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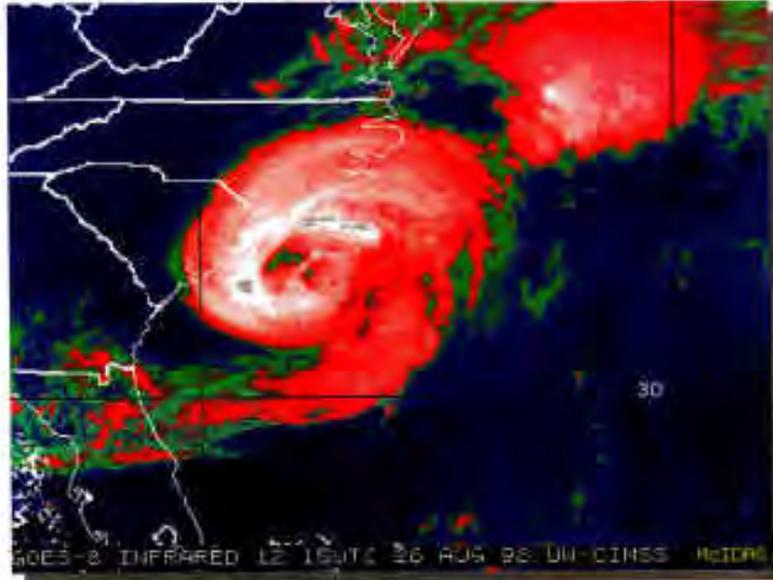
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Hurricane Bonnie Assessment

Review of Hurricane Evacuation Studies Utilization and Information Dissemination



April 1999



US Army Corps of Engineers



HURRICANE BONNIE ASSESSMENT

landfall 26 Aug 1998

Review of Hurricane Evacuation Studies Utilization And Information Dissemination Prepared for U.S. Army Corps of Engineers South Atlantic Division And Federal Emergency Management Agency Region IV

Prepared by Post, Buckley, Schuh & Jernigan, Inc. April 1999

Executive Summary

On Wednesday, the 26th of August 1998, Hurricane Bonnie passed just east of Cape Fear, North Carolina, making landfall near Wilmington, North Carolina early on the morning of the 27th. Although the storm was just a Category 2 hurricane at landfall, three deaths resulted and insured property damage totaled an estimated 360 million dollars nationwide.

Prior to Hurricane Bonnie, comprehensive hurricane evacuation restudies had been underway for both South Carolina and North Carolina. A restudy had not been initiated for Virginia. With completed early and mid 1980's studies in hand and with some draft restudy products on the table, Bonnie provided an opportunity to answer several key questions regarding these major FEMA/Corps planning efforts:

- Did local and state officials use the products produced in these major studies?
- Were study data regarding storm hazards, behavioral characteristics of the threatened population, shelter information, evacuation times, and decision-making accurate and reliable?
- Which study products were most useful and which least useful - what improvements could be made to current methodologies and products?

To answer these questions, study teams comprised of representatives from FEMA; the US Army Corps of Engineers; and Post, Buckley, Schuh & Jernigan, Inc. visited with local and state officials throughout the directly impacted areas of South Carolina, North Carolina and Virginia.

Interviews and analysis conducted for the post Bonnie effort revealed modest evacuation participation rates on the part of the permanent population. Shelter usage was low except in Horry County, South Carolina, where many tourists went to public shelters. Few traffic problems were reported. The lack of traffic problems indicates that local and state officials started the evacuation in a timely manner, that traffic control was appropriate and effective, and that participation rates were much less than the 100% rates used in the study calculations.

State and local officials are anxious for restudy products to be finalized and delivered. Most were very pleased with the beta version of the new HURREVAC model. Attention needs to be given to evacuation zone delineations - those with newer studies evacuated in a manner consistent with the zone systems used in the transportation analysis. Those with older zone systems did not use the transportation analysis zones, saying they were too complicated to describe to the public.

Major recommendations from this post-Bonnie effort include:

1. Many of the areas interviewed for Bonnie are waiting for finalized surge mapping. There is still a wide variety of technology being used to produce the mapping around the country and within the interviewed areas. It is recommended that an ICCOH subcommittee be reorganized to address the mapping issue and determine what methods are the most cost effective and acceptable to state and local officials.
2. Update Virginia's hurricane evacuation study and provide a transportation analysis tool that

will allow local jurisdictions the ability to update clearance times as housing unit growth/road construction dictates.

- 3. In the North Carolina restudy, make sure inland routing of traffic is taken to I-95 and inland bottlenecks noted.
- 4. Appoint an ICCOH subcommittee to address the evacuation zone delineation issues that face local and state EM officials as well as HES study managers.
- 5. Encourage NCDOT to implement some permanent traffic count stations that could strategically feed real time and post storm traffic count data to the EM community.
- 6. Finalize the South Carolina HES transportation analysis.
- 7. Update clearance time data and incorporate into the new HURREVAC model.
- 8. Conduct extensive training sessions with local EM's regarding the new HURREVAC model.
- 9. Continue to discuss and refine shelter selection criteria with the American Red Cross.
- 10. Address backside flooding along the Albemarle Sound from an exiting storm.
- 11. Determine what public information products the BES process should produce for state and local officials

Bonnie Hurricane Watch and Warning Summary

Table 3. Tropical Cyclone watch and warning summary for Hurricane Bonnie.

| Date/Time (UTC) | Action | Location |
|-----------------|--|--|
| 20/0300 | Tropical Storm Watch issued | Antigua, Barbuda, Anguilla, St. Maarten, Saba and St. Eustatius |
| 20/1500 | Tropical Storm Watch issued | U.S. and British Virgin Islands |
| 20/2100 | Tropical Storm Warning issued | U.S. and British Virgin Islands |
| 20/2100 | Tropical Storm Watch issued | Puerto Rico |
| 21/0900 | Tropical Storm Watch issued | Turk and Caicos and the southeastern Bahamas |
| 21/1200 | Tropical Storm Watch discontinued | Antigua, Barbuda, Anguilla, St. Maarten, Saba and St. Eustatius |
| 21/1500 | Tropical Storm Warnings and a Hurricane Watch | Turk and Caicos and southeastern Bahamas |
| 21/1500 | Hurricane watch issued | Central Bahamas |
| 21/1500 | Tropical Storm Warning discontinued | U.S. and British Virgin Islands |
| 21/1500 | Tropical Storm Watch discontinued | Puerto Rico |
| 22/0900 | Hurricane Warning issued | Central Bahamas |
| 22/1500 | Hurricane Watch issued | Northwestern Bahamas |
| 23/0000 | Hurricane Warning discontinued | Turks and Caicos |
| 23/0000 | Hurricane Warning replaced by Tropical Storm Warning | Southeastern Bahamas |
| 24/0900 | Tropical Storm Warning discontinued | Southeastern Bahamas |
| 24/2100 | Hurricane Watch issued | Savannah, Georgia to the North Carolina/Virginia border including the Pamlico and Albemarle Sounds |
| 25/0900 | Hurricane Warning issued | from Murrells Inlet, S.C. To the north Carolina Virginia border, including the Palmico and Albemarle Sounds |
| 25/1200 | Hurricane Watch issued | from North Carolina/Virginia border to Cape Henlopen, Delaware including the Chesapeake Bay southward from Windmill point. |
| 25/1500 | Tropical Storm Warning issued | from Murrells inlet to Cape Romain, S.C. |

Bonnie Hurricane Watch and Warning Summary

| | | |
|---------|--|---|
| 25/1500 | Tropical Storm Warning issued | from Murrels Inlet to Cape Romain, S.C. |
| 25/1800 | Hurricane Warning extended northward | to Chincoteague, VA |
| 25/2100 | Hurricane Warning extended southward | to Cape Romain, S.C. |
| 26/0600 | Hurricane Warning extended southward | to Edisto Beach, S.C. |
| 26/1500 | Hurricane Warning and Watches discontinued | south of Cape Romain |

| | | |
|---------|--|--|
| 26/2100 | Hurricane Warnings and Watches revised. Tropical Storm Warning and Hurricane Watch issued | from North Carolina/ Virginia border to Chincoteague, Virginia and for the Chesapeake Bay from Smith Point southward |
| 26/2100 | Tropical Storm Warning issued | from Chincoteague, Virginia to Cape Henlopen, Delaware |
| 27/0100 | Hurricane warning replaced by Tropical Storm Warning | south of Murrels Inlet to Cape Romain |
| 27/0900 | Hurricane Warning replaced by Tropical Storm Warnings | south of Little River Inlet, NC to Murrels Inlet, SC |
| 27/0900 | Tropical Storm Watch issued | from north of Cape Henlopen to Sandy Hook, NJ including Delaware Bay |
| 27/0900 | Tropical Storm Warning discontinued | from south of Murrels Inlet |
| 27/1500 | Tropical Storm Warning issued | from new River Inlet, NC to Cape Henlopen, DE including Palmico and Albemarle Sounds and Chesapeake Bay southward from Smith Point |
| 27/1500 | Tropical Storm Watch issued | Chesapeake bay from Smith Point to Drum Point and for the Potomac River from Cobb Point to Smith Point |
| 27/2100 | Tropical Storm Warnings extended northward | from New River Inlet NC to watch Hill, RI including Palmico and Albemarle Sounds, Chesapeake Bay southward from Smith Point and Delaware Bay |
| 27/2100 | Tropical Storm Watch issued | from east of Watch Hill, RI to Plymouth, MA |
| 28/0300 | Tropical Storm Warning discontinued | south of Cape Lookout, NC |
| 28/0900 | Tropical Storm Warning issued | from Watch Hill to Plymouth |
| 28/0900 | Tropical Storm Warning discontinued | south of Ocracoke, NC and for the Chesapeake Bay and Potomac River north of Smith Point |
| 28/1500 | Tropical Storm Warning discontinued | south of NC/VA border including Pamlico and Albemarle Sounds and for Chesapeake and Delaware Bays |

| | | |
|---------|-------------------------------------|--|
| | | and for Chesapeake and Delaware Bays |
| 28/2100 | Tropical Storm Warning discontinued | south of Watch Hill including Delaware Bay and Long Island Sound |
| 29/0300 | Tropical Storm Warning discontinued | remainder of the U.S. East coast |

* Tropical Cyclone watches and warnings are issued by respectively countries in coordination with the National Hurricane Center.

Chapter 1 - Introduction

On Wednesday, the 26th of August 1998, Hurricane Bonnie passed just east of Cape Fear, North Carolina, making landfall near Wilmington, North Carolina early on the morning of the 27th. Although the storm was just a Category 2 hurricane at landfall, three deaths resulted and insured property damage totaled an estimated 360 million dollars nationwide.

As reported over Lowes and FEMA's Storm 98 web site, Bonnie developed from a tropical wave over the Atlantic about 900 miles east of the Leeward Islands on Aug. 19 and became a tropical storm a day later. It moved on a west-northwestward track skirting the Leeward Islands. Late on the 21't the storm strengthened into a hurricane located about 200 miles north-northeast of eastern Hispaniola. Bonnie strengthened to its maximum winds of 115 mph late on the 23rd while located about 175 miles east of San Salvador in the Bahamas. The hurricane turned toward the northwest and stayed east of the Bahamas. Bonnie then headed toward the southeast U.S. coast in the general direction of the Carolinas gradually turning toward the north-northwest and then north. As the center neared the coast its forward speed slowed. Bonnie weakened to a tropical storm while moving slowly over eastern North Carolina. As the storm moved off the coast in the vicinity of the outer banks near Kitty Hawk, it re-strengthened into a hurricane. Bonnie soon weakened back to a tropical storm as it moved northeastward to eastward over the Atlantic into cooler waters.

