LEARNING FROM HURRICANE HUGO:

IMPLICATIONS FOR PUBLIC POLICY

An Annotated Bibliography

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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 came to be known as Hurricane Hugo made its way across the Caribbean Islands and up the southeastern coast of the United States, and came ashore along the South Carolina coast. It resulted in 49 deaths, widespread damages and losses estimated to exceed $9 billion, the temporary displacement of hundreds of thousands of people, and disruption of the lives of about 2 million people. The long-term impacts of the disaster 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 similar documentation. This bibliography is a collection of citations and annotations to the material written about Hugo that has relevance to present or future public policy. Such a collection should assist both the public officials who must plan for or cope with hurricanes, and the researchers whose work helps them make their decisions.

Documents were reviewed and selected for this bibliography on the basis of two criteria. First, the document must have originated with a person or organization with recognized expertise in or official standing with regard to the subject matter. Second, the document had to include information from which something could be learned that would have implications for public policy, as opposed to the concerns of the private sector. Based on these criteria, most of the entries are the reports of scholarly or scientific studies, or are the work of local, state, or federal officials whose agencies have some responsibility for natural disasters like hurricanes. The following were not included: newspaper and magazine stories, victims' accounts of their experiences, letters to the editor, photographic essays, explanations of how particular businesses or industries survived the storm or its aftermath, news stories in trade journals, and the like.

The bibliography is organized by topic, and alphabetically by author's name within each topic. An index to authors' names appears at the end of the bibliography. Multi-topic works were entered under the heading that best describes their main focus. Copies of most of the materials listed in this bibliography are also entered in 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 at the University of Colorado. A companion document, *Learning from Hurricane Hugo: Implications for Public Policy*, lists key findings or lessons from the reports and studies reviewed for this project.

PHYSICAL CHARACTERISTICS OF THE STORM

Coch, Nicholas K., and Manfred P. Wolff 1990. Probable effects of a storm like Hurricane Hugo on Long Island, New York. *Northeastern Environmental Science* 9(1/2):33–47.

> Hurricane Hugo and the 1938 hurricane that struck Long Island were similar in their shore-normal tracks and the types of devastation they spread far inland. Further, the geomorphology, coastal features, and degree of urban and suburban development in the Charleston area is similar to that on Long Island today. Taking the effects of the two storms and these background similarities, the authors project the damages that the New York coast would suffer at the landfall of a hurricane like Hugo. They recommend more stringent and restrictive setbacks and building codes; maintenance of dune height and continuity; unimpeded sand flow along the shoreline; a well-designed evacuation plan; and provisions for maintaining law and order after such a major disaster.

Garcia, A. W., B. R. Jarvinen, and R. E. Schuck-Kolben 1990. Storm surge observations and model hindcast comparison for Hurricane Hugo. *Shore and Beach* 58(4):15–21.

> This article describes the extent and distribution of storm surge during Hurricane Hugo as deduced from tide gage data and high-water mark observations and compares them with hindcast results from SLOSH. The model results match the observed high-water marks quite closely at most sites and differ only up to 15% at others. Although the model does not reproduce Hurricane Hugo's initial water level rise, it did reproduce the time of arrival and elevation of the storm surge peak.

Marshall, Richard D. 1991. Lessons learned by a wind engineer. Pp. 160–69 in Benjamin L. Sill and Peter R. Sparks, eds., *Hurricane Hugo One Year Later, Proceedings of a Symposium and Public Forum.* New York: American Society of Civil Engineers.

> Surface wind speeds during the passage of Hurricane Hugo through the U.S. Virgin Islands and Puerto Rico are described in this article. Although damage to the affected areas was extensive, an assessment of relevant data indicates that the actual wind speeds were far lower than those reported by the news media. The consequences of overstating the wind speeds are examined and actions to improve the accuracy of measuring and reporting wind speeds are outlined.

Powell, Mark D. 1991. Meteorological aspects of Hurricane Hugo. Pp.11–40 in Benjamin L. Sill and Peter R. Sparks, eds., *Hurricane Hugo One Year Later, Proceedings of a Symposium and Public Forum.* New York: American Society of Civil Engineers.

