THE LEGACY OF HURRICANE FLOYD--INLAND FLOODING AND A MASSIVE EVACUATION

INTRODUCTION

Hurricane Floyd was a large, intense Cape Verde hurricane that pounded the central and northern Bahamas and threatened the eastern coastline of the United States from Florida to North Carolina. Floyd was near the threshold of Category 5 intensity on the Saffir/Simpson Hurricane Scale as it approached the Bahamas and remained a strong Category 4 hurricane while heading north along the Florida Coast. Floyd then began to slowly weaken and paralleled the Atlantic coastline before turning north-northeast, making landfall near Cape Fear, North Carolina, on September 16, 1999, as a Category 2 hurricane. Hurricane Floyd caused over 3 million people to evacuate and produced a flood disaster of immense proportions in the eastern United States, particularly in North Carolina, as it moved up the east coast into New England. (Figure 1-1)

To put the inland flooding problem in perspective, this article will (a) examine the event from a historical viewpoint; (b) describe, in some detail, the meteorological impacts, the warning and forecast support, and the human and economic losses associated with Floyd; and (c) summarize the public's response from a behavioral standpoint.

During a session on Improving Public Response to Hurricane Warnings, held at the National Hurricane Conference in April 2000, Mr. John Gambel, Federal Emergency Management Agency's (FEMA) National Hurricane Program Coordinator, stated the massive evacuation by the public during Hurricane Floyd highlighted the serious problem that has been created by the migration of significant numbers of people to the United States coastal regions and the barrier islands. Sufficient plans do not exist and the transportation infrastructure was not adequate to handle an evacuation of this magnitude. The results of an assessment completed by FEMA and the United States Army Corps of Engineers following Hurricane Floyd were presented and provided revealing insights on how the public will respond to similar evacuations in the future.

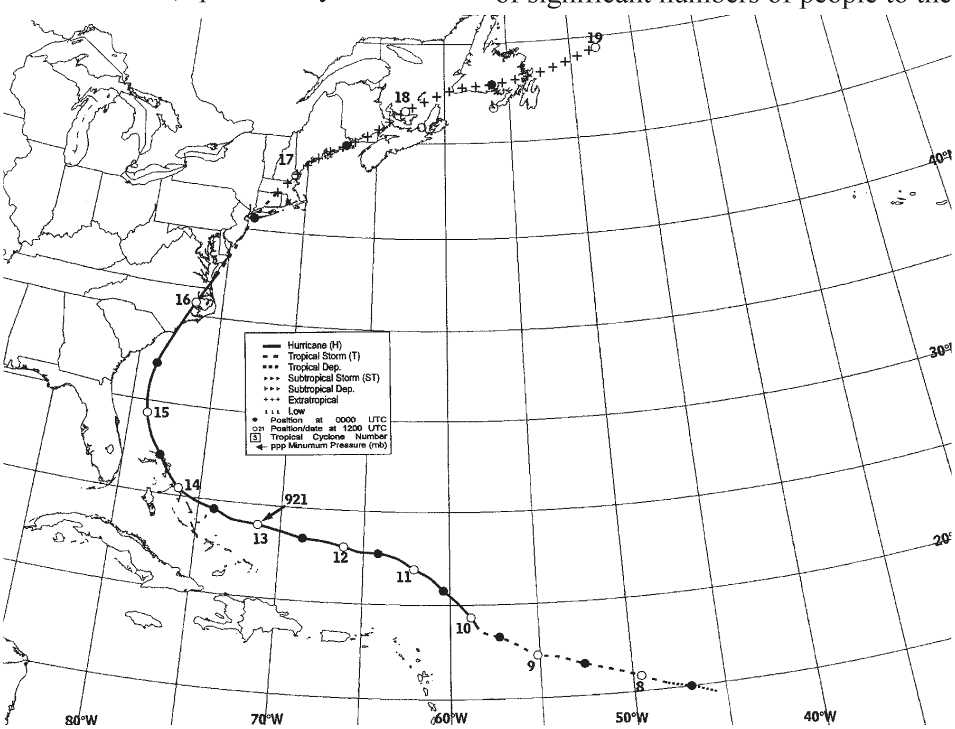

Figure 1-1. Best track of Hurricane Floyd - September 7-17, 1999.

This article was prepared by Mr. Robert Dumont, OFCM Staff.

HISTORY OF THE INLAND FLOODING PROBLEM

In a recent study, Dr. Edward Rappaport, Tropical Prediction Center/National Hurricane Center (TPC/NHC), reported a total of 600 fatalities in the contiguous United States and its coastal waters associated with Atlantic tropical cyclones during 1970-1999. Drowning accounted for 479 deaths, or 82 percent, of the fatalities with wind-related events responsible for most of the others. When it comes to hurricanes, it is obvious that wind speeds do not tell the whole story. Hurricanes produce storm surge, tornadoes, and often the most deadly of all--inland flooding. Intense rainfall is not directly related to the wind speed of tropical cyclones. In fact, some of the greatest rainfall amounts occur from weaker storms that drift slowly or stall over an area. Examples of tropical cyclones that produced significant impacts after moving inland include:

- Tropical Storm Charley (1998) dropped 16.83 inches of rain on Del Rio, Texas, on August 23, 1998, easily surpassing the previous daily record of 8.79 inches. Charley was responsible for 13 freshwater drowning deaths.