Prior to Hurricane Bonnie, comprehensive hurricane evacuation restudies had been underway for both South Carolina and North Carolina. A restudy had not been initiated for Virginia. These studies and their associated work products are jointly funded by the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers and the National Weather Service. The State of North Carolina also contributed study monies. The Wilmington District of the Corps of Engineers serves as study manager for the North Carolina Restudy effort and the Charleston District as study manager for the South Carolina Restudy effort.

With early and mid 1980's studies in hand and with some draft restudy products on the table, Bonnie provided an opportunity to answer several key questions regarding these major FEMA/Corps planning efforts:

- Did local and state officials use the products produced in these major studies?
- Were study data regarding storm hazards, behavioral characteristics of the threatened population, shelter information, evacuation times, and decision-making accurate and reliable?
- Which study products were most useful and which least useful - what improvements could be made to current methodologies and products?

To answer these questions, study teams comprised of representatives from FEMA; the Corps of Engineers; and Post, Buckley, Schuh & Jernigan, Inc. visited with local and state officials throughout the directly impacted areas of South Carolina, North Carolina and Virginia. Post, Buckley, Schuh & Jernigan, Inc. was retained to accompany the study team and document all relevant findings. Many local and state officials provided their observations. Local emergency management directors, law enforcement officers, and Red Cross personnel were involved in meetings held in each area that

responded to Hurricane Bonnie. Separate meetings were held to discuss study product usage with local media representatives. Appendix A lists those individuals who either attended meetings or provided input through telephone conversations.

Discussion with local emergency management officials focused on study products and their use relative to the evacuation decision process, evacuation and clearance time, sheltering, and public information. Discussions with state officials centered on the role the state played in the evacuation process, including the use of study products in communicating with local officials. Media representatives were asked to focus on study related materials that they possessed and that were broadcast to the general public. They also addressed the types of materials and public information they could have used that had not been developed or delivered to them to date.

In addition to the meetings held with state and local officials, Hazards Management Group conducted and analyzed a residential behavioral sample survey for selected communities in North Carolina. Telephone interviews were conducted to ascertain actual evacuation response in Bonnie and to predict evacuation response parameters for the comprehensive hurricane evacuation restudy. The behavioral analysis focused on the actual percent of the affected population that evacuated during Bonnie, when the evacuees left their residence, what sort of refuge evacuees was used, where the refuge was located, and the number of vehicles used by evacuating households.

This report documents the findings of the study team and is organized by general category of hurricane evacuation study product. Those general categories that are addressed include:

- Hazards/Vulnerability Data
- Behavioral Characteristics of Evacuees
- Shelter Issues
- Transportation/Clearance Time Data
- Evacuation Decision-Making

Public Information

Each chapter describes typical study components and products produced in comprehensive hurricane evacuation studies. The chapter then summarizes actual data related to Bonnie and where relevant, compares it with study produced data for a relevant storm scenario. Recommendations are then given for future study efforts concerning that study topic.

Chapter 2 - Hazards/Vulnerability Data

In FEMA/Corps comprehensive hurricane evacuation studies, the primary objective of the hazards analysis is to determine the probable worst-case effects for the various intensities of hurricanes that could strike an area. Specifically, a hazards analysis quantifies the expected hurricane-caused inundation that would require emergency evacuation of the population. Historically, the hazards analysis also has assumed that mobile homes outside the surge inundation area must be evacuated due to their vulnerability to winds. The National Weather Services' SLOSH (Sea, Lake, and Overland Surge from Hurricanes) numerical storm surge prediction model was used as the basis of the hazards analysis for studies that have been completed or restudies that are ongoing in North Carolina, South Carolina and Virginia.

The vulnerability analysis uses the hazards analysis to identify the population potentially at risk to coastal flooding caused by the hurricane storm surge. Storm tide atlases are produced showing the inland extent of surge inundation for various hurricane intensities. Hazards and vulnerability issues related to Bonnie that were discussed with local and state officials included the following:

- What technical data/mapping was used to choose the areas to evacuate?
- Did the technical data provide a good depiction of the hazard area?

Since North Carolina was the landfall state for Bonnie, it was the only area where SLOSH predictions could be compared with actual high water marks. The Wilmington District of the US Army Corps of Engineers prepared the high water mark data and then transmitted it to the National Hurricane Center for comparison with the SLOSH model. [Figure 2-1](#) shows a comparison between the observed storm tide high water marks and the SLOSH model calculated storm tide profile along the North Carolina Atlantic Coastline for Hurricane Bonnie (1998). In addition, several individual comparisons between observed and SLOSH model calculated values are made inside of Pamlico Sound and on the Neuse and Pamlico rivers (i.e. Observed value given and calculated value below in parenthesis). All values are given in feet above NGVD. Also included in the figure is the radius of maximum wind at time of landfall. The results are similar to previous hurricane storm surge comparisons and generally show that the SLOSH model calculates the storm surge within plus or minus 20 percent of the observed values.

In addition to the SLOSH model comparison, the National Hurricane Center provided their preliminary forecast and warning critique for Hurricane Bonnie. Appendix B includes the "Best Track" positions for Hurricane Bonnie, including positions, barometric pressure, wind speed, and storm classification by date. The appendix also includes a table reporting selected surface observations at various localities throughout the impacted areas and a tropical cyclone watch and warning summary for Bonnie.

An excerpt from the NHC report regarding forecast error is provided as follows:

On the 22nd, most of the models suggested that Bonnie was going to remain out to sea. Thereafter, during the 23rd and 24th, there was a significant change in the model forecasts and some of them turned the hurricane toward the west while others kept it out to sea. At that point, the forecast became very difficult and highly uncertain.

Consequently, watches and warnings were required for a large portion of the southeast U.S. coast. In spite of the model's scatter, the official forecast tracks remained basically unchanged and in the middle of the model forecast ensemble. Apparently, during the earlier runs, the models weakened the ridge to the north of the hurricane too soon and forecast a premature recurvature. The official forecast errors for Bonnie were, in general, very close to the most recent 10 year average. There was only a small improvement in the 48 and 72 hour forecast if compared to the average. With the exception of a few 72 hour forecast errors at the beginning of Bonnie's life, the NHC intensity forecasts for Bonnie were smaller than the past 10 year average errors.

Recommendations:

Many of the areas interviewed for Bonnie are waiting for finalized surge mapping. There is still a wide variety of technology being used to produce the mapping around the country and within the interviewed areas. It is recommended that an ICCOH subcommittee be reorganized to address the mapping issue and determine what methods are the most cost effective and acceptable to state and local officials.

Chapter 3 - Permanent Resident Public Response

In Eastern North Carolina To Hurricane Bonnie (Prepared by Hazards Management Group) The narrative below is provided by Hazards Management Group (HMG) for the post Bonnie evacuation assessment and focuses on describing the evacuation behavior of permanent residents in eastern North Carolina during the Bonnie event. It should be noted that FEMA and the US Army Corps of Engineers are working with HMG to ascertain the behavioral characteristics of the tourist population and their response to Bonnie. This work should be completed by summer 1999. In addition, HMG will publish a study document in February 1999 outlining behavioral parameters that should be used for the North Carolina restudy.

Method/Sample

Telephone interviews were conducted with residents of the following areas: approximately 200 on the Outer Banks (including Manteo), approximately 100 in areas subject to inundation in category 3 hurricanes along Pamlico and Albemarle Sounds, and approximately 100 in non-surge areas of counties bordering Pamlico and Albemarle Sounds. The Outer Banks/Manteo sample was broken into four sectors for reporting of results: Hatteras refers to the southern extent of the study area from Ocracoke through Rodanthe; Kill Devil Hills includes Nags Head and Wanchese; Southern Shores is the label used to refer to Kitty Hawk and point north on the Outer Banks; Manteo indicates the town of Manteo and Roanoke Island.

Statistical Reliability

Figures reported in surveys cited in this chapter are based upon samples taken from larger populations. The sample values provide estimates of the values of the larger populations from which they were selected, but are usually not precisely the same as the true population values. In general, the larger the number of people in the sample, the closer the sample value will be to the true population value. A sample of 200 will provide estimates which one can be 90% "confident" are within 4 to 6 percentage points of the true population values, compared to a sample of 100, which will provide estimates which one can be 90% "confident" are within 5 to 8 percentage points of the true population values. With a sample of 50, one can be 90% "confident" of being within 7 to 11 percentage points of the actual population value. A sample of 25 is 90% "accurate" only within 10 to 17 percentage points. Estimates derived from samples smaller than 25 should be considered suspect.

This is particularly noteworthy in drawing conclusions about whether two survey results are "different" from one another. Differences of a few percentage points in sample results of 100 or less do not necessarily mean the populations from which the samples were drawn are different. When the aggregate samples are broken down into subgroups, the reliability of estimates for the subgroups suffers.

Questionnaire

Respondents were asked whether they evacuated their homes in Bonnie, and if so when they left, what sort of refuge they took, why they took it, and how they got there. All respondents were also asked why they responded as they did and they were asked a number of background questions to help explain their actions. The complete questionnaire is shown in Appendix C.

Evacuation Participation

The evacuation in Bonnie was not substantial in eastern North Carolina. Even on the Outer Banks only 27% said they left their homes to go someplace safer, and only 19% did so along the surgeprone areas on Albemarle and Pamlico Sounds. The Outer Banks response varied by location on the Outer Banks, however, with a high of 38% in the Southern Shores and Kill Devil Hills areas. If Manteo and Roanoke Island are excluded (not actually parts of the Outer Banks), the overall figure increases slightly.

Percent evacuating by risk area

| Outer Banks/Manteo (N=202) | Coastal Sound (N=101) | Non-surge (N=99) |
|-------------------------------|--------------------------|---------------------|
| 27 | 19 | 4 |

Percent evacuating by Outer Banks sectors

| Hatteras (N=48) | Kill Devil Hills (N=53) | Southern Shores (N=32) | Manteo (N=60) |
|--------------------|----------------------------|---------------------------|------------------|
| 25 | 38 | 38 | 15 |

People who evacuated in Bonnie were asked what convinced them to leave. Respondents could give more than one reason, and some did. The answers are best interpreted as factors which influenced the decisions to leave. No single explanation dominates. The three sets of reasons given most frequently were 1) someone urged evacuation, 2) concern about the effects of the storm if it hit, and 3) concern that the storm would in fact hit.