This paper discusses the meteorological aspects of Hugo that influenced the storm's track, the changes in intensity before landfall, and the surface wind distribution at various stages during the decay of the storm. The surface wind distribution is emphasized because of its effect on structural damage overland and its importance in forcing the storm surge and waves responsible for much of the coastal damage. Expansion of the surface observation network is recommended to improve data on surface wind fields in future storms.

Powell, M. D., and P. G. Black 1990. Meteorological aspects of Hurricane Hugo's landfall in the Carolinas. *Shore and Beach* 58(4):3–13.

Although meteorologists continue to learn about hurricane motion and track prediction, which should lead to improved future forecasts, little is known about predicting changes in intensity of storms like Hugo. A 24-hour forecast of intensity is especially important to emergency preparedness officials, because a more intense storm can result in a larger area of inundation, requiring preparedness and evacuation of a much larger population. This paper discusses the factors influencing Hurricane Hugo's storm track, the changes in intensity before landfall, and the surface wind distribution at various stages during the storm's decay. It concludes that Hurricane Hugo's rapid intensification (1 millibar/hour) over the six hours before landfall was associated with both low upper-level wind shear in the storm periphery and the passage of Hugo over the Gulf Stream. Determination of the surface wind field at landfall was hampered by lack of data, and expansion of the surface observation network and use of remote sensing instruments is recommended.

Rosenthal, Stanley L. 1990. Summary of the special sessions on Hurricane Hugo: 70th Annual Meeting of the American Meteorological Society. *Bulletin of the American Meteorological Society* 71(9):1339–42.

This article summarizes five special sessions about different aspects of Hurricane Hugo, beginning with a track of the storm's path, intensity, and speed. Forecast models used to predict the storm's movement from its origin off the coast of Africa until tracking stopped in the far north Atlantic two weeks later were compared for their accuracy. The impacts of the storm in the Caribbean and on the U.S. mainland were presented. Differences between flight-level winds and surface winds were discussed and suggestions for developing surface windfields from flight-level data were made. An analysis by a model known as HURISK computed the return period of a storm of Hugo's intensity as 430 years and the probability of having no hurricanes in the area for 25 years as 2%. Measurements of vertical electrical field, liquid water, and vertical velocity obtained by penetration of Hurricane Hugo's eyewall by National Oceanic and Atmospheric Administration's P-3 aircraft on September 15, 16, and 19 were presented. It was suggested that Hugo and other recent hurricanes signal the return to more intense Atlantic hurricane activity such as that of the 1950s and 1960s. The evolution of Hugo's precipitation structure based on radar reflectivity data was discussed, along with the reasonable accuracy of predicting Hugo's track and timing displayed by the ECMWF operational forecast model. Two other presentations described the in-flight emergency (loss of one engine) suffered by one P-3 during penetration of the storm and the

possibility that a small "suction" vortex, similar to that encountered in tornados, was responsible. A final segment was the presentation of several videos of satellite, infrared, color-enhanced, radar, and other imagery.

Schuck-Kolben, R. Erik 1990. *Storm-tide elevations produced by Hurricane Hugo along the South Carolina coast, September 21-22, 1989.* Open-file report 90-386. Columbia, S.C.: U.S. Geological Survey.

High-water marks produced by the storm tide from Hurricane Hugo on September 21-22, 1989, were identified, described, and level-surveyed along the South Carolina coast from North Myrtle Beach to Seabrook Island. Three hundred and fifteen marks are presented in tables with the latitude and longitude, quality of the mark, water surface elevation, and ground elevation noted. The marks and contours of approximate storm-tide elevations are plotted on 31 7 1/2-minute topographic quadrangle maps. The average elevation of the storm tide above sea level ranged from 7 feet at the North Edisto River mouth to 20 feet near Moores Landing.

Sparks, Peter R. 1991. The facts about Hurricane Hugo—what it was, what it wasn't and why it caused so much damage. Pp. 278-85 in Benjamin L. Sill and Peter R. Sparks, eds., *Hurricane Hugo One Year Later, Proceedings of a Symposium and Public Forum.* New York: American Society of Civil Engineers.

