# LEARNING FROM HURRICANE HUGO:

# IMPLICATIONS FOR PUBLIC POLICY

prepared for the

FEDERAL INSURANCE ADMINISTRATION
FEDERAL EMERGENCY MANAGEMENT AGENCY
500 C Street, S.W.
Washington, D.C. 20472

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under contract no. EMW-90-G-3304,A001

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# CONTENTS

This report is one of the products of a cooperative effort by the National Oceanic and Atmospheric Administration (NOAA), the National Committee on Property Insurance (NCPI), and the Federal Emergency Management Agency (FEMA). This alliance was forged in early 1990 to build upon the experience of Hurricane Hugo, and to reduce the loss of life and property and the economic and social disruption resulting from coastal storms.

# INTRODUCTION

Between September 10 and 22, 1989, the storm that became known as Hurricane Hugo made its way across the Caribbean Islands, up the southeastern coast of the United States, and came ashore along the South Carolina coast. The results of the storm included 49 deaths, widespread damages and losses estimated to exceed $9 billion, temporary displacement of hundreds of thousands of people, and disruption of the lives of about 2 million people. Its long-term impacts will be felt for years.

Like other natural disasters, Hugo spawned a large number of research investigations, post-disaster evaluations, case studies, assessments, conferences, journal articles, and other documentation. This report is a collection of the findings and conclusions from that body of material that have or could have public policy implications. The goal was to provide a succinct summary of the information gleaned from the Hugo experience that would be relevant to public officials at any level who have to plan for or manage disasters.

Information for this report was collected and reviewed on the basis of two criteria. First, the information must have originated with a person or organization with recognized expertise in or official standing with regard to the subject matter. Second, the information had to have fairly specific implications for public policy, as opposed to the concerns of the private sector. Consequently, this report does not include recitations of facts or personal opinions, or policy recommendations made in conjunction with professional or scientific observations. It is expected that the future users of this report, who have their own specific plans and policies to follow, will be interested primarily in what actually was discovered or demonstrated about a particular action, technique, or guideline as a result of Hugo, rather than in what a researcher or another public official thought at the time would be an appropriate use of that information.

A compilation of this sort has inherent limitations. Foremost, as will be evident to any reader who visited the impact area after Hugo, one cannot get a "feel" for the special characteristics of the disaster from reading this report. In many ways not conveyed in the findings presented here, the Hugo disaster was unusual. Considering the size of the storm and the relatively small population in the areas hardest hit, there was a surprising amount of property damage. The fact that much of the impact area was heavily forested was uncommon for U.S. hurricane, and resulted in vast amounts of secondary damage due to falling trees, as well as significant economic impacts on the timbering industry—a major regional employer. On the mainland, the brunt of the storm was borne by South Carolina, a state that does not have a statewide building code requirement. National resources for coping with the hurricane were already stretched when it hit the mainland, because of Presidential disaster declarations for Hugo's impact on Caribbean areas just days before. A severe earthquake in California a few weeks later made relief and recovery assistance—not to mention media attention and resultant public involvement—harder to obtain. Few of these general but nonetheless important considerations can be gleaned from the collection of findings presented here.

A second, related limitation is that only issues that were actually addressed by researchers or public officials could be included. Situations or issues that were not investigated or written about—no matter how important—are necessarily missing. For example, the enormous destruction Hugo caused in the Virgin Islands and the massive problems with relief and recovery that followed are understated here, simply because there were so few researchers in the stricken area.

Because of these limitations, and because this report does not purport to analyze or evaluate the hurricane, its impact, its aftermath, or the public policy issues surrounding it, the reader cannot expect to gain from these pages a thorough understanding of the Hurricane Hugo experience. This distanced perspective is a real asset, however, in providing a straightforward list of opportunities for learning from a past experience and thereby reducing the impacts of a future hurricane. It is hoped that this report therefore will be a starting point for the more focussed investigations and efforts of a wide range of planning, emergency management, regulatory, and other personnel, as well as those of professional groups whose ongoing efforts include attempts to minimize hurricane disaster losses.

The report is organized by topic, using terms and issues familiar to most public officials who must cope with disasters. The subheadings follow an index style, in order to help point out the wide variety of findings and also the occasional disagreement among them. Parenthetical notes give the source of each finding or conclusion, and full citations can be found in the reference list. A companion document, *Learning from Hurricane Hugo: Implications for Public Policy, An Annotated Bibliography*, provides citations for a more comprehensive documentation of Hurricane Hugo and its impact. Many of the works listed in the bibliography and in this report can be accessed through the Floodplain Management Resource Center database and library, which are maintained for the Association of State Floodplain Managers by the Natural Hazards Research and Applications Information Center of the University of Colorado.

# PHYSICAL CHARACTERISTICS OF THE STORM

### *——limitations of data on*

During Hugo, collection of meteorological data was reasonably adequate while the collection of comparable oceanographic data was lacking (Wood 1990).

Hugo demonstrated that coastal engineers and scientists can at present approximate the consequences of landfall only on a coarse scale and that for some effects important to coastal design even that ability is lacking. This is due in large part to the lack of accurate, comprehensive field data on both the oceanographic results of large storms (waves, surges, currents) and their effects on beaches, dunes, inlets, structures, and other coastal features (Richardson 1990).

Beach profile programs tied into reference points well back from the active beach and as far offshore as possible would have been helpful in assessing Hugo's characteristics and impacts (Stauble et al. 1990).

Installing and maintaining a network of wave and tide gages and current meters along densely populated coastlines would be prudent and help verify the effectiveness of models (Garcia et al. 1990)

## WIND SPEEDS

The overall wind damage from Hugo's landfall on the mainland United States was greatly reduced in part because the strongest winds in the storm occurred over a coastal wildlife refuge; all the development in that region was landward of the Intracoastal Waterway in forested areas, where the effective wind speeds were somewhat diminished (Sparks 1991).

Although the maximum surface wind speeds during Hugo throughout the Caribbean and the mainland United States reached recurrence intervals of 200–300 years, the actual wind speeds were generally far less than those reported by the news media. This contributed to confusion in early evaluation of the performance of buildings, the evaluation of codes, and the decisions about reconstruction (Marshall 1991).

### *——obstacles to measuring*

Hugo demonstrated the inadequacies of recording and reporting wind data in the United States (McDonald and Smith 1990; Sparks 1990b).

Determination of the surface wind field in Hugo at landfall was hampered by a lack of data in the part of the storm where aircraft had previously measured maximum flight level wind speeds (Powell 1991).

The low density of surface wind observations in the Caribbean and the Carolinas presented problems during and after Hugo in trying to reconstruct Hugo's movement and intensity (U.S. Department of Commerce 1990).

In the entire Hurricane Hugo impact area not a single anemometer was at standard height; the readings from many anemometers were affected by nearby buildings or forests. No station made a fastest-mile recording—the type used as the basis for design wind conditions (Sparks 1990a).

### *——uncertainty about*

It was widely believed that Hugo was a 135-mph storm but the maximum sustained wind speeds were calculated to have been 115–120 mph (McDonald and Smith 1990).

# IMPACTS ON NATURAL SYSTEMS

## BIOLOGICAL SYSTEMS

Hugo showed that some wildlife populations are at increasing risk from natural disasters because their formerly extensive habitats have been reduced to isolated pockets (Cely 1991).

The extent of wildlife losses as a result of Hugo was not clear, because accurate baseline counts were not available for many species before the storm, because post-storm conditions made making counts difficult at that time, and because wildlife personnel were assigned to protect human health and welfare instead. In the years after the storm, hunters gave conflicting reports about the numbers and health of the animals and birds in the affected areas (The Fontaine Company, Inc. 1991).

Shellfish populations along the South Carolina coast suffered little long-term impact from Hugo, although some were temporarily affected by poor water quality and sewage contamination (The Fontaine Company, Inc. 1991).

Immediately after Hugo, hypoxia and the reduction in salinity in the river channels and marsh creeks in the vicinity of Charleston Harbor caused massive mortality among the nektonic communities (very small organisms swimming near the surface). However, even the most severely affected areas were repopulated within two months as the water quality recovered (Knott and Martore 1991).

High water levels, river bottom turbulence, and debris in the waterways during and after Hugo resulted in low dissolved oxygen concentrations and elevated levels of phenols in many bodies of water after the storm. Continuous removal of storm debris from waterways, lakes, rivers, and swamps was necessary to insure good water quality, minimize adverse psychological effects on area citizens, and lessen the threat of floods due to blocked waterways and drainage systems (The Fontaine Company, Inc. 1991).

The amount of downed timber, brush, and debris (up to 15 times the normal amount) created by Hugo dramatically increased the risk of wildfires in forest, residential, and business areas in the Carolinas (Interagency Hazard Mitigation Team 1989).

## DUNES and BEACHES

Most oceanfront sand dunes were flattened by Hugo. Erosion losses along about 150 miles of coastline of the Carolinas occurred 50-200 feet landward of the original seaward line of dune vegetation (Rogers 1991).

As a result of Hugo, the geomorphological classification of the South Carolina coast from Garden City to Folly Beach changed from mostly dune fields and dune ridges to flattened washover sheets (Thieler and Young 1991).

In spite of its intensity, Hugo had only a modest impact on the geomorphology of the undeveloped coastal landscape at North Inlet, South Carolina. This was probably due to the storm's perpendicular approach, the relatively light precipitation, and the fact that natural barrier systems are resilient in the face of the wind and wave forces associated with severe storms (Gardner et al. 1991).

The fine sand beaches of North Myrtle Beach did not change slope as a result of Hugo, but were eroded uniformly along their entire profiles. The beaches of coarser sand to the south, on the other hand, were flattened and had more washover deposits of sand (Nelson 1989).

Along the beaches of Myrtle Beach and North Myrtle Beach, South Carolina, zones with higher pre-storm erosion rates were also areas of greater overwash penetration during Hugo. Other factors contributed to the high overwash penetration, namely the presence of low-elevation areas landward of the beach, and large open stretches of pavement such as parking lots and streets perpendicular to the beach (Hall and Halsey 1991).

On Isle of Palms, South Carolina, Hugo caused most beaches to be narrowed and their slopes flattened. However, there was only a minor overall decrease in the volume of sediment, because the sediment eroded from the beach-dune system was redeposited in the form of sand ridges within the intertidal and shallow subtidal zones (Katuna 1991).

A study of the numerous ebb-scour channels that formed during Hugo along a sample segment of Folly Island, South Carolina, showed that the channels were the result of several factors but that their formation was fostered by the failure of shoreline protection structures and by the absence of vegetation (Lennon 1991).

