2 Introduction

2.1 Purpose

This report presents the Federal Emergency Management Agency's (FEMA) Building Performance Assessment Team's (BPAT) observations on the success and failure of buildings in the Florida Keys and Gulf Coast areas of the United States to withstand the wind and flood forces generated by Hurricane Georges. Recommendations to improve the building performance in future natural disasters in this area are included as well. A separate assessment and report has also been prepared on the effects of Hurricane Georges in Puerto Rico (FEMA 339).

2.2 Background of Storm

Hurricane Georges formed 400 miles south-southwest of the Cape Verde Islands and moved across the Atlantic into the Caribbean on September 16, 1998. On September 17, Hurricane Georges was upgraded to a Category 4 hurricane on the Saffir-Simpson scale as it moved west through the Caribbean packing 150-mph winds. Hurricane Georges was downgraded to a Category 2 hurricane once it moved through the Leeward, U.S. and British Virgin Islands on September 21. The storm passed the Florida Keys on September 25, 1998. It was still a Category 2 hurricane when it made landfall at Biloxi, Mississippi and was downgraded to a tropical storm by late afternoon on September 28, 1998.

At approximately 4:00 a.m. on September 28, 1998, Hurricane Georges made final landfall in the Ocean Springs/Biloxi, Mississippi area (Figure 2-1). Over the next 30 hours, the storm moved slowly north and east, causing heavy damage along the Gulf Coast in Mississippi, Alabama, and Florida.

Preliminary data from National Weather Service (NWS) reports indicate that at landfall, maximum sustained winds in the Gulf Coast region reached 105-mph [U.S. Army Corps of Engineers 1998]. Maximum sustained winds during the storm varied from 46-mph in Pensacola, Florida, 51-mph at the Mobile Regional Airport, Alabama, and 61-mph at Gulfport Harbor, Mississippi. A maximum gust of 117-mph was recorded at Mississippi Power and Light in downtown Gulfport, Mississippi. When the storm passed the Florida Keys, the highest measured sustained wind reported was 91-mph with peak gusts to 107-mph at Sombrero Key. Higher gusts were estimated on Cudjoe and Big Pine Keys [NWS 1998].

