Ocean. Hurricanes form by passing through increasingly intense phases:

-tropical depression (winds less than 40 miles per hour)
-tropical storm (winds between 40 and 73 miles per hour)
-hurricane (winds greater than 73 miles per hour)

Although the hurricane season runs from June through November, 90% of all recorded hurricanes in North Carolina have occurred in August, September, and October. Hurricanes tend to follow a westward parabolic path and generally move forward at a speed of around 15 miles per hour. Both the direction and the forward spead of the hurricane path, however, can vary dramatically (McElyea et al, 1983).

Presently, local governments in New Hanover County have the responsibility of ordering evacuation based on their judgement that a hurricane is threatening. The local governments generally use the Hurricane Watch and Warning system of the National Weather Service as signals for action. A Hurricane Watch is issued when a hurricane is near enough that everyone in the area should listen for subsequent advisories and be ready to take action. The National Weather Service issues a Hurricane Warning when hurricane conditions are considered to be highly likely. The goal of the Service is to issue the warning at least 12-18 hours before the hurricane eye reaches the area. The Hurricane Warning generally is the signal used by local governments to order evacuation.

Attempting to predict the path and travel time of a hurricane is complicated by the tendency of the hurricane to vacillate significantly along its path, by the large approximately 125 mile diameter of a hurricane, and by a lack of recorded data on previous hurricanes. The National Weather Service has recently developed a probability system in hurricane forecasting. This system gives the probability increments, in percentages, of a hurricane eye gaining landfall within 65 miles of a given community for five time periods: (1) through 24 hours, (2) 24-36 hours, (3) 36-48 hours, (4) 48-72 hours, and the total probability through 72 hours. These probabilities, however, are not related to the intensity of the storm. This new probability system presently operates in addition to and independent of the Hurricane Watch and Warning System (Carter, 1983).

B. POTENTIAL HURRICANE IMPACTS

Since the turn of the century, casualties from hurricanes have generally decreased due to improvements in monitoring and warning systems and local preparedness and evacuation planning. The potential for substantial loss of life remains, however, as coastal population increases and the tourism traffic grows. Property damage, in contrast to casualties, has increased exponentially. These trends are shown in Figure 1.

Hurricanes are typically classified according to the Saffir/Simpson Damage Potential Scale. Hurricanes are designated on a scale of 1 to 5 (described in Table 1) based on the hurricanes present wind speed, storm surge level, and atmosphere pressure.

Additional hurricane factors causing casualties and damage include wave action and erosion.

(1) Wind damage
Wind strengths will increase as the hurricane center approaches land. Peak gusts may exceed 200 miles per hour. Friction from the land surface will generally dissipate high winds although a narrowing zone of wind damage, 30-35 percent of that at the shoreline, can extend much further inland. In addition, tornadoes may occur with the hurricane. Hurricane Agnes, for example, spawned 15 tornadoes in Florida, resulting in 4.5 million dollars of damage (McElyea et al 1983).

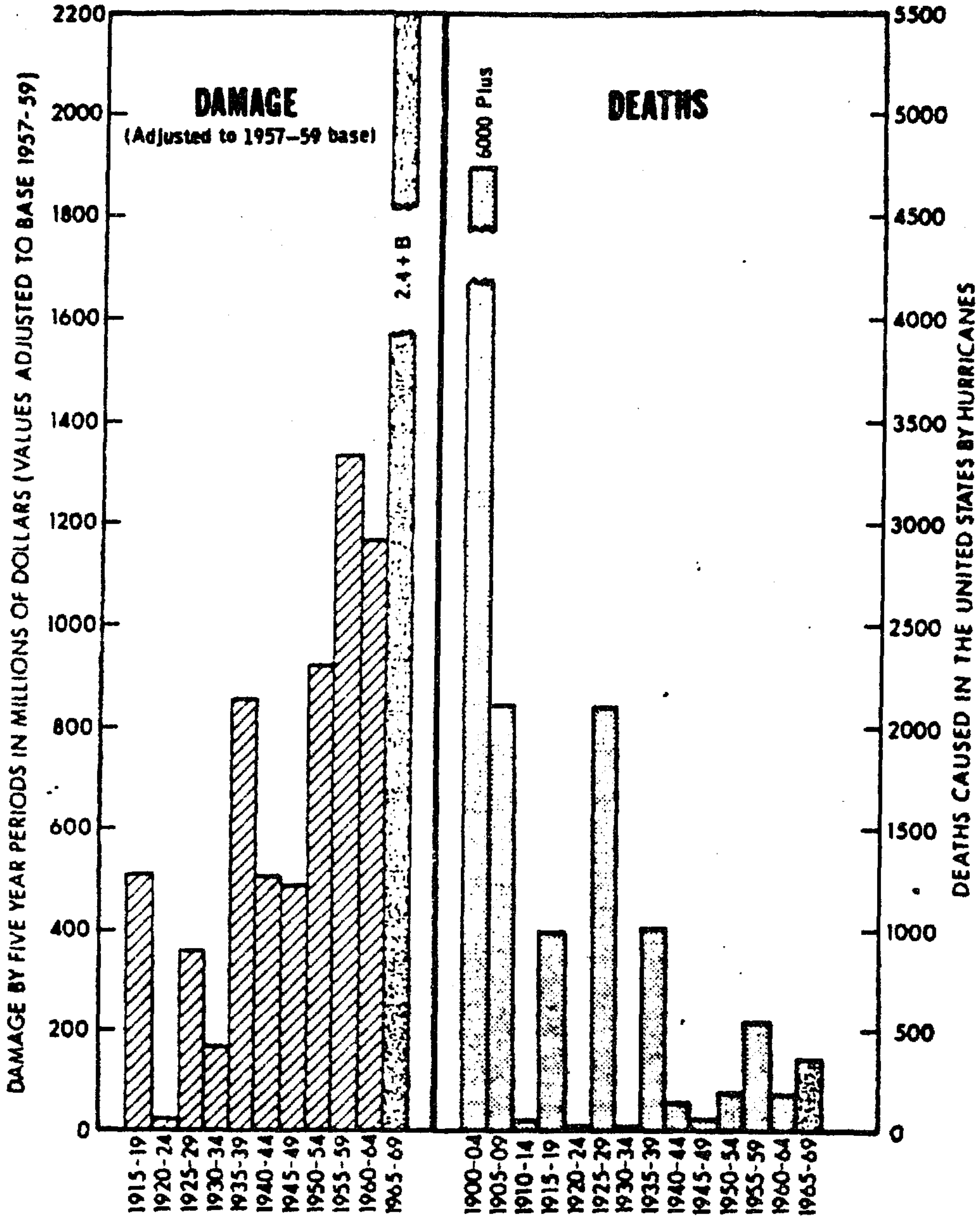
(2) Flooding Damage
Approximately 90% of hurricane deaths and the majority of property damages result from flooding caused by hurricane storm surges and precipitation. The storm surge results from the hurricane winds and low pressure system pushing up an enormous swell of water before it. The height of the surge depends on wind speed, normal water depth, storm trajectory, forward speed of the storm, and tide conditions. Hurricane Hazel in 1954 created a surge of 14.7 feet above mean sea level at Holden Beach. The increase in flood elevation may be 50% greater behind the barrier islands due to funneling of the water in shallow and narrow estuaries and bays. Flooding damage is worsened by the lifting up and use of debris, boats, and structures as battering rams. Saltwater contamination of land may result. Precipitation, adding to the flooding problems, may equal 10" or more in a 24 hour period (McElyea et al 1983)