### ——*effects of human intervention on*

Although the exact mechanism varies, it is clear from Hugo's impact on the northern South Carolina coast that coastal development influences the nearshore dynamics during a storm and that developed coastlines respond differently than do coastlines fronted by groins or by no development at all (Gayes 1991).

The natural movement of the water and sediment at the shoreline during and after Hugo apparently overpowered the detrimental effects of coastal protection structures and the positive effects of dunes and eroding headlands on the northern South Carolina beaches. Neither of those features had any effect on the intertidal beach slope or on the longshore continuity of the beach. Erosion was not increased in front of seawalls or riprap revetments (Nelson 1989).

Scraping the lower intertidal beach to form dunes may have increased beach erosion during Hugo in some locales in northern South Carolina, but had no effect in others (Nelson 1989).

Prior erosion along the Folly Island beaches, resulting from sand deprivation by the Charleston jetties, contributed greatly to the severe surge damage during Hugo (Coch and Wolff 1991).

### ——*protective capacity of*

Dunes proved to be the most effective barrier to Hugo's storm surge in South Carolina. Natural dunes were more effective than bulldozed ones because they are generally higher, better vegetated, and have rhombohedral grain packing, which makes the dune more resistant to erosion because of lower porosity and higher bulk density (Coch and Wolff 1991).

Vertical erosion losses underneath most buildings in the Carolinas were 2–4 feet, lower than in many other storms, probably due to the region's low ground elevations, small sand dunes, fine-grained sand, large tide range, and flat wide beaches (Rogers 1991).

### ——*limitations on protective capacity of*

The experience of the town of McClellanville, South Carolina, during Hugo showed that barrier beaches and salt marshes are of little protection on the right side of a coast-normal hurricane no matter how high the dunes or how wide the marshes (Coch and Wolff 1991).

## Beach Nourishment

### ——*problems with*

The City of North Myrtle Beach, having no plan for replenishing its beaches after a storm like Hugo, took sand from a large shoal that was said to have formed at Hog Inlet; Hog Inlet now suffers from erosion. Although some sand did build up during and soon after the storm, the inlet was still changing and had not reached equilibrium when the city removed the "surplus" sand. In contrast, the City of Myrtle Beach had purchased before the storm a large inland sand pit for use in beach nourishment (Pilkey et al. 1990).

### ——*role in recovery of beaches*

Within one week of Hugo's passage, sand was beginning to return to the lower zones of South Carolina beaches in the form of swash bars, particularly along beaches that had been recently nourished (Stauble et al. 1990).

The recovery of the natural nearshore systems of the northern South Carolina coast after Hugo was significant during the first eight months after the storm. Sandbars were already forming a few days afterward. This recovery was aided in several areas by an emergency renourishment program (Gayes 1991).

Eroded sand deposited in large quantities in the surf zone by Hurricane Hugo was reclaimed to rebuild emergency berms along about 17 miles of South Carolina beaches. This technique appeared to be successful because of the excess of nearshore sand. By spring of 1990, the berms had survived a mild winter, and were starting to look like dunes: natural processes had smoothed their shapes and a beach berm was forming in many places. The compaction and shaping of the emergency berm during construction seemed to contribute to its durability and success. (Rhodes 1990)

### ——*role in reducing hurricane damages*

Areas of the South Carolina coast with recent beach nourishment projects seemed to suffer less damage to upland structures during Hugo, possibly because of the wider pre-storm dry beach area, than adjacent unnourished beaches (Stauble et al. 1991).

Two South Carolina sites at which sandy clay had been deposited on the beach to slow erosion exhibited much less erosion than adjacent natural beaches. The local promontories that resulted from this technique had no observable effect on the intertidal beach in front of them during the storm (Nelson 1989).

# IMPACTS ON HUMANS AND HUMAN SYSTEMS

Debris from Hugo slowed response efforts, complicated search and rescue as well as transport of supplies, and added significantly to the costs of recovery (Rubin and Popkin 1991).

One year after Hugo, about 10% of the population of St. Croix, 5% of St. Thomas, and 2% of St. John had not returned to the islands. There was also an apparent exodus of school-age children, especially those nearing graduation: 12% of St. Croix's schoolchildren, about 4% of St. Thomas', and about 3% of St. John's had left the islands and not returned (Christian 1992).

In the absence of safe-refuge sites, many commercial and recreational craft in the Carolinas were damaged or destroyed and, when carried or washed ashore, also damaged inland structures (Interagency Hazard Mitigation Team 1989).

## DEATHS and INJURIES

In the past, hurricane-related mortality has resulted primarily from impact-phase drownings associated with storm surge. But relatively few impact-phase drownings occurred in Puerto Rico or the Carolinas during Hugo, undoubtedly because of the early warning and widespread evacuation. Most Hugo-related deaths occurred after the storm had passed, during the cleanup (Badolato et al. 1990; Centers for Disease Control 1989a; *Morbidity and Mortality Weekly Report* 1989; Sexton 1990; Sill 1991).

Low casualties in Montserrat during Hugo can be attributed to the effectiveness of the warning systems and the precautions taken by the citizens in seeking shelter (Berke and Wenger 1991c).

The most serious electric safety accidents after Hugo in South Carolina and Puerto Rico involved electric current that backed up from portable generators through downed power lines, injuring and killing several members of repair crews (Badolato et al. 1990).

## HOUSING

The dollar value of damage to the interiors of buildings in the Carolinas as a result of roof failures was 10–30 times that of the damage to the roofs themselves. In some cases, the per-square-foot cost of the roof had been less than that of the carpet it was supposed to protect (Sill 1991).

Planning for and providing replacement housing for victims of Hugo in at least four South Carolina counties was left largely to private, nonprofit agencies like churches. The county governments lacked redevelopment, planning, or housing agencies and capabilities (Miller and Simile 1992; Rubin and Popkin 1991).

The Hugo disaster revealed the substandard housing conditions of the substantial number of rural poor in the Charleston area, and emphasized the lack of governmental and nongovernmental programs to assist their recovery from the hurricane (Miller and Simile 1991).

Various nonprofit, ad hoc groups provided the principal means of repairing and rebuilding damaged homes in parts of South Carolina after Hugo. Often the groups chose to rebuild the house to a higher standard than its pre-Hugo state, especially if it did not have plumbing or electricity (a not-uncommon situation in some areas). But the issue of how the occupants, living in poverty, would pay increased assessments, taxes, and utility bills was not addressed (Rubin and Popkin 1991).

There was no local government effort in at least four South Carolina counties to either generate low- or moderate-income replacement housing for victims of Hugo or to subsidize rents for low-income persons who needed to be rehoused after the hurricane (Rubin and Popkin 1991).

In at least one case after Hugo in South Carolina local officials allowed a cluster of manufactured homes to be rebuilt, on concrete pilings, in a V zone (Rubin and Popkin 1991).

## UTILITIES

The loss of electric power throughout Hugo's impact area on the U.S. mainland had farreaching secondary impacts because otherwise undamaged facilities—many of them critical to response and recovery—were unable to function (Interagency Hazard Mitigation Team 1989).

Electric transmission lines with metal support structures in the Carolinas remained intact during Hugo, but timber poles were heavily damaged, apparently due to foundation failure from insufficient embedment (Cook 1991).

Above-ground electric distribution systems can expect very heavy damage from a storm of Hugo's intensity; underground installations are much less likely to be damaged or lost (Badolato et al. 1990; Sill 1991).

On the mainland Carolinas, the major damage to electric distribution lines was the result of trees falling on the lines (Cook 1991).

Telephone systems in the Carolinas performed well during Hugo, primarily because 80% of the lines were underground (Cook 1991).

## TRANSPORTATION SYSTEMS

Hugo caused minor structural damage to mainland roads and bridges in the Carolinas; the main impact was the debris left covering roadways and the loss of signs and signals. These effects hindered repair efforts, caused traffic congestion, and impaired safety (Cook 1991).

After Hugo, debris from the destroyed marina facilities, sunken boats, and fuel spills hindered navigation in the Intracoastal Waterway and in Charleston Harbor (Taylor 1991).

Traffic counts conducted after the hurricane along several arterials in Charleston found an increase in traffic volume of about 20%. There was a 14% increase in accidents in Charleston during the three months after the hurricane. There was an estimated 35% increase in the overall cost of operating a vehicle in Charleston in the few months after the hurricane, due to delays in traffic (Peña 1991).

## THE ECONOMY

Many South Carolinians were the victims of price gouging and fraud immediately after Hugo. But emergency ordinances, an executive order, special consumer hot lines, and distribution of information on consumer fraud by state and local agencies prevented it from being more widespread (Hamm 1990).

Hugo did not lead to economic devastation in South Carolina. The economy grew during the year after the storm, although not all sectors and areas of the state benefited from the reconstruction effort (The Fontaine Company, Inc. 1991).

Loss of revenue to South Carolina localities because of the devalued property after Hugo underscores the problems of basing local revenues almost exclusively on property taxes. Local governments were faced with either cutting services at a time when they were needed most, or raising property taxes at a similarly inopportune time (Felts 1990).

## PSYCHOLOGICAL EFFECTS

### *— —descriptions of*

Hugo confirmed that psychological recovery after a disaster correlates positively with socioeconomic status. Healthy, educated middle-class adults were challenged by the aftermath of Hugo; marginally functional segments of the population were overwhelmed (Austin 1991).

Because its impact was community-wide, and because it was predictable, Hugo did not result in the same types of emotional trauma and psychiatric need that arise in other kinds of disasters (Austin 1991).

Although in general Hugo did not dramatically increase the levels of stress experienced by Charleston area residents, stress levels after Hugo were higher among those who had participated in disaster preparedness education and conducted appropriate household planning for the disaster (Faupel and Kelley 1991).

### *— —coping with*

Few victims of Hugo sought individualized psychiatric services from licensed professionals; rather, the entire impact area became a mass group psychotherapy marathon that lasted for months. Repeated discussion of the event and reliving the emotional trauma in almost any social encounter helped people master their anxiety and depression without individualized professional intervention (Austin 1991).

The experience of Hugo confirms the lessons of previous disasters: it is imperative to take clinical aid to the population at their natural gathering places, rather than waiting for victims to come to traditional mental health care delivery sites. Psychiatrists were asked repeatedly to formally address and to moderate discussions in churches, schools, businesses, agencies, and the media in order to help people cope with their emotional reactions to the disaster (Austin 1991).