- Tropical Storm Alberto (1994) drifted over the Southeast United States and produced torrential rainfall--more than 21 inches of rain fell at Americus, Texas. Thirty-three people drowned and damages exceeded $750 million.
- Hurricane Agnes (1972) produced floods in the Northeast United States which contributed to 122 deaths and $6.4 million in damages--the largest loss in the last 30 years.
- In 1955, Hurricane Diane brought inland flooding to Pennsylvania, New York, and New England. Diane contributed to nearly 200 deaths and $4.2 billion in damages.

Loss of life from Atlantic tropical cyclones has occurred inland hundreds of miles from the coast. While most deaths in the eastern United States occurred from the Appalachian Mountains eastward, many locations not suffering losses in the last 30 years were simply fortunate to be out of harm's way. For example, Hurricane Camille (1969) caused a large loss of life in West Virginia after its center had moved about 700 miles over land and Hurricane Hazel (1954) caused inland deaths northward from North Carolina to Canada.

In the last 30 years, freshwater floods from excessive tropical cyclone-related rains led to about 300 deaths in inland counties and dominate the fatality totals for those areas. A disproportionately large percentage (75-80 percent) of the children killed by tropical cyclones drowned in freshwater floods. Such meteorological and hydrological factors as storm speed (e.g., Alberto's near stall over Georgia), size and character of the precipitation field, orography, interactions with other weather features, including low-level frontal zones (e.g., Floyd) or disturbances aloft (e.g., Agnes), soil nature, and wetness (e.g., Hurricane Dennis' rains preceding Floyd in North Carolina) were important in determining the magnitude of the inland flooding threat. Combining coastal and inland statistics, 59 percent of the deaths occurred by drowning in freshwater.

SYNOPTIC HISTORY AND METEOROLOGICAL IMPACT AT LANDFALL

Hurricane Floyd can be traced back to a tropical wave that emerged from western Africa on September 2, 1999. Overall, the system was broad and disorganized, yet easily recognizable as a synoptic-scale entity. Floyd slowly strengthened and became a hurricane by 1200 UTC, September 10, while centered about 200 nautical miles (nm) east-northeast of the northern Leeward Islands. After strengthening to nearly Category 3 status early on the September 11, the hurricane weakened to 85 knots around 0000 UTC on September 12. Early on the 12th, rising mid- and upper-tropospheric heights to the north of Floyd forced a turn toward the west which marked the beginning of a major strengthening episode (this phenomenon has also been observed with many past hurricanes; e.g., Hurricane Andrew--1992). Maximum sustained winds increased from 95 knots to 135 knots and the central pressure fell about 40 millibars (mb) by early September 13. From 0600-1800 UTC on September 13, Hurricane Floyd was at the top end of Category 4 intensity.

One potential contributor to the significant strengthening of Floyd was the presence of enhanced upper ocean heat content along its track. Analyses from the Physical Oceanography Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) showed relatively high values of heat content just to the east of the Bahamas a day or two before Floyd passed through the area.

Hurricane Floyd was moving toward the central Bahamas until late on the 13th when the heading became west-northwestward. The eye passed just 20-30 nm northeast and north of the San Salvador and Cat Islands on the night of September 13. Floyd's eyewall passed over central and northern Eleuthera on the morning of September 14 and, after turning toward the northwest, Floyd struck Abaco Island on the afternoon of the 14th. By the time Hurricane Floyd hit Abaco, it had weakened somewhat from its peak but was still a borderline Category 3 or 4 hurricane.

As a mid- to upper-tropospheric trough over the eastern United States eroded the subtropical ridge over the extreme western Atlantic, Floyd continued to gradually turn to the right. The center of the storm paralleled the central Florida coast, passing about 95 nm east of Cape Canaveral around 0900 UTC on September 15. By the afternoon, Floyd was abeam of the Florida/Georgia border and headed northward toward the Carolinas.

Although there was a fluctuation in intensity related to an eyewall replacement event, overall the intensity of Floyd diminished from September 13-15. Environmental causes for intensity change are not entirely understood, but two large scale factors probably contributed to the gradual decline: (1) the entrainment of drier air at low levels from the northwest and (2) increasing south-southwesterly vertical shear. As Floyd neared the North Carolina coast late on September 15, its maximum winds decreased below Category 3 status.

After turning toward the north-northeast with forward speed increasing to near 15 knots, Hurricane Floyd made landfall near Cape Fear, North Carolina, at 0630 UTC, September 16, as a Category 2 hurricane with estimated maximum winds near 90 knots. Floyd was losing its eyewall structure as it made landfall and continued to accelerate north-northeastward over extreme eastern North Carolina on the morning of September 16 and over the greater Norfolk, Virginia, area around 1500 UTC that day. Floyd then weakened to a tropical storm and moved swiftly along the coasts of the Delmarva peninsula and New Jersey on the afternoon and early evening of September 16 and reached Long Island by 0000 UTC, September 17. By that time, the storm's speed had increased to near 29 knots. The storm decelerated as it moved into New England and became more involved with a frontal zone that existed along the Atlantic seaboard. The system then took the form of a frontal low and, thus, became extratropical by the time it reached the coast of Maine at 1200 UTC, September 17.