(3) Wave Action
The impacts of the storm surge are increased greatly by the effects of waves. First, waves on top of a surge can reach and flood areas not reached by the surge itself. Second, waves act as direct battering rams, their force depending upn the velocity and size of waves. The waves are likely to be greatest along the ocean shoreline where winds are greatest and where the ocean bottom falls off rapidly. Generally, the waves height will be equal to 50% of the depth of the storm surge (McElyea, et al 1983).

(4) Erosion
High winds, storm surge, and waves may cause significant erosion, especially on barrier islands. Vast amounts of sand may be removed from the beach front. Dunes may be breached by washover from waves. Finally, inlets tend to form or widen in response to storm surge build-up behind the barrier island. In 1967, Hurricane Beula cut 31 inlets through Padre Island, Texas. Although many of the inlets may eventually fill back in, the damage to structures and transportation networks will already have occurred.

Figure 1

Figure 2.3: Deaths and Damages from Hurricanes in the United States



Source: (McElyea et al, 1983)

Table 1: Saffir/Simpson Damage Potential Scale

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

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

Scale No. 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. And/or: storm surge 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline possibly required.

Scale No. 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. And/or: storm surge 13 to 18 feet above normal. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. 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. Massive evacuation of all residences within 500 yards of shore possibly required, and of single-story residences on low ground within 2 miles of shore.

Scale No. 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. And/or: storm surge greater than 18 feet above normal. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Massive evacuation of residential areas on low ground within 5 to 10 miles of shore possibly required.

Source: (McElyea et al, 1983)

C. HURRICANES AND NEW HANOVER COUNTY

Since 1899, North Carolina has received direct hits from 21 hurricanes, eight of them classified as "major" (3, 4, or 5 on the Saffir/Simpson Scale). Numerous other hurricanes have also impacted North Carolina, including lesser hurricanes and hurricanes staying out at sea or hitting South Carolina. As indicated in Figure 2, New Hanover County has approximately a 6% chance of being directly struck by a hurricane any given year. As indicated in Table 2, a number of hurricanes have either directly or indirectly impacted New Hanover County beaches in the 20th Century (USCOE, 1983). It should be noted that certain impacts such as erosion along beaches may be caused by indirect impacts of hurricanes or of lesser storms, such as "northeasters."

