1 Introduction

1.1 Purpose

The purpose of this report is to present the observations of the Federal Emergency Management Agency's (FEMA's) Building Performance Assessment Team (BPAT) regarding the successes and failures of buildings that experienced the wind and flood effects of Hurricane Fran in North Carolina, to comment on the failure modes of damaged buildings, and to provide recommendations for improvements intended to enhance the performance of coastal buildings in future hurricanes.

1.2 Storm Conditions

On September 5, 1996, Hurricane Fran made landfall in the vicinity of the Cape Fear, North Carolina (see Figure 1-1). According to the National Hurricane Center, Fran was ranked as a Category 3 (major) hurricane on the Saffir-Simpson Scale. Hurricane Fran was the most intense hurricane to make landfall along the U.S. mainland during 1996. Although Fran's destructive storm surge, waves, and winds impacted the immediate coastal areas east and north of Cape Fear, heavy rainfall and high winds occurred well inland and resulted in riverine flooding and wind damage to residential and commercial buildings, manufactured homes, trees and crops, and power distribution systems in North Carolina, Virginia, West Virginia, and Maryland. Much of the wind-realted damage was not caused directly by the wind but by wind-downed trees. In areas where soils were saturated by the heavy rainfall, many trees were unable to resist the high winds and caused extensive damage when they fell.

The National Hurricane Center and the National Weather Service estimated that Hurricane Fran's maximum 1-minute sustained wind speed was 115 miles per hour (mph). It appears that Hurricane Fran may have reached design wind speeds (110 mph, fastest mile for 50-year return frequency) in a small area along the immediate oceanfront near Figure Eight Island. However, most coastal buildings in the study area appear to have received less than design wind speeds. A peak gust of 95 mph was recorded 940 feet from the ocean in Kure Beach. Although the storm generated high winds along the coast and well inland, severe damage to buildings was concentrated in those areas also affected by the storm surge and waves.

Independent of the BPAT process, FEMA's Mitigation Directorate and the Federal Insurance Administration conducted a high water mark survey in the wake of Hurricane Fran from just west and south of Cape Fear to just west of Cape Lookout. The goal of the survey was to determine and map approximate high water mark elevations that indicate the stillwater storm surge elevation and the combined effect of storm surge and waves in areas significantly affected by Hurricane Fran. The resulting historical record will prove useful to FEMA in the revision of Flood Insurance Studies and to the insurance industry in the settlement of claims regarding flood and wind damage. Selected elevation measurements made during this survey are shown in Figure 1-1. Storm surge elevations approached or exceeded National Flood Insurance Program (NFIP) Base Flood Elevations (BFEs) from Kure Beach to North Topsail Beach, along approximately 50 miles of coastline. As shown in the figure, a maximum storm surge elevation of 11.9 feet above mean sea level (m.s.l.) — as measured inside a structure — was recorded at Figure Eight Island, North Carolina. The