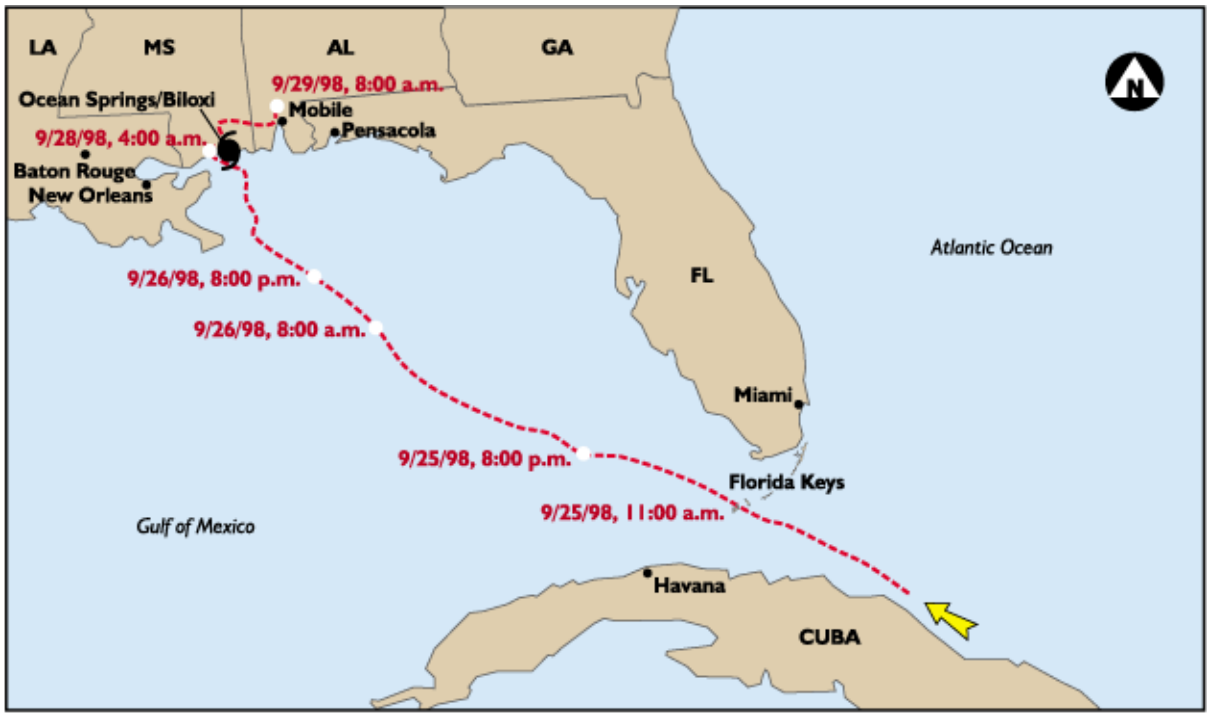

FIGURE 2-1 Track of Hurricane Georges.

Storm surge elevations over the area varied from 5.0 feet in Navarre, Florida, 7.7 feet in Pensacola Beach, Florida, to 8.2 feet in Biloxi and 9.4 feet in Pascagoula, Mississippi (Figure 2-2). According to the U.S. Army Corps of Engineers, storm surges in downtown Mobile, Alabama reached 8.9 feet. Storm surge elevations on the Gulf side of Dauphin Island were 6.7 feet and 9.0 feet in Gulf Shores, Alabama [U.S. Army Corps of Engineers 1998]. In the Florida Keys, the storm surge elevations ranged from 3 feet to 6 feet [NWS 1998].

According to NWS, total rainfall exceeded 16 inches in Pascagoula, Mississippi; 13 inches in downtown Mobile, Alabama; 26 inches in Pensacola, Florida; and 8.4 inches in Key West, Florida [NWS 1998]. The Town of Munson, Florida in Santa Rosa County received the highest recorded level of rainfall with more than 38 inches. Figure 2-3 displays the distribution of rainfall from Hurricane Georges over the Gulf Coast region.