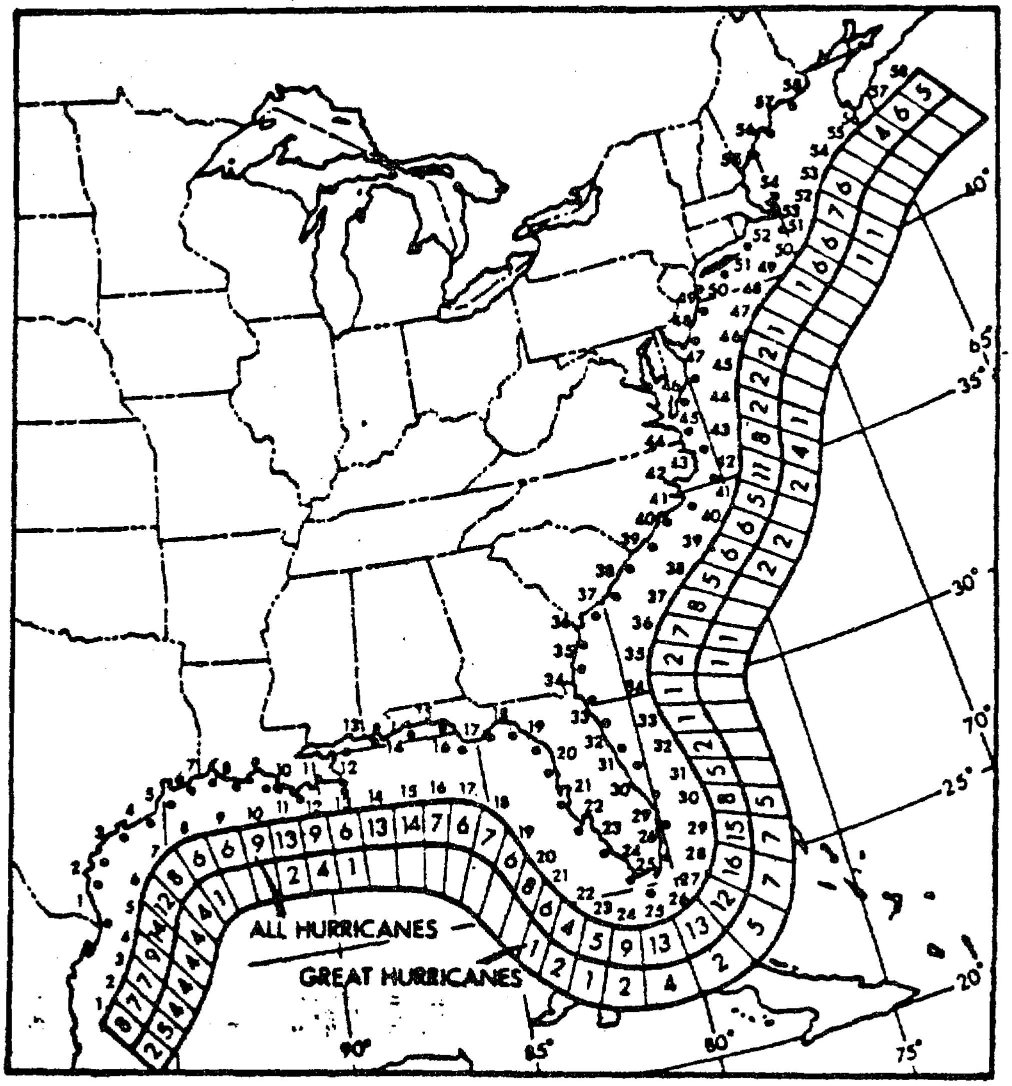
An account of Hurricane Hazel when it struck North Carolina on October 15, 1954, illustrates the impacts caused by a hurricane. The storm surge exceeded 14 feet and wind velocities were estimated at 140 miles per hour. Every fishing pier in North Carolina was destroyed. All buildings were destroyed at Holden Beach and Ocean Isle. At Long Beach, 352 of 357 homes were lost. At Carolina Beach, 475 buildings were destroyed and 1,365 were damaged. Over 1,000,000 cubic yards of sand were deposited on Carolina Beach roads. Wrightsville Beach was submerged under five feet of water and 89 homes were lost. A total of 191 people were killed in the State and $125,309,000 of damage were caused (McElyea, 1983).

III. THE SEVERITY OF EXPOSURE OF NEW HANOVER COUNTY TO HURRICANES

All of New Hanover County is vulnerable to hurricane forces to a varying degree, as evidenced by Table 3. The entire County will be subject to possible wind damage. However, certain areas will be highly exposed to shoreline erosion and scouring, wave action and battering, and flooding, in addition to direct wind damage. These areas, which have a severity rank of one, are Ocean Erodible Areas of Environmental Concern (AECs), Inlet Hazard AECs, and Estuarine Shoreline AECs. These areas are the most critical areas for hurricane protection planning with regard to exposure to hurricane forces.

Ocean Erodible AECs start at mean low water and go landward a distance from the vegetation line equal to 30 times the long term annual erosion rate plus the shoreline recession projected for a 100 year storm. This width generally varies between 200-400 feet. Inlet Hazard AECs are based on statistical analysis of inlet migration (using a 99.9% confidence interval for a 10 year period) and such factors as man-made alterations or unusual hydrologic features. The width of this area may vary from as little as 250 feet for stable inlets to 4,000 feet in more dynamic areas. This hazard area applies only to existing inlets, not to past or potential inlets (Owens, 1981). Detailed maps prepared by the U. S. Corps of Engineers and the N. C. Office of Coastal Management at a scale of 1" = 400' are available for review at the County Planning Department.

Figure 2 Percentage Probability that a Hurricane (winds exceeding 73 mph) or a Great Hurricane (winds exceeding 125 mph) Will Strike a 50-Mile Segment of the U. S. Coastline in Any Given Year.



Source: (McElyea et al., 1983)

Table 2

HISTORICAL RECORDS

Source: (USCOE, 1982)

1. Lists of Hurricanes. The following tables present a chronological list of tropical hurricanes which have likely affected the Wrightsville Beach area. However, many of them caused no appreciable damage and others prior to 1871, which caused some damage, may not be listed:

Records of 18th and 19th Century Hurricanes Affecting the North Carolina Coastal Area

Date Year, Month, and Day		
18th Century		
1700	September	16
1713	September	16
1728	August	-
1728	September	14
1752	September	15
1753	September	15
1757	October	-
1758	August	23
1761	June	1
1761	September	23
1770	June	6
1781	August	10
1783	-	-
1785	September	22-24
1797	September	-
19th Century		
1804	September	7
1811	September	10
1813	August	27
1814	July	1
1815	September	28
1821	September	2
1822	August	-
1822	September	27
1827	July	30
1827	August	24-25
1830	August	16
1837	August	1
1837	August	20
1837	October	9
1838	November	26-28
1842	August	24

Date Year, Month, and Day		
19th Century (cont'd)		
1844	September	14
1846	August	16
1853	September	7
1854	September	8
1857	September	12
1861	October	-
1871	August	18-19
1871	November	14
1873	September	22-24
1873	October	6-8
1873	November	17
1874	September	28
1874	November	22
1875	October	13
1876	September	17
1877	November	2
1878	September	12
1878	October	22
1879	August	19
1880	August	15
1881	August	27
1881	September	9
1883	September	11
1885	August	24-25
1888	October	11
1893	August	28
1893	October	13
1894	September	27
1894	October	9
1896	September	20
1897	November	7
1898	October	2
1899/	October	30

Table 2 cont.