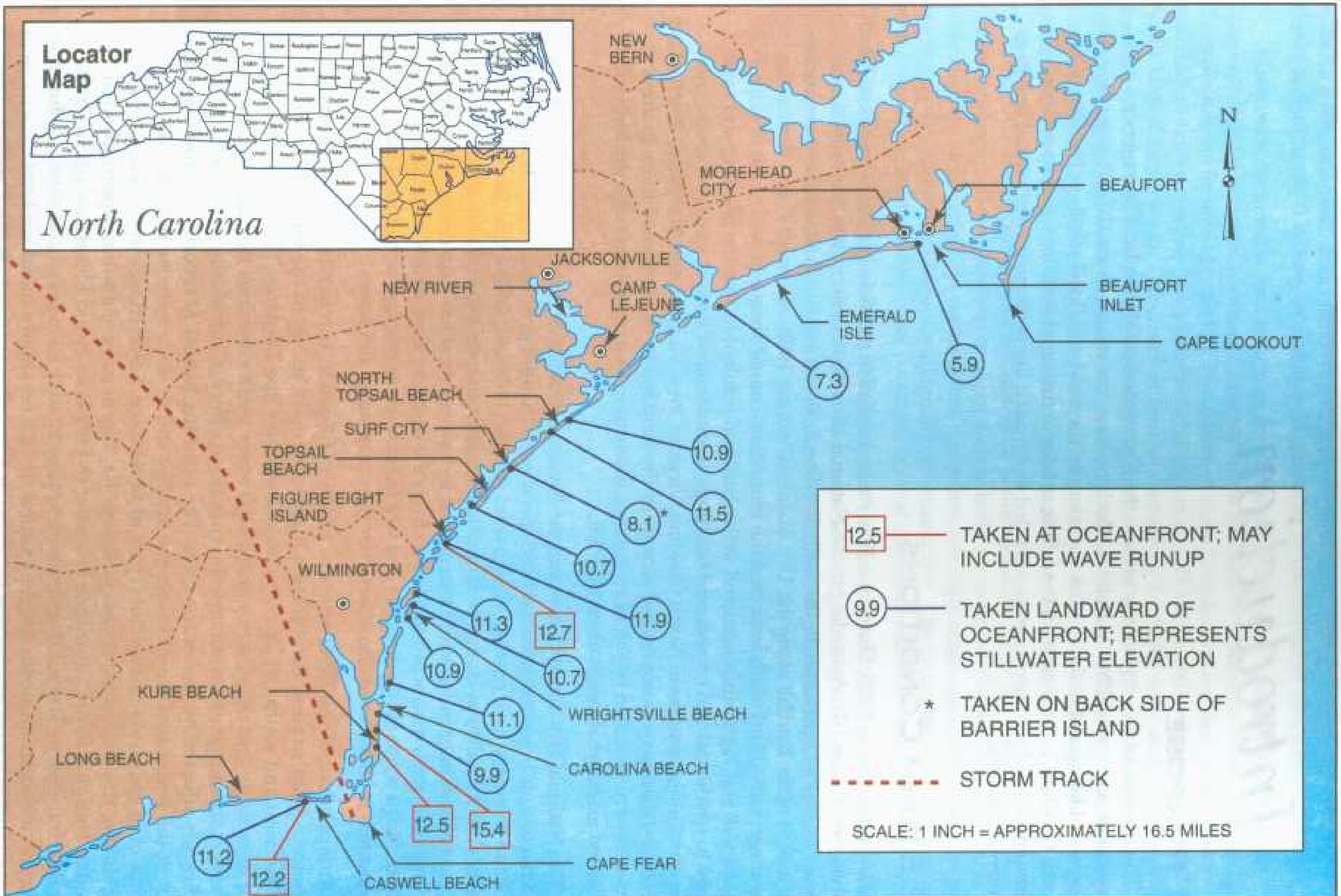


Figure 1-1 *High water mark elevations, in feet above Mean Sea Level, surveyed after Hurricane Fran.*

maximum recorded high water mark of 15.4 feet m.s.l. (assumed to reflect storm surge plus wave height) was at the southern end of Kure Beach, North Carolina.

The severity of erosion of oceanfront sand dunes is closely related to the storm surge elevation at the shoreline. It is reasonable to assume that dune erosion due solely to Fran was a 100-year event. However, 2 months prior to Fran, Hurricane Bertha made landfall in the same area. Wind speeds and water levels were significantly less than those associated with Fran and significantly below design conditions. Storm-induced dune erosion is at least partly temporary, but there had been insufficient time for much recovery following Bertha's estimated storm surge of 6 to 9 feet m.s.l. The cumulative effect of back-to-back hurricanes appears to have caused dune erosion distances in excess of what would be expected to occur in a single 100-year storm surge.

This report focuses on the damages along the North Carolina coast that resulted from storm-induced flood surge, wave action, erosion, and scour.