The wind and surge conditions during Hugo are described, and the extent of damage to buildings and utilities and the reasons for their poor performance are discussed. The paper concludes that there was a considerable amount of misinformation circulating about the conditions during Hugo; in general, the public was led to believe that the wind and surge conditions were more severe than they actually were.

IMPACTS ON HUMANS AND HUMAN SYSTEMS

Christian, Cora L. E. 1992. *Hurricane Hugo's Impact on the Virgin Islands.* Working Paper no. 73. Boulder, Colo.: University of Colorado, Natural Hazards Research and Applications Information Center. 66 pp. $ 4.50.

> A research team from the Virgin Islands Department of Health conducted two surveys of the island population, one shortly after Hurricane Hugo, and another one year later. From the data obtained the researchers developed a demographic profile of the population before and after Hugo, assessed the effects of the storm on the physical and mental health of the residents, and ascertained possible long-term effects of Hugo on the psychological and social environment of the islands. Among the conclusions are that a portion of the population permanently left the islands after Hugo; that socioeconomic and educational differences among various segments of the population can exacerbate the impacts of a disaster; and that radio was the overwhelming means of alerting the public to the impending storm.

Hamm, Steven W. 1990. Battling disaster profiteering. *State Government News* 33(3):22–23.

> Emergency ordinances barring price gouging, special price-gouging hotlines, and stern public statements by officials, such as the mayor of Charleston, all helped prevent the damage done by Hugo from becoming even more expensive for the affected citizens. Public information campaigns were mounted to advise consumers how to avoid being defrauded in attempts to get their property repaired promptly.

Hornig, Susanna, Lynne Walters, and Julie Templin 1990. Voices in the news: newspaper coverage of Hurricane Hugo and the Loma Prieta earthquake. Paper presented at the Association of Education in Journalism and Mass Communication Annual Meeting, Minneapolis, 1990. Reprints available from authors, Department of Journalism, Texas A&M University, 230 Reed McDonald Building, College Station, TX 77843-4111, (409) 845–4611.

> This paper summarizes the results of a study of how newspaper coverage of the Loma Prieta earthquake and Hurricane Hugo used quotations from expert sources to construct claims about institutional needs and responsibilities. The study showed that specialized information used in newspapers usually comes from an appropriate expert source, although there was a strong tendency to obtain general comments or observations—rather than appropriately specific ones—from all types of sources, including experts. Elected officials and government agency representatives were the sources of 55% of all the quotations used. When experts were quoted, their general comments were almost as likely to be used as those based on their professional expertise. The authors conclude that their data support the assertion that the news stories were forums in which various interests competed to establish a public definition

of the disaster situation that recognized their own claims to primacy and to the resources necessary to accomplish their objectives.

Kaniasty, Krzysztof, and Fran H. Norris 1991. In search of "altruistic community": social support following Hurricane Hugo. Poster session presented at the Third Biennial Conference of the Society of Community Research and Action, Tempe, Arizona, June 1991.

Although many victims of catastrophic events receive substantial help (tangible physical or financial assistance, guidance, and emotional support) through altruistic communities that emerge after the disaster, not all victims participate or benefit fully. In a sample of 1,000 persons, 750 of whom resided in the Hugo impact area, it was found that several demographic factors—mainly age, education, sex, and network size—were consistently related to supportive behavior. Blacks, older, and less educated respondents were victims not only of disaster but also of a "pattern of neglect" in that they received proportionately less help than white, younger, and more educated victims.

Miller, Kristen S., and Catherine Simile 1992. "They could see stars from their beds": the plight of the rural poor in the aftermath of Hurricane Hugo. Paper presented at the Society for Applied Anthropology Annual Meetings, Memphis, Tennessee, March 1992.

This paper analyzes the impacts of Hugo on the housing situation of the rural poor of the Charleston area—an isolated, invisible population that rarely interfaces with outsiders. Three types of groups responded to their needs: church-based outreach programs, community service programs of businesses, and government programs. All three entities had both resources and personnel available to address the housing problems manifested by Hugo, but all were also limited to alleviating symptoms rather than finding solutions to long-term inadequacies in housing that were only exacerbated by the hurricane.