Reasons given for evacuating (N=78) (percent giving reason; multiple reasons possible)

| | |
|--|----|
| Officials said evacuate | 21 |
| NWS said evacuate | 19 |
| Police/Fire said evacuate | 5 |
| Media said evacuate | 13 |
| Friend/Relative said evacuate | 15 |
| Concern about severity of storm | 24 |
| Concern about increase in storm severity | 4 |
| Concern about flooding | 13 |
| Concern about wind | 13 |
| Concern about road flooding | 3 |
| Concern storm would strike | 12 |
| High strike probabilities | 4 |
| Other | 17 |

Reasons given for not evacuating (percent giving reason; multiple reasons possible)

| | Outer Banks (N=147) | Coastal Sound (N=82) | Non-Surge (N=95) |
|----------------------------------|------------------------|-------------------------|---------------------|
| Storm not severe/house safe | 49 | 68 | 80 |
| Officials said stay | <1 | 5 | 6 |
| Media said stay | 2 | 9 | 6 |
| Friends/relatives said stay | 3 | 6 | 4 |
| Officials didn't say to evacuate | 3 | 5 | 8 |
| Low probability of hit | 20 | 12 | 32 |
| Would miss | 13 | 10 | 11 |
| No transportation | <1 | 0 | 0 |
| No place to go | 1 | 2 | 2 |
| Protect against looters | 5 | 1 | 0 |
| Prevent damage | 11 | 4 | 6 |
| False alarms | 7 | 2 | 4 |
| Job | 10 | 2 | 4 |
| Waited too long | 2 | 0 | 1 |
| Traffic bad | 2 | 0 | 0 |
| Too dangerous | 3 | 0 | 1 |
| No pets allowed in shelters | <1 | 0 | 0 |
| Other | 12 | 16 | 4 |

Similarly, those who did not evacuate were asked why they did not. By far the most common response was that the storm would not be strong enough to be a threat to the respondent's safety, either because the storm was not expected to be strong or because one's house was built adequately. The second most frequent reason given was that the storm was not expected to strike the respondent's location. Finally, some said they stayed because their job required it, some thought they could prevent damage from the storm if they were present when it struck, and some wanted to protect the property from looters.

The previous questions about reasons for leaving and staying were "open-ended." That is, respondents were simply asked the question, and their answers were placed into categories. Actual evacuation participation is often explained successfully if one knows whether the respondent believes he or she was told by authorities to evacuate. Such information would only come out in the previous questions if the respondent volunteered it. To ensure that the information was available from everyone in the sample, people were asked whether they heard during the threat from officials that they should evacuate. Those answering yes were then asked whether the notice indicated that their evacuation was mandatory or whether it was just recommended. The results are shown in [Table 3-5](#).

On the Outer Banks 65% said they heard from evacuation notices from officials, but only 35% believed the notices was compulsory. Although there appears to be some variation among locations on the Outer Banks, the differences are not statistically significant, given the relatively small samples in each location. Only 27% of the coastal sound sample said they heard from officials that they should evacuate.

Type of evacuation notice heard, by Outer Banks sector (percent of respondents)

| | Hatteras (N=48) | Kill Devil Hills (N=53) | Southern Shores (N=31) | Manteo (N=56) |
|------------------------|--------------------|-------------------------------|------------------------------|------------------|
| Mandatory Order | 35 | 40 | 45 | 30 |
| Recommendation | 31 | 23 | 26 | 30 |
| None | 33 | 38 | 29 | 39 |

Residents who said they heard from officials that they should leave were more likely to do so, compared to people who said they did not hear evacuation notices from officials. The evacuation participation rates were not high even for those saying they had been ordered to leave from the Outer Banks, however, and the differences between those saying that the notice was mandatory versus voluntary are small. Sample sizes vary from cell to cell within and evacuation rates given for people receiving evacuation notices are reasonably reliable only in the Outer Banks/Manteo area. Sample sizes did not allow the Outer Banks/Manteo sample to be broken down further for this analysis.

Percent evacuating by type of official evacuation notice heard by risk area

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|------------------------|---------------------|------------------|-----------|
| Mandatory Order | 34 | 50 | * |
| Recommendation | 33 | 13 | * |
| None | 14 | 14 | 4 |

*Figures based on fewer than 10 respondents.

Previous studies have shown that evacuation behavior is also strongly related to one's perception of personal vulnerability, and eastern North Carolina residents were asked two questions to assess this variable. First, they were asked whether their own home would experience dangerous flooding in a 115 MPH hurricane, which Bonnie had been at one time prior to landfall. People who believe their homes would flood dangerously should be more likely to evacuate than other people. Fewer than half the respondents said their homes would flood, even on the Outer Banks and in the coastal sound area subject to flooding in a category 3 hurricane. Because of the scale of available SLOSH inundation maps, we cannot say with certainty that everyone in the sample would be subject to flooding in at least some 115 MPH hurricanes, but in generating the sample it was our intention to include respondents in the Outer Banks and coastal sound samples who would be told to evacuate in category 3 hurricanes. This belief by residents of these locations will make it less likely that the residents will evacuate when advised or even ordered to do so. In none of the four subgroups of the Outer Banks used in our sample did a majority believe they would be at risk to dangerous flooding in a 115 MPH hurricane.

Belief that home would experience dangerous flooding in 115 MPH hurricane, by risk area (percent of respondents)

| | Outer Banks/ Manteo (N=201) | Coastal Sound (N=101) | Non-Surge (N=99) |
|-----------------|-----------------------------------|-----------------------------|---------------------|
| Would Flood | 40 | 43 | 21 |
| Would Not Flood | 53 | 51 | 74 |
| Don't Know | 7 | 7 | 5 |

Belief that home would experience dangerous flooding in 115 MPH hurricane, by Outer Banks sector (percent of respondents)

| | Hatteras (N=48) | Kill Devil Hills (N=53) | Southern Shores (N=31) | Manteo (N=60) |
|-----------------|--------------------|-------------------------------|------------------------------|------------------|
| Would Flood | 48 | 40 | 36 | 40 |
| Would Not Flood | 50 | 51 | 55 | 52 |
| Don't Know | 2 | 9 | 10 | 8 |

On the Outer Banks, people believing they would be at risk to flooding were more likely than others to evacuate in Bonnie, 40% vs. 18%. There was no statistically significant difference among residents living in the coastal sound risk area. Although people on the Outer Banks who perceived themselves to be at risk to flooding were twice as likely as others to leave in Bonnie, still fewer than half actually evacuated. Reasons would include the fact that Bonnie was not anticipated to have 115 MPH winds when she struck the Outer Banks, and respondents might not have expected the storm to strike their area at all.

Percent evacuating by belief home would flood in 115 MPH hurricane, by risk area

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|-----------------|------------------------|------------------|-----------|
| Would Flood | 40 | 19 | 5 |
| Would Not Flood | 18 | 16 | 3 |
| Don't Know | * | * | * |

[These Tables](#) extend the flood perception analysis to include wind. Respondents were asked whether it would be safe to stay in their homes in a 115 MPH hurricane, considering both wind and water. Note that the response pattern is reversed - this time they were asked whether their home would be safe, while in the previous question they were asked whether it would be at risk. Fewer than 50% said their home would not be safe, with another 12% saying they weren't sure. This was also true on the Outer Banks.

People saying their homes would not be safe were about twice as likely as others to evacuate in Bonnie, although most did not. In this case, however, there was also a difference among residents along the sound.

Finally, an analysis was performed to assess the effect of several of the above factors simultaneously.

Among respondents on the Outer Banks who said they heard from officials that they should evacuate in Bonnie and who believe their homes would be unsafe in a 115 MPH hurricane, 48% left. Excluding Manteo from the Outer Banks sample raises the evacuation participation for the above residents to 50%.

Other Predictors

People who evacuated in Fran, also tended to evacuate in Bonnie, and those who stayed in Fran tended to stay in Bonnie. This was true in all three risk zones as can be seen in [this Table](#).

There were not many mobile home residents in the sample, but those who were included were more likely than others to evacuate in Bonnie. This was true on the Outer Banks and also in the coastal sound area.

Length of residence in one's present home and length of residence on the Carolina coast were good predictors of evacuation. People living in their homes or the region fewer than 10 years were substantially more likely than others to evacuate in Bonnie. This could have something to do with hurricane experience, but it might also be that another explanatory variable is correlated with length of residence. More recently developed areas on the Outer Banks might be more vulnerable, for example see [these Tables](#).

Finally, people who said they relied on the Weather Channel a fair amount or a great deal for information about Bonnie were more likely than others to evacuate (23% vs. 6%). In the coastal sound and non-surge areas renters were more likely to evacuate and home owners. People with lower incomes tended to be more likely than others to evacuate, although the exact relationship varied among risk areas.

These variables were not found to be associated with evacuation in Bonnie:

- * Receiving storm information from local government.
- * Receiving storm information from state government.
- * Living in the area when Fran threatened.
- * Hearing evacuation notices in Fran.
- * Number of people living in the home.
- * Presence of children in the home.
- * Presence of pets in the home.
- * Race (except in non-surge areas, where non-whites were more likely to evacuate)

Evacuation Timing

Evacuees were asked the day and time when they evacuated, and to refresh their memories they were reminded of the times when a hurricane watch and then a warning was first issued. [Figure 3-1](#) displays the cumulative evacuation rate in Bonnie. That is, the line shows, of those who eventually evacuate, the cumulative percentage who had left by various times.

The hurricane watch was issued at 5 PM on Monday, August 24k", and the warning, which included all of the North Carolina coast, was issued at 5 AM on Tuesday, August 25th, just before the time when the graph in Figure 1 commences. Evacuation continued steadily throughout the 25h, and paused around 10 PM that night. It then resumed around 6 AM on the following morning. When the evacuation paused Tuesday night, 70% of the eventual evacuees had left. When it resumed Wednesday morning it did so at a

slower rate.

Type of Refuge

Evacuees were asked whether they went to a public shelter, the home of a friend or relative, a hotel or motel, or someplace else ([see this Table](#)). The surprising response was that no one said they went to a public shelter. Because so few evacuated, the number of evacuees answering the question was less than 100, but still this was surprising. Most people went to the homes of friends and relatives, which is common in most evacuations.

Tests were performed to assess whether refuge choice was related to type of structure lived in, age, years in present home, years in the region, number of people in the household, owning vs. renting, pets, race, and income. All were unrelated to the sort of refuge used by evacuees. People with children were more likely than others to go to motels, and less likely to go to friends and relatives.

Location of Refuge

Regardless of the type of refuge used in Bonnie, respondents were asked its location. From the Outer Banks 80 percent of the evacuees left their own county. As shown in the [Table](#) almost half (47%) went someplace else in North Carolina, and 26% went north to Virginia. A few scattered elsewhere. From the coastal sound area, more evacuees went to destinations in their own neighborhoods, and fewer went great distances.

The number of evacuees from each location on the Outer Banks is too few to be statistically reliable. However, the breakdown is presented [Here](#) so that readers can combine sectors as they wish in order to create data sets with geographically meaningful and statistically reliable groupings.

Vehicle Use

Not all vehicles available to evacuating households are always taken. This is often because the family doesn't wish to become separated more than necessary. Respondents who evacuated in Bonnie were asked the number of vehicles that were available to be used in the evacuation and the number actually taken. Based on those responses, only 53% of the available vehicles were used. This figure is low but not completely unheard of, compared to results elsewhere in other hurricanes. The low figure could result from residents evacuating with friends and neighbors, for example. The 53% figure corresponds to an average of 1.18 vehicles being used by each evacuating household. Only three households said they took motorhomes or pulled trailers. All were on the Outer Banks, which accounts for 4% of the evacuating households.

Six percent of the households surveyed said someone in the household needed assistance in evacuating. Two-and-a-half percent indicated a special need, whereas 3.5% needed transportation only. Four percent said they had no vehicles of their own available. All of the assistance was provided either from within the household or by friends and relatives. No one said the assistance was provided by an agency.

Information Sources

Respondents were asked how much they relied on a variety of sources of information about Bonnie. The Weather Channel and local television stations were the most heavily used sources. On the Outer Banks the Weather Channel was number one, and in the other two areas, local stations prevailed. It was mentioned earlier that people who said they relied on the Weather Channel were more likely than others to evacuate. The results can be seen in this [Table](#).