Relief workers and volunteers in South Carolina often failed to realize that hurricane victims needed to go through a stage of denying their predicament as part of the gradual process of adapting to their losses (Aptekar 1991).

### — —and relief effort

Aid in the form of food, clothing, money, housing, and insurance substantially improved the morale and behavior of Hugo victims in some South Carolina communities. High-spirited volunteer labor was particularly important to the victims and, when it was unavailable, morale declined and was replaced by anger, bitterness, and despondency (Boore et al. 1990).

Dismissing victim volunteers who offered their assistance immediately after the hurricane reduced the ability of the "official" relief workers to function well in the community in the later phases of the relief effort (Aptekar 1991).

The relief effort in some South Carolina communities after Hugo showed that time spent learning about a stricken community's history, politics, and tensions is well worth it in improved functioning of relief agencies in the local area and in provision of more effective counseling (Aptekar 1991).

South Carolina's state relief effort was hampered because persons relied upon during disasters (police, medical personnel, mental health professionals, etc.) were themselves victims and thus unavailable or incapacitated by stress. Persons from outside sent in to provide assistance in turn became stressed and needed counseling before becoming effective (South Carolina Human Services Coordinating Council 1990).

The stress brought about by Hugo worsened the pre-existing physical and emotional handicaps of some victims, making it necessary to provide additional specialized counselling and job placement services (South Carolina Human Services Coordinating Council 1990).

# INSURANCE

Hugo pointed out the need for the insurance industry and the federal government to educate the public about the differences in coverage for wind, flood, and other damages provided by private insurance and the National Flood Insurance Program (Lord and McConnell 1991; *Journal of American Insurance* 1990; *Watermark* 1990).

Hugo illustrated the need for federal agencies, insurance companies, and state and local governments to reduce bureaucratic red tape in times of a major disaster. South Carolina waived the state licensing rule for adjusters so that outsiders could assist with the thousands of insurance claims. The state also implemented the "single adjuster" concept, which allowed one adjuster to handle claims when two companies (one for flood and one for wind) were involved (Lord and McConnell 1991).

A benefit of the National Flood Insurance Program's "write your own" program was illustrated by the experience of Hugo: a purely government insurance program would not have been able to provide the over 6,000 adjusters that were needed in the impact area. But because private companies write flood policies under the NFIP, their adjuster resources were available to provide the needed personnel (*Watermark* 1990).

Hugo demonstrated the importance of the requirement that insurance companies maintain a large surplus fund for use in disasters. Very few insurance companies became insolvent because of claims emanating from Hugo damage (Lord and McConnell 1991; *Journal of American Insurance* 1990).

### — —*mapping for*

The methods currently applied to evaluate coastal flood hazards and depict them on Flood Insurance Rate Maps are reasonable. Their accuracy depends upon the use of up-to-date coastline information and the proper inclusion of the effects of storm-induced erosion and wave setup. In areas of rapid shoreline change, Flood Insurance Rate Maps may need to be revised frequently to reflect current conditions (Deegan and Lasch 1990).

Structures in coastal A zones, which lie just landward of the V zones, suffered wave and velocity water damage from Hugo (Wilson et al. 1990).

# COASTAL DEVELOPMENT

### ——*distribution of damage to*

The worst destruction during Hugo occurred in the first few seaward rows of homes (Rogers 1991). Along the beach in Garden City, South Carolina, homes in the first two, three, or four rows were either obliterated or washed landward, damaging other homes as far back as the fifth row (Coch and Wolff 1990).

On Pawleys Island relatively little damage occurred where houses were well elevated, well back from the beach, behind the frontal dune, and enveloped by dune and maritime forest. The most serious damage was found where the interior dunes and maritime forest had been removed to build roads, houses, driveways, and parking lots (Pilkey et al. 1990).

Relative damage to beachfront houses in the various affected areas of South Carolina—some with wide beaches and established dunes, some with narrow, armored beaches—illustrates the importance of acquiring data on historical shoreline change and oceanographic processes and using it to establish coastal erosion zones and setbacks (Leatherman 1990).

### ——*contribution to damages*

Hugo's impact in both South Carolina and Puerto Rico demonstrated that storm-surge ebb is intensified when it is funneled by development, such as driveways, parking lots, and other paved areas (Bush 1991).

Water, sand, and debris were carried to the interior of Pawleys Island along roads and boat ramps that lay perpendicular to the shore. After Hugo passed and the surge water started to flow back to the sea, many storm-surge ebb channels were scoured along these pathways. A similar process took place forming several washouts along the length of Folly Island. These scour channels undermined roadways and resulted in serious damage to houses and property (Pilkey et al. 1990).

On Sullivan's Island, Hugo resulted in long gullies washed through numerous breaches in the dunes, almost all of which appeared to have been caused by pedestrians walking through the dunes to get to the beach (Brooks 1991).

### ——*regulation of*

The serious damage inflicted by Hugo on the coastal barrier community of Folly Beach, South Carolina, demonstrated that federal requirements for elevation of structures above flood levels cannot mitigate the ongoing risk posed by shoreline erosion (Platt et al. 1991).

The post-Hugo recovery and reconstruction especially on Folly Beach, South Carolina, showed how strong political and economic considerations are compared to environmentally sensitive restrictions on building in coastal areas (Platt et al. 1991).

Attempts to enforce the provisions of the South Carolina Beachfront Management Act after Hurricane Hugo showed that the legitimate extent of government regulation of private property needs to be settled well before a disaster occurs. The implementing government should determine which provisions are likely to result in "takings" of property or in substantial devaluation, and develop mechanisms either for allowing limited development in those cases or for funding compensation payments (Beatley 1990).

## SETBACKS

### *——effectiveness of*

In South Carolina, buildings in areas with wide beaches suffered much less surge damage than those where the beach was narrower (Coch and Wolff 1990; Wang 1990).

Hugo's impact on South Carolina highlighted the ability of dunes to dissipate wave energy and protect landward structures in all but the most severe conditions or when the storm surge level was higher than the dune crest (Richardson 1990; Wang 1990).

Natural dunes and artificially constructed sand ridges parallel to the South Carolina beach were severely eroded, though they proved to be the most effective barrier to storm surge as Hugo made landfall (Coch and Wolff 1990).

Low, narrow dunes along the South Carolina coast were flattened by Hugo; dunes that were high enough not to be submerged by the storm surge and were at least 30 meters wide generally survived and protected structures behind them (Stauble et al. 1991; Thieler and Young 1991).

The South Carolina experience with Hugo shows the importance of maintaining the widest and most continuous dunes as well as the widest possible beaches in order to minimize damage from wave surge (Coch and Wolff 1991; URS Consultants 1991a).

Of the South Carolina coastal buildings completely destroyed or removed from their foundations by Hugo, 84% were fronted by dune fields less than 15 meters wide; 50% were fronted by a "deadly" combination of dry beaches less than 3 meters wide and dune fields less than 15 meters wide (Thieler and Young 1991).

Beachfront houses at Isle of Palms were generally protected by a wide beach and sand dunes; this natural buffer zone served its purpose well, with damage from Hugo concentrated in areas where the beaches were narrow and dunes small or absent (Leatherman 1990).

The greater the setback on Isle of Palms and Sullivans Island, the fewer the damages from waves and storm surge (Miller 1990).

### ——*ineffectiveness of*

The miles of marshes between the town of McClellanville and the ocean provided little protection from Hugo, which approached in a path perpendicular to the coast and whose right (northern) arm passed over the town (Coch and Wolff 1990).

Most low sand dune systems along the South Carolina coast provided little protection to the structures behind them during Hugo because the dunes themselves were severely eroded or destroyed by the storm (Miller 1990; Nelson 1989; Wilson et al. 1990).

## COASTAL PROTECTION STRUCTURES

### ——*effectiveness of*

Well-built conventional erosion protection projects like seawalls, especially larger wooden or concrete ones, survived Hugo and functioned in South Carolina (Richardson 1990; Stauble et al. 1990).

### ——*ineffectiveness of*

Almost all of the smaller, privately built coastal erosion-control structures in South Carolina—seawalls, bulkheads, retaining walls, and revetments—were ineffective at protecting oceanfront buildings from hurricanes along an open coast. They were consistently underdesigned, improperly engineered, and used undersized materials and components. Return walls were far too short; the possibility of overtopping appeared to have been ignored. Many were old and inadequately maintained. They were destroyed, flanked, or overtopped. (Rhodes 1990; Richarson 1990; Rogers 1991; Rogers and Sparks 1990; Stauble et al. 1990; Wang 1990).

Many of the South Carolina seawalls that survived Hugo were overtopped and had little erosion abatement effect. Failed seawalls left no evidence in the beach profile that they had prevented any erosion (Nelson 1989).

Hurricane Hugo's effects in South Carolina showed that (because the ends are so vulnerable) an adequate protection structure for a single or double lot may have to completely enclose the area being protected, a somewhat impractical concept (Rhodes 1990).

In some cases, inadequate landward return walls were flanked by erosion, producing an outlet for the water that overtopped the structure. This accelerated the loss of backfill material behind the structure (Rhodes 1990).

### ——*damages to and failure of*

Scouring around seawalls due to overtopping was the most prevalent type of damage to those structures in South Carolina (Wang 1990).

A frequent cause of damage to revetments and other structures in South Carolina was insufficient height and insufficient backfill protection. In some cases the structure was overtopped and the loss of backfill resulted in damage or destruction of the structure; in others, the structure survived, but the loss of backfill resulted in damage to the building supposedly being protected (Rhodes 1990).

Many timber bulkheads in South Carolina were damaged or destroyed by Hugo because there was no toe protection to prevent scour seaward of the structure (Rhodes 1990).

Inlet jetties in South Carolina received damage to their seaward ends during Hugo, but for the most part retained their structural integrity (Stauble et al. 1990).

### — —*effectiveness of riprap*

In North Myrtle Beach, all known riprap emplacements survived and adequately protected the structures behind them without significant loss of rock or sand washout from behind the rocks (Nelson 1989).

### — —*ineffectiveness of riprap*

At Folly Beach, where the beaches already were critically narrow because of long-term erosion, large stones and concrete rubble that residents had been dumping on the beaches to form riprap revetments were largely ineffective, allowing waves to inflict heavy damage on the beachfront houses (Leatherman 1990).