Heavy rainfall preceded Floyd over the Mid-Atlantic states due to a pre-existing frontal zone and the associated overrunning. Hence, although the tropical cyclone was moving fairly quickly, precipitation amounts were very large. Rainfall totals as high as 15 to 20 inches were recorded in portions of eastern North Carolina and Virginia. At Wilmington, North Carolina, the storm total of 19.06 inches included a 24-hour record of 15.06 inches. Totals of 12 to 14 inches were observed in Maryland, Delaware, and New Jersey. A new record of 6.63 inches was set in Philadelphia for the most rainfall in a calendar day. In southeastern New York, rainfall totals were generally in the 4 to 7 inch range, but there was a report of 13.70 inches at Brewster. Totals of nearly 11 inches were measured in portions of New England. (Figure 1-2)

As Floyd made landfall in North Carolina, the winds ahead of the eye drove water onshore on the Atlantic shoreline and westward in the Pamlico and Albemarle Sounds and up several of the rivers located on the west side of the sounds. The highest storm surge values ranged from 5.5 to 9.0 feet. The 9.0 foot storm surge maximum (the highest observed in Floyd) was reported by an observer near Wilmington, North Carolina. The maximum observed storm surge plus the astronomical tide component totaled 10.3 feet--the actual water elevation observed.

A number of tornadoes were sighted in eastern North Carolina. There was a confirmed tornado in Bertie County and another in Perquimans County which destroyed two houses and damaged several others. At least ten tornadoes were reported by spotters in the Newport/Morehead City County Warning Area and these apparently caused some structural damage. Four tornadoes or funnel clouds were seen in the Wilmington area, but no damage was apparent.

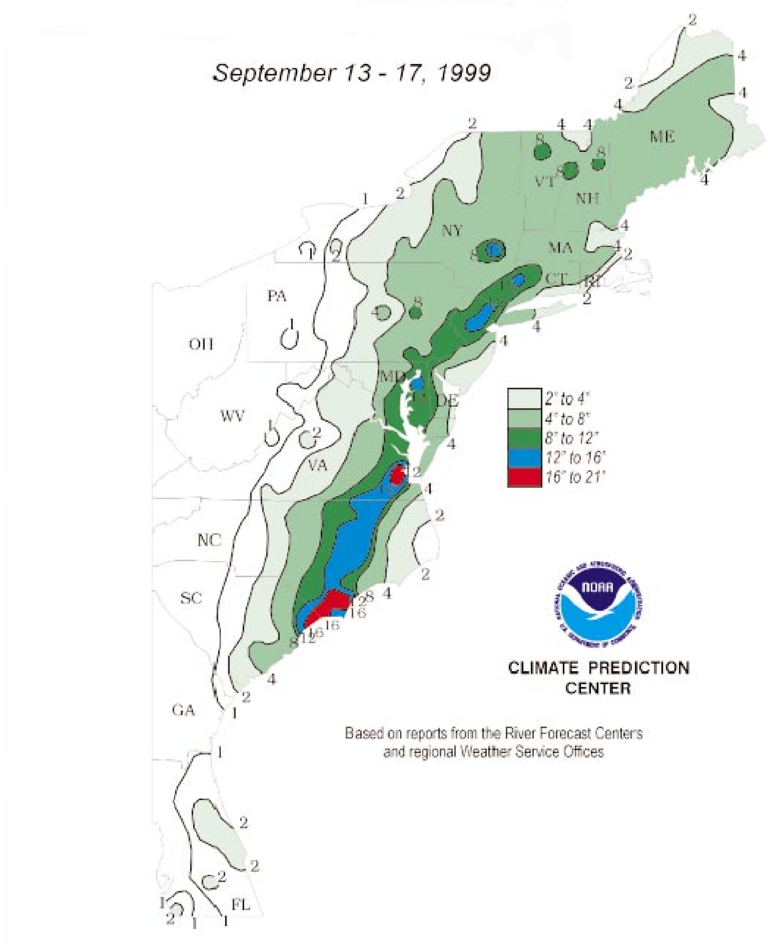

Figure 1-2. Total precipitation (inches) from Hurricane Floyd.

WARNING AND FORECAST SUPPORT

Tropical Prediction Center/National Hurricane Center

When averaged over the entire lifetime of the hurricane, the TPC/NHC track forecasts for Floyd were excellent. The average official forecast errors at 12, 24, 36, 48, and 72 hours were 32, 61, 84, 84, and 120 miles, respectively. These errors are much smaller than the most recent 10-year average errors of 55, 103, 147, 189, and 279 miles. The overall average official forecast errors for Floyd were small; however, the official forecasts for the period when hurricane warnings were in effect for the United States (5 p.m. on September 13 to 11 a.m. on September 16) were average. The average 24-hour track forecast error for this latter period was roughly the same as the most recent 10-year average. In general, the track forecasts for this period had a westward bias and were somewhat slow.