South Carolina Human Services Coordinating Council 1990. The State Human Services Agency Response to Hurricane Hugo. Columbia, S.C.: South Carolina Human Services Coordinating Council. 27 pp.

This is the report of a survey of the impact from Hugo on state human services agency operations, costs of the relief effort, barriers to restoring services, and recommendations for improving response in future disasters. Most agencies surveyed indicated that their liability insurance would cover most of the $5.1 million in damages. Some of the barriers impeding the relief effort were damage to facilities, power outages, lack of central authority and plans for coordination, stressed staff, and inconsistency of federal regulations for assistance. The report recommends better training on psychological trauma; a plan for specific staff assignments; a comprehensive public education and information dissemination network; and training of emergency personnel to assist clients with special needs, such as the elderly, disabled, and the homeless.

PSYCHOLOGICAL EFFECTS

Aptekar, Lewis 1991. *The Psychosocial Process of Adjusting to Natural Disasters*. 47 pp. Working Paper #70. Boulder, Colo.: University of Colorado, Natural Hazards Research and Applications Information Center. $4.50.

> This paper examines how victims and relief workers in two communities, one hit by Hurricane Hugo and the other by the Loma Prieta earthquake, responded to the disasters. The author identifies four phases—altruism, denial, anger, and final resolution—of psychological recovery from disasters. The demographic and political components of the communities, the differences between the two types of disasters, and the relationship between the victims and relief workers are all discussed in terms of how they affected victims' responses. The author recommends role-playing techniques to train relief workers to recognize and properly deal with the stress, denial, anger, frustration, and sense of loss that disaster victims experience.

Austin, Linda S., M.D. 1991. In the wake of Hugo: the role of the psychiatrist. *Psychiatric Annals* 21(9):520-24.

> A community-based disaster like Hugo is a different sort of stress from the individually experienced traumas that psychiatrists are accustomed to treating. Because the damages and losses are so widespread and evident, the community will naturally and spontaneously engage in mass group therapy to heal the emotional trauma of a hurricane. The psychiatrist will be called upon to facilitate this process using large-group interventions and the media.

Belter, R. W., S. E. Dunn, and P. Jeney 1991. The psychological impact of Hurricane Hugo on children—a needs assessment. *Advances in Behaviour Research and Therapy* 13(3):155–61.

> The researchers collected data through questionnaires administered to both parents and children in three elementary schools in the Charleston area about five months after Hurricane Hugo. The parents' responses at all three schools clearly revealed that the material, financial, and emotional impact of the hurricane on the families was enormous. About 90% of the children could be classified as experiencing "severe psychic trauma," according to the responses to the children's questionnaire. In contrast, the parental reporting of the children's emotional symptoms indicated that only about 69% could be so classified. Parents and children's responses both revealed that the hurricane was sufficiently traumatic to cause the overwhelming majority of children to be significantly distressed even five months after the storm. However, the overall global adjustment of the children (ability to function smoothly in their daily lives) was not adversely affected.

Boore, Judith A., Gina Earle, and Lewis Aptekar 1990. *Psychological Effects of Disaster on Children and Their Families: Hurricane Hugo and the Loma Prieta Earthquake*. QR#40. Boulder, Colo.: University of Colorado, Natural Hazards Research and Applications Information Center. 37 pp. $3.75.

> This study explores the relationship between resiliency and the psychopathology or emotional reaction of children in two major natural disasters. One to four weeks after the disasters parents and children were evaluated using interviews and checklists. The research indicated

that factors such as family dynamics and parental emotional state are important indicators of a child's resiliency. The authors also noted that outside aid in the form of food, clothing, money, housing, and insurance seemed to have a substantial positive effect on the parents' and children's morale and behavior; likewise, the presence of enthusiastic volunteer labor appeared to lift victims out of their helplessness and depression.

Norris, Fran H., and Krzysztof Kaniasty 1992. Reliability of delayed self-reports in disaster research. *Journal of Traumatic Stress* (in press).