# PERFORMANCE OF STRUCTURES

## EFFECTS OF WIND AND/OR WATER

Nonengineered structures in the Carolinas, especially homes and signs, generally received the most extensive damage from wind and water. Among marginally engineered buildings (low-rise apartments, motels, and businesses) there were many roof and wall failures. In fully engineered buildings (high-rise hotels, condominiums, offices), no damage was observed to main structural systems although there were some roofing, wall panel, and cladding failures (Manning 1989; Manning and Nichols 1989; McDonald and Smith 1990; Miller 1990).

Small commercial buildings, motels, and other buildings of unreinforced or lightly reinforced concrete block fared poorly in both flood and wind damages during Hugo's passage through South Carolina (Miller 1990).

The distribution of damage from Hugo in the Caribbean was related to gust wind speeds, the proportion of manufactured homes in a given area, and, for surge damage, proximity to the ocean (Sparks n.d.).

### *——avoidability of*

Much of the wind and floodwater damage to new construction could have been prevented at a reasonable cost using available construction techniques (Rogers and Sparks 1990).

Properly designed, built, and inspected structures generally sustained little wind or flood damage from Hugo (Sill 1991).

Hugo demonstrated that a structural system is only as strong as its weakest link. Therefore, if a house was elevated and well built, but its ocean-facing windows were poorly installed, high winds caused them to fail, which was followed by loss of the roof and finally collapse of the whole structure (Sill 1991).

There was evidence in South Carolina that larger-pile buildings near shore reduced damage to those behind them that were less well built (Richardson 1990).

## EFFECTS OF WATER, WAVES, OR EROSION

Hugo presented few surprises in coastal construction. The buildings destroyed or severely damaged by water, waves, or erosion were those expected to be damaged; those expected to do well survived some of the worst storm conditions (Rogers 1991).

No building whose wood or pre-stressed concrete piling foundation was adequately embedded and whose floor beams were elevated above waves had a major structural failure caused by flooding, waves, or erosion (Rogers 1990a).

Hugo showed that buildings can survive the water, wave force, and erosion of a major hurricane as long as 1) there is a minimal understanding of the hazards likely at the building's site, 2) there is a floor elevation high enough to keep the main structure from getting wet or hit by a wave, 3) there is a piling foundation that will resist waves (where appropriate), and 4) piles are adequately embedded to avoid undermining by erosion (Rogers 1991; URS Consultants 1991a).

## EFFECTS of WIND

In Hugo, as in other storms, the strongest wind forces occurred in suction. Thus, roofs and windows tended to lift up and off, and side walls and windows were sucked outward, not blown in (McDonald and Smith 1990; Sill 1991).

Major structural failures in one- and two-family residences due to wind were the result of loss of roofs leading to collapse of walls and foundation failures (Sparks 1991).

All of the inland structures that collapsed in Hugo's high winds were unreinforced masonry; failures seemed to occur with equal frequency in areas with and without building codes. Most were older structures and, in the Charleston area at least, building officials have indicated that they no longer accept unreinforced masonry walls (Murden 1991).

Wind damage to structures on Montserrat was generally consistent with that observed after previous hurricanes, including loss of corrugated metal sheeting, loss of asphalt shingles, loss of the roof structure, blown out windows and doors, and collapsed timber and concrete block wall buildings (Consulting Engineers Partnership, Ltd. 1991).

### *— —protection from*

Hugo showed that, in the Carolinas, shelter provided by adjacent structures or trees greatly reduced wind damage to even old or cheaply constructed buildings (Sill 1991).

Single-family and other small buildings in some parts of both North and South Carolina, even if poorly constructed, escaped serious wind damages because they were sheltered by trees and other buildings (McDonald and Smith 1990; Murden 1991; Rogers and Sparks 1990; Sill 1991; Sparks 1990a).

### *— —on nonstructural vs. structural components*

In Hugo, as in other hurricanes, the steel and concrete frames of buildings designed by structural engineers to meet the wind loading requirements in the building codes performed well. The nonstructural wall cladding, roof system, roof covering, appurtenances, and window glass, often selected by nonengineers without reference to wind-load requirements, performed very poorly (Manning and Nichols 1990; McDonald and Smith 1990; Rogers and Sparks 1990; Sill 1991; Sparks 1991).

The main structural systems of steel- or concrete-framed buildings in the Carolinas performed well in Hugo's winds (Murden 1991).

The structural frames of medium-rise buildings in the Charleston area appeared to be adequately designed to withstand Hugo's winds, but the cladding on them was inadequate (Saffir 1991).

There were widespread cladding failures throughout the Carolinas during Hugo, probably because the cladding systems (especially gypsum board over metal studs followed by rigid foam insulation and stucco finish) were selected without regard to their ability to resist suction or wind loads (Murden 1991).

In Puerto Rico, few engineered industrial steel structures failed in the face of Hugo's winds. Most of the damage to this type of structure was to sidings, roofs, and mechanical systems. The structures that did fail were found to have construction flaws (poor quality concrete, improper casting of steel beams) (Rodriguez et al. 1991).

In Puerto Rico, there was no structural wind damage reported to institutional multistory reinforced concrete buildings or to similarly constructed apartment buildings, although there were numerous instances of damages to facades, windows, and mechanical systems (Rodriguez et al. 1991).

### ——*on connections*

Increased internal pressure after window failure caused separation of roof-to-wall connections and subsequent damage in unreinforced concrete block wall buildings, such as those common in shopping centers and community buildings. Such total collapses occurred as much as 100–180 miles inland in the Carolinas, even in walls built to code (Rogers and Sparks 1990; Sill 1991).

Most wind damage in the Carolinas was due to inadequate connections within the structure (Mahoney 1990; Manning and Nichols 1990).

Many of the structural failures of low-rise apartments, motels, and businesses in the Carolinas were roof failures due to inadequately sized hurricane clips (Manning and Nichols 1990).

### ——*on signs*

About 70–80% of the signs in Charleston suffered major damage from the wind, and the pieces of the signs became missiles that damaged other property (Manning 1989).

### ——*at certain speeds*

Almost all of the severe wind damage caused by Hugo in the Carolinas resulted from wind speeds below the design standard (Wilson et al. 1990; Manning and Nichols 1990; McDonald and Smith 1990; Miller 1990).

Damage to roof coverings, wall cladding, and signs in the Carolinas occurred where the fastest-mile wind speed exceeded 60 mph (Sparks 1990a).

Major structural damage in both North and South Carolina, including loss of roof structure, collapse of single story masonry buildings, complete destruction of manufactured homes, and extensive damage to wood-framed construction and older pre-engineered metal buildings took place where the fastest-mile wind speed exceeded 85 mph (Murden 1991; Sparks 1990a).

### — —*on roofs*

Most property damage to one- and two-family residences in the Carolinas was the result of the contents of the building getting damaged by wind and rain after a portion of the roofing material had been lost in the wind. This minor roof failure, repeated throughout the region, contributed significantly to the total cost of Hugo (McDonald and Smith 1990; Sill 1991; Sparks 1991).

Wind damage to roofs in coastal South Carolina was the result of aged roofing materials, poor roof maintenance, poor roof covering installation practices, and the use of inadequately sized hurricane clips (or no clips at all) (Miller 1990).

Lack of attention to such details as roof fasteners and edges was the weak link which started damage during Hugo and often led to complete failure of the roof system due to wind (Sill 1991).

Fully 80% of the roofs in Charleston suffered wind damage during Hugo (Miller 1990).

Roof failures were far less common in Hugo than in recent hurricanes, probably due to the regional popularity of steep-pitched roofs and the use of hurricane clips. In the highest wind speeds, however, failures occurred even where anchors had been used, particularly after window damage (Sparks 1991).

In the Virgin Islands, where many residents rely on cistern water, few cisterns themselves were damaged; however, wind damage to roofs disrupted the water-collection system for the cisterns and caused most of the stored water to be contaminated by wind-borne debris (Morris and Krishna 1991).

## FOUNDATIONS

Foundation failures due to wind were more common from Hugo than is typical because it was common in South Carolina to elevate small buildings a full story on unreinforced or minimally reinforced masonry columns on shallow concrete pads. These unbraced columns frequently failed (Rogers 1991; Murden 1991; Rogers and Sparks 1990; URS Consultants, Inc. 1991a).

In high-rise buildings supported on piles, if bearing walls were perpendicular to the shoreline, the first floor units were gutted by waves, but the upper floors remained stable and untouched. Conversely, where load-bearing walls were parallel to the shoreline, they failed and the upper two or three units collapsed (Rogers and Sparks 1990).

A large number of the older buildings were damaged because their foundations were inadequately constructed. Problems included inadequate reinforcement between the footing and the column and within the columns, and using undersized masonry units (Mahoney 1990).

## Slabs

Homes built directly on concrete slabs in coastal South Carolina were the most heavily damaged. The slabs were undermined by wave erosion, broken apart, and then the pieces were carried landward, causing damage to other structures (Coch and Wolff 1990).

Slab-on-grade foundations were repeatedly demonstrated by Hugo to be unfit for coastal areas. Structures on such foundations were either totally demolished by wave force or lifted by flood waters and floated away (Wang 1990).

## Piers and Columns

Piers were shown by Hugo to be vulnerable in the zones of dynamic water forces in the Carolinas. Most of the footings were too shallow, having been dug and poured in place. As the overburden was eroded away, the footings simply toppled. Bulky shallow footings fared worst because they promoted local scouring of 1-1.5 feet (Rogers 1991; Rogers and Sparks 1990; Interagency Hazard Mitigation Team 1989; Wang 1990).

Masonry columns performed more poorly in the face of Hugo's storm surge than wood or poured concrete. Many of these structures in the Carolinas were embedded only two or three feet into the ground, so that surge-related erosion and scour easily undermined them. Other problems included inadequate reinforcing between the base of the column and the footing resulting in connection failure, inadequate connection between the top of the column and wood flood beam, poor workmanship on the fill, and inadequate reinforcement of the column itself. The columns simply lacked sufficient strength to resist lateral loads due to winds or waves, even far inland, and the shallow embedment was the greatest weakness of the system (Interagency Hazard Mitigation Team 1989; Mahoney 1990; Manning and Nichols 1990; Rogers 1991; URS Consultants, Inc. 1991a; Wang 1990).

Poured concrete piers failed due to inadequate or improperly placed reinforcing bars (Rogers and Sparks 1990; Wang 1990).