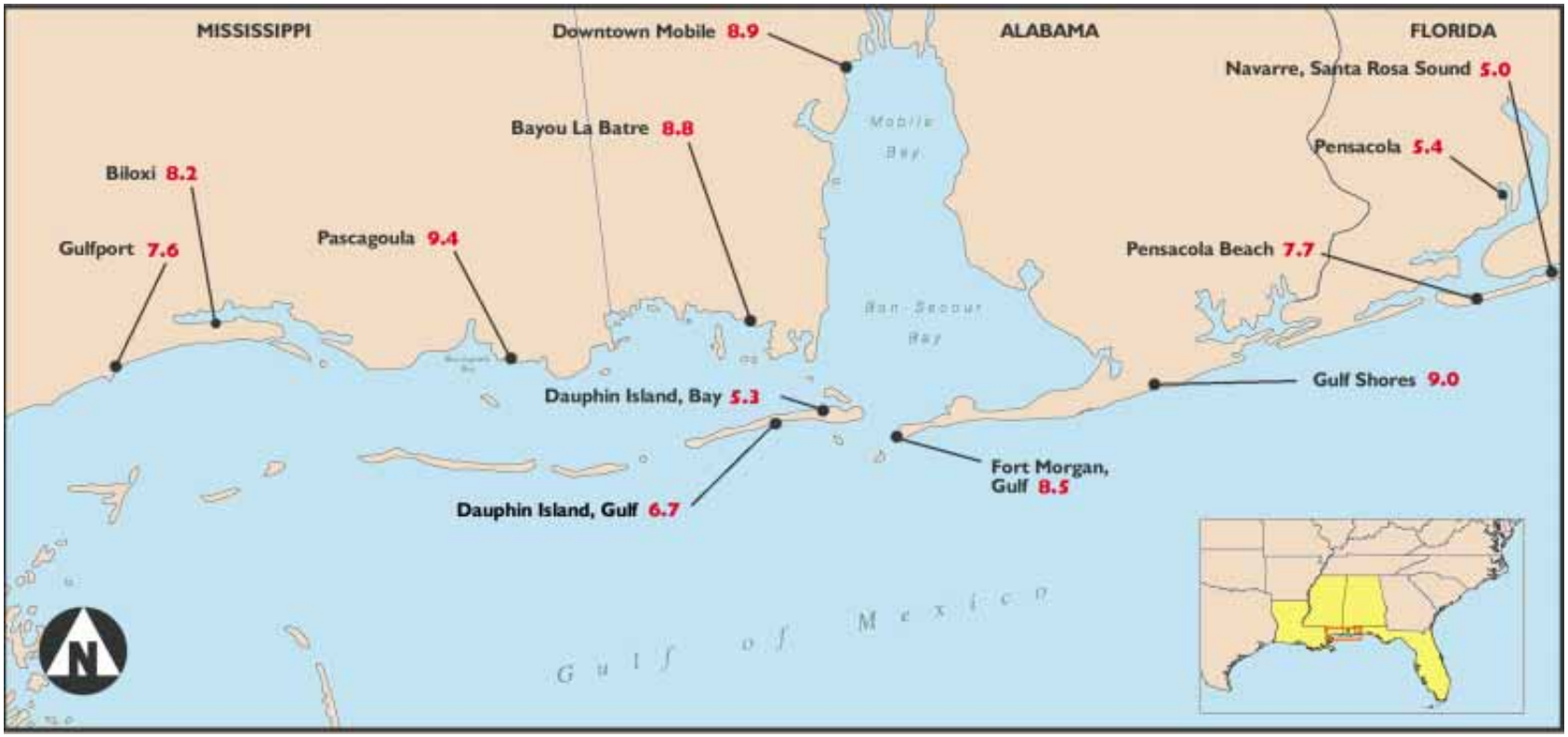

FIGURE 2-2 Representative storm surge elevations, Hurricane Georges.

Sources: Base map from USGS Center for Coastal Geology, October 21, 1998
Storm surge data from U.S. Army Corps of Engineers Report, Mobile District, Hurricane Georges, September 1998