Records of 20th Century Hurricanes Affecting New Hanover County, N.C., Beach Areas

Year	Month and Day	Notes, Severity, Damage Areas, etc.
		Major and Moderate
[1]1904	September 14	Moderate, S.E.N.C.
1904	November 13	Moderate, N.C. coast
[1]1906	September 17	Severe, S.E.N.C. Barometer at Wilm., 27.90
1910	October 19	Moderate, Wilmington area - inland
[1]1913	September 2-3	Hatteras - major, N.E.N.C.
1916	July 19-20	Moderate, N.E.N.C. Heavy rainfall
1918	August 24	Hatteras, moderate, small, N.E.N.C.
1924	August 25	Moderate, skirted N.C. at Hatteras
[1]1925	December 2	Moderate, N.E.N.C. Unusual storm Barometer 28.90 near Wilmington
1930	September 12	Hatteras and vicinity - moderate. Barometer 29.71 at Wilmington.
[1]1933	September 16	Severe N. of New Bern to Va. Capes, moderate to minor elsewhere. Barometer at Hatteras, 28.25 inches.
1934	July 21-25	Very minor in vicinity of Wilmington
[1]1944	August 1-2	Wilmington - severe, S.E.N.C. Barometer at Wilmington, 29.41
[1]1944	September 14	Hatteras - severe. Barometer at Hatteras, 27.97.
1945	September 15-16	Beaufort area - moderate.
1954	August 30	Moderate to light - whole coast - "Carol" Barometer 29.41 at Wilmington.
[1]1954	October 15	Very severe, S.E.N.C. "Hazel." Barometer, 27.70 at Little River, S.C.

1 Storms actually striking or entering N.C. coast with destructive force.

Table 2 cont.

Records of 20th Century Hurricanes Affecting New Hanover County, N.C., Beach Areas

Year	Month and Day	Notes, Severity, Damage Areas, etc.
		Major and Moderate -- Cont'd
[1]1955	August 11-12	Severe, E.N.C., heavy rains - "Connie." Barometer, 28.40 at Fort Macon, N.C.
[1]1955	August 17	Moderate in Wilmington Area - "Diane." Barometer, 29.13 at Wilmington, N.C.
[1]1955	September 19	Severe, E.N.C., excessive precipitation. Barometer, 28.35 at Morehead City, N.C. "Ione."
[1]1958	September 27	"Helene." Severe in Cape Fear area. Maximum 5-minute wind, 69 mph. Minimum barometer 28.80 inches - both at Wilm., N.C.
[1]1960	September 11-12	"Donna." Severe in Cape Fear area, worse in vicinity of Morehead City, N.C. Maximum 1-minute wind velocity in Wilmington, 53 mph, NW; minimum barometer 28.41 inches.
		Minor
1901	September 18	
1902	June 16	
1903	September 16	Very minor - delayed flight of Wright Brothers
1908	August 31	Cape Lookout damaged - very unusual storm.
1916	July 14	Heavy rain in interior.
[1]1920	September 20	Cape Fear River area - small storm - little damage.
1923	October 23	
1924	September 16-17	
1924	September 30	Minor in Wilmington area.
1928	September 18	S.E.N.C. Barometer, 29.12 at Wilmington, N.C.

Table 2 cont.

Records of 20th Century Hurricanes Affecting New Hanover County, N.C., Beach Areas

Year	Month and Day	Notes, Severity, Damage Areas, etc.
		Minor -- Cont'd
1929	September 1-2	Very minor
1934	September 7-8	Barometer at Hatteras, 28.56
1935	September 5-6	
1937	July 31	Minor, not a hurricane in N.C.
1937	August 2-8	Minor, not a hurricane in N.C.
1937	September 26-30	Minor, not a hurricane in N.C.
1938	September 21	Hatteras and vicinity
1938	October 23-24	Minor, not a hurricane in N.C.
1940	August 15	Very minor, heavy rain
1940	September 1	Heavy rains
1942	October 11-12	Very minor, not a hurricane in N.C.
1944	October 20	
1945	June 24	
1945	November 5	Very minor
1946	July 6	Very minor
1946	September 19	Minor
1947	October 12-13	
1950	August 19-20	
1951	October 4	
1952	August 30	Very minor "Able."
1953	August 13	"Barbara" Cape Lookout area.
1954	September 10	"Edna"
1973	February 17	Erosion and some property damage
1979	September 5	"David" 1-year frequency storm

Table 3
Severity of Risk in Hazard Areas

Hazard Area	Exposure to Damaging Forces				
	Severity Rank	Erosion/ Scour	Wave Action/ Battering	Flooding	High Wind
Ocean Erodible AEC	1	●	●	●	●
Inlet Hazard AEC	1	●	●	●	●
Estuarine Shoreline AEC	1	●	●	●	●
V-zone	2	o	●	●	●
Wetland AEC	2	o	●	●	●
A-zone	3			●	●
Rest of Community	4				●

Exposure Level: High (●), Moderate (o), Low ( )

Source: (McElyea et al, 1983)