## Pilings

Of all foundation types, only deeply embedded wooden or prestressed concrete piles at least 9 inches in diameter—wooden or concrete—invariably performed well in the face of Hugo's waves and surge. Failures were mainly due to rot, or to over-notching of the pile for the floor beam (Interagency Hazard Mitigation Team 1989; Miller 1990; Richardson 1990; Rogers 1990a; Rogers and Sparks 1990; Wang 1990).

Wooden piles, 10 inches or more in diameter, driven or jetted 10-15 feet into the ground were most effective during Hugo (URS Consultants 1991a).

The Hugo experience suggested that the lateral strength of wood piles and/or the lateral soil resistance of all types of piles in sandy soils has been significantly underestimated. Those foundations appeared to consistently survive water, wave, and erosion conditions under which damage would have been expected (Rogers 1990a).

A number of oceanfront buildings were completely lost during Hugo due to the practice of encasing the wooden pilings in concrete collars just below the ground elevation, which are highly susceptible to collapse when erosion exceeds the shallow embedment and also increase the surface area of the foundation exposed to wave forces (Rogers 1990a).

### *— —cross bracing with*

Cross bracing between pilings was found to be more unreliable during Hugo's surge than expected. Wooden bracing 2–3 inches thick and 6–12 inches wide broke frequently; steel rods up to 1/2 inch in diameter were susceptible to inward bending upon impact with floating debris. No foundation or structural damage was noted as a result of the bracing failures, however (Rogers 1990a).

Steel rod cross bracing appeared to perform better than wood because wood was susceptible to breaking or buckling by wave forces and wood tended to separate or rotate from the main members (Wang 1990).

## ELEVATION

Practically all residential structures not elevated above the base flood level sustained major damage or complete destruction, from either collapse under wave force, floating off foundations, or water washing through and demolishing the structures (Mahoney 1990; Miller 1990; URS Consultants, Inc. 1991a; Wang 1990).

Manufactured homes installed on minimally elevated foundations in the Carolinas were completely destroyed by storm surge (Interagency Hazard Mitigation Team 1989).

As long as adequate openings were left under the living space, Hugo's surge and waves passed unimpeded beneath [properly elevated] structures (Coch and Wolff 1990).

The provision of underhouse parking (by elevating the house 8–10 feet above grade) appears to have provided an additional margin of safety from flood waters in many cases. However, using improperly built masonry columns to elevate the building for this purpose was a common cause of serious damage in the coastal Carolinas (Rogers and Sparks 1990).

## Lower Area Enclosures

Most high-rise buildings along the northern South Carolina coast had enclosed ground floors (lower areas); almost everything on the ground level was lost to surge and wave action during Hugo (Miller 1990).

During Hugo, wave forces against concrete block walls enclosing the lower areas of older buildings in the Carolinas overloaded the column or piling foundations and resulted in foundation collapse and subsequent structural failure (Mahoney 1990).

Hugo showed that conventional wood frame construction breaks apart under the force of storm surge and waves with little adverse impact to the foundation if the foundation is properly constructed. This suggests that most lower area enclosures may be a lesser structural threat than previously believed (URS Consultants 1991b).

During Hugo, breakaway walls in the lower areas of elevated structures in South Carolina consistently collapsed under even shallow flooding and small waves regardless of the design of the wall or the strength of the connections to the foundation; damage to the foundation was minimal in almost all cases (Rogers 1990b).

In a significant number of cases in South Carolina, elevated buildings were damaged during Hugo because plumbing and electrical wiring were embedded in breakaway walls in the lower areas (Rogers 1990b).

## CONNECTIONS

Most wind damage in the Carolinas was due to inadequate connections within the structure (Mahoney 1990; Manning and Nichols 1990).

During Hugo's storm surge, improper connections between floor beams and the tops of the foundations caused structures to lean, shift, collapse, float away, and sometimes damage other structures. Improper nailing and the use of nails that were too small caused numerous member separations under minor shifts. Missing and inadequate hurricane clips also were prevalent (Mahoney 1990; Miller 1990; Wang 1990).

Many of the roofs of nonengineered buildings in the Carolinas were blown off during Hugo due to the lack of a proper connection between the roof and exterior walls (Manning 1989; Manning and Nichols 1990).

Hugo showed that hurricane fasteners are a cost-effective way to reduce damage (URS Consultants 1991a).

## MANUFACTURED HOUSING

Of a sample of damaged manufactured homes inspected in the Charleston area, 70% had shifted from their piers; one half of those had totally fallen off their supports, for one or more of the following reasons: anchor failure due to saturated ground; strap failure; improper attachment of anchor straps to I-beams; and improperly installed ground anchors (National Conference of States on Building Codes and Standards 1989).

### *——performance in wind*

Manufactured homes along the coast suffered more wind damage during Hugo than conventionally built homes (Interagency Hazard Mitigation Team 1989; Murden 1991; Sparks 1990a; Wilson et al. 1990).

Of manufactured homes in the Charleston area that were totally destroyed during Hugo, some overturned due to anchor and strap failure, and others were destroyed when wind pressures severed the entire roof and the exterior walls subsequently collapsed (National Conference of States on Building Codes and Standards 1989).

About 15% of manufactured homes inspected lost some siding and/or soffit covering, primarily due to the leeward suction forces on the edges and ends of the structures. About 15% of the inspected manufactured homes were missing some or all of their metal roof covering, while homes with shingled roofs experienced much less damage (National Conference of States on Building Codes and Standards 1989).

### ——performance in storm surge

Manufactured homes installed on inadequately elevated foundations along the South Carolina coast were destroyed by the storm surge, while properly elevated and anchored manufactured homes generally sustained minimal damage (Interagency Hazard Mitigation Team 1989; Wilson et al. 1990).

It was apparent from Hugo's impact on the Carolinas that manufactured housing anchoring systems designed to resist wind loads are no match for wave forces (URS Consultants 1991a).

## APPURTENANT STRUCTURES

Gazebos, patio decks, recreational furniture, stairways, and even moored boats became floating debris that produced serious damages to structures in coastal South Carolina that otherwise were expected to be storm resistant (Coch and Wolff 1990).

Decks with access ways to beaches caused a surprising amount of damage during Hugo. Most were secured to the main structure but not designed or built to resist the force of water. Ground floor garage doors, air conditioning units, water tanks, nonbreakaway walls, etc. all contributed additional damages to the main structures. Revetment armor units (riprap) behaved like missiles powered by waves (Wang 1990).

# BUILDING DESIGN AND CONSTRUCTION

Most high-rise structures in South Carolina suffered relatively little damage from Hugo because of the involvement of design professionals in their plan and construction, the use of continuous and reinforced structural systems, and a plan review process in the permitting phase (Hogan and Karwoski 1991).

Hugo showed that technical guidelines are needed for better residential roof design and construction practice in the United States (URS Consultants 1991a).

The engineering community has known the proper design loads for wind for at least 30 years; if this information had been implemented, much of Hugo's damage could have been averted (Sill 1991).

Because the vast majority of buildings in South Carolina experienced only relatively moderate wind conditions (recurrence intervals of between 20 and 50 years) during Hugo, the multi-billion dollar damage indicates that minimum design, construction, and performance standards for wind were not being utilized during construction (Miller 1990; Sparks 1991).

The magnitude of Hugo's damage in the Virgin Islands can only be attributed to lack of engineering design and poor construction codes and practices (Saffir 1991).

## DESIGN

Some conventional building practices, such as the construction of gable end walls, are inadequate for resisting hurricane-force winds (McDonald and Smith 1990).

The current design of many roofing systems is inadequate to resist hurricane winds (Levinson 1990; McDonald and Smith 1990).

Hugo left many examples in the Carolinas of how damages could have been reduced or eliminated with nominal changes to a structure's design or construction, if only the public had been aware of the options for such damage prevention (Richardson 1990).

### ——*value of traditional*

Historic buildings in the Virgin Islands, Montserrat, and the Carolinas performed best because of their traditional style. Of Charleston's 3,600 historic structures, only 16 were completely destroyed, and only 2% of historic urban structures on St. Croix were destroyed. Working shutters; high-pitched or hipped, short-span roofs with no overhangs; and elevated first floors were the characteristics of colonial buildings that saved them (Consulting Engineers Partnership, Ltd. 1991; Levinson 1990)

Disproportionate damage was done by Hugo to modern buildings in Montserrat. Many of the traditional building designs stood up to Hugo better than the newer ones (United Nations 1991).

## BUILDING CODES

### *——adequacy of provisions of*

Hugo showed that damage to structures can be greatly reduced by adhering to newer coastal building codes (All-Industry Research Advisory Council 1989; Richardson 1990).

Model codes are adequate (Levinson 1990; Wang 1990).

Buildings and structures that were designed and constructed in complete accordance with current wind code provisions withstood the wind forces from Hugo with minimal damage (Manning 1989).

Relatively new (about 6 years old) metal building systems in Charleston showed no structural damage at all from Hugo's winds, contrasted to the considerable damage inflicted on nearby buildings constructed to earlier codes, standards, and design methods that reflected inadequate wind loads (Harris 1991).

Hugo's impact on the U.S. Navy's base at Charleston showed that structures built to present navy design standards, which use ANSI A58.1 criteria for wind, will withstand hurricane wind forces. More attention should be paid, however, to the choice and installation of cladding and cladding fasteners (Curry 1991).

### *——inadequacy of provisions of*

Hugo's impact on the Charleston area gave testimony to the deficiencies in long-term planning and in building code requirements for wind loading (Saffir 1991).

Many of the older pre-engineered metal buildings in exposed locations in the Carolinas were seriously damaged or destroyed during Hugo because of their sensitivity to the weaknesses of the wind loading provisions of the old [pre-1988] [Standard] building code (Murden 1991).

Many of the South Carolina buildings that collapsed due to wind loading met the prescriptive requirements of the building code (Sparks 1991).

Pre-engineered metal buildings designed to the procedure specified in ANSI A58.1 performed better under Hugo's wind loads than those designed to normal Standard Building Code provisions (Sparks 1991).

The inability of the flood codes to dictate well-embedded, erosion-resistant foundations severely limits the success of the National Flood Insurance Program in reducing hurricane damages along the coast (Rogers and Sparks 1990).

### *——inadequacy of adoption and enforcement of*

Hugo demonstrated that strong, enforced building codes and training for building inspectors are needed in South Carolina (Felts 1990).

Widespread failure in South Carolina to enforce the National Flood Insurance Program regulations for anchoring and elevating manufactured housing resulted in overturned manufactured houses that toppled off unattached, uncemented concrete blocks; anchors that pulled out of wet soil; and inadequate hold-down straps (Miller 1990).