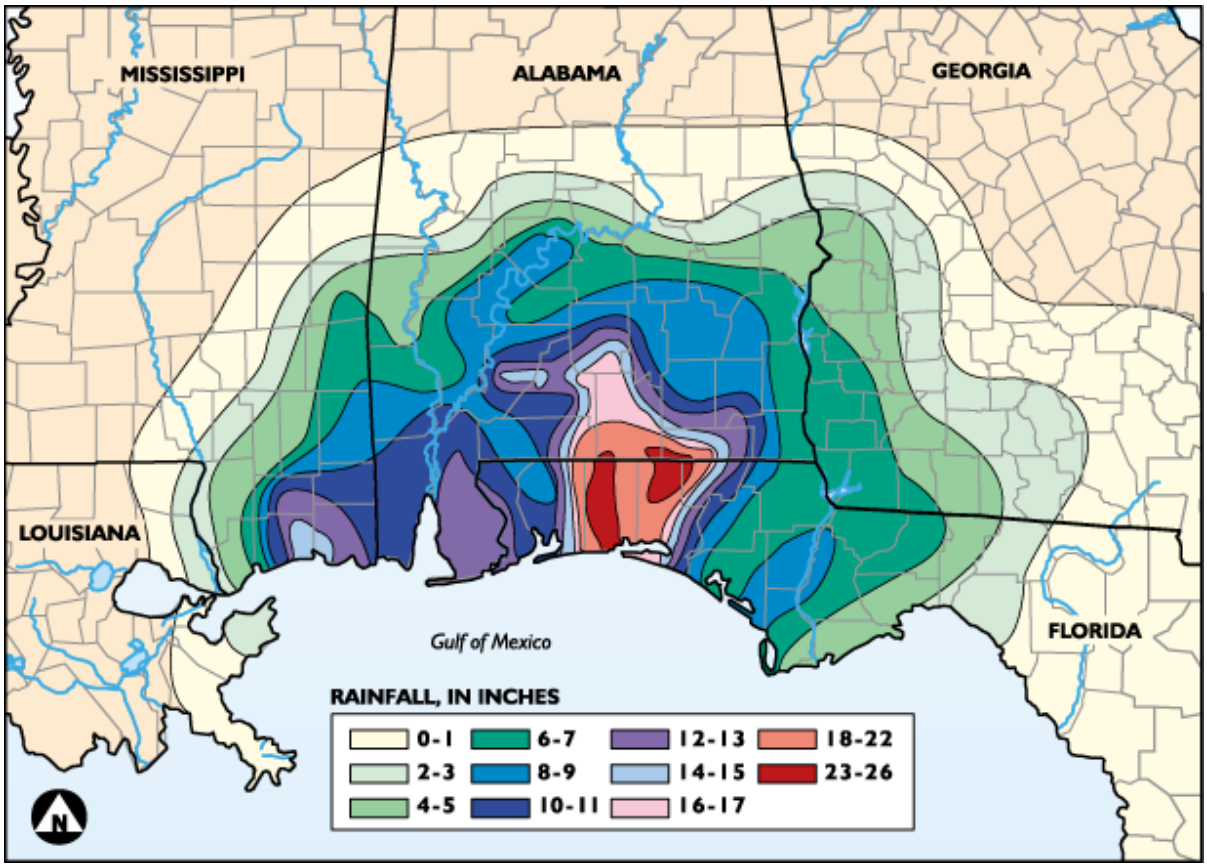

FIGURE 2-3 Hurricane Georges total rainfall distribution.
Source: National Oceanic and Atmospheric Administration (NOAA)/NWS Southwest River Forecast Center

Riverine flooding was extensive and variable throughout the study area (Figure 2-4). In general, flooding increased the farther east the storm moved [U.S. Geological Survey 1998]. Based upon preliminary United States Geological Survey (USGS) river flow data, in Mississippi, most of the recurrence intervals were estimated between 25 and 50 years. Flow estimates in the Mobile, Alabama area indicated similar estimates of recurrence intervals. However, in eastern Alabama and in Escambia, Santa Rosa, and Okaloosa counties in Florida, recurrence intervals were estimated from 25 to 400 years.

Hurricane Georges caused extensive erosion to the Gulf Coast. Many coastal barrier islands, including Dauphin Island and the Chandeleur Islands, were overwashed and several vertical feet of beach sand were displaced. High tides and rain washed out major highways and flooded beachfront homes in many areas of Alabama, Florida, and Mississippi. More than 370 deaths in the Caribbean and four in the United States (two each in Louisiana and Florida) were directly attributed to Hurricane Georges [Associated Press 1998].