1.3 Building Siting and Construction Regulations

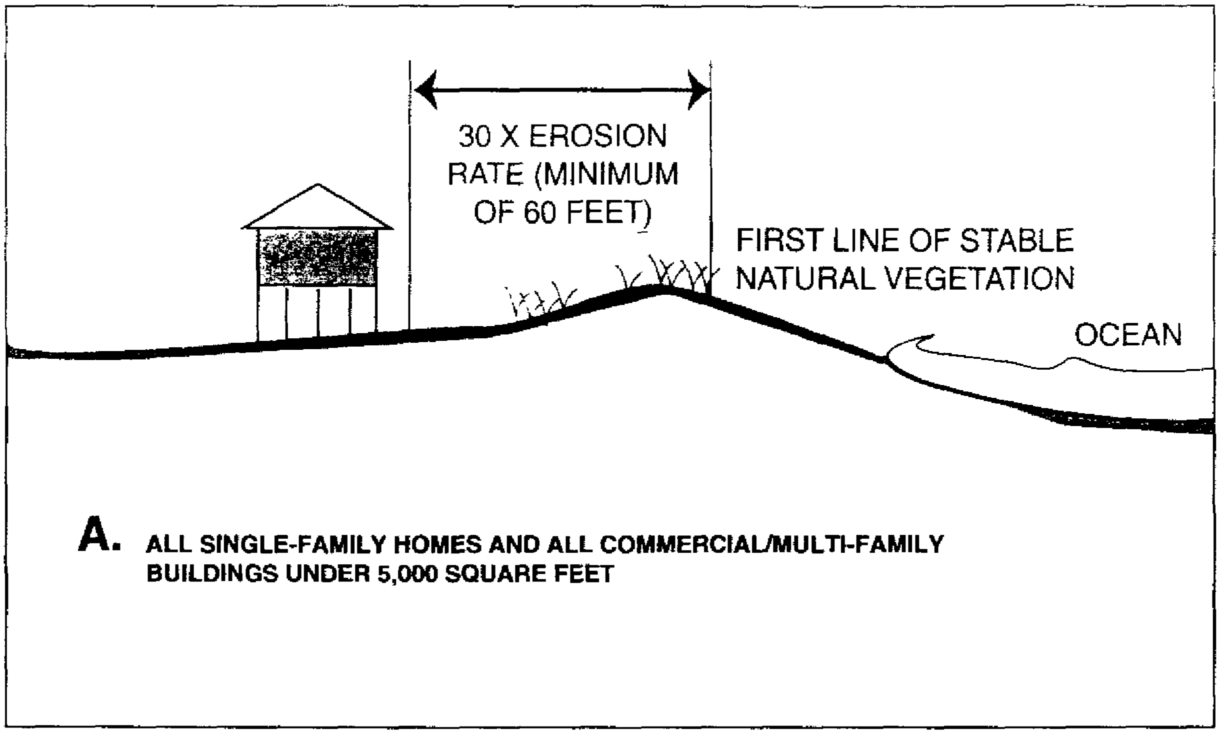
Building construction regulations on the North Carolina coast have been established by the North Carolina Coastal Area Management Act (CAMA), the North Carolina State Building Code, and the NFIP. CAMA identifies ocean hazard areas, establishes oceanfront setback lines for new construction, and protects sand dunes. The State Building Code regulates most structural requirements. NFIP Flood Insurance Rate Maps (FIRMs) identify flood hazard areas and provide BFEs. BFEs are used to establish minimum floor elevations for buildings in 100-year flood hazard areas and other prescriptive and descriptive requirements of the NFIP. State requirements regarding most other construction criteria are more stringent than those of the NFIP.