In studies of traumatic stress, researchers often find themselves asking questions about an event and its aftermath long after the crisis has passed. This study assessed the reliability of these delayed self-reports. In January 1991, 65 Charleston residents were interviewed by telephone about their experiences after Hurricane Hugo, which had occurred 16 months before. The interview included assessments of disaster related losses, preparedness, social support received from others, and social support provided to others. In October 1991 (25 months after the event), the same persons were reinterviewed and asked the same questions. For reports of losses and preparedness, the accuracy of the later reports showed remarkable stability over time. There was a tendency to remember more social support as time passed.

Shaw, Darlene L., Pat Jarrell, John Freedy, and Cheryl Bene 1991. *Psychological Sequela of Hurricane Hugo: An Application of the Conservation of Resources Model of Stress*. QR#45. Boulder, Colo.: University of Colorado, Natural Hazards Research and Applications Information Center. 36 pp. $3.75.

This study aimed to generate empirical data to evaluate the applicability of the "conservation of resources model," which measures how stress reactions occur. The model is based on the supposition that people strive to retain, protect, and build four types of resources: 1) objects (property, material belongings); 2) conditions (marriage, job roles); 3) personal characteristics (self-esteem, sense of control); and 4) energies (time, money). The results of a survey of 1,200 faculty and 250 students at the Medical University of South Carolina about eight weeks after Hugo revealed that, in general, a significant proportion of both faculty and students suffered loss of resources, psychological distress, and changes in their health habits after Hugo. For both groups, higher losses of resources resulted in greater distress.

Sullivan, M. A., C. F. Saylor, and K. Y. Foster 1991. Post-hurricane adjustment of preschoolers and their families. *Advances in Behaviour Research and Therapy* 13(3):163–71.

Through questionnaires distributed to parents of 632 children in three preschools, this study assessed parental reports of the children's reactions 6–8 weeks after Hurricane Hugo. Preschoolers displayed significant changes in their behavior after the hurricane, including increases in the number of problem behaviors exhibited, and in the severity of those behaviors. Most behaviors remained in the normal range, however. The increase in behavior problems was attributed in part to pre-disaster behavior problems, total stressors experienced, and the parents' level of stress.

DEATHS AND INJURIES

Centers for Disease Control 1989. Medical examiner/coroner reports of deaths associated with Hurricane Hugo—South Carolina. *Journal of the American Medical Association* 262(22):3111–12.

> This article provides information about the demographic characteristics, cause, and circumstances of each of the 35 hurricane-related deaths reported between September 21 and October 6, 1989 in 25 South Carolina counties. During the storm, 13 people were drowned or crushed by falling objects. After the storm, 22 people died in house fires, from electrocution, from being crushed by falling trees, or from stress-related heart attacks. One death was the result of a chainsaw injury sustained during the cleanup. The article also discusses the definition of "hurricane-related death" and how the information was gathered through medical examiner/coroner systems.

Centers for Disease Control 1989. Update: work-related electrocutions associated with Hurricane Hugo—Puerto Rico. *Journal of the American Medical Association* 262(20):2806.

> Five of the six Hugo-related electrocutions in Puerto Rico were work-related. They involved linemen, a tree trimmer, and a meter-reader—all with many years of experience. The article describes the circumstances of the accidents and the recommendations that were made to health departments and electric companies to avoid future occurrences.

Morbidity and Mortality Weekly Report 1989. Deaths associated with Hurricane Hugo—Puerto Rico. *Morbidity and Mortality Weekly Report* 38(39):680–82.

> Nine hurricane-related deaths were reported by the Medical Examiner in Puerto Rico between September 18 and September 29, 1989. Seven were electrocutions and two were drownings of persons who refused to be evacuated to safer locations.

Philen, Rossanne M., Debra L. Combs, Lynn Miller, Lee M. Sanderson, R. Gibson Parrish, and Roy Ing 1992. Hurricane Hugo-related deaths: South Carolina and Puerto Rico, 1989. *Disasters* 16(1):53–59.

> Medical examiners and coroners contacted for this study identified 44 hurricane-related deaths in Puerto Rico and South Carolina from the day before Hugo struck the area to 12 days afterward. Among the dead were 32 men and 12 women, ranging in age from 1 year old to 94. There were eight drownings, eight instances of death by blunt trauma (falling trees and parts of buildings), eleven electrocutions, nine deaths in house