Figure 1-3. Mr. Max Mayfield, Director, Tropical Prediction Center/National Hurricane Center, provides an update to a national television audience.

The official intensity forecasts averaged over Floyd's lifetime were good. The average official errors at 12, 24, 36, 48, and 72 hours were 12, 17, 20, 20, and 14 mph, respectively. These errors were considerably smaller than the errors of forecasts based upon climatology and persistence (the usual benchmark for evaluation of forecast skill) of 15, 22, 28, 32, and 44 mph. After Floyd reached its maximum intensity, the official forecasts did not predict enough weakening. From September 13 on, the wind speed was over-forecast in the advisories at nearly every forecast interval.

As Hurricane Floyd moved toward south Florida and then up the East Coast, the TPC/NHC (Figure 1-3) issued tropical storm warnings from as far south as the Florida Keys to as far north as Merrimack River, Massachusetts. At various times during the storm, hurricane warnings were posted along sections of the coastline from Florida City, Florida, to Plymouth, Massachusetts. In reality, only a small fraction of the coast with hurricane warnings experienced sustained hurricane-force winds. Hurricane warnings were issued for the coast of North Carolina at 11 p.m. on September 14--about 27 hours prior to the arrival of the eyewall in the Cape Fear area. For the coasts of South Carolina and North Carolina, hurricane warnings were issued at least 24 hours before the onset of tropical storm-force winds.

River Forecast Centers (RFC)

Hurricane Floyd's track impacted three NWS RFCs: the Southeast (SERFC), the Mid-Atlantic (MARFC), and the Northeast (NERFC). Recognizing the potential for severe flooding early on, all three centers extended their operating hours from 16- to 24-hours a day prior to the arrival of Floyd. On Tuesday, September 14, SERFC and MARFC issued contingency forecasts based on 9 inches of forecasted rainfall. This information was coordinated internally via telephone and fax to impacted Weather Forecast Offices (WFO) and communicated to many emergency managers. These forecasts indicated the risk of major-to-record flooding if that amount of rainfall were to occur.

RFCs issued timely river forecasts through the River Forecast product. The accuracy of these forecasts increased as flood crests approached. The three affected RFCs issued a total of 252 river forecasts. These forecasts were issued daily and updated every 6 hours, or when needed. The initial flood warnings were low and were raised with the ingest of observed rainfall and higher Quantitative Precipitation Forecasts (QPF). Official forecasts provided lead times of several hours to a few days prior to the onset of flooding, depending on the response times of the rivers. Lead times of up to several days were achieved on river crest forecasts. In addition, hydrologists at all RFCs coordinated closely with WFOs and local officials.

Weather Forecast Offices (WFO)

The NWS WFOs have the responsibility of issuing timely meteorologic and hydrologic warnings, forecasts, and statements. These offices are the contact for state, county, and local agencies as well as the media and the general public. During Hurricane Floyd, 13 WFOs were impacted with high winds and tornadoes, coastal flooding, flash flooding, and river flooding, or a combination of all these events. Six WFOs (Wakefield, Virginia; Raleigh, North Carolina; Wilmington, North Carolina; Morehead City, North Carolina; Mt. Holly, New Jersey; and Brookhaven, New York) had record river flooding, record rainfall, or both. While the rainfall from Floyd was the primary contributor to the devastating flooding, rainfall from Hurricane Dennis, a week before, set the stage for these events.

Nineteen official NWS river forecast points reported record flooding due to the rainfall from Dennis and Floyd. Another 36 forecast points recorded major flooding. Record river flooding occurred in both the Southeast (North Carolina, South Carolina, and Virginia) and the Northeast (New Jersey and Pennsylvania). WFOs issued a total of 300 Flood Warnings and Flood Statements for flooding associated with Hurricane Floyd.

The coastal North Carolina WFOs

were severely impacted by Hurricane Floyd. River flooding due to Dennis was ongoing when Floyd brought high winds, tornadoes, and coastal and flash flooding. The day before Floyd made landfall, WFOs Morehead City and Wilmington, North Carolina, issued 28 tornado warnings in a 10-hour period. Hurricane-spawned tornadoes were occurring at the same time as hurricane-force winds and flash flooding. The flash flooding was more severe than residents had ever remembered.

The northeast WFOs did not have the long-lasting flooding of the South but were affected by record flash and urban flooding. A particular problem in the Northeast region, where population density is high and terrain is flat, is the extreme effect just a foot rise along some area tributaries can have on the areal extent of flooding. This situation was particularly a problem in portions of New Jersey. The result was property damage affecting thousands of homes and businesses.