Chapter 4 - Shelter Issues

The primary objectives of shelter analyses prepared for FEMA/Corps comprehensive hurricane evacuation studies are to list public shelter locations, assess their vulnerability relative to storm surge flooding, and to estimate the number of people who would seek local public shelter for a particular hurricane intensity or threat. Shelter location/capacity data are obtained from state and local emergency management staff working in conjunction with the American Red Cross, school board or other local agencies. Comparisons are then made with SLOSH data to assess flooding potential. Public shelter capacity is usually compared to public shelter demand figures generated in the transportation analysis to determine potential deficits or surpluses in sheltering. The behavioral analysis is important to this process as assumptions for the transportation analysis (regarding the percent of evacuees going to public shelter) come from the behavioral analysis or behavioral parameters recommended by the local directors.

Shelter issues related to Bonnie were discussed with local and state officials. Discussions focused on the following topics:

- When were shelters opened and when did evacuees arrive/stop arriving?
- How many shelters were opened and how many people were sheltered?
- Were any flooding, wind, or loss of power problems encountered with shelters during the storm?

[Table 4-1](#) summarizes the responses to each of these topics gathered for the counties interviewed in South Carolina, North Carolina and Virginia.

In general, the number of evacuees going to public shelters was less than what was anticipated even in the old hurricane evacuation studies for each area. Horry County, South Carolina was somewhat of an exception due to the significant number of tourists who traveled to local public shelters. For all other jurisdictions, public shelter evacuees were primarily permanent residents. Since evacuation participation rates of permanent residents from potential storm surge areas were much less than 100%, lower actual public shelter demand figures are to be expected.

In the Virginia jurisdictions very little evacuation took place making any comparison to study figures meaningless. Only isolated problems regarding shelter staffing and loss of power were reported. Several instances occurred where the public showed up at shelters before they were staffed and officially opened. Communications to evacuees traveling to inland county public shelters is a concern to some local directors particularly in eastern North Carolina.

Chapter 5 - Transportation/Clearance Time Data

In FEMA/Corps of Engineers comprehensive hurricane evacuation studies, the primary objective of the transportation analysis is to determine the clearance times needed to conduct a safe and timely evacuation for a range of hurricane threats. Information from the vulnerability, shelter, and behavioral analyses are directly input as well as various sources of permanent and seasonal population data.

For North Carolina, clearance times had been updated for Brunswick, New Hanover, Onslow and Pender Counties prior to Bonnie. The remainder of the state had to rely on older clearance times developed in the mid 1980's. Horry and Georgetown Counties in South Carolina had received draft updated clearance time data in the spring of 1998. For Virginia, clearance time data was somewhat dated as their base hurricane evacuation study had been accomplished in 1990. Each of these studies provided clearance times for a range of scenarios reflecting differing storm intensities, seasonal occupancy levels, and differing mobilization rates. Hurricane Bonnie provided a limited opportunity to analyze the validity of these study products.

Transportation and clearance time issues related to Bonnie and discussed by the study teams with local and state officials included the following:

- Was the evacuation roadway network accurate - did evacuees use projected routes?
- Were any traffic control actions taken to speed up flow?
- When was the evacuation essentially completed - how long did the evacuation take?
- Were any major problems encountered in this evacuation?

[Table 5-1](#) provides a summary of the responses received regarding transportation and clearance time data. Very little data is available for Virginia as little evacuation took place in each local jurisdiction. The most significant evacuations took place along the Outer Banks area (where tourists moved inland) and lower southeast coastal counties of North Carolina. Evacuations also took place in Georgetown and Horry Counties in South Carolina. However, in both North Carolina and South Carolina, local emergency management directors felt that participation in the evacuation by tourists was much better than that of the permanent residents who were asked to relocate.

In those counties where evacuations were carried out, traffic was reported to move smoothly. The lack of traffic problems indicates that local and state officials started the evacuations in a timely manner, that traffic control was appropriate and effective and that evacuation participation rates were modest out of those areas that potentially could have been impacted. Those local bottlenecks and congestion areas that were reported for Bonnie had been anticipated in the studies.

One of the most important sources of post-Bonnie traffic data was the traffic count summaries provided by the South Carolina Department of Transportation through the South Carolina Emergency Preparedness Division. Just as for hurricanes Bertha and Fran, SCDOT did an excellent job collecting and reporting the traffic associated with Bonnie for several key evacuation routes. Figures [5-1](#), [5-2](#), [5-3](#), and [5-4](#) show the evacuation traffic versus normal daily traffic for SC 9, US 501, US 17, and I-20.

Benchmarks along the timeline show when the voluntary relocation recommendation and mandatory evacuation orders were issued relative to traffic peaking. The duration of evacuation in the graphics helps verify the clearance times reported in Table 5-1. The peak traffic flow rate on 1-20 westbound of about 1100 vehicles per hour falls well short of the theoretical maximum flow rate of 3000 vehicles per hour, indicating modest levels of evacuation taking place in the coastal counties.

Recommendations:

- 1. Update Virginia's hurricane evacuation study and provide a transportation analysis tool that will allow local jurisdictions the ability to update clearance times as housing unit growth/road construction dictates.
- 2. In the North Carolina restudy, make sure inland routing of traffic is taken to 1-95 and inland bottlenecks noted.
- 3. Appoint an ICCOH subcommittee to address the evacuation zone delineation issues that face local and state EM officials as well as HES study managers.
- 4. Encourage NCDOT to implement some permanent traffic count stations that could strategically feed real time and post storm traffic count data to the EM community.
- 5. Finalize the South Carolina BES transportation analysis.

Chapter 6 - Decision Making

Some of the most important products developed as a part of the FEMA/Corps of Engineers hurricane evacuation studies and delivered to local and state officials have been evacuation decision making tools. These tools are decision arc maps and tables as well as computer software such as HURREVAC. These products graphically tie together real-time storm characteristics with HES produced hazards, shelter and clearance time data. Their purpose is to give emergency management directors a means of retrieving Technical Data Report information without having to dig through a report during an emergency. Evacuation decision tools provide guidance and assistance to decision makers as to when an evacuation should begin relative to a specific hurricane, its associated wind field, forward speed, probabilities, forecast track, and intensity.

Discussions initiated by the FEMA/Corps study teams with local and state officials regarding the evacuation decision process focused on the following questions:

- When was the Emergency Operating Center fully activated and what prompted this decision?
- What study products/decision aides were used to decide when to evacuate and who should evacuate?
- Was the new HURREVAC product used?
- When was the evacuation order or request made?

[Table 6-1](#) provides a summary of the responses and information gathered from each county. In general, most jurisdictions were impressed with the new HURREVAC beta version that was available for the Bonnie event. Those counties that didn't access it, used HURRTRAC and/or the old version of HURREVAC. Some North Carolina counties as well as Norfolk, Virginia still use the decision arc systems developed in the old HES studies. Many of the Virginia and North Carolina counties did not use the evacuation zone concepts developed in the older studies. However, Horry and Georgetown Counties in South Carolina did successfully use their recently delineated evacuation area concepts from draft restudy products. Most local jurisdictions desire evacuation zone systems that can be easily described over radio and TV.

In South Carolina and North Carolina, EOC's were activated on Monday, August 24th with evacuations taking place on Tuesday, the 25th. Virginia jurisdictions activated on Wednesday, the 26th and due to the storm's exiting characteristics, evacuated very little of their resident population.

Recommendations:

1. Update clearance time data and incorporate into the new HURREVAC model.
2. Conduct extensive training sessions with local EM's regarding the new HURREVAC model.
3. Deliver new SLOSH storm tide atlases to North Carolina and South Carolina Counties as soon as possible.
4. Work with state and locals to refine evacuation zone concepts.

Chapter 7 - Public Information

Although not a major part of previous FEMA/Corps of Engineers hurricane evacuation study efforts, public information is recognized as an important final element that must be addressed. Study products and data must ultimately be tailored to a format that the media and general public can understand so that correct evacuation decisions and preparations can be made at the household level. Bonnie provided a glimpse of the current means of getting hurricane evacuation information into the hands of the general public. Bonnie also provided local and state officials with an opportunity to assess additional needs regarding public information.

Methods used and suggestions offered in the study areas to inform the public in Bonnie and future events included the following:

- 1. Public information brochures were developed and widely distributed early in the season showing vulnerable areas, evacuation levels, and tips on hurricane preparedness.
- 2. Press briefings with national and local media to insure that they (radio, TV, newspapers) disseminate consistent information to the public - Media were given packets of hurricane materials early in the season by some emergency officials.
- 3. Law enforcement officials drove through neighborhoods with sirens and P.A. systems to encourage people to evacuate - this technique was used in some beach communities - some officials went door-to-door.
- 4. Some communities were able to provide evacuation information to the public through printed information in the local phone book.
- 5. An important means was through radio and television - some communities used cable TV overrides to alert the public of evacuation advisories and provide PSAs.
- 6. The Weather Channel was used extensively by local emergency management staff and citizens for public education and information.
- 7. Some emergency management officials faxed advisory and teleconference information to media every six hours.
- 8. Some counties used their web sites to display storm information and advisories.
- 9. Brunswick County, North Carolina used portable "drive-by" FM broadcasters at intersections to advise the public of evacuation orders.
- 10. The North Carolina state hurricane brochures are popular in some areas. Motels that ran out of them called local EM directors for more.
- 11. Decision arc systems are good for public and school education as they are easy to understand.
- 12. County public information officers are important resources during the event to interface with the media and public.
- 13. There is a mixture of ideas from the media regarding "canned" HES media products. Many would rather develop their own graphics.
- 14. Some selected areas would like hurricane information in Spanish.

[Go Back](#)**Evacuation destinations in Bonnie, by risk area (percent of respondents)**

| | Outer Banks/ Manteo (N=53) | Coastal Sound (N=19) | Non- Surge (N=5) |
|-----------------------------|----------------------------------|----------------------------|------------------------|
| Own Neighborhood | 11 | 32 | * |
| Elsewhere in Own County | 9 | 10 | * |
| Elsewhere in North Carolina | 47 | 42 | * |
| Virginia | 26 | 16 | * |
| Kentucky | 2 | 0 | * |
| Maryland | 2 | 0 | * |
| Pennsylvania | 2 | 0 | * |

Evacuation destinations in Bonnie, by Outer Banks sector (percent of respondents)

| | Hatteras (N=11) | Kill Devil Hills (N=20) | Southern Shores (N=12) | Manteo (N=13) |
|-----------------------------|--------------------|-------------------------------|------------------------------|------------------|
| Own Neighborhood | 0 | 25 | 0 | 8 |
| Elsewhere in Own County | 9 | 5 | 17 | 8 |
| Elsewhere in North Carolina | 64 | 30 | 58 | 62 |
| Virginia | 27 | 30 | 25 | 15 |
| Kentucky | 0 | 5 | 0 | 0 |
| Maryland | 0 | 0 | 0 | 8 |
| Pennsylvania | 0 | 5 | 0 | 0 |

Bonnie Best Track positions. [Table of Track Positions](#)