1.3.1 North Carolina Coastal Area Management Act

In 1979 CAMA identified ocean hazard areas along the North Carolina coastline. All new buildings were required to be set back from the seaward line of stable dune vegetation at least 30 times the long-term erosion rate determined by the North Carolina Division of Coastal Management (see Figure 1-2 A). A minimum erosion rate of 2 feet per year was adopted. Additional setbacks were required on the largest primary or frontal sand dunes. On previously subdivided lots too small to meet the setback requirement, exemptions were allowed for single-family houses as close as 60 feet from the vegetation line. In 1985 the minimum setback distance for commercial buildings larger than 5,000 square feet was increased to 60 times the long-term erosion rate (see Figure 1-2 B), with additional exemptions where the rate is greater than 3.5 feet per year.

1.3.2 North Carolina State Building Code

The North Carolina State Building Code is based on the Standard Building Code with significant revisions adopted by the North Carolina Building Code Council. A separate Residential Building Code provides more prescriptive criteria for one- and two-family dwellings and is now based on the Council of American Building Officials (CABO) Code with substantial amendments by the Council. Most of the buildings observed near the coast had been constructed under the Residential Code, which was first adopted in the mid-1960's and has undergone several major revisions. After seven major hurricanes affected the North Carolina coast in the 1950's, the



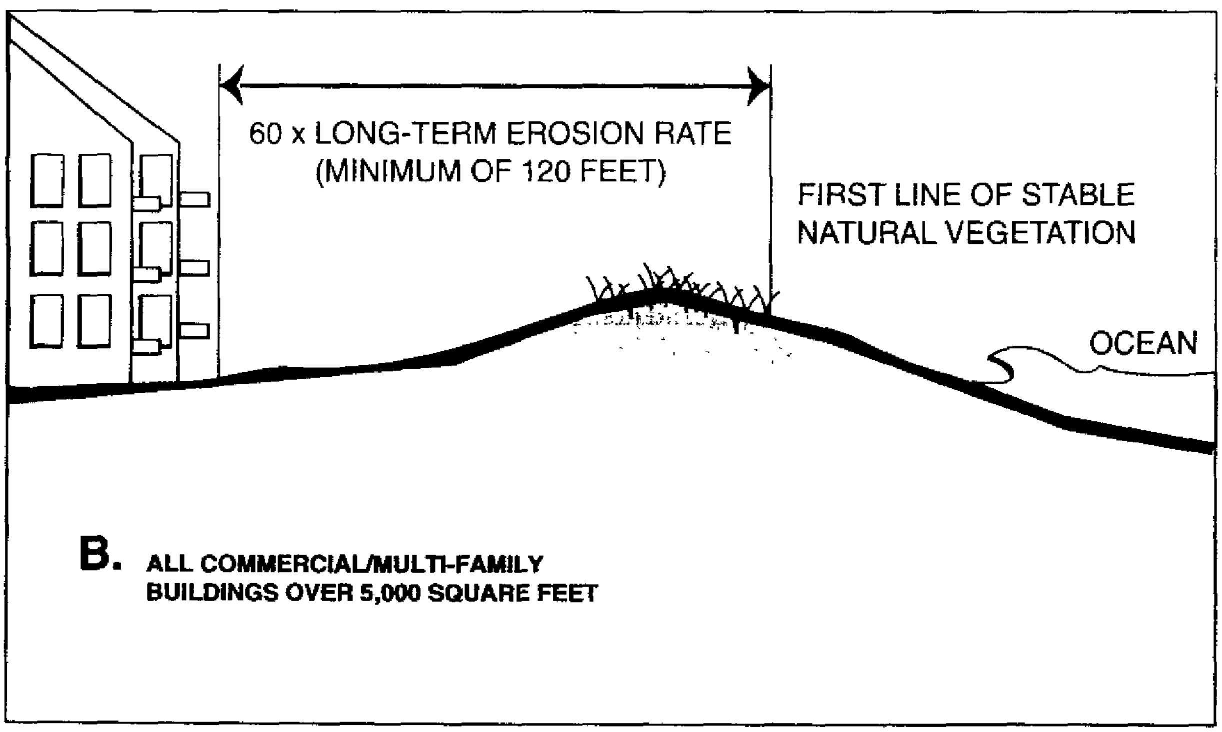


Figure 1-2 *Minimum oceanfront setback requirements under the North Carolina Coastal Area Management Act.*

Council adopted specific hurricane-resistant criteria for small residential buildings on the barrier islands. These were initially an optional appendix but soon became mandatory, with enforcement by local building officials. With a push from the State Building Code, building designs quickly shifted away from low floor elevations with shallow foundations to piling foundations elevated for underhouse parking. Since the 1960's, most houses on the barrier islands have been constructed on pilings.