Every affected WFO issued either a Special Weather Statement or Flood Potential Statement to highlight the high flood danger 30 to 48 hours before flooding by Floyd began. Flood or Flash Flood Watches were issued by all affected WFOs from 12 to 36 hours before the onset of flooding. A total of 532 Flash Flood Warnings were issued by the 13 WFOs for areas from northeast South Carolina through New England. Verification of these warnings for the 13 WFOs combined was outstanding.

All WFOs impacted by Floyd were proactive in their efforts to get the word out early. Perhaps most appreciated by emergency officials were WFO efforts in using conference calls to provide advance notice and continual updates of Floyd's track and resulting river flood crests. All WFOs made advance "heads up" calls to emergency management officials from 2 to 5 days before rainfall from Floyd began. With the realization that Floyd would cause

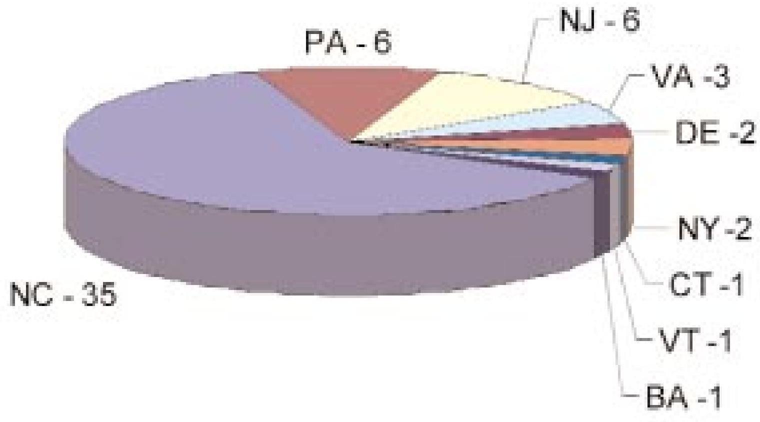

Figure 1-4. Distribution of fatalities along Hurricane Floyd's path.

massive inland flooding, emergency officials were again briefed days in advance. As the events of Floyd unfolded, WFOs continued to conduct once- or twice-a-day conference calls with state and county emergency officials. These conference calls typically occurred just following the internal NWS conference calls, thus providing emergency officials with the latest updates on Floyd.

Floyd's Impact

There were 57 deaths directly attributable to Floyd with 56 in the continental United States and 1 on Grand Bahama Island (Figure 1-4). Most of these deaths (50) were due to drowning in freshwater flooding. A massive rescue effort is credited with saving another 1,400 people from Floyd's flood waters. In fact, 32 of the 50 deaths (64 per cent) occurred when the individuals were in, or attempting to abandon, their vehicles. Over the last 30 years, at least 138 victims (23 percent) died in this manner and almost all of these incidents occurred in association with freshwater-flooded roads.

In addition to the loss of life, the wrath of Floyd resulted in the destruction of homes, businesses, and infrastructure; loss of livestock and crops; and a disruption of commerce. For North Carolina alone, FEMA's documented economic impact which only includes losses to businesses and agriculture was $6 billion--$1 billion for business structures, $4 billion in lost business revenues, and $1 billion in agricultural losses.

For the agricultural business sector, Hurricane Floyd had a significant regional impact on individual farmers and other agricultural producers. Crop losses were in excess of $500 million--over half of which were in cotton and tobacco. Almost 3 million chickens and turkeys, 30,000 hogs, and 1,000 cattle were lost. Farm equipment and facility losses were over $300 million. Losses to the fisheries and forestry industries totaled $25 million and $90 million, respectively. Following Floyd, federal and state officials anticipated that flood waters would have widespread, long-term environmental effects on the health, welfare, and usability of the impacted areas. Fortunately, according to FEMA's economic impact assessment, the environmental effects appear to have been less than anticipated due in part to the quick action of emergency response teams.

Flood insurance claims from Hurricane Floyd will rank as the second-highest. As of March 1, 2000, the National Flood Insurance Program (NFIP), which is administered by FEMA, had paid more $310 million to settle 14,614 claims for flood damage that occurred as Hurricane Floyd dumped torrential rains from Florida to Maine. With approximately

9,500 claims still open, FEMA expects that the total insurance payments from Floyd will reach $460 million. In the history of the NFIP, this total is only exceeded by the Louisiana floods of May 1995 which resulted in nearly $584 million in paid claims.

While making its trek along the Atlantic coastline, Hurricane Floyd was responsible for the largest peace-time evacuation in United States history and over 3 million people responded to the evacuation order. Following Hurricane Floyd, the United States Army Corps of Engineers, Savannah District, and FEMA-Region IV contracted for a Hurricane Floyd Assessment to review hurricane evacuation studies utilization and information dissemination. The following information is excerpted from that report:

PUBLIC RESPONSE--A BEHAVIORAL ANALYSIS

Method

During the months following Hurricane Floyd, nearly 7,000 members of the public were interviewed to (a) document and explain their response to Floyd and (b) anticipate their behavior in future evacuations. The sample was divided into 11 clusters of counties from Dade County, Florida, through North Carolina's Outer Banks. The sampling was designed to conform to hurricane planning regions used by the respective states. The regions were:

- Eastern North Carolina--the Outer Banks and counties along Albemarle and Pamlico Sounds
- Southeastern North Carolina--from the South Carolina border to the Outer Banks, including Wilmington
- Northern South Carolina--including the Myrtle Beach "Grand Strand" area
- Central South Carolina--including Charleston and vicinity
- Southern South Carolina--including the Beaufort area
- Northern Georgia--including Savannah
- Southern Georgia--including Brunswick and Camden County
- Northeast Florida--including Jacksonville and St. Augustine
- East-Central Florida--including Daytona Beach and Melbourne
- Treasure Coast Florida--including Palm Beach and Fort Pierce
- Southeast Florida--Dade and Broward Counties

Each of the 11 clusters were then stratified into four risk areas: (1) areas which would flood due to storm surge in Category 1 hurricanes, (2) areas which would flood due to storm surge in stronger hurricanes, (3) areas of coastal counties which would not flood from storm surge in any hurricane, and (4) non-coastal counties bordering the coastal counties.

Evacuation Participation Rates

There was considerable variation in evacuation rates among the 11 survey areas. Evacuation (i.e., leaving one's home to go to some place safer) was highest in Georgia and southern South Carolina. In the Category 1 zone, up to 90 percent left the Savannah area and numbers were almost that high around Brunswick, Georgia, and Beaufort, South Carolina. Rates dropped off gradually both north and south, with major dropoffs for the Treasure Coast and southeast Florida and eastern North Carolina areas. Evacuation was also high in Georgia and in the Beaufort, South Carolina, area for people living in areas subject to surge inundation in storms stronger than Category 1 with 75-85 percent leaving from those areas. Again, the dropoff was gradual in both directions, with more significant decreases at the end of the study area. In Florida, only Category 1 surge areas were ordered to evacuate. In Georgia and southern South Carolina, entire coastal counties were told to evacuate. Participation rates for Category 1 surge zone areas are detailed in Figure 1-5.

In the Charleston, Beaufort, and Savannah areas, evacuation from non-surge zones was unusually high. In all three areas, all or most of the counties were told to evacuate. Even away from those locations, between 20-40 percent of the non-surge residents left in most survey areas. These "shadow" evacuees contributed to the large number of people on evacuation routes. Evacuation in adjacent non-coastal counties were also surprisingly high and averaged approximately 25 percent. In the Charleston vicinity,

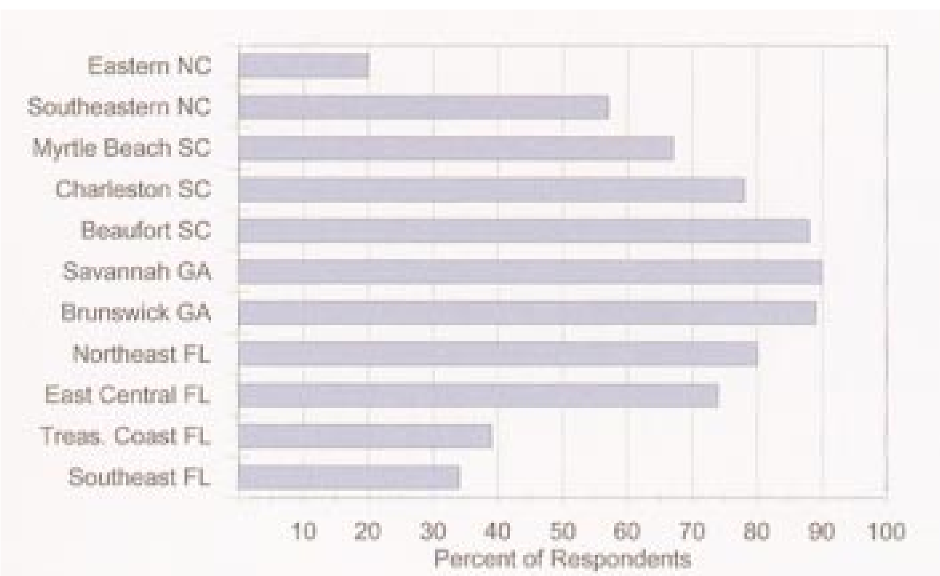

Figure 1-5. Evacuation participation rates for Category 1 Storm Surge Zones.

almost half of the residents in adjacent non-coastal counties evacuated their homes. When asked why they left, most respondents gave a combination of reasons; such as, evacuation notices from public officials, storm severity, and recommendations from friends, family, and the media. When asked which was the main influence on their decision to evacuate, information coming from public officials (or which they perceived to be coming from public officials) had the greatest effect for most people. With the exception of the two southernmost Florida locations, a majority of people living in the Category 1 surge areas said they heard officials call for their evacuation. The highest percentage that actually evacuated was in the Charleston area--80 percent. Some residents living in non-surge areas also believed they heard officials say that they should evacuate. In Georgia and parts of South Carolina, more than 60 percent of the non-surge residents of coastal counties said they heard official evacuation notices which applied to them, and that was probably correct for most. In other states and in non-coastal counties, up to 25 percent of the respondents believed they heard officials say that they should evacuate, and that was probably not correct, except for people living in mobile homes. These results emphasize the fact that it is extremely important for officials to reach those for whom the evacuation notices are intended and to avoid confusing those for whom the notices are not intended.