The Estuarine Shoreline AEC's cover all land within 75 feet of the mean high water line. Estuarine lands may be subject to storm surge and general flooding. Federal Flood Insurance V zones, which tend to overlap the above AECs, represent those areas likely to be flooded by a 100 year storm and exposed to scouring /erosive wave action. Coastal Wetland AECs, located generally within the Estuarine Shoreline AEC, are low lying areas and would tend to be flooded. Federal Flood Insurance A Zones are likely to be inundated in a 100 year storm but would not be subject to scouring/erosive wave action. The extent of the Estuarine Shorelines and Coastal Wetlands are mapped on Figure 4. (attached as fold-out maps in the back of this report) A more detailed map at 1" = 3000' is available for review at the County Planning Department. The extent of the V and A zones are mapped on Figure 5. (attached as fold-out maps in the back of this report) Maps at a scale of 1" = 2000' prepared by Federal Emergency Management Agency (FEMA) of the V and A zones are available for review at the County Planning Department.

IV ANALYSIS OF EVACUATION TIME

A. COMPONENTS OF HURRICANE EVACUATION TIME

Evacuation time is defined as
"...the minimum amount of time before projected hurricane eye landfall that local decision makers must allow for safely completing the evacuation under the particular conditions of the approaching hurricane." (Stone, 1983, p. 7)

Evacuation time is composed of two separate components, clearance time and pre-landfall hazards time.

(1) Clearance Time

Clearance time is defined as the time necessary for the relocation of all vulnerable evacuees to a safe area once the official evacuation order is issued. Clearance time is composed of three subcomponents: mobilization time, travel time, and queuing delay time.

(a) Mobilization time is that period between the issuance of the evacuation order and the departure of the vehicles. It represents time for evacuees to learn of the evacuation order, pack some belongings and leave. Three hours/household for mobilization is a typical time period used in other studies and corresponds with preliminary survey results of residents and tourists during August and September, 1983, on Wrightsville, Carolina and Kure Beaches.

(b) Travel time is the period necessary for the vehicles to travel the length of the evacuation route at an anticipated speed, assuming no queuing delays

(c) Queuing delay time is the amount of time spent by vehicles in traffic jams when the capacity of the evacuation routes are exceeded by the number of vehicles entering those routes. A bottleneck would occur, for instance, where four lanes converge onto a two lane bridge.

The roadway capacity factors for the study, taken from the carrying capacity study for Currituck (Collins, 1983) are 1575 vehicles per hour (vph) for two lane roads and 3222 vph for a four lane road. These levels of capacity would increase for roads with shoulders or parking lanes. These factors take into account the following adjustments:

- common roadway capacity standards for engineering purposes
- 35% reduction in capacity due to adverse weather
- 15% further reduction for stalled cars
- 10% further reduction for emergency vehicle use

It should be noted that traffic during evacuation should be strictly controlled, using policemen for directing traffic and generally requiring one way traffic.

(2) <u>Pre-Landfall Hazards Time</u>

This represents the period of time between when evacuation from the vulnerable area first becomes extremely difficult due to either gale force winds or storm surges that inundate evacuation routes, and when the eye of the hurricane reaches the coast. A typical value for a severe hurricane scoring a "5" on the Saffir/Simpson Scale is four hours. This amount of time plus clearance time equals evacuation time.

B. EVACUATION TIME FOR NEW HANOVER COUNTY

A conservative analysis of the components of evacuation time is presented below for Wrightsville Beach, for the area south of Snow's Cut, and for Figure Eight Island. Although other areas in the County along the sounds, creeks, and rivers are within hazard areas (estuarine shoreline and 100-year flood plain), evacuation for these areas are considered to be adequate because of the short length of the evacuation routes, lack of bridges, and low concentrations of population served by the routes.

The analysis utilizes methods and assumptions drawn from work developed by the State Office of Coastal Management (McElyea, et al 1983), the Sea Grant Program at NCSU (Stone, 1983), and an analysis prepared for Currituck County (Collins, 1983). The analysis assumes the following "worst case" scenario:

A severe hurricane, measuring five on the Saffir/Simpson Scale, has suddenly shifted direction and is heading rapidly toward New Hanover County. The eye of the hurricane is expected to reach land within 12 hours. The National Weather Service has issued a Hurricane Warning and the County's local governments have correspondingly issued evacuation orders. Can the beaches be evacuated in a safe and timely manner?

The analysis below is considered conservative because of certain assumptions concerning traffic flow and because, in reality, up to 30% of the short-term renters and residents would likely leave before the evacuation order is issued (Stone, 1983).

WRIGHTSVILLE BEACH

Total Evacuation Time = Total Clearance Time + Pre-Landfall Hazard Time

= 6.61 hours + 4 hours

= 10.61 hours

The total evacuation time of 11 hours indicates that Wrightsville Beach could be safely evacuated if evacuation is ordered concurrent with a typical 12 hour advance Hurricane Warning. This conservative estimate includes

Total Clearance Time = Mobilization Time + Travel Time + Queuing Delay Time

= 3 hours + .25 hours/1 + 3.36 hours/2

= 6.61 hours

/1 Travel Time: Under free flow traffic conditions, a car should be able to travel from any point on Wrightsville Beach to the mainland in a maximum of 15 minutes.

/2 Queuing Delay Time: Queuing delays will result from vehicles coming from residential streets onto Highways 74 and 76 (Waynick Blvd., Lumina Ave., and Causeway Dr.). It is assumed that traffic coming off the drawbridge onto the mainland will be controlled to prevent traffic back-up Calculations are given below:

-Assume that a total of 3150 households and motel room groups require evacuation. Each has an average of 1.6 vehicles per household, for a total of 5040 vehicles.

