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IMPACT OF HURRICANE BONNIE (AUGUST 1998): NORTH CAROLINA AND VIRGINIA WITH SPECIAL EMPHASIS ON ESTUARINE/MAINLAND SHORES AND A NOTE ABOUT HURRICANE GEORGES, ALABAMA

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IMPACT OF HURRICANE BONNIE (AUGUST 1998): NORTH CAROLINA AND VIRGINIA WITH SPECIAL EMPHASIS ON ESTUARINE/MAINLAND SHORES AND A NOTE ABOUT HURRICANE GEORGES,

ALABAMA

Hurricane Bonnie was a Category 3 storm that made landfall near Cape Fear/Wilmington, North Carolina on August 27, 1998. The strength of the storm was very similar to that of Hurricane Fran, which devastated the area two years ago. However, Bonnie slowed considerably in its forward movement and made a slow, sweeping arc across the coastal plain of North Carolina and the Tidewater area of Virginia. Bonnie's very slow, and at times stationary, movement increased the local flooding from rainfall, but greatly decreased the coastal flooding from storm surge.

Bonnie seemed to have had a dispersed wind field. That is, even though the maximum winds reported by the National Hurricane Center were 115 mph, at any given time relatively little area covered by the storm received maximum winds. In general, Bonnie was not a significant event other than from the standpoint of learning how little we know about hurricanes and how poorly we are able to predict the impacts of a given storm on a given coastal area.

Bonnie's Potential Impacts

A major anticipated impact of Hurricane Bonnie was that by sweeping to the north over the Outer Banks of North Carolina, the front quadrant winds would blow water into Albemarle and Pamlico sounds. As the storm passed to the north, the reversed direction of the rear quadrant winds would forcibly blow the storm surge water back out to sea, quite probably opening a series of new inlets along the Outer Banks as Hurricane Hazel did in 1954. However, because of Bonnie's lower overall wind speeds, slow movement and specific path, storm surge was not high, and storm surge ebb processes not intense.

Field Investigation Team and Field Work Plan

Field work was coordinated through the Program for the Study of Developed Shorelines at Duke University, Dr. Orrin Pilkey, director. Tracy Monegan Rice and Matthew Stutz are graduate students at Duke

University investigating risk assessment of mainland/estuarine shorelines. Andrew Coburn is president of Coburn & Associates Coastal Planning Consultants and helped develop the coastal risk mapping technique for ocean shorelines and barrier islands. Rob Young is assistant professor of geology at Western Carolina University and was also involved in development of the coastal risk mapping technique. Team leader was David Bush, assistant professor of geology at the State University of West Georgia.

In order to cover as much ground as quickly as possible, Rob Young headed to the southern North Carolina coast, Dave Bush headed to the northern North Carolina and Tidewater Virginia coast, Tracy Rice and Matt Stutz looked at mainland shorelines, and Andy Coburn was responsible for gathering aerial video and still photographs.

Supplemental funding for the project was provided by Duke University and the State University of West Georgia.

Aerial Reconnaissance

A low-altitude aerial reconnaissance inspection covered the impact area from Myrtle Beach, South Carolina, to just north of Cape Lookout, North Carolina. Unfortunately, time constraints prevented covering the area north to Virginia Beach, Virginia. The south-facing beaches of Brunswick County incurred some minor structural damage with little, if any, overwash.

The first signs of overwash north of Myrtle Beach were observed on the eastern side of Bald Head Island, North Carolina (east of the mouth of the Cape Fear River) and persisted up to the western edge of Bogue Banks. Washover was more prevalent in undeveloped areas, with overwash fans extending well into the sound-side marshes in many undeveloped areas.

Approximately 60% of the artificial dune created on Topsail Island after Fran was removed by Bonnie, with many structures (possibly up to 100) in Surf City and North Topsail Beach now well out on the beach.

Of particular interest were the thousands of tires - dumped into the ocean in the mid 1980s to create artificial reefs - that washed ashore on Bogue

Banks.

Ground Investigation - Ocean Shore, Cape Hatteras, North Carolina, to Sandbridge, Virginia

Minor erosion was observed on the landward side of Roanoke Island. The south side of U.S 64 leading onto the Outer Banks contained marsh grass that had been washed onto road. Vegetation debris washed onto the road had already been cleaned off. There also was evidence that small rocks from the revetment stabilizing the causeway had been washed onto the road.

On the northern Outer Banks, observations were made from near Cape Hatteras heading north to Sandbridge, Virginia. There was minor, localized overwash. The Hatteras fishing pier had approximately 50 cm of sand in the parking lot, and nearby dunes looked somewhat scarped. At the Cape Hatteras lighthouse, there actually was accretion of sand. The protective sandbags around the base of the lighthouse were almost entirely covered, in stark contrast to before the storm when the sand bags were exposed. Undoubtedly, winds from the south reversed local longshore sediment transport and moved sand to the north and onshore in this vicinity. Low-growing shrubs near the lighthouse were plastered with a sand layer approximately 5 cm thick.