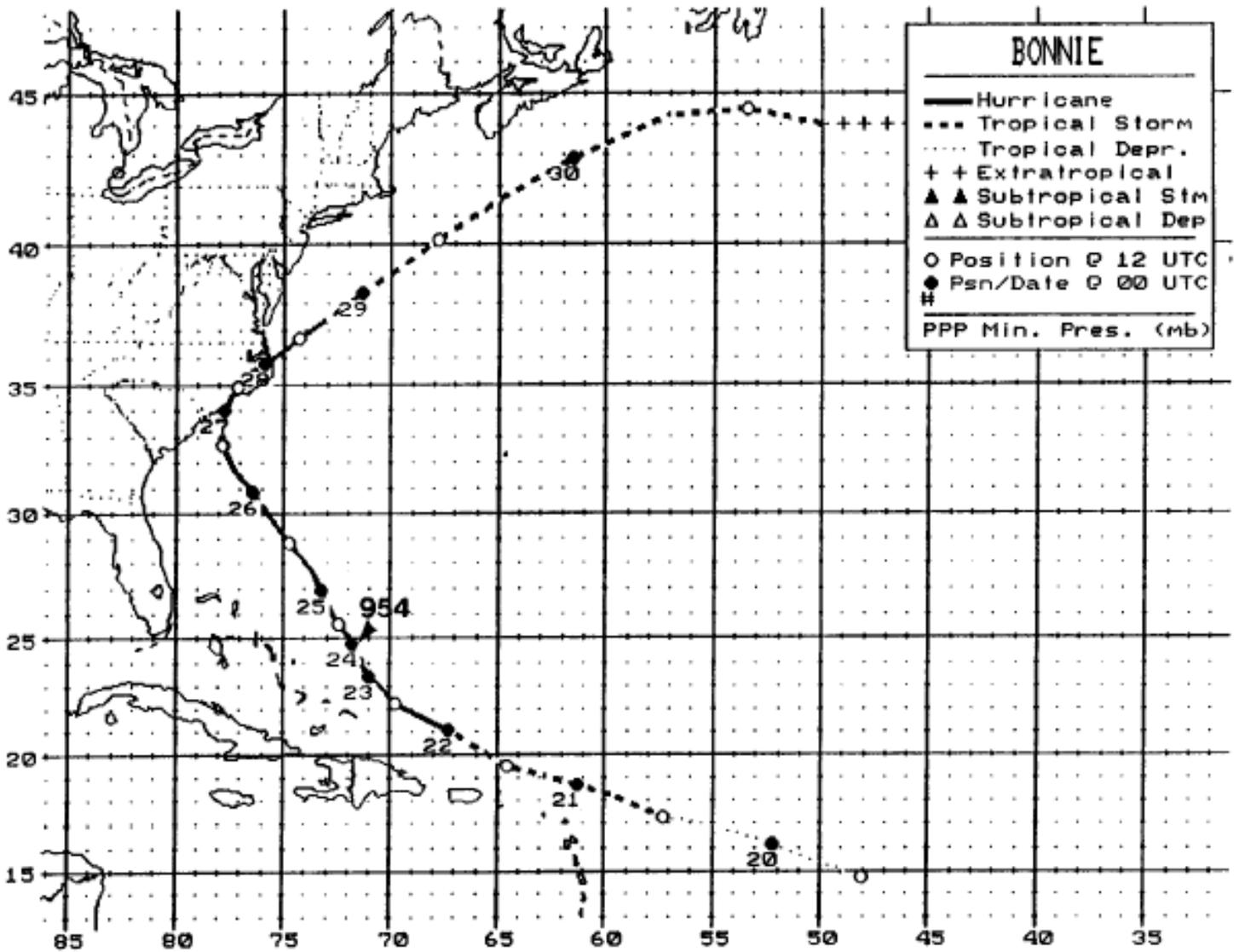


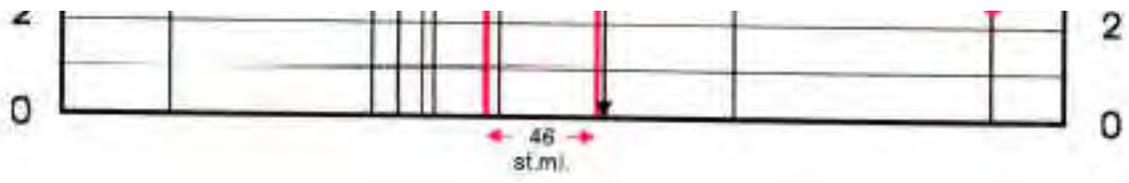
Fig. 1. Best track positions for Hurricane Bonnie, 19-30 August 1998.

Table 1. Best track, Hurricane Bonnie, 19- 30 August, 1998

| Date/Time (UTC) | Position | | Pressure (mb) | Wind Speed (kt) | Stage |
|-----------------|-----------|-----------|---------------|-----------------|---------------------|
| | Lat. (°N) | Lon. (°W) | | | |
| 19/1200 | 14.7 | 48.1 | 1009 | 25 | tropical depression |
| 1800 | 15.4 | 50.1 | 1009 | 30 | " |
| 20/0000 | 16.2 | 52.2 | 1009 | 30 | " |
| 0600 | 16.9 | 54.7 | 1008 | 30 | " |
| 1200 | 17.3 | 57.3 | 1007 | 35 | tropical storm |
| 1800 | 18.2 | 59.6 | 1006 | 35 | " |
| 21/0000 | 18.7 | 61.3 | 1005 | 40 | " |
| 0600 | 19.1 | 62.9 | 1002 | 45 | " |

| | | | | | |
|---------|------|------|------|-----|-----------------------------|
| 0600 | 19.1 | 62.9 | 1002 | 45 | " |
| 1200 | 19.5 | 64.5 | 1000 | 50 | " |
| 1800 | 20.3 | 65.9 | 999 | 55 | " |
| 22/0000 | 21.1 | 67.3 | 991 | 65 | hurricane |
| 0600 | 21.8 | 68.7 | 989 | 70 | " |
| 1200 | 22.3 | 69.8 | 980 | 75 | " |
| 1800 | 23.0 | 70.5 | 970 | 85 | " |
| 23/0000 | 23.4 | 71.0 | 962 | 90 | " |
| 0600 | 23.8 | 71.3 | 960 | 95 | " |
| 1200 | 24.1 | 71.5 | 958 | 100 | " |
| 1800 | 24.4 | 71.7 | 955 | 100 | " |
| 24/0000 | 24.8 | 71.8 | 954 | 100 | " |
| 0600 | 25.2 | 72.1 | 960 | 100 | " |
| 1200 | 25.6 | 72.4 | 962 | 100 | " |
| 1800 | 26.1 | 72.8 | 963 | 100 | " |
| 25/0000 | 26.9 | 73.2 | 963 | 100 | " |
| 0600 | 27.8 | 73.8 | 962 | 100 | " |
| 1200 | 28.8 | 74.7 | 963 | 100 | " |
| 1800 | 29.8 | 75.6 | 963 | 100 | " |
| 26/0000 | 30.8 | 76.4 | 958 | 100 | " |
| 0600 | 31.7 | 77.3 | 964 | 100 | " |
| 1200 | 32.7 | 77.8 | 965 | 100 | " |
| 1800 | 33.4 | 77.8 | 962 | 100 | " |
| 27/0000 | 34.0 | 77.7 | 963 | 95 | " |
| 0600 | 34.5 | 77.5 | 965 | 85 | " |
| 1200 | 34.9 | 77.1 | 974 | 75 | " |
| 1800 | 35.4 | 76.6 | 980 | 60 | tropical storm |
| 28/0000 | 35.8 | 75.9 | 983 | 65 | hurricane |
| 0600 | 36.2 | 75.1 | 985 | 75 | " |
| 1200 | 36.7 | 74.3 | 990 | 65 | " |
| 1800 | 37.3 | 73.2 | 991 | 60 | tropical storm |
| 29/0000 | 38.3 | 71.4 | 993 | 45 | " |
| 0600 | 39.2 | 69.6 | 999 | 45 | " |
| 1200 | 40.2 | 67.8 | 999 | 45 | " |
| 1800 | 41.6 | 64.8 | 1000 | 45 | " |
| 30/0000 | 42.9 | 61.5 | 1000 | 45 | " |
| 0600 | 44.3 | 57.0 | 1000 | 45 | " |
| 1200 | 44.5 | 53.5 | 1000 | 45 | " |
| 1800 | 44.0 | 50.0 | 998 | 45 | extratropical |
| 31/0000 | 44.0 | 45.0 | 996 | 45 | " |
| 0600 | 43.0 | 41.0 | | | absorbed by a front |
| 24/0000 | 24.8 | 71.8 | 954 | 100 | minimum pressure |
| 27/0400 | 34.4 | 77.7 | 964 | 95 | Landfall near Wilmington NC |

Figure 2



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Figure 3-1 Cumulative Evacuation in Bonnie

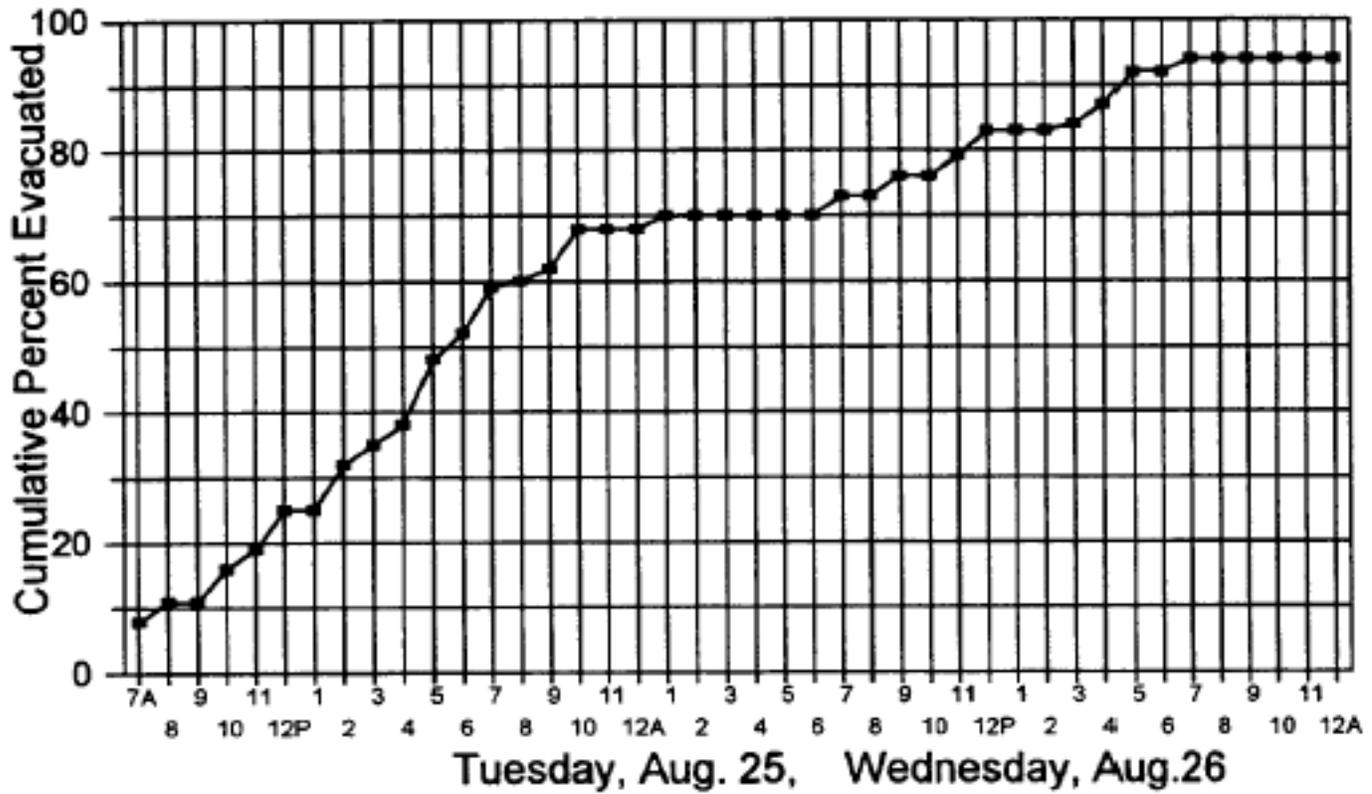
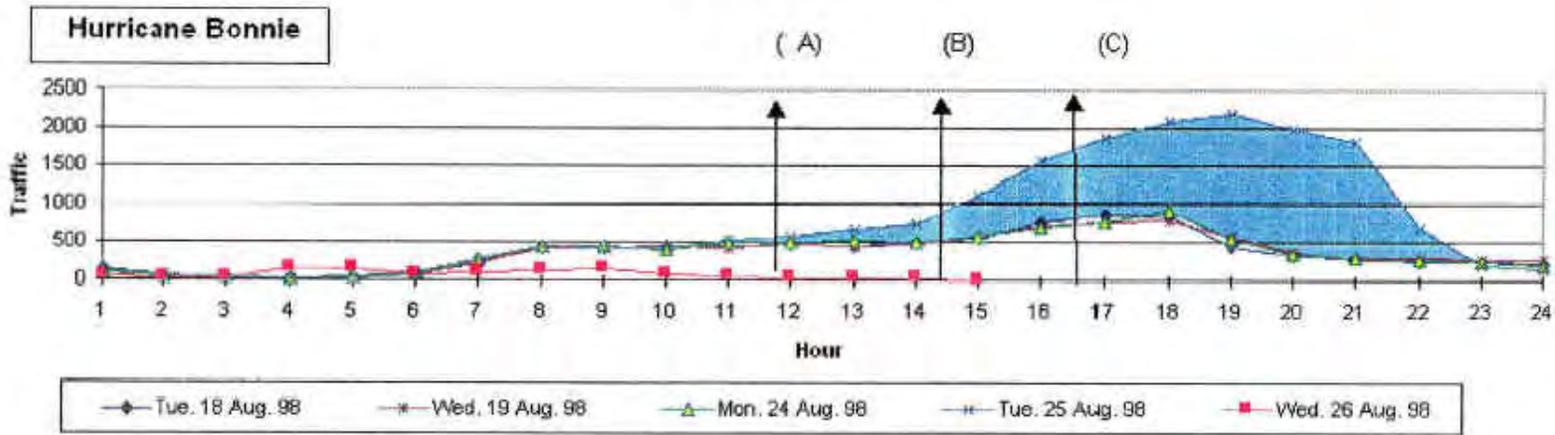