-Assume that one half (2200) of the vehicles will evacuate from the southern end of the Beach and more than one half (2840) simultaneously from the northern end, along two-lane roads. The number of vehicles evacuating from the northern end include those from the anticipated development from Shell Island. For simultaneous evacuation of households along those two separate, two-lane stretches of road, therefore, maximum queuing delay time would be determined by the larger of the two:

$$\text{Queuing delay time} = \frac{2840 \text{ vehicles}}{1575 \text{ vph capacity}}$$

$$= 1.8 \text{ hours}$$

-Assume that all vehicles (5040) must travel on a four lane road to the mainland. This maximum queuing delay time would equal:

$$\text{Queuing delay time} = \frac{5040 \text{ vehicles}}{3232 \text{ vph capacity}}$$

$$= 1.56 \text{ hours}$$

-The Wrightsville Beach drawbridge, according to the N. C. Dept. of Transportation, will not be opened during high winds and, therefore, would not be a significant delay in traffic.

-Total maximum Queuing delay time = 1.8 hours + 1.56 hours

= 3.36 hours

AREA OF COUNTY SOUTH OF SNOW'S CUT

Total Evacuation Time = Total Clearance Time + Pre-landfall Hazards Time

= 6.22 hours + 4 hours

= 10.22 hours

The total evacuation time of 10.22 hours indicates that this area of the County could be safely evacuated if evacuation is ordered concurrent with a typical 12 hour advance warning.

Total Clearance Time = Mobilization Time + Travel Time + Queuing Delay Time

= 3 hours + .5 hours/1 + 2.72 hours/2

= 6.22 hours

/1 Travel Time: Under free flow traffic conditions, a car should be able to travel from any point in the County south of Snow's Cut to north of Snow's Cut within 30 minutes.

/2 Queuing delay Time: Queuing delays will result from vehicles coming from residential streets onto US 421 (Carolina Beach Road) Calculations are given below:

-Assume that a total of 3635 households and motel room groups will require evacuation. Each has an average of 1.6 vehicles per household, for a total of 5816 vehicles.

-Assume that one quarter (1454) of the vehicles will evacuate from the area south of Carolina Beach north to Carolina Beach, using the two-lane section of US 421.

$$\text{Queuing Delay Time} = \frac{1454 \text{ vehicles}}{1575 \text{ vph capacity}} = .92 \text{ hours}$$

-Assume that all vehicles (5816) will evacuate north from Carolina Beach to north of Snow's Cut, using the four lane section of US 421.

$$\text{Queuing Delay Time} = \frac{5816 \text{ vehicles}}{3232 \text{ vph capacity}} = 1.80 \text{ hours}$$

-Total maximum queuing delay time = .92 hours + 1.80 hours

= 2.72 hours

FIGURE EIGHT ISLAND

Total Evacuation Time = Total Clearance Time + Pre-Landfall Hazard Time

= 4.12 hours + 4 hours
= 8.12 hours

The total evacuation time of 8.12 hours indicates that Figure Eight Island would be safely evacuated if evacuation is ordered concurrent with a 12 hour Hurricane Warning.

Total Clearance Time		**Mobilization Time**		**Travel/1 Time**		**Queuing Delay/2 Time**
4.12 hours	**=**	**3 hours**	**+**	**.25 hours**	**+**	**.87 hours**

/1 Travel Time: Under free flow traffic conditions, a car should be able to travel from either end of Figure Eight Island to the mainlnd in 15 minutes.

/2 Queuing Delay Time: Queuing delays will result from vehicles coming from residences onto Beach Road and then onto Bridge Road. Calculations are given below:

-Assume that a total of 562 households require evacuation. Each has an average of 1.6 vehicles per household, for a total of 900 vehicles.

-Assume that one half of the vehicles (450) will evacuate simultaneously from the northern end. For these two-lane stretches of road, therefore, maximum queuing delay time would be:

$$\text{Queuing Delay Time} = \frac{450 \text{ vehicles}}{1575 \text{ vph capacity}}$$

$$= .29 \text{ hours}$$

-Assume that all vehicles must travel on the two-lane Bridge Road to the mainland. This maximum queuing delay time would be:

$$\text{Queuing Delay Time} = \frac{900 \text{ vehicles}}{1575 \text{ vph capacity}}$$

$$= .58 \text{ hours}$$

$$\text{-Total Maximum Queuing Delay Time} = .29 \text{ hours} + .58 \text{ hours}$$

$$= .87 \text{ hours}$$

V. ANALYSIS OF EVACUATION SHELTERS

According to the American Red Cross, contracts have been made between the Red Cross and County schools to use the schools as needed for evacuation shelters. Although the Red Cross in Wilmington has certain limited supplies (cots, food, clothing) readily available, the Red Cross has established agreements with local stores and Red Cross chapters elsewhere to obtain additional emergency supplies as needed. The Red Cross also has established provisions for emergency medical services and supplies. The Red Cross performs these functions as part of their Federal mandate and in accordance with North Carolina guidelines from the N. C. Department of Social Services. Principal evacuation routes and shelters are shown in Figure 6 attached to the back of the report.

The local government is responsible for providing utilities and water. The National Guard is generally relied on for these services. In addition, the local Civil Preparedness Office is responsible for coordinating the provision of shelter, supplies, and services.

According to the Red Cross, the County schools have the capacity to shelter 17,000 persons. Assuming that only 20-35% of all evacuees (Stone, 1983) would utilize the public shelter and that the rest would go to family, friends, motels, or outside of the County, this capacity would greatly exceed anticipated use in case of a hurricane.