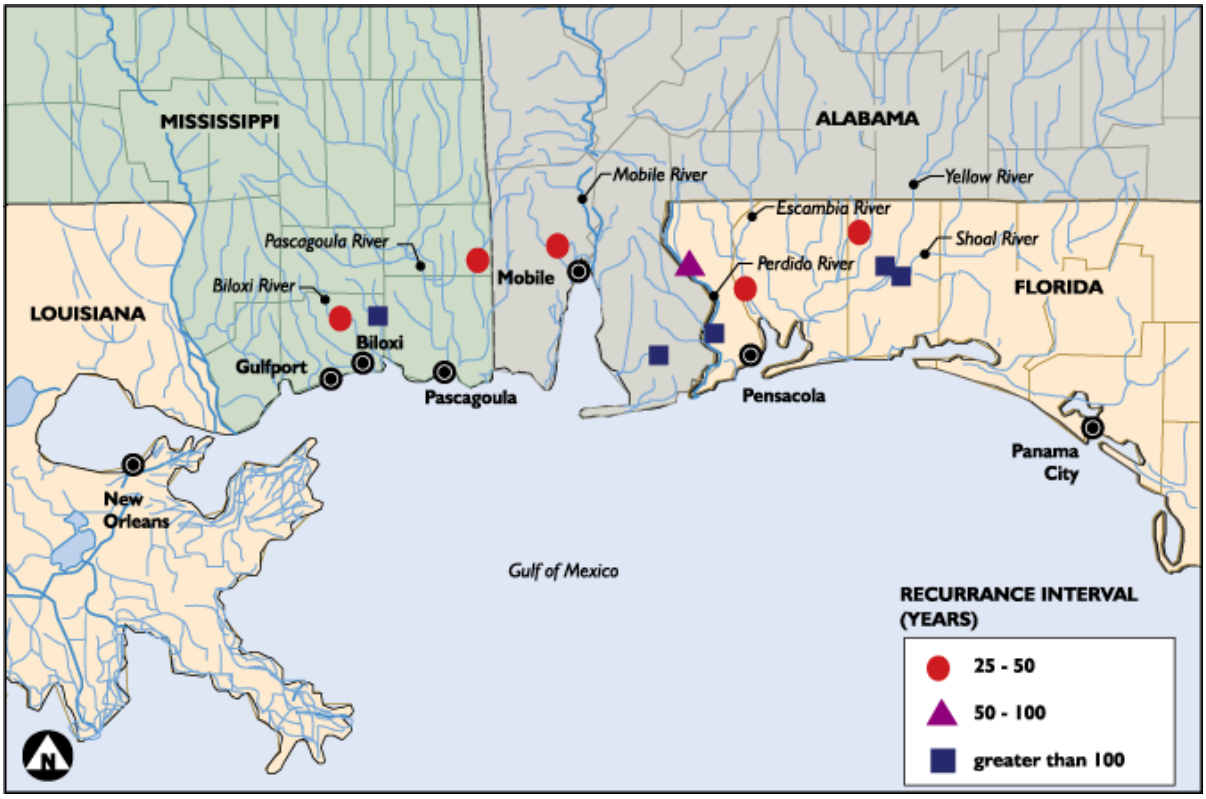

FIGURE 2-4 Hurricane Georges peak flow data.
Source: U.S. Geological Survey, Water Resources Investigations Report 98-4231

2.3 History of Storms

Coastal Alabama, the Florida Panhandle, and Mississippi have experienced many destructive hurricanes in recent years. In 1975, Hurricane Eloise affected the region, causing significant damage to residences with slab-on-grade first floors and other non-elevated structures with shallow footings. In September 1979, Hurricane Frederic made landfall near Gulf Shores-Mobile, Alabama with maximum sustained winds of more than 100 mph (Category 2). The peak storm surge of 12 feet at Gulf Shores, Alabama, destroyed much of the community. Daulphin Island, Alabama recorded an 11-foot storm surge that destroyed the causeway connecting the island to the mainland. During Hurricane Frederic, over 50 homes were destroyed along the 22-mile reach from Fort Morgan to Gulf Shores, Alabama. Approximately 73 percent of the front- row buildings were destroyed.

Hurricane Elena in 1985 made landfall in the Gulfport-Biloxi, Mississippi, area. Wind damage to structures was significant. Many homes lost their roofs, roof overhangs and porches, and many windows were broken by flying debris [FEMA 1986]. The next significant storm to hit the area was Hurricane Opal, which made landfall near Santa Rosa Island, Florida in October 1995. Hurricane Opal was classified as a Category 3 hurricane with recorded sustained wind speeds of approximately 110-115 mph. Opal caused significant storm surge damage to the Gulf of Mexico shoreline in Florida. Data indicated that approximately 990 coastal structures incurred 50 percent or more damage [FEMA 1996].

The most recent hurricane prior to Hurricane Georges was Hurricane Danny, which affected the Mobile Bay area of Alabama in 1997. Hurricane Danny was a slow-moving Category 1 hurricane that made landfall near the mouth of the Mississippi River and in the Mobile Bay area. It produced enormous amounts of rain over extreme southern Alabama.

Storm tides of generally 2 to 5 feet occurred from the Florida/Alabama border to Dauphin Island. A maximum storm tide of 6.5 feet was reported about midway between Gulf Shores and Fort Morgan [National Hurricane Center 1997].

2.4 Team Composition

On October 2, 1998, the FEMA Mitigation Directorate deployed a BPAT to the Gulf Coast to assess damages caused by Hurricane Georges. The team included FEMA Headquarters and Regional Office engineers, planners, and a coastal geologist; consulting engineers; floodplain management specialists; and a forensic engineer. Members of the BPAT are listed in the Appendix of this report.

The BPAT's mission was to assess the performance of buildings in the Gulf Coast area and make recommendations for improving building performance in future hurricanes. The assessment included areas of the Gulf Coast from Pensacola Beach, Florida, to Gulfport, Mississippi (including Mobile Bay, Alabama), and the Florida Keys. It also included inland areas along major streams and rivers that experienced flooding. The BPAT process is intended to provide state and local governments guidance on post-hurricane reconstruction with the goal of enhancing future building design and construction.