A great deal of the damage from Hugo was done to structures that would not have met the standards of the Southern Building Code, if it had been in force (The Fontaine Company, Inc. 1991).

The construction requirements in the codes being enforced by local governments on the South Carolina coast before Hugo were frequently misunderstood by building officials; in other cases, the codes did not include special construction requirements for coastal areas (Manning and Nichols 1990).

Early adoption of a building code, use of deemed-to-comply standards (which are easier for builders and officials to interpret), and better enforcement could have substantially reduced Hugo damages (Rogers and Sparks 1990).

Hugo showed that owners and insurers relied heavily on local and state government to ensure proper construction standards, but the decentralized form of building control adopted by South Carolina did not work well with regard to wind effects. The code was unsuitable, the building officials not properly trained, the communities lacked resources for proper enforcement, and there was an absence of political will at the local and state levels to impose restrictions on construction (Sparks 1991).

Lack of enforcement and field inspection keeps the provisions of model codes from preventing damage (Levinson 1990; Wang 1990).

For the most part, inspection of South Carolina residential structures damaged by Hugo was left to homeowners because building officials were overwhelmed (Mittler 1991).

The sign codes and ordinances in South Carolina either did not contain wind load provisions or those provisions were not enforced (Manning and Nichols 1990).

There are no codes applicable to many of the structures used in marina facilities (docks, slips, gangways, piers, breakwaters, drystacks, retaining walls, etc.), and neither insurance companies nor lending institutions require professional design of marina projects (Taylor 1991).

Extensive damage to buildings in Montserrat might have been avoided if basic building standards and design guidelines adopted by other Caribbean islands had been adhered to (Consulting Engineers Partnership, Ltd. 1991).

### ——*exemplary enforcement of*

In at least one South Carolina county, the council strictly forbade any suspension of building inspections immediately after Hugo. Extra inspectors were located and hired, and damages were prioritized so that the most seriously damaged structures would be inspected first (Mittler 1991).

In at least three South Carolina counties permit fees were reduced or waived in efforts to encourage homeowners to obtain permits to repair Hugo damages (Mittler 1991).

### — — *value of enforcement of*

Throughout South Carolina, where codes were well-enforced over the past five years, damages from Hugo's winds and storm surge were less than in areas without enforcement (Miller 1990).

The strictest code enforcement before Hugo was the result of the insistence of the Federal Insurance Administration that provisions of the National Flood Insurance Program be adhered to (Mittler 1991).

The political and emotional pressure to be lenient in enforcing the provisions of the South Carolina Beachfront Management Act was substantial after Hugo (Beatley 1990).

Hugo demonstrated that what is needed in Puerto Rico is not a revision of the building code but rather enforcement of it (Rodriguez et al. 1991).

## NATIONAL FLOOD INSURANCE PROGRAM STANDARDS

The majority of South Carolina residential structures damaged by Hugo were built before the adoption and enforcement of National Flood Insurance Program criteria. They usually used slab-on-grade foundations, unreinforced concrete block walls, and spread footing/concrete block piers (Interagency Hazard Mitigation Team 1989; Leatherman 1990; Miller 1990).

Structures built to meet or exceed the requirements of the National Flood Insurance Program suffered minimal flood damage from Hugo (Manning and Nichols 1990; McDonald and Smith 1990; Miller 1990; Rogers and Sparks 1990; URS Consultants, Inc. 1991a).

Hugo demonstrated the need to reconsider the V-zone limits as delineated under the National Flood Insurance Program. Coastal hazards during Hugo extended farther landward than indicated by the existing V-zone analysis (URS Consultants 1991a).

## CONSTRUCTION PRACTICES

A lack of communication and coordination between the designer/fabricator and the builder/contractor of metal buildings contributed to some failures during Hugo; poor maintenance contributed also (McDonald and Smith 1990).

In a few cases in South Carolina, wood pilings, especially square ones 15-20 years old, failed during Hugo due to rotting. The pilings probably had received inadequate preservative treatment before construction (Rogers 1990a).

Almost all of Myrtle Beach's ground-mounted signs simply blew over; fortunately, due to the city's practice of setting the signs directly in the ground without concrete, they were easy to reinstall (Sexton 1990).

A common cause of serious damage to houses in the coastal Carolinas and in isolated cases (due to wind) inland was the use of improperly built masonry columns constructed of hollow concrete blocks with several small reinforcing rods in the concrete-filled core. These buildings failed because of a wide range of poor building practices: insufficient reinforcing was installed and consistently placed improperly, the reinforcing and concrete were sometimes omitted completely, and the pad below the columns was far too shallowly embedded (Rogers 1990a, 1991).

In some cases of new roofs in the Caribbean areas damaged by Hugo, there was evidence of failure to apply sound building techniques (United Nations 1991).

Exterior panels whose rated use took into account only wind overpressure were used as siding on condominiums in South Carolina. Many of them failed during Hugo by being pulled away from the building (All-Industry Research Advisory Council 1989; Richardson 1990).

Hugo demonstrated that measures can be taken in the construction of new residences that exceed code standards or requirements, add only about 7% of the capital cost of the house, and enable the structure to withstand the winds and waters of a hurricane with only minor damage even in an exposed location (Miller 1990).

## MAINTENANCE

Rusted anchoring components were one of the causes of collapse of transmission towers on Montserrat (Consulting Engineers Partnership, Ltd. 1991).

Some 15-20-year-old wood pilings failed during Hugo because of rotting. Signs of the rotting probably were visible above the ground surface before the storm (Rogers 1990a).

Inadequate maintenance contributed to the failure during Hugo's high winds of some of the buildings and structures on Montserrat. In metal framed buildings, particularly schools, corrosion of the metal frame and metal roof members was a significant factor leading to failure (Consulting Engineers Partnership, Ltd. 1991).

# EMERGENCY MANAGEMENT

## PREPAREDNESS

### — — *value of*

Studies of tidal and storm surges and evacuation planning developed by federal, state, and local governments in South Carolina enabled the state to provide timely and sound advice to the population and to evacuate 264,000 people (Peterson 1990).

The Hugo evacuation was successful in large part due to the thorough planning and testing of emergency and evacuation plans that had been done in the Carolinas (U.S. Department of Commerce 1990).

The fact that Montserrat was able to initiate disaster response and restoration activities within 72 hours after Hugo can be credited to strong internal preparedness arrangements supported at the highest levels of government (Pan Caribbean Disaster Preparedness and Prevention Project 1989).

In Montserrat, the organizations that had disaster plans responded to Hugo more effectively than those that operated on an ad hoc basis (Berke and Wenger 1991c).

A region-wide disaster simulation exercise held in the summer before the disaster undoubtedly facilitated the close and smooth working relationship among disaster agencies in the Caribbean after Hugo (Pan Caribbean Disaster Preparedness and Prevention Project 1989).

The advanced level of warning and mobilization for Hugo in the Caribbean can be attributed directly to the evaluation by the Pan Caribbean Disaster Preparedness and Prevention Project of the Caribbean states warnings of Hurricane Dean (Pan Caribbean Disaster Preparedness and Prevention Project 1989).

### — — *limitations of*

Earthquake education workshops held in the Charleston area significantly contributed to adaptive response to Hurricane Hugo only for those who had not been through a hurricane; past hurricane experience is a more important predictor of who will take action to prepare than is preparedness education (Faupel and Kelley 1991).

Even though much information was made available to the public, people still could not adequately appreciate what the predicted conditions (depth of water, height of waves, speed of wind) will mean unless they had lived through a storm (U.S. Department of Commerce 1990).

The importance of wind-resistant design of essential facilities in South Carolina was reinforced by the Hugo experience. Many emergency shelters are constructed of unreinforced masonry, which was shown during Hugo to be vulnerable to high winds as much as 100 miles inland; many emergency shelters experienced roof failures during Hugo (McDonald and Smith 1990; Sill 1991).

Electric utility companies in the Carolinas had plans to deal with the effects of a hurricane on their facilities and operations, but Hugo's damages exceeded their expectations (Cook 1991).

Hugo's impact on Charlotte, North Carolina, and on Charleston, South Carolina, showed that, although representatives from lifeline organizations are often included as Emergency Operations Center personnel after a disaster, very little attempt is made to integrate them into the ongoing planning process (Nigg 1990).

Hugo revealed some inadequacies in the Montserrat National Disaster Plan, including a failure to anticipate the loss of communication facilities on the island, a focus on pre-hurricane activities to the exclusion of post-hurricane measures, and the inadequate provision of disaster management training for both district and national officials (Berke and Wenger 1991c).

### *— — lack of*

Attempts to provide emergency electrical power after Hugo struck the Carolinas were hampered by the lack of knowledge on the part of the managers of even undamaged facilities of their power requirements, local resources, or access to proper equipment (Interagency Hazard Mitigation Team 1989).

The facilities, level of training, coordination, and planning on the part of state and local agencies in South Carolina were inadequate for a disaster the size of Hugo (Interagency Hazard Mitigation Team 1989).

Hugo's impact on Charlotte, North Carolina, and on Charleston, South Carolina, suggested that inland communities are much less likely to take preparedness measures in the face of hurricane watches and warnings than coastal communities, because of their misperceptions about the safety of an inland location (Nigg 1990).

Interorganizational cooperation on St. Kitts and Nevis after Hugo facilitated the response and recovery efforts. However, virtually none of this cooperation was the result of the pre-existing disaster plans, which were widely viewed as "paper" documents, prepared by outsiders with minimal government involvement, and unfamiliar to the officials of the agencies assigned responsibility under the plans (Berke and Wenger 1991b).

The ineffectiveness during Hugo of the Antigua disaster plan and program can be attributed to the fact that it was never formally adopted by the Cabinet and thus had no budget or staff, that there were no meetings to review or update agency responsibilities or drills to reinforce procedures in the three years before Hugo, and that the plan gives no guidance to organizations that might be involved in recovery and mitigation (Berke and Wenger 1991a).

South Carolina county (as opposed to municipal) governments lacked the wherewithal to manage a large response effort; their staffs were small, inadequately trained, had limited funding, and in general were not well informed about the roles of the federal, state, and local governments and their programs for disaster relief or about other basic operational and procedural requirements (Rubin and Popkin 1991).

## Forecasting and Warning

Television broadcasting played a major role in disseminating the advisories and warnings in the Carolinas and in constantly alerting the public to the threat (Rosenthal 1990)

### ——*value of*

State and local officials in both the Caribbean and the Carolinas relied on National Weather Service personnel for the information necessary to make important decisions about safety precautions and evacuations (U.S. Department of Commerce 1990).