VI. CONCLUSIONS AND RECOMMENDATIONS

The results, shown below, of this study indicate that the decision to evacuate the beach areas should be made well ahead of the anticipated landfall of the hurricane eye:

Area of County	Clearance Time: Mobilization Time	Clearance Time: Travel Time	Queuing Delay Time	Pre-landfall Hazards Time	Total Evacuation Time
Wrightsville Beach	3 hrs.	.25 hrs.	3.36 hrs.	4 hrs.	10.61 hrs.
South of Snows Cut	3 hrs.	.5 hrs.	2.72 hrs.	4 hrs.	10.22 hrs.
Figure 8 Island	3 hrs.	.25 hrs.	.87 hrs.	4 hrs.	8.12 hrs.

Mobilization time, essentially, is the time required for people to learn of the evacuation decision and pack-up. Travel time is the time required to drive from the beach. Queuing delay time is the additional time spent in traffic jams or other delays. Pre-landfall hazards time is the time when hurricane conditions arrive making evacuation unsafe before landfall of the hurricane eye.

It is important to note that these results are conservative on the safe side. The study assumed "worst case" conditions, for instance, in assuming a four hour pre-landfall hazards time. In addition, the study assumed that no one would leave the beach before evacuation is ordered when, in reality, up to 30% of the beach population would probably leave before the order is issued. If this "early departure" value was factored in, queuing delay times would be reduced.

The County's decision to evacuate presently is dependent upon the issuance of a Hurricane Warning by the National Weather Service. Because the Hurricane Warning generally is given at least 12 hours before anticipated landfall of the hurricane eye, the calculated total evacuation times indicate the County's present decision making framework is adequate for safe and timely evacuation. This fortunate situation is primarily due to the presence of four-lane highways along major sections of the evacuation routes that would be traveled to reach the safety of the mainland. Shelters are also more than adequate.

It is important to note, however, that total evacuation times for Wrightsville Beach and for the area south of Snow's Cut may be approaching the critical point where safe evacuation may become excessively difficult. This fact emphasizes the need for maintenance of strict control procedures to minimize mobilization and queuing delay times, e. g. not permitting sightseers to cross over the bridges into the evacuation areas and controlling access at boat ramps and marinas, and the need for development of a decision making structure that can quickly order evacuation once the Hurricane Warning is issued, if not before.

In addition, continued growth at Wrightsville Beach and the area south of Snow's Cut, particularly Carolina Beach, could eventually result in queuing delays that would make evacuation more difficult. The potential of such impacts should be considered in the planning of future developments for these areas.