The State Building Code initially required pilings to be embedded 8 feet below grade. Later, it became apparent that this piling penetration requirement was inadequate for erosion-prone oceanfront buildings. The Code was revised on January 1, 1986, to require piling foundations in all coastal high hazard areas (NFIP V zones) and ocean hazard areas (identified by CAMA). Buildings constructed closer to the seaward edge of the vegetation line than 60 times CAMA's long-term erosion rate are now required to have pilings extending to -5.0 feet m s.l. or 16 feet below grade, whichever is <u>less</u>. At the same time, requirements for cross-bracing between pilings were added to improve wind resistance, making buildings with longer pilings readily distinguishable from older buildings on unbraced pilings with shallower embedment.

Wind-resistant construction techniques emphasizing improved connections from roof to foundation were in standard practice before 1970. Major increases in the wind criteria in the Residential Building Code have already been adopted and are scheduled to take effect sometime in 1997. The new criteria will, for the first time, apply up to 100 miles inland from the coast, rather than only on the barrier islands.

1.3.3 National Flood Insurance Program

All communities on North Carolina barrier islands participate in the NFIP. The NFIP was created by an act of Congress in 1968 to make flood insurance available to property owners in communities that agree to enact and administer floodplain management regulations that meet program requirements. The regulations require that new and substantially improved buildings in floodprone areas be built in such a manner as to reduce flood hazards and loss of life and property resulting from floods. In coastal areas, this means that buildings must be adequately elevated and protected from the effects of high-velocity flood flow. In V zones, buildings must be elevated on piling foundations and the lowest horizontal structural member of the lowest floor must be at or above the BFE. In addition, the area below the building must be free of obstructions or enclosed by non-supporting breakaway walls intended to collapse under wind an water loads without causing damage to the foundation or the elevated portion of the building. In coastal A zones, which are less likely to be affected by high-velocity flow, the lowest floor of the building must be at or above the BFE and the areas below the BFE can be enclosed with non-breakaway walls.

In the mid-1970's, FEMA issued a FIRM for each of the barrier island communities in North Carolina. When the communities began implementing their required floodplain management regulations in the late 1970's, the minimum lowest floor elevation requirements based on the BFEs shown on the FIRMs superseded the previous State Building Code requirement that the lowest floor be 2 feet above the highest known historical water mark. The resulting common use of piling foundations with underhouse parking generally placed the elevated floors well above minimum elevations required by the NFIP. However, finished underhouse enclosures constructed with non-load-bearing walls were common in older buildings and, in some communities, in new buildings.

Concerns about the accuracy of the information shown on FIRMs for areas near the ocean had been previously raised in North Carolina communities affected by Hurricane Fran. According to the FIRMs, many oceanfront lots are within B zones and C zones, outside the 100-year flood hazard area. In general, minimal elevation requirements at the building sites on these lots did not include consideration of waves above the stillwater flood elevation. The accuracy of the FIRMs and the steps being taken by FEMA in response to this issue are discussed in Section 2.10 of this report.

An important provision that communities participating in the NFIP must include in their floodplain management regulations is the requirement that substantially damaged buildings, if restored, meet the same requirements imposed for new buildings. The NFIP defines substantial damage as "damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damage condition would equal or exceed 50 percent of the market value of the structure before the damage occurred." The BPAT observed several hundred buildings in the area between Kure Beach and North Topsail Beach that may have been substantially damaged. The vast majority of these were oceanfront residential buildings removed from their foundations by flood forces.