In South Carolina the decisions of public officials about evacuation in the face of Hugo were made much easier by the consistency and validity of the forecasts provided by the National Hurricane Center (Baker 1990).

In both the Caribbean and the Carolinas, hurricane probabilities were used in varying degrees by decisionmakers to incorporate forecast uncertainties in their planning efforts (U.S. Department of Commerce 1990).

Civil defense directors in the Virgin Islands, Puerto Rico, and San Juan all indicated that the margin of error of about 60 miles in National Weather Service forecasts of Hugo's path made little difference in their planning; they all prepared for a direct hit (U.S. Department of Commerce 1990).

### ——*deficiencies in*

The National Weather Service's late 1950s radar system was unable during Hugo to measure wind velocity or integrate data obtained from different altitudes or from different parts of the storm. Such information was either inferred or simply left out of the warning process (U.S. Department of Commerce 1990).

The lack of emphasis by the National Hurricane Center of the potential for high winds in the inland Carolinas left the media and local officials with little guidance on how to respond (U.S. Department of Commerce 1990).

Hugo demonstrated the need for better equipment to monitor a storm's activity and forecast its path and intensity (Lord and McConnell 1991).

Hugo's impact on the Carolinas revealed that few broadcasters and government officials understand when the Emergency Broadcast System should be activated or how it works (Wagar 1990).

## Evacuation

### ——*public decisionmaking with regard to*

In South Carolina coastal officials relied very heavily upon the Charleston office of the National Weather Service for advice and judgement about evacuation suitability and timing, and that interaction was more influential than any other input (Baker·1990).

Most emergency management directors in the Carolinas based their decisions of who to evacuate primarily on the Federal Emergency Management Agency/Corps of Engineers inundation and evacuation zone maps. The maps were also shown on CNN and local newspapers. After the storm, the local officials were satisfied with the accuracy of the maps and their decisions (Baker 1990; Federal Emergency Management Agency and the U.S. Army Corps of Engineers 1990).

The clearance time calculations generated by a consultant for the Charleston district of the Corps of Engineers as a part of the hurricane evacuation study for South Carolina provided the basis for local decisions about the timing of the evacuation, and proved to be quite accurate (Baker 1990).

Public officials in the coastal counties of Georgia, South Carolina, and North Carolina employed with varying proficiency the aids (graphical devices and/or computer software) provided by the Corps of Engineers or the Federal Emergency Management Agency to compute the time necessary to evacuate, but at least some used them effectively. A few of the users had gross misconceptions about the capabilities of the tools (Baker 1990).

Few officials in South Carolina exhibited evidence of systematically employing uncertainty information, particularly the National Hurricane Center probabilities, in responding to Hugo. They had only a general concern that the forecast or clearance time calculations might be in error, and were more focused upon the forecast and clearance times themselves (Baker 1990).

### — —*public behavior with regard to*

In areas other than the high-risk barrier islands and beaches in South Carolina (where about 96% of the residents left the area), the evacuation was not extensive enough to be called a complete success (it is estimated that 75–80% of the population of moderate risk areas evacuated), primarily because too many people did not believe that they were being ordered by officials to evacuate (Baker 1990).

Public response to Hugo was extremely good and demonstrated the impact public officials can have on evacuation behavior. Public shelter use and local refuge demand were relieved considerably by officials' urging evacuees to seek other alternatives. Relatively few evacuees left before explicit official recommendations or orders, but in some locales (high-risk barrier islands, for example) a substantial portion did so (Baker 1990).

Of those residents who said they heard neither an official advisory nor an order to leave the area, 61% evacuated anyway (Baker 1990; Federal Emergency Management Agency and the U.S. Army Corps of Engineers 1990).

The majority of South Carolina's at-risk citizens did not leave the area until hours after the mandatory evacuation order had been issued (Peña 1991).

There was no significant difference in the likelihood of evacuating before Hugo between persons who had received disaster preparedness education and those who had not (Faupel and Kelley 1991).

Very few evacuees in the Carolinas or Georgia went to public shelters. More than half went to the homes of friends or relatives, and a smaller proportion stayed in commercial lodgings. People with lower incomes (less than $10,000), residents of manufactured homes, and non-white persons were more likely to go to public shelters after evacuating (Baker 1990; Federal Emergency Management Agency and U.S. Army Corps of Engineers 1990).

Although in August Puerto Rico had mobilized for a direct hit by Hurricane Dean—which stalled at the last minute and turned north, missing the island—residents did not seem hesitant to prepare and evacuate for Hugo (U.S. Department of Commerce 1990).

### ——*value of*

The minimal loss of life from Hugo can be attributed to the development and execution of an emergency preparedness plan by the state and local governments in South Carolina, which resulted in the evacuation of most of the population that was at risk before landfall (Sexton 1990; Sill 1991).

The greatest contributor to the low number of deaths during Hugo was probably luck—the fact that the right side of the eyewall crossed the South Carolina coast in one of the least populated reaches. Although improved and more detailed evacuation maps and studies had been done since 1983, the evacuation procedure used during Hugo—people in most locations did not evacuate until the National Hurricane Center issued a warning—was the same as that used for the last two decades (Baker 1990).

Relatively few impact-phase drownings occurred in Puerto Rico or the Carolinas during Hugo, undoubtedly because of the early warning and widespread evacuation (Centers for Disease Control 1989a; *Morbidity and Mortality Weekly Report* 1989).

The number of deaths and injuries in the storm would probably have been much higher had the governor not ordered the evacuation of all manufactured-home dwellers in coastal counties of South Carolina (Murden 1991; Sparks 1990a).

### ——*limitations of*

Although evacuation notices for South Carolina were timely, they were disseminated successfully only in the most hazardous beachfront and island locations (Baker 1990).

Most residents reported after the storm that they had heard an evacuation notice; very few had interpreted the notice as being mandatory (Baker 1990; Federal Emergency Management Agency and the U.S. Army Corps of Engineers 1990).

## RESPONSE

The South Carolina state network for providing services for the elderly was not prepared for Hugo. County disaster preparedness agencies had differing priorities for their respective response efforts; there was no systematic procedure for accounting for the whereabouts of nursing home residents after they were evacuated, relocated, or their building damaged; the numerous elderly, illiterate South Carolinians had trouble with state and federal assistance procedures. Remedies to these situations were hindered by lack of coordination and communication among responsible agencies and organizations (South Carolina Human Services Coordinating Council 1990).

After Hugo, the interest in and need for onsite, hands-on technical assistance on the part of local officials in South Carolina was great; the officials seemed to be more comfortable with assistance from their peers in unaffected counties or municipalities than from staffs of other levels of government or from experts or consultants (Rubin and Popkin 1991).

Based on the Hugo experience in South Carolina, extensive surveys of channels to identify shoals and obstructions to navigation after hurricanes do not appear to be necessary (Dowd 1990).

Organized, pre-arranged surveillance of public shelters housing evacuees in Puerto Rico during and after Hurricane Hugo not only helped identify and remedy deficiencies at certain sites (potable water, personal hygiene education, portable toilets), but also helped dispel false rumors about outbreaks of infectious diseases (including cholera) in the shelters (*Morbidity and Mortality Weekly Report* 1990).

The Hugo response effort in the Eastern Caribbean was an example of a successful disaster response emphasizing coordination of activities at local rather than national levels (United Nations 1991).

### ——obstacles to

The overflow of donated food and clothing sent to the Charleston area after Hugo contributed to roadway congestion, caused floods of telephone calls into the area, got in the way of shipments of chain saws and other needed goods, and burdened disaster personnel who had other more important functions (Rubin and Popkin 1991).

The fact that right-of-ways were not uniform (they varied from 0 to 185 feet) throughout the South Carolina disaster area and that disposal sites had not been identified or sized by localities at the beginning of the hurricane season caused great confusion and slowed debris removal after Hugo (Dowd 1990).

Hugo showed that assessing state and local needs for disaster relief and the ability of those agencies to provide certain services can be difficult, especially if communications and power are out and roads are blocked, or if the local and state governments are overwhelmed by the needs of their people. Additional aerial surveys can usefully supplement the damage information that the local and state governments are able to provide (Hudak 1991).

Enormous coordination problems and conflicts occurred between county and municipal emergency managers and political executives in South Carolina when the governor set up a separate emergency operations command post in the State House, which functioned independently of the customary Emergency Operating Center established and run by the state's Emergency Preparedness Division (Rubin and Popkin 1991).

### ——need for agency and organizational cooperation in

With the exception of the evacuation process, interactions among the emergency management personnel at each level of government in South Carolina during and after Hugo generally did not go well; the declaration process did not move smoothly (Rubin 1990).

Lack of communication and cooperation among state human services agencies in South Carolina and the lack of a central authority to coordinate staff and resources hampered the state's response to Hugo (South Carolina Human Services Coordinating Council 1990).

The role of the federal government in responding to disaster is neither clear nor universally accepted. The Stafford Act authorized the federal government to supplement the response of the state and local governments on request of the state. But in Hugo, the federal government ended up being the first responder and was criticized for not doing a good job (Peterson 1990).

The capabilities of the state and local emergency management community in South Carolina were not sufficient to respond to a disaster like Hugo or to act as the link to the federal government in its response (Peterson 1990).

In Hugo we found out that the local and state government agencies that are assumed to be first responders to disasters can be victims too (Peterson 1990).

## Disaster Aid and Assistance

In both St. Kitts and Nevis, nongovernmental organizations were generally more effective than governmental agencies at monitoring the distribution of disaster aid after Hugo and at ensuring that recipients complied with guidelines for use of the aid (Berke and Wenger 1991b).

Montserrat's post-Hugo experience showed that if external donor organizations impose inflexible and stringent conditions on how disaster aid is to be used by domestic organizations, the commitment and capacity of those domestic organizations to carry out recovery programs can be severely diminished (Berke and Wenger 1991b).

Antigua's post-Hugo experience showed that if external donor organizations impose inflexible and stringent conditions on how disaster aid is to be used by domestic organizations, then the pace of recovery is constrained due to bureaucratic red tape (Berke and Wenger 1991b).

Inflated damage estimates from inexperienced Antiguan officials after Hugo undermined Antigua's credibility with the international relief agencies and resulted in delays in the provision of aid (Berke and Wenger 1991a).