One reason there was substantial evacuation from areas not targeted by officials is that many residents of non-surge areas perceived themselves to be vulnerable to major hurricanes. When asked whether their homes would be safe in a 125 mph hurricane 20-40 percent of the people living in coastal county non-surge areas believed their homes would be unsafe from storm surge and waves; 25-60 percent believed their homes would be unsafe, considering both wind and surge. Even in adjacent non-coastal counties 15-35 percent believed their homes would experience dangerous flooding from storm surge and waves; 40 percent to nearly 60 percent believed their homes would be unsafe, considering both wind and water.

The importance of perception cannot be overlooked. People who believe their homes are unsafe are much more likely than others in their same risk area to evacuate. In most locations, people who believe their homes are unsafe are about twice as likely as others to leave. This is a good thing when applied to people who really need to evacuate, but it can contribute to overcrowding on evacuation routes and in shelters when applied to people who could stay home and be safe.

There are various ways to reach the public with evacuation and vulnerability information during a hurricane threat, but local television and *The Weather Channel* are the most-relied upon sources of information in most locations. Eventually, the Internet and online computer services will gain increased importance, but currently less than 10 percent of coastal residents say they rely heavily on those sources for hurricane threat information. Survey results are depicted in Figure 1-6.

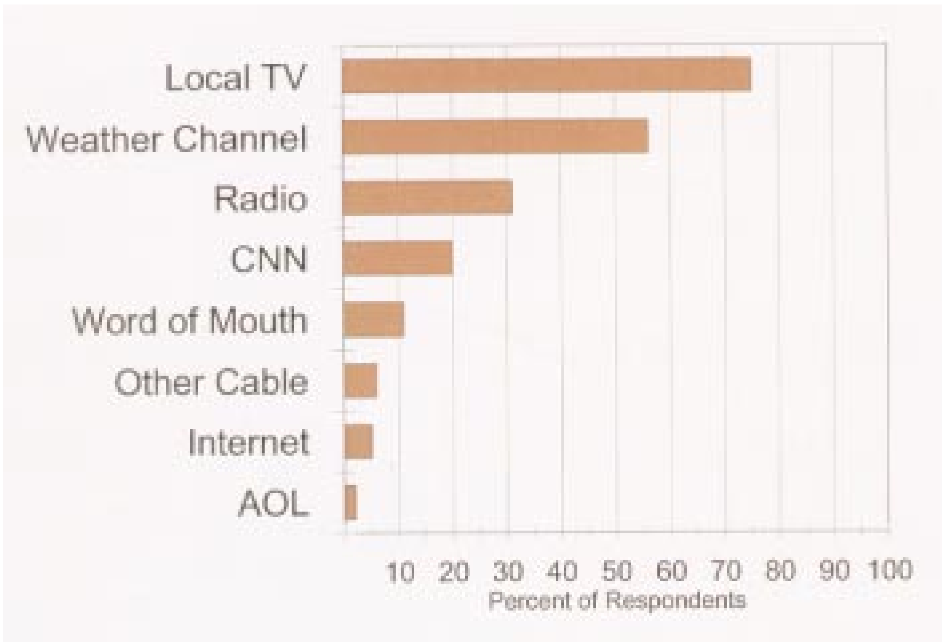

Figure 1-6. Survey results regarding relied upon sources of information.

<u>Evacuation Destinations</u>

Evacuation congestion is made worse when large numbers of evacuees leave the local area rather than simply going to safe locations within their own community. During Hurricane Floyd, an unusual percentage of evacuees went to destinations outside their own county. Among evacuees from Category 1 and larger surge zones, as many as 98 percent left their own county and in 8 of 11 study locations more than 70 percent did the same. These percentages are unusually high, but even in non-surge areas, more than half of the evacuees went out-of-county in 8 of 10 non-surge locations. In adjacent non-coastal counties, more than half of the evacuees went out of the county from half the survey sites.

When asked why they left their county, for many evacuees the answer was obvious. Georgia and some South Carolina locations evacuated entire coastal counties, so there were no places to go within those counties and still comply with evacuation notices. Moreover, in those locations, residents appear to appreciate and acknowledge

Figure 1-7. Evacuation order in South Carolina resulted in major traffic congestion along Interstate 26. (Photo: Post & Courier; Charleston, South Carolina)

the vulnerability of their counties. In many locations, public shelters are not operated in coastal counties or even in the next tier of counties inland. Respondents gave three predominant explanations for going out of county: (1) that was the location of friends or relatives with whom they could stay, (2) the storm was strong enough so they wanted to get far away from it, and (3) they had to go as far as they did to find vacant lodging. For most locations, the decision to go out of county was influenced more by hearing from public officials rather than by other messages heard through the media or information from friends and relatives.