Only a few spots along NC-Highway 12 showed any impacts of the storm, including standing water and minor overwash. Evidence of high water was observed, however, in Salvo, where vegetation debris washed up almost 1 meter above road level. The new artificial frontal dune remained intact.

The fishing pier in Rodanthe had no damage, although the parking lot had approximately 10 cm of sand.

The Sandbridge subdivision of Virginia Beach, Virginia, suffered some minor wind damage. Although there was overwash up to 0.5 meters thick in places, it was not pervasive. There was also evidence that water reached a maximum of 1 meter above road level in places.

Where the Sandbridge seawall is continuous there was no overwash. As expected the very center part of the subdivision, where Sandbridge Road enters, had the thickest and most continuous overwash. This stretch is the main swimming beach in the community and has no houses or seawalls. Most of the nourished beach seemed to be intact, however.

Ground Investigation - Mainland and Estuarine Shores

Carteret County was the only place along the mainland shoreline that showed any significant storm impacts, with wracklines covering approximately 1/3 of the coasts. Storm surge in the county was estimated between 4 and 6 ft, but the only place it significantly penetrated inland was in downtown Swansboro (actually Onslow County). No structures were observed to have been penetrated by storm surge, but many were impacted from rain-induced flooding. The Cape Lookout National Seashore station on Harkers Island was the only location that had marsh grasses bent over and eroded banks. Cedar Island was virtually unaffected, and the ferry personnel said they had only lost a couple of signs.

Local newspaper accounts reported that Stumpy Point, on the mainland just south of Roanoke Island, had buildings that sustained 5 ft of flooding from Bonnie.

The town of Belhaven, North Carolina, is at an interesting location and bears monitoring during future storms. It is situated on the southern side of the peninsula (upland drainage divide between rivers) between the Albemarle Sound to the north, and the Pamlico River to the south. The Pungo River intersects the southern shoreline of the peninsula in a northwest-southeast trend, and Belhaven sits at the end of the indentation caused by the Pungo River. This area and the surrounding peninsula is an ideal site to monitor in the coming years because it has the proper orientation for a long fetch from the southeast and has historically been hit by hurricanes. Belhaven is especially at risk, since the community is remodeling and doubling the size of its hospital, which is on the waterfront at about 2 ft elevation. The hospital helipad has a bulkhead at one edge, and the entire complex is not elevated at all. While the entire town is designated on FEMA's Flood Insurance Rate Maps as "A" zones with no "V" zones, all of its docks and piers were torn to pieces by Bonnie. Virtually the entire shoreline is hardened in one way or another, and no wracklines were observed.

The opposite shore of the Pungo River that forms a peninsula with the Pamlico River to the south had extensive wracklines/debris lines. In a few waterfront neighborhoods located back from the main roads, the water level rose to at least 28 inches at 2-4 ft property elevation. One neighborhood had 6- to 8-foot-tall wracklines filled with construction debris that was trapped by underbrush. The properties between the water and debris was perfectly flat with minimal vegetation and extended over 1000 ft indicating that the surge was caught/baffled by thick underbrush.

In Washington, North Carolina, (which is higher in elevation and much farther inland than Belhaven) downtown buildings along the Pamlico River experienced approximately 3-foott flooding, which puts the surge/flooding at 8 ft. The area has roughly 5 ft of bulkhead/seawall along the waterfront, and again the water penetrated probably 1000 ft or more into town. One local property owner, who allowed access to his buildings to see the water lines, said he gets flooded in every storm, and that Fran had done the same thing. Wracklines elsewhere in town showed less penetration but could have been left behind by subsequent flooding from the rains.

Beaufort County was heavily impacted by Bonnie because local estuaries trend east/west. Although Belhaven has estuaries running in both east/west and north/south directions, it looks like the estuaries trending east/west caused more damage during Bonnie.

The goal of an ongoing FEMA-funded cooperative study between Duke University and the State University of West Georgia is to modify our coastal risk mapping technique into a Coastal Risk Assessment Method for the Mainland (CRAMM). It does not appear that Hurricane Bonnie gave any real answers about mainland assessment.

Estuarine/Mainland Shore Summary With Perspective on Mobile Bay after Hurricane Georges

Tracy Rice revisited the North Carolina estuarine/mainland shoreline in more detail the weeks after Hurricane Bonnie and had the opportunity to visit Mobile Bay, Alabama, and surrounding area after Hurricane Georges. Based on that perspective, the following conclusions can be drawn. These observations and conclusions will help in revising the coastal risk mapping technique to include mainland shores and inland areas.

1 Marshes appear to have no impact on storm surge propogation once a critical depth of storm surge is reached. If the storm surge is of sufficient depth, the grasses cease to have a baffling or hindering effect on the propogation of the surge and its associated waves. Some grasses remain bent over in the direction of surge propogation after the floodwaters have receded, but almost all of the marsh grasses observed after Hurricanes Bonnie and Georges did not show any obvious sign of damage or bending.

2 Mainland estuarine shorelines have longer durations of flooding than barrier islands during "wet" hurricanes due to the tremendous amounts of freshwater drainage from inland areas following high amounts of rainfall. Floodwaters can remain in urban waterfront areas for longer than a day as the estuarine system drains hurricane precipitation off the mainland.