In conducting this assessment, the BPAT also focused on:

- The success and effectiveness of flood and wind hazard mitigation initiatives undertaken prior to Hurricane Georges, including acquisition and removal of structures located in floodprone areas, elevation of floodprone buildings, and installation of storm shutters and high-wind roofing systems;
- Siting and other planning issues that contributed to building success, damage, or failure;
- Floodplain management issues, including repetitive loss structures and floodplain mapping; and
- Impacts of the hurricane on the shoreline/beach system.

An aerial survey and on-the-ground site investigations were conducted to observe building conditions in selected areas affected by the storm. The BPAT's mission did not include recording the numbers of buildings damaged by the hurricane, determining the frequency of specific types of damage, or collecting data that could serve as the basis of statistical analysis. Collectively, the team invested more than 1,000 hours conducting site investigations, inspecting damages, preparing documentation, and preparing this report. Documentation of observations made during the ground and aerial surveys included field notes and photographs.

2.5 Methodology

On October 3, 1998, the BPAT conducted an aerial survey along the Gulf Coast from Navarre Beach, Florida, to Gulfport, Mississippi. Ground observations were conducted from October 4 to October 11. Inspections were made along the Gulf Coast from Pensacola Beach, Florida, to Gulfport, Mississippi, and extended into inland areas in Florida, Alabama, and Mississippi that were subject to riverine flooding and wind damage. In addition, a supplemental assessment of manufactured home performance was conducted in the Florida Keys on October 11, 1998.

One- and two-family, one- to three-story wood-frame structures elevated on pilings were the primary building types assessed in coastal areas, although some slab-on-grade structures

were included. In riverine areas, one-family wood-frame structures were the primary structures inspected. Foundation types included piles, perimeter wall/crawl space, and slab-on-grade. Several public and commercial buildings in coastal and riverine areas were also evaluated, including a hospital, a convention center, fire houses, municipal buildings, schools, and casinos.

2.6 Local, State, and Federal Regulations Affecting Development and Construction

Construction along the coastal and riverine areas of Alabama, Florida, Mississippi, and the Florida Keys is governed by one or more of the following building codes:

1. The Standard Building Code (SBC), which is enforced by local (city or county) governments;
2. The National Flood Insurance Program (NFIP) construction requirements in identified Special Flood Hazard Areas (SFHAs), which are enforced by local governments through adopted laws and ordinances;
3. In Florida and Alabama, state requirements regarding construction seaward of the Coastal Construction Control Line (CCCL); and
4. State codes that convey to local governments the authority for land-use management through planning, zoning, subdivision, and other special-purpose ordinances.

Additionally, residential construction on Santa Rosa Island, Florida is under the jurisdiction of the Santa Rosa Island Authority, which regulates to more stringent requirements than the NFIP and SBC. They include higher mandated building elevations in V-Zones and A-Zones, and additional pile foundation requirements.

FEMA's Flood Insurance Rate Maps (FIRMs) provide the base flood elevations (BFEs) for coastal and riverine Special Flood Hazard Areas (SFHAs). The base flood, commonly referred to as the 100-year or 1-percent flood, is the flood that has a 1-percent probability of being equaled or exceeded in any given year. It is the basis for the NFIP's regulatory requirements. In coastal areas subject to wave action, BFEs include wave height effects. All of the communities that the BPAT visited participate in the NFIP and therefore have adopted floodplain management ordinances that require, among other things, the lowest floor elevation for new construction or substantial improvements to be at or above the BFE in A-Zones. In addition, in V-Zone areas, the lowest horizontal structural members supporting the lowest floor for new construction and substantial improvements must be at or above the BFE.

Florida established the CCCL along the state's sandy beach shorelines to delineate those areas subject to erosion or other adverse impacts during the 100-year storm. In areas seaward of the CCCL, the state enforces construction requirements that are more stringent than the SBC or the NFIP requirements.

Alabama also established a CCCL. It is a fixed line referenced by State Plane Coordinates and was originally based on the crest of the primary frontal dune that existed prior to the landfall of Hurricane Frederic in 1979. Unlike Florida, Alabama prohibits new construction seaward of the CCCL. There are exceptions, however. In some areas, previously platted lots were "grandfathered" and construction, with restrictions, is allowed.