Figure 5-1 [Go Back](#)

Station 36- SC 9 Horry County (North Bound)



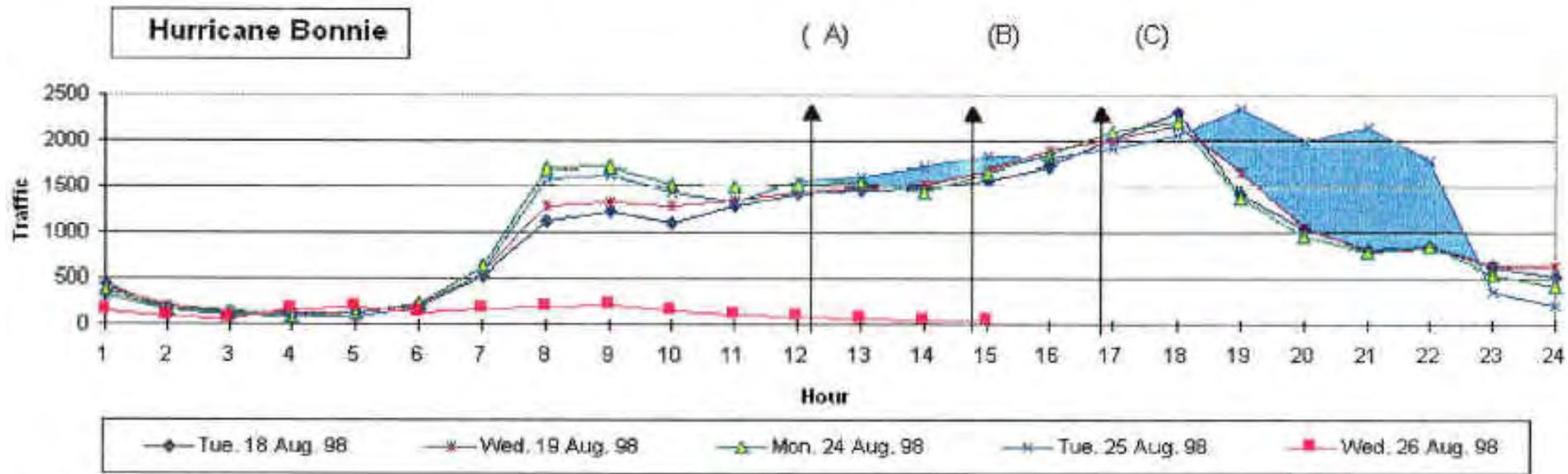
(A) Governors Voluntary
Evacuation

(B) Notification of 5PM
Mandatory evacuation

(C) Mandatory Evacuation

Figure 5-2 [Go Back](#)

**Station 18- US 501 MYRTLE BEACH
(North Bound)**



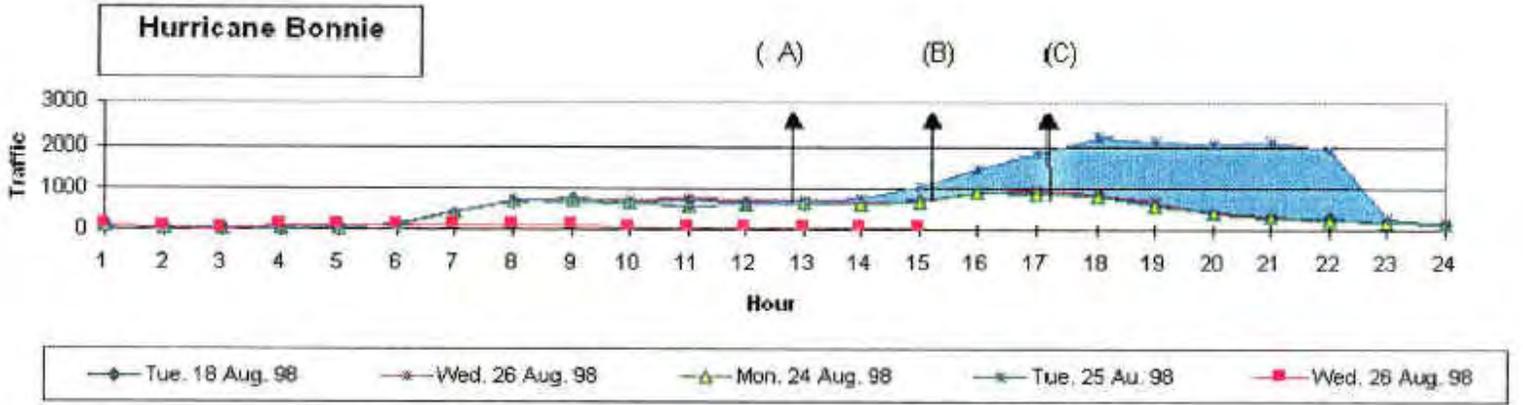
(A) Governors Voluntary Evacuation

(B) Notification of 5PM Mandatory evacuation

(C) Mandatory Evacuation

Figure 5-3 [Go Back](#)

Station 11- US 17 GEORGETOWN
(South Bound)



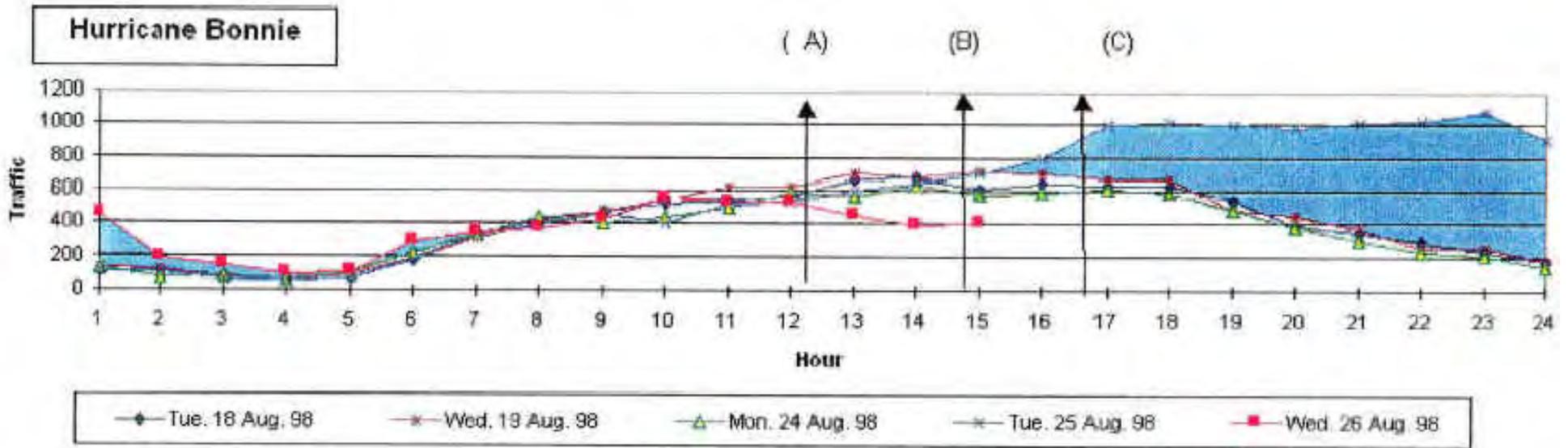
(A) Governors Voluntary Evacuation

(B) Notification of 5PM Mandatory evacuation

(C) Mandatory Evacuation

Figure 5-4 [Go Back](#)

Station 42- I-20 @ SC 403 Lee County Line
(West Bound)



(A) Governors Voluntary Evacuation

(B) Notification of 5PM Mandatory evacuation

(C) Mandatory Evacuation

Hurricane Bonnie Surface Observations

Table 2. Hurricane Bonnie selected surface observations, August 1998.