3 While trees or forested areas are thought to reduce storm surge and wave propogation during a storm, the presence or absence of thick underbrush appears to be a more controlling factor. In Hurricane Bonnie, undeveloped areas on the Pungo River estuary in Beaufort County, North Carolina, (south of Belhaven) were observed to have piles of storm debris 4 to 6 ft high "caught" in the first reach of underbrush inland. Storm debris piles were several feet thick and contained marsh grasses, lumber, portions of decks and roofs, and other vegetation and human debris (i.e., coolers, trash, toolboxes, fishing gear). Similar storm debris piles were seen along the southeastern area of Mobile Bay, Alabama, near Mullet Point; the storm debris had similar content and size as that from Hurricane Bonnie in North Carolina, but extended for a farther stretch of mainland shoreline. In both cases the debris lines were inland of the one row of homes located along the shoreline,

approximately several hundred to one thousand ft inland. Both stretches of shoreline were flat and at low elevation (less than 5 ft above local sea level); more vegetation was present along the Mobile Bay shoreline than the Pungo River shoreline, but both were limited to trees and shrubs (typical landscaping). Both storm debris lines were stacked up against thick underbrush on the inland side of a two-land road; the Pungo River storm debris line backed up against a 10- to 15-foot-wide drainage canal that had thick underbrush on both sides, while the Mobile Bay storm debris line backed up against a buffer of thick underbrush and forest alongside an inland marsh/wetland. The presence of thick underbrush clearly stopped the potentially damaging storm debris from travelling further inland and was conveniently located alongside a road for clean-up. Both roads remained clear of debris, although other obstructions such as fences, electrical boxes, and clumping of shrubs also "caught" debris within personal yards.

4 Causeways experienced minor erosion and undercutting from the storm surge propogating inland into the estuaries in both Hurricane Bonnie and Georges. If the causeways were at sufficiently low elevations they appeared to be completely submerged during the height of the storm.

5 The presence of riprap or bulkheads along the estuarine shorelines observed did not appear to hinder the propogation of wracklines inland beyond the shoreline.

6 Mainland beaches, where present, were flattened in subaerial profile. Sand overwash was virtually nonexistent where sandy beaches were not present along the mainland shoreline.

7 Wind damage appeared moderate, with various homes missing sections of siding, roof shingles, or roof overhangs (i.e., porch roofs, gable ends). Gas station canopies were commonly destroyed or heavily damaged. Some trees were downed, but more commonly wind damage broke off limbs rather than entire trees.

8 Low-lying (less than 5 ft elevation) islands in the middle of the northern end of Mobile Bay that are used for highway causeways were completely overwashed by incoming and outgoing Hurricane

Georges storm surge. Commercial buildings located on the islands were severely damaged. One particular Texaco gas station oriented parallel to Mobile Bay's long axis (north-south) was completely gutted as storm surge water and waves propogated right through the mostly glass building. While the station canopy remained largely intact, all of the gas pumps were missing. The highway remained intact because it was submerged during the storm, but commercial structures along these low-lying islands in the middle of the bay were heavily damaged.

9 Storm surge heights appeared to reach 5 to 8 ft across eastern mainland North Carolina during Hurricane Bonnie, as evidenced by wracklines and water lines. Washington, North Carolina, experienced higher flood levels than Belhaven, North Carolina, due to its more inland location along the narrowest reach of the Pamlico River estuary. Storm surge is funneled into the narrower reaches of estuaries and frequently reaches higher flood levels farther inland.

Conclusions

It appears that Bonnie stayed just offshore, putting the immediate coast on the western side of the eye where the winds probably were not close to the 115 mph that was reported. Also, based on the fact that there was almost no overwash on the south-facing beaches of Brunswick County, the winds must have been coming out of the north-northeast, thereby placing the eye farther east than originally thought.

It is clear from Bonnie's impacts that we are unable to predict wind fields over land. What appeared on weather radar to be an extensive and pervasive wind field was, in fact, one that did little damage.

Bonnie must be considered a minor storm that did not negatively impact a large number of individual property owners or cause extensive claims for insurance companies. However, such storms still affect taxpayers because of infrastructure impacts such as downed power lines and debris removal, and we cannot claim that our society has learned many property damage mitigation lessons over the past decade because a

Category 3 storm did little property damage.
Based on several post-storm field investigations, funded in part by the Natural Hazards Center, we have developed a coastal risk mapping technique that is undergoing continual revision (Bush et al., 1996; Webb, 1996; Pilkey et al., 1998). By evaluating the geomorphic, geologic, and oceanographic settings of coastal areas, zones of relative risk for property damage from hurricanes and other coastal storms are mapped. The maps have been well received by the Federal Emergency Management Agency and have been adopted by several coastal communities as part of their pre-storm mitigation and post-storm reconstruction plans. The next step is to modify the mapping technique to include the mainland shores behind barrier islands. The forecasted path of Hurricane Bonnie was such that significant mainland shore and estuarine shore impacts were anticipated. Actual impacts, however, were not severe.

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