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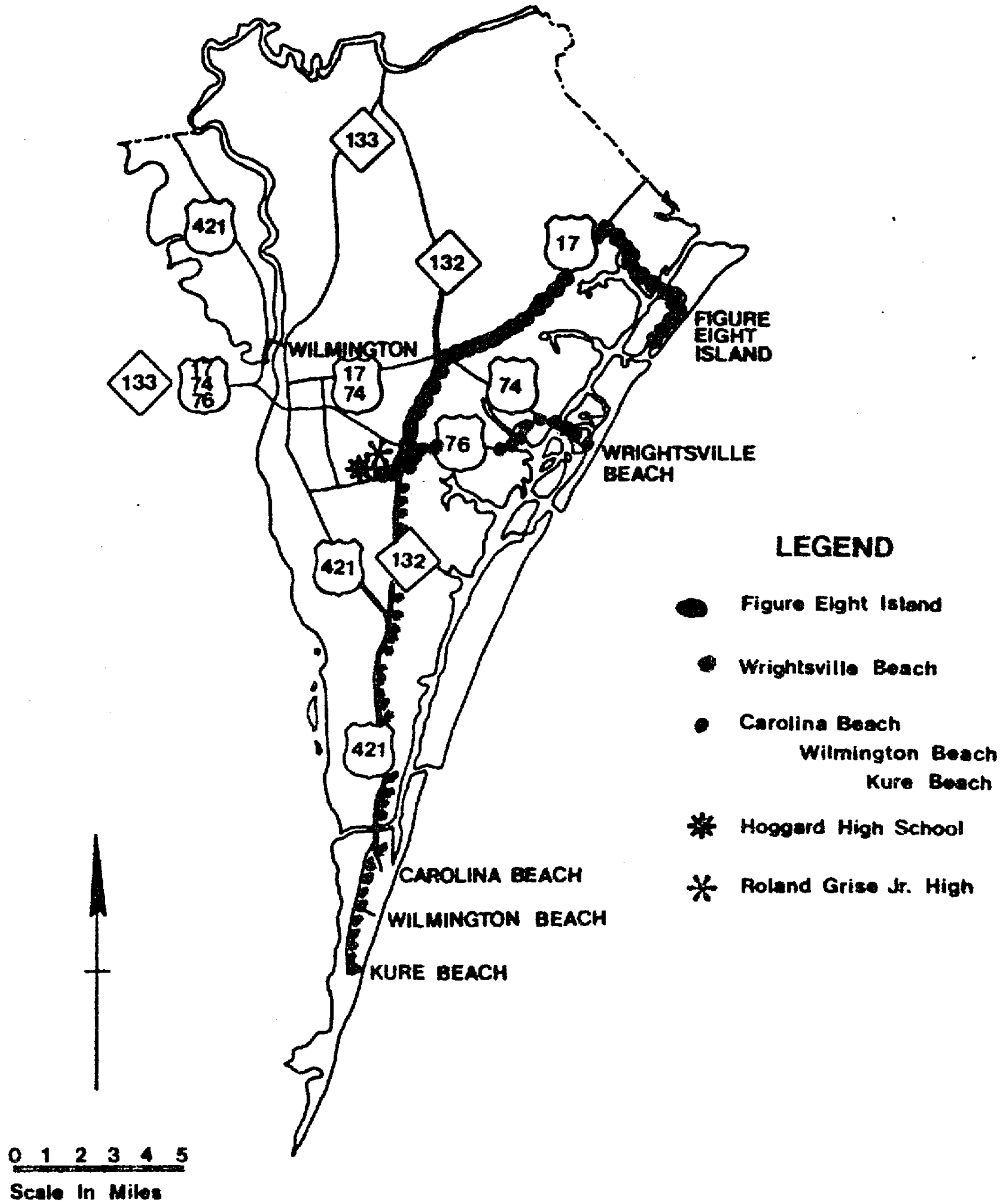
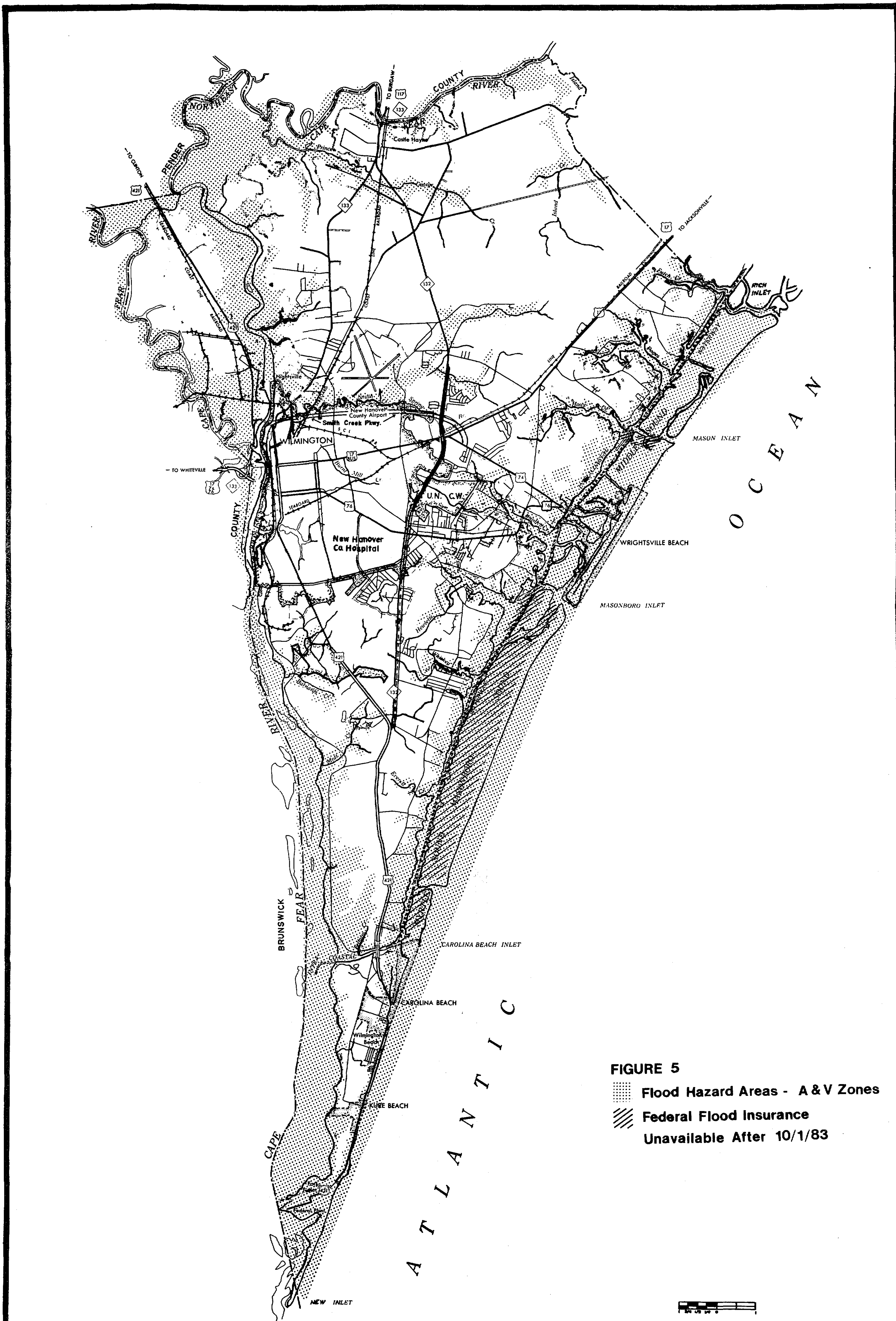


PRINCIPAL EVACUATION ROUTES and SHELTERS

NEW HANOVER COUNTY, NC

FIGURE 4

Estuarine Shoreline AEC's



NORTHEAST
CAPE
FEAR
COUNTY
RIVER
PENDER
TO BURGAW
TO CLINTON
Castle Hayne
TO JACKSONVILLE
RICH INLET
New Hanover County Airport
Smith Creek Pkwy.
WILMINGTON
TO WHITEVILLE
U.N.C.W.
New Hanover Co Hospital
MASON INLET
WRIGHTSVILLE BEACH
MASONBORO INLET
OCEAN
ATLANTIC
CAROLINA BEACH INLET
CAROLINA BEACH
Wilmington Beach
KURE BEACH
BRUNSWICK
NEW INLET
FIGURE 5
Flood Hazard Areas - A & V Zones
Federal Flood Insurance
Unavailable After 10/1/83