| Location | Press. (mb) | Date/ time (UTC) | Sustained wind (kts) ^a | Peak gust (kts) | Date/ time (UTC) ^b | Storm surge (ft) ^c | Storm tide (ft) ^d | total rain (in) |
|--------------------------------------|----------------|------------------------|---|-----------------------|-------------------------------------|-------------------------------------|------------------------------------|-----------------------|
| U.S. Virgin Islands | | | | | | | | |
| St. Thomas | 1006.1 | 21/1128 | 23 | 33 | 21/0851 | | | 0.29 |
| Airport | | | | | | | | |
| Puerto Rico | | | | | | | | |
| Ceiba | 1006.8 | 21/1121 | 24 | 33 | 21/0156 | | | 0.51 |
| Carolina | | | | | | | | 1.10 |
| Grand Turk | | | | | | | | |
| South Carolina | | | | | | | | |
| Charleston | 1007.0 | 26/1856 | 25 | 33 | 26/2034 | | | |
| International Airport | | | | | | | | |
| Charleston City Office | | | 25 | 39 | 26/1230 | | | |
| Myrtle Beach (MYR) | | | 38 | 52 | 26/1715 | | | |
| North Carolina | | | | | | | | |
| Wilmington | 969.9 | 27/0053 | 49 | 64 | 26/1827 | | | 9.04 |
| Kure Beach | | | | 77 | 26/1630 | | | |
| Florence Air. | | | 34 | 44 | 26/2150 | | | |
| Elizabeth City | 995.7 | 28/0030 | 51 | 63 | 28/0333 | | | 1.42 |
| Ocracoke | 990.5 | 27/1815 | | 66 | 27/1457 | | | 6.60 |
| Oregon inlet | 989.1 | | | 54 | 27/2015 | | | |
| Emerald isle | 976.9 | | | 62 | | | | |
| Newport | 985.1 | 27/1030 | | 52 | 27/0553 | | | 9.51 |
| Greenville | | | | 63 | 27/0915 | | | 8.20 |
| Morehead City | | | | | | | | 10.70 |
| Cherry Point | | | 41 | 61 | 27/0114 | | | 10.93 |
| Jacksonville | | | | 62 | 27/1133 | | | 11.00 |
| Frisco | | | 49 | 69 | 27/1109 | | | |
| New Hanover | | | | | | | 7-9 | |
| Tide Gage on Masonboro Isl. | | | | | | | 9.1 | |
| Wrightsville Beach | | | | | | | 7-7.3 | |
| Virginia | | | | | | | | |
| Cape Henry | | | 70 | 90 | 28/0300 | | | |
| Chesapeake Light Stn. Brookley Field | | | 68 | 81 | 28/0350 | | | |
| Currituck County EOC | | | | 81 | 28/0400 | | | |
| Oceana NAS | 999.0 | | 38 | 54 | 28/0357 | | | |
| Langley AFB | 1005.0 | | 46 | 58 | 27/2355 | | | |
| Norfolk Airport (ORF) | 1000.4 | 28/0024 | 40 | 56 | 28/0141 | | | 6.77 |
| Portsmouth | 1000.0 | 28/0105 | | 55 | 28/0222 | | | 2.44 |
| Norfolk NAS | 1002.0 | | 36 | 48 | 27/2315 | | | 4.91 |
| Sewells Point | | | | | | | 6.0 | |
| Coastal Pasquotank | | | | | | 6.0 | | |
| Chowan County | | | | | | 5-6 | | |
| New Jersey/Delaware | | | | | | | | |
| Delaware Light BouCrestviewy | 1005.2 | 28/1800 | 32 | 40 | 28/1700 | | | |
| Reedy Point | | | | | | | | 6.28 |

Hurricane Bonnie Surface Observations

| | | | | | | | |
|--------------------|------------|--------|---------|----|----|---------|------|
| Delaware Light Bou | Crestviewy | 1005.2 | 28/1800 | 32 | 40 | 28/1700 | |
| Reedy Point | | | | | | | 6.28 |
| Cape May | | | | | | | 6.05 |
| Atlantic City | | | | | | | 4.97 |
| Sandy Hook | | | | | | | 5.64 |
| Georges Bank bouy | | 990.2 | 29/1600 | 35 | 45 | 29/1700 | |

C-MAN Stations

| | | | | | | | |
|---------------------------|--|-------|---------|-----------------|----|---------|--|
| Frying Pan Shoals (FPSN7) | | 964.0 | 26/1630 | 76 ^f | 90 | 26/2130 | |
| Cape Lookout (CLKN7) | | 994.2 | 27/1300 | 48 | 75 | 27/1211 | |
| Diamond Shoals (DSLN7) | | 996.8 | 27/2200 | 68 | 79 | 27/2034 | |
| Duck NC (DUCN7) | | 993.5 | 28/0100 | 45 | 55 | 27/2000 | |
| Cheasepeake Lt. (CHLV7) | | 995.7 | 28/0600 | 72 ^f | 86 | 28/0532 | |

Buoys

| | | | | | | | |
|-------|--|-------|---------|-----------------|----|---------|--|
| 41002 | | 998.7 | 26/0300 | 42 ^f | 57 | 26/0426 | |
| 41004 | | 990.5 | 26/1300 | 38 | 49 | 26/1600 | |
| 44004 | | 994.3 | 29/0600 | 36 ^f | 46 | 29/0131 | |
| 44014 | | 989.8 | 28/1000 | 37 | 47 | 28/0200 | |
| 44137 | | 998.2 | 30/0000 | 50 | | 30/0300 | |
| 44144 | | 990.8 | 30/0300 | 47 | | 30/0300 | |

^a Standard NWS ASOS and C-MAN maveraging period is 2 min; buoys are 8 min unless otherwise indicated.

^b Date/time is for sustained wind when both sustained and gust are listed.

^c Storm surge is water height above normal astronomical tide level.

^d Storm tide is water height above NGVD.

^e Estimated.

^f 10 min average wind.

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Percent of respondents saying they relied a fair amount or a great deal on sources of information about Bonnie, by risk area

| | Outer Banks/ Manteo (N=53) | Coastal Sound (N=19) | Non- Surge (N=5) |
|------------------|----------------------------------|----------------------------|------------------------|
| Local Radio | 29 | 27 | 22 |
| Local TV | 42 | 70 | 71 |
| CNN | 25 | 34 | 23 |
| Weather Channel | 73 | 56 | 52 |
| Other Cable | 14 | 10 | 11 |
| Internet | 7 | 6 | 7 |
| On-line Services | 3 | 4 | 4 |
| Word of Mouth | 16 | 21 | 5 |

Meeting Participants

| <u>NAME</u> | <u>ORGANIZATION</u> |
|---------------------|----------------------------------|
| Stanley Kite | EMC – Craven County |
| Doug Haas | NCEM – Area 3 |
| Robbie J. York | Pamlico |
| Timothy P. Harvey | EMC – Pamlico County |
| George Sullivan | NCEM – Area 2 Coordinator |
| Jeff M. Credle | EMC/Hyde County Manager |
| Dale Lilley | EMC/Martin County |
| Lesley Williams | NCEM/DROC |
| Daden H. Wolfe, Jr. | EMC/Beaufort County |
| Roger Lambertson | PIO – Currituck County |
| Kathlyn S. Flora | Director, DSS – Currituck County |
| Stanley D. Griggs | EM – Currituck County |
| Bill Richardson | Currituck County Manager |
| Dan Scanlon | Currituck County |
| Donald C. Lewis | PBS&J |
| Lisa Goddard | WBTB 13 |
| Rusty Glusing | WPDE-TV 15 |
| Robert Smith | FEMA |
| Brent Campbell | WPDE-TV 15 |
| Cheryl Henry | PIO/Horry County |
| Paul Whitten | EPD/Horry County |
| Allan McDuffie | U.S. Army Engineers, Wilmington |
| Tom Collins | NCDEM |
| Leslie Williams | NCDEM |
| Cecil Logan | EM/Brunswick County |
| Patricia Byrd | EM/Georgetown |
| Charmel Menzel | EPD/South Carolina |
| Dan Summers | EM/New Hanover |
| Karen Wagley | EM/Onslow County |
| Paula Brown | NC DEM |
| Al Bjorkquist | Corps of Engineers – Wilmington |
| James Smith | NCDEM |
| Chris Coudriet | NCDEM |
| Frank McGovern | US Army Corps of Engineers – SA |
| Jerry Canupp | USCOE – SAD |

Meeting Participants (Continued)

| <u>NAME</u> | <u>ORGANIZATION</u> |
|----------------------|-------------------------------------|
| Bill Massey | FEMA |
| Don Needham | NCDEM |
| Patricia Chappell | EMO |
| Paul Moyer | US Army Corps of Engineers, Norfolk |
| Lisa Moon | PBS&J |
| Tom Cooke | Fire Dept & Emergency Services |
| Mark Marchbank | EM-Virginia Beach |
| Pat Gilbert | OEM |
| Jim Talbot | Emergency Services-Norfolk |
| Bruce Sterling | Emergency Services |
| Jeff Messinger | Emergency Services |
| NH Sanderson | FEMA |
| Eddie King | EM/Pender |
| Carson Smith | EM/Pender |
| Cathy Henry | NC EM |
| Susan Dwyer | USACE |
| Ron Fascher | USCOE-Wilmington |
| Dianne Hood | USACE- |
| Ann Keyes | EM-Washington County |
| Jan Stzins | Albemarle Pamlico Red Cross |
| Kenneth Ray Cullepha | EM/Perquimans County |
| Christy Saunders | EM |
| Douglas L. Belch | Emergency Services/Chowan County |
| James Smith | NCEM |
| Bobby Joyner | Pitt County |
| Phillip Williams | WNCT – TV 9 |
| Lesley Williams | NCEM |
| Al Hadley | Carteret County EM |
| Geneva Perry | Dare County Commission |

Table 3-5 [Go Back](#)**Type of evacuation notice heard by risk area (percent of respondents)**

| | Outer Banks/ Manteo (N=201) | Coastal Sound (N=98) | Non-Surge (N=99) |
|------------------------|--|-------------------------------------|-----------------------------|
| Mandatory Order | 35 | 14 | 0 |
| Recommendation | 30 | 13 | 5 |
| None | 35 | 72 | 94 |

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**Table 4-1
Public Shelter Data Summary
Hurricane Bonnie Evacuation Assessment**

| Location | Number of Shelters Opened | Number of People Sheltered | Tech. Data Report Shelters/Expected Shelter Demand | Time Opened/Duration | Problems Encountered |
|--------------------------|---------------------------|---|--|--|--|
| North Carolina | | | | | |
| Dare | Not Applicable | - | - | - | - |
| Hyde (Oracoke) | Not Applicable | - | - | - | - |
| Carteret | 5 | 750 | N/A | 6 PM on 8/25/98; 48 hrs | Loss of power; over capacity at Beaufort; locals waited for shelters to open |
| Albemarle Sound Counties | 1 shelter in each | Washington Cnty 104 Perquimans Cnty 250 Chowan Cnty 125 | N/A | Washington Cnty 4 PM Perquimans Cnty 6 PM Chowan Cnty 6 PM Pasquotank Cnty 6 PM Camden Cnty 6 PM | All counties want a statewide shelter plan |
| Currituck | None local | - | - | - | Public needs better information about inland public shelters |
| Pender | 2 | 893 | 2500 | 4 PM on 8/25/98 3 days | Power loss |
| Onslow | 7 | 1600 | 7600 | - | Need better generators; would like to know how many people churches are sheltering |
| New Hanover | 4 | 800 (Mostly permanent residents) | 3800 | 2 opened on 8/25/98 at 5 PM; other 2 opened on 8/26/98 | Loss of power; sewer lift stations down; minor structural problems; shelter staffing |
| Brunswick | 4 | 3000 | 4450 | 10 AM on 8/25/98 | Shalote Middle School handled overflow of evacuees from other 3 shelters |

**Table 4-1 (Continued)
Public Shelter Data Summary
Hurricane Bonnie Evacuation Assessment**

| Location | Number of Shelters Opened | Number of People Sheltered | Tech. Data Report Shelters/Expected Shelter Demand | Time Opened/Duration | Problems Encountered |
|------------------------|------------------------------------|---|--|--|---|
| Pamlico Sound Counties | Martin 4 Craven 4 Beaufort 3 | Martin 800 Pamlico 225 Beaufort 800 | N/A | Beaufort 8/25/98 2:00 PM 3 Days | - |
| Virginia | | | | | |
| Norfolk | 1 | 28 | N/A | 8/26/98 | Roof damage |
| Virginia Beach | 2 | 300 | N/A | 8/25/98 3 1/2 days | Power loss |
| Chesapeake | 3 | 35 | N/A | 08/25/98 | - |
| Suffolk | 2 | 20 | N/A | 8/26/98 1 day | - |
| Portsmouth | 1 | 35 | N/A | 8/26/1998 5:00AM | - |
| South Carolina | | | | | |
| Georgetown | 2 | 543 | 2000 | Pleasant Hill 20 hours Andrews 48 hours | Evacuees arrived before shelter staff; loss of power; loss of water |
| Horry | 10 | 6510 | 6100 | 48 hours | Power outages; lots of tourists in shelters; once full, permanent residents seeking shelter were sent inland. |
| Inland Counties | 35 | 3269 | - | 8/25/98 through 8/27/98 | - |