The majority of evacuees went to homes of friends and relatives which is common in most evacuations. Between 20 and 30 percent in most locations went to hotels and motels; fewer than 10 percent (closer to 5 percent in most locations) went to public shelters. Approximately 40 percent of the evacuees said they heard announcements concerning the availability of shelters or refuges after they left home, but fewer than 10 percent of those who heard took advantage of the offers.

Transportation

Of all the vehicles available to evacuating households, between 65 and 75 percent were used in Floyd--a typical statistic for most evacuations. Evacuees in Charleston had the longest average travel times--almost 9 hours. Beaufort and the two Georgia sites also had average travel times exceeding 6 hours. When asked how long they expected the evacuation to take, the expectations of the evacuees were, not surprisingly, shorter than reality. When asked the reasons for the traffic delays, most blamed the large volume of traffic and too many people leaving at the same time. In most locations, fewer than 30 percent attributed the delays to poor management. The exception was Charleston, where over 40 percent blamed management. Some people mentioned the need to reverse traffic lanes along evacuation routes. Evacuees were asked whether they would be willing to delay their departure in an evacuation to let people in areas of greater risk leave first in order to avoid congestion (Figure 1-7). Between 80 and 90 percent said they would.

Between 35 and 60 percent of the evacuees said they used interstate highways for a substantial portion of the evacuation and between 70 and 90 percent said they were familiar with the road systems in the areas through which they were evacuating. This response implies that evacuees would be able to take advantage of information about alternative routes if they received the information. In Floyd, between 20 and 55 percent of the evacuees said they heard announcements about evacuation route problems before leaving home. Of those hearing the announcements, approximately 30 percent changed their plans concerning routes to use. As evidenced by their behavior in Floyd, evacuees appear to be receptive to route announcements. In fact, when asked whether they would be willing to use a route other than the one they had planned to use if urged to do so by emergency officials, more than 70 percent said they would.

Next Time

A key question asked following Hurricane Floyd was whether the unpleasant experiences during the evacuation would deter people from leaving in future hurricane events. Certainly many evacuees had bad experiences, but when asked to describe the sorts of difficulties they endured, most respondents, even in Charleston, reported none other than aggravation. The most common complaint was a lack of restroom facilities, followed by food and water. It is important for public safety officials to recognize the fact that the people who complain about events by contacting agencies, writing to newspapers, and so forth don't constitute a random sample of the public.

When asked what they would do differently if faced with a similar hurricane threat in the future, fewer than 20 percent of the evacuees in most locations said they would not evacuate next time. Some of the evacuees didn't need to evacuate during Floyd, so their inclination to stay in the future is not negative. Most of those who do need to go can be convinced to do so in an actual threat. The most common response when asked what they would do differently was to leave earlier next time.

SUMMARY AND CONCLUSIONS

Inland flooding from landfalling tropical cyclones is a clear and present danger. We cannot afford to let the media spotlight and public attention diffuse and shift away from the ending drama at the coast to other current events rather than following the usually weakening tropical cyclone while it moves inland. The National Weather Service performed superbly during Hurricane Floyd, but we look to future meteorological research efforts to improve our capabilities. The Hurricane Landfall and Quantitative Precipitation Forecasting components of the United States Weather Research Program are indicative of the significance of the tropical cyclone threat to this country, as well as our focused commitment to minimize the impacts of that threat in the future.

During the National Hurricane Conference session on Improving Public Response to Hurricane Warnings, Dr. Jay Baker, Department of Geography, Florida State University, who participated in the Hurricane Floyd Assessment, described four important points with regard to understanding the public's response.

(1) Evacuation orders are the most effective means for evoking a response from the public, as long as they are heard and understood by those who need to respond.

(2) People must understand their own personal vulnerability. One problem is that the public tends to underestimate high risks and overestimate low risks, as evidenced during Floyd.

(3) We need to tell and convince people they need to only go a certain distance to be safe, and

(4) We need to understand and use the public's sources of information to disseminate information.

Recommendations for the future include:

- Better education of the public regarding their vulnerability.
- Wording evacuation notices to ensure they are not misinterpreted and effectively disseminating them.
- Telling people what to do and why.
- Not forgetting those who didn't leave but should have.

As demonstrated by the experiences during Hurricane Floyd, facilitating the transportation of those who evacuate is another challenge. During the Office of the Federal Coordinator for Meteorology (OFCM) sponsored 54th Interdepartmental Hurricane Conference in February 2000, Mr. Howard R. Chapman, Charleston Area Rapid Transit Authority, elaborated on the problems that were experienced in the Charleston area. He also described the plans to alleviate these problems in the future which include a lane reversal plan for Interstate 26, plans for the Governor to stagger evacuations, and a call for earlier, initial evacuations. Their plans also provide for constant information about conditions to be disseminated by National Public Radio and educational television and for improved access to secondary roads as alternate routes of evacuation. The key to the future success of our Nation's response to landfalling hurricanes is to act on the lessons learned from the past. Hurricane Floyd certainly provided federal, state, and local officials with a wealth of lessons learned that will help refine current and shape future plans.

REFERENCES:

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