An ad hoc Disaster Relief Committee established shortly after Hugo to acquire, distribute, and coordinate housing aid in Antigua was considered to be very effective for three reasons. First, the committee functioned outside of existing governmental organizations and thus had a separate identity and authority and was not viewed as being politically motivated. Second, the committee was headed by an Antiguan official, rather than an expatriate, thus projecting a confident impression that the Antiguans were in charge of their own redevelopment effort. Third, the committee members had considerable experience in housing (Berke and Wenger 1991a).

## Communications

Hugo demonstrated that neither cable nor broadcast television is a reliable mode of communication with the public during a disaster. The VHF and cable stations in the impact area of the Carolinas were out of service hours before the eye of the storm arrived. Most residents were without power to operate televisions anyway. Likewise, only one AM radio station in the path of the storm was able to maintain service, because it had its own emergency generator. Most of the radio and television stations in the Emergency Broadcast System were damaged or lost power and were unable to transmit for several days (Badolato et al. 1990; Cook 1991).

Hugo showed that communications systems are so critical to manipulation of other resources in emergencies that they must be considered among the most valuable of those resources (Griswold et al. 1990)

The South Carolina Law Enforcement Division's statewide FM radio net with its long-range automatic repeaters strategically placed around the state was the most reliable emergency communications link between the state Emergency Operations Center and areas affected by the storm. Hugo also demonstrated the value of cellular phones and FAX machines (Badolato et al. 1990).

Because of power outages, the best means of communication with the citizens of the Charlotte, North Carolina, area immediately after Hugo was the daily newspaper (Shook and Steger 1989).

Charleston Public Works officials had a difficult time getting the media and public informed about which areas had safe water and which areas had questionable water after power was restored to the main treatment plant (Cook 1991).

Public services announcements on the radio and television and in the newspapers were successful in advising the public of the U.S. Virgin Islands about the status of the drinking water, extent of contamination, and measures to take to purify it or obtain water from alternative sources (Christian 1992).

## Utilities

Hugo's impact on Charlotte, North Carolina, and on Charleston, South Carolina, showed that the loss of electrical power has direct effects on the ability of a community to begin recovering from a disaster because the power system is central to the operations of other lifeline systems. Although water and sewerage facilities, for example, are able to withstand significant hurricanes with little physical damage, the systems cannot function without electrical power (Nigg 1990).

Of the 80 remote lift stations of the Charleston wastewater treatment system, only 4 had onsite emergency generators. The rest were inoperable for extended periods. A few instances of sewage overflow occurred before portable generators could be installed (Cook 1991).

The extensive nature of the power outages in the Carolinas and the fact that the recurrence interval for Hugo was 25 years or less in most areas makes it obvious that there were an enormous number of deficiencies in the power transmission and distribution systems (Saffir 1991; Sill 1991).

Hugo showed that the energy industries can respond to natural disasters and emergencies capably and quickly and that state, local, and federal planning for natural disasters that takes such industrial capability into account can be effective (Badolato et al. 1990).

Hugo demonstrated that the availability and operation of emergency electric power generators are major considerations in emergency preparedness planning for natural disasters. All sizes of generators proved invaluable in the Carolinas, especially in rural communities (Badolato et al. 1990; Shook and Steger 1989).

Restoring gas and electricity to the Carolinas after Hugo required significant control of traffic and people, and debris removal operations by designated security forces (the National Guard) (Badolato et al. 1990).

The most serious electric safety accidents after Hugo in South Carolina and Puerto Rico involved backfeeding current from portable generators through downed lines (Badolato et al. 1990).

## RECOVERY

### ——need for organizational and agency cooperation in

Serious problems in beginning immediate recovery in the counties around Charleston stemmed from the lack of knowledge about the federal role in major disasters, about the Federal Emergency Management Agency's mandated functions, and about the complex intergovernmental relationships typical of disaster recovery (Rubin and Popkin 1991).

Damage assessment, project design, and reconstruction in the areas of South Carolina that were hardest hit by Hugo were aided immensely by volunteer engineers and architects (Mittler 1991).

Lack of interorganizational coordination and advance disaster planning on Montserrat after Hugo slowed the pace of recovery. Conflicts, duplication of effort, and ad hoc decisionmaking used up scarce staff time and resources (Berke and Wenger 1991c).

Pre-existing collaboration between the Antiguan Department of Agriculture and local rural development cooperatives on St. Kitts made it possible for individual farmers and fishers to obtain recovery aid in a timely, effective, and accurate manner after Hugo (Berke and Wenger 1991b).

### ——value of financial assistance in

The Economic Development Administration (EDA) direct loans for infrastructure repairs and reconstruction, state matching grants, and Federal Emergency Management Agency awards were the primary reasons many communities in South Carolina made such rapid progress in the recovery process. The EDA grants also allowed for the expansion of business and industry, thus creating new job opportunities within the disaster counties (The Fontaine Company, Inc. 1991).

### ——lack of planning for

When Hugo hit South Carolina, the warning and evacuation activities worked well, but when the storm was over no one seemed to know what to do next because at all levels of government recovery planning either had not been done or had been done poorly (Rubin and Popkin 1991).

### ——obstacles to

In the course of attempting the massive repair and reconstruction needed in South Carolina after Hugo, it was discovered that there was a deficiency of qualified building officials in the stricken counties and no way to identify or contact the ones that did exist. Furthermore, many of the engineers, architects, builders, and building officials that were available in the area had inadequate training in proper construction standards for coastal and other hazardous environments (Lindbergh 1991).

# MITIGATION

## ——*value of*

Hugo demonstrated that mitigation activities are significant in reducing both life and property losses. Newer structures meeting the construction standards of the National Flood Insurance Program suffered less damage (Peterson 1990).

Hugo demonstrated that government intervention in the market in the form of firm and fair code enforcement and regulation of the sort practiced by the South Carolina Coastal Council can increase the survivability, profitability, and continuity of businesses while enhancing the environment and public health and welfare (Miller 1990).

## ——*inadequacy of current efforts*

If all that we know about preventing and reducing losses to buildings, infrastructure, and other human systems had been properly put into practice before Hugo, the storm's damage would have been reduced by several billion dollars (Sill 1991).

The status of the response and recovery effort after Hugo in South Carolina suggests that the Federal Emergency Management Agency's (and/or other organizations' and agencies') provision of training and education and its support of state training in emergency management and recovery are ineffective; there was a serious lack of research- and experience-based knowledge about recovery and mitigation (Rubin and Popkin 1991).

Poor drainage and clogged ditches left from unremedied Hugo damage were partially responsible for floods in South Carolina's Orangeburg and Calhoun counties in 1990 (The Fontaine Company, Inc. 1991).

In view of the enthusiastic redevelopment of the South Carolina coast after Hugo it is clear that the current state of public education about coastal storm occurrence, its related erosion, its long-term impacts, and the possible responses to it is simply inadequate (Wood 1990).

In most cases, public officials and private citizens in South Carolina were not sufficiently motivated after Hugo to demand that damaged buildings be reconstructed to withstand future natural disasters. Underlying negative attitudes toward building codes and their enforcement hindered the application of improved methods (Mittler 1991).

The widespread publicity in the press and in technical publications that Hugo was a 135-mph storm (when the maximum sustained wind speeds were calculated at 115–120 mph), will have an adverse effect on mitigation of future damage, because people wrongly believe that the surviving buildings performed well in high winds and that Hugo was an exceptionally severe storm (McDonald and Smith 1990).

Especially in the more seriously damaged jurisdictions of South Carolina, building officials were overwhelmed by the number of structures requiring inspection after Hugo. In some areas, homeowners claiming not to have structural damage were instructed to proceed with repairs without permits; another city suspended the enforcement of all building codes (Mittler 1991).

Building officials in several South Carolina cities and counties indicated that there was no reason for contractors to bother with variance requests for repair or rebuilding of Hugo-damaged structures because they could get their plans approved by simply ignoring the code requirements or by claiming that their plans did comply with the code (Mittler 1991).

No South Carolina community attempted to enforce the building code on all the repairs of all structures damaged by Hugo (Mittler 1991).

In Puerto Rico, many of the repairs and reconstruction done after Hugo were carried out according to pre-existing practice, making the same mistakes in design and construction (Rodriguez et al. 1991).

### ——post-Hugo recommendations for

Hugo-related deaths might have been avoided through efforts to educate the public about 1) hazards of power outages, including electrocution and the danger of using candles or open flames for light and heat; 2) the need to evacuate from manufactured homes; 3) hazards of boating during high winds; 4) risks of injuries during disaster cleanup, especially when unfamiliar equipment is being used; and 5) avoiding exacerbation of medical conditions by becoming fatigued, stressed, or separated from needed medical support. (Centers for Disease Control 1989a; *Morbidity and Mortality Weekly Report* 1989).

The performance of structures during Hugo showed that a long-term impartial organization for testing the way high winds affect buildings and their components is needed in the United States (Levinson 1990).

A comprehensive electric safety education program emphasizing the hazards of downed power lines, of "feedback" energy from emergency generators in presumably de-energized lines, and by metal objects near utility lines could have helped avoid post-Hugo injuries (Centers for Disease Control 1989b).

If a local-option sales tax had been in place in South Carolina immediately after Hugo, communities could have benefitted from the post-Hugo building boom, helping to compensate for property tax revenues lost when substantial numbers of hurricane-damaged buildings were devalued (Felts 1990).

Hugo demonstrated clearly the great need for better training and education about the known phenomena, behavior, procedures, and needs common during and after a major disaster (Rubin and Popkin 1991).

Hugo provided new insights into the levels of effort and knowledge needed to effectively accomplish recovery that incorporates mitigation measures. The difficulties entailed in these processes continue to be significantly underestimated (Rubin and Popkin 1991).

The good news from Hugo is that we know how to reduce the impacts of coastal storms; the bad news is that we are doing it piecemeal at best (Richardson 1990).

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# ACKNOWLEDGEMENTS

The work upon which this report is based was funded by the Federal Emergency Management Agency (FEMA) and carried out by the Association of State Floodplain Managers, Inc., (ASFPM) under contract no. EMW-90-G-3304,A001. The research and writing was done by Jacquelyn L. Monday under contract to the ASFPM. Larry Larson, Executive Director of the ASFPM, coordinated the work on the Association's end, and Cecelia Rosenberg was the Project Officer for the Federal Insurance Administration of FEMA. The Association thanks Elizabeth Lemersal, Porter Martin, Bill Massey, Billy McKinnon, Claire Rubin, Pat Stahlschmidt, and French Wetmore for their review and comments on the draft report.