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**Table 5-1
Transportation/Clearance Time Data Summary
Hurricane Bonnie Evacuation Assessment**

| Location | Evacuation Roadway Network Accurate | Traffic Control Actions | Clearance Time Experienced | Study Calculated Time | Problems Encountered |
|--------------------------|-------------------------------------|---|--|-----------------------|--|
| North Carolina | | | | | |
| Dare | Yes | Highway patrol stationed at critical points | 14 Hours | N/A | 2 lane highway section from Corolla congestion; bottleneck in Elizabeth City late in the evening; permanent population didn't participate to the degree the tourists did; inland NCDOT road construction |
| Hyde (Oracoke) | Yes | - | Need 36 hours | N/A | Would like to relocate Swan Quarter Ferry |
| Carteret | Yes | Coordination of traffic signals | 5 hours reported but shelter arrivals would imply 8-10 hours | N/A | Minor traffic problems at NC24/NC58 in Cape Carteret and in Morehead City at bridge terminus with US70 |
| Albemarle Sound Counties | Yes | - | Not applicable | N/A | Traffic study needs to go all the way to I-95; signing needed directing traffic to I-95; bottlenecks at 64/32 and 343/158 |
| Currituck | Yes | Manned traffic control points | Dare/Currituck traffic ended after midnight | N/A | Major accident on 168; bottlenecks at 158/12, 158/168, 158/34, 168 at Virginia State Line |
| Pender | Yes | None needed | 8 Hours | 9 1/4 | None |
| Onslow | Yes | Manned traffic control points; evacuation routes already signed | 6-8 Hours | 9 1/4 | None |
| New Hanover | Yes | Manned traffic control points; some rerouting; variable message sign used | 10-12 Hours | 9 1/2 | Clearance times okay but close; 88-90% participation of beach communities; Brunswick traffic to I-40 was initially a problem |
| Brunswick | Yes | Highway patrol pre-staged and manned intersections | 8-10 Hours | 11 1/2 | Traffic flow was smooth; concerned about participation rates on some barrier islands |

Table 5-1 (Continued)
Transportation/Clearance Time Data Summary
Hurricane Bonnie Evacuation Assessment

| Location | Evacuation Roadway Network Accurate | Traffic Control Actions | Clearance Time Experienced | Study Calculated Time | Problems Encountered |
|------------------------|--|--|-----------------------------------|--------------------------------|---|
| Pamlico Sound Counties | Yes | None reported | Hyde - 24 hours | N/A | Some traffic stopping where evacuation signs ended; US 264 Business floods early in Washington |
| Virginia | | | | | |
| Norfolk | Not applicable (NA) | NA | NA | NA | Truck congestion on Chesapeake Bay Bridge |
| Virginia Beach | NA | NA | NA | NA | Hotels filled with NC evacuees |
| Chesapeake | NA | NA | NA | NA | NC evacuees created congestion along 17, 168 and I-64 |
| Suffolk | NA | NA | NA | NA | NC evacuees traffic congestion |
| Portsmouth | NA | NA | NA | NA | |
| South Carolina | | | | | |
| Georgetown | Yes | Police officers manned bottlenecks | 8-10 Hours | 13 (northern conglomerates) | Manner in which traffic was routed through Georgetown caused problems; rerouted during evacuation; traffic moved well |
| Horry | Yes | Signal modification and police at key intersections/traffic control points | 12-13 Hours | 13 (northern conglomerates) | Bottlenecks at 21st Avenue and 17 ByPass and at 501 in Conway; good participation from tourists, not as good from permanent residents; traffic moved well |

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**Table 6-1
Evacuation Decision Process Summary
Hurricane Bonnie Evacuation Assessment**

| Location | Time EOC was Activated | What Prompted Decision to Activate | What Study Products/ Decision Aids were Used in Decision Making | Time of Evacuation Order/Number Evacuated | How Well Study Products Worked |
|--------------------------|-----------------------------|--|---|---|--|
| North Carolina | | | | | |
| Dare | 8/23/98 | Newport, Wakefield NWS offices - Miami NHC information, HURREVAC, HURRTRAC | New HURREVAC; surge inundation mapping | 8/25/98 6:00 AM; 200,000+ | Good information; zones don't work - best to evacuate whole county; need better graphics for flood predictions |
| Hyde (Oracoke) | - | NHC information, communication with Billy Wagner of liaison team | Decision arcs | 2,000+ | - |
| Carteret | 8/25/98 | State information, Newport NWS | SLOSH mapping; new HURREVAC | 8/25/98 2:00 PM (Tourists 11:00 AM) 30,000+ | Good |
| Albemarle Sound Counties | 8/25/98 AM in most counties | Local NWS office information | Didn't use 87 Study but did use old HURREVAC information that state was providing | 8/25/98 Washington Cnty 2:00 PM Perquimans Cnty 7:00 PM Pasquotank Cnty 4:00 PM Camden Cnty 4:00 PM | SLOSH didn't model back-side storm effect; inland wind model not user friendly |
| Currituck | 8/24/98 | Decision arcs, weather channel, Dare Cnty actions, NWS information | Decision arcs | 8/25/98 8:00 AM 40,000+ | Okay, would like broader zones; would like SLOSH flooding depths |
| Pender | 8/25/98 7:00 AM | Wakefield NWS, storm track DTN information | - | 8/25/98 Noon 15000± | Didn't use study decision aids |
| Onslow | 8/24/98 | HURREVAC (old version), inland winds model, NHC information/downloads | HURREVAC (old version) | 8/25/98 1:00 PM | Did not use zones or decision arcs; clearance times okay |
| New Hanover | 8/25/98 Noon | Increase in strike probability, HURREVAC, DTN information, decision arcs | HURREVAC (manual input) decision arcs | 8/25/98 11:00 AM voluntary; 5:00 PM mandatory evacuation 6,000 from beaches | Well; zones not used because too difficult to describe |
| Brunswick | 8/25/98 | Bald Head Is. evacuation time requirements | Decision arcs; old version of HURREVAC | 8/29/98 11:00 AM 12,000± | Good |

Table 6-1 (Continued)
Evacuation Decision Process Summary
Hurricane Bonnie Evacuation Assessment

| Location | Time EOC was Activated | What Prompted Decision to Activate | What Study Products/ Decision Aids were Used in Decision Making | Time of Evacuation Order/Number Evacuated | How Well Study Products Worked |
|------------------------|---|---|--|---|---|
| Pamlico Sound Counties | - | Newport NWS information, conference call with state | Did not use 87 Study; Beaufort Cnty used old version of HURREVAC and decision arcs | Except for Hyde mainland and Beaufort, no ordered evacuation Beaufort 8/25/98 2:00 PM | Did not use zones; need study updated |
| Virginia | | | | | |
| Norfolk | 8/26/98 | HURREVAC, HURRTRAC, DTN information, decision arcs, probabilities, coordination with military | HURREVAC, decision arcs | Minimal evacuation | Would like to see category 5 added to SLOSH runs |
| Virginia Beach | 8/26/98 | HURRTRAC, HURREVAC, HURWIN 95, tides, SLOSH programs | HURREVAC, study mapping | Minimal evacuation for wind concerns | Would like study updated and zones looked at again; need easier to use format |
| Chesapeake | 8/26/98 | HURREVAC (old version), tides, SLOSH | HURREVAC (old version) | Minimal evacuation for wind concerns | Need study updated; zones re-examined |
| Suffolk | 8/26/98 5:00 PM | HURREVAC (old version), DTN data, conference calls | HURREVAC (old version) | Voluntary evacuation of campgrounds only | - |
| Portsmouth | 8/26/98 partial activation | HURWIN 95, HURRTRAC | HURWIN 95 | No evacuations carried out | Relook at zones; new HURREVAC looks good; need re-study |
| South Carolina | | | | | |
| Georgetown | Partial 8/24/98 8:30 AM Full 8/25/98 | Old HURREVAC model, governor/state actions, DTN information, governor's video conference | HURREVAC (old version) | 8/25/1998 12:30 PM Voluntary evacuation mandatory in late afternoon 12,000± | Used new evacuation areas from restudy |
| Horry | 8/24/1998 1:00 PM | Storm movement, National Guard mobilization, DTN information, new HURREVAC, governor's directives | New HURREVAC | 8/25/1998 12:00 PM Voluntary relocation; 3:30 PM mandatory; unknown number of total evacuees | Well; used evacuation area concept from restudy |

[Go Back](#)**Belief that home would be safe in 115 MPH hurricane, by risk area (percent of respondents)**

| | Outer Banks/ Manteo (N=201) | Coastal Sound (N=101) | Non-Surge (N=99) |
|-------------------|-----------------------------------|-----------------------------|---------------------|
| Would Be Safe | 43 | 45 | 54 |
| Would Not Be Safe | 46 | 44 | 34 |
| Don't Know | 11 | 12 | 12 |

Belief home would be safe in 115 MPH hurricane, by Outer Banks sector (percent of respondents)

| | Hatteras (N=47) | Kill Devil Hills (N=53) | Southern Shores (N=31) | Manteo (N=60) |
|----------------------|--------------------|-------------------------------|------------------------------|------------------|
| Would Be Safe | 49 | 45 | 45 | 37 |
| Would Not Be Safe | 40 | 47 | 45 | 47 |
| Don't Know | 11 | 8 | 10 | 17 |

Percent evacuating by belief home would be safe in 115 MPH hurricane, by risk area

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|-------------------|------------------------|------------------|-----------|
| Would Be Safe | 20 | 9 | 2 |
| Would Not Be Safe | 36 | 30 | 6 |
| Don't Know | * | * | * |

[Go Back](#)**Percent evacuating in Bonnie, by years lived in present home, by risk area**

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|-------------------------------|--------------------------------|--------------------------|------------------|
| Less Than 10 Years | 35 | 31 | 11 |
| 10 to 20 Years | 23 | 6 | 0 |
| At Least 20 Years | 17 | 11 | 0 |

Percent evacuating in Bonnie, by years lived in present region, by risk area

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|-------------------------------|--------------------------------|--------------------------|------------------|
| Less Than 10 Years | 42 | 50 | 25 |
| 10 to 20 Years | 28 | 14 | 0 |
| 20 to 40 Years | 23 | 14 | 3 |
| At Least 40 Years | 13 | 18 | 0 |

[Go Back](#)**Percent evacuating in Bonnie, by response in Fran, by risk area**

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|-----------------------|------------------------|------------------|-----------|
| Left in Fran | 64 | 67 | 13 |
| Stayed in Fran | 18 | 10 | 2 |

Percent evacuating in Bonnie, by housing type, by risk area

| | Outer Banks/ Manteo | Coastal Sound | Non-Surge |
|----------------------|------------------------|------------------|-----------|
| Mobile Homes | 46 | 30 | * |
| Other Housing | 26 | 18 | 4 |

[Go Back](#)**Type of Refuge in Bonnie, by risk area**

| | Outer Banks/ Manteo (N=54) | Coastal Sound (N=19) | Non-Surge (N=5) |
|------------------------|---|-------------------------------------|----------------------------|
| Public Shelter | 0 | 0 | * |
| Friend/Relative | 59 | 63 | * |
| Hotel/Motel | 33 | 16 | * |
| Other | 7 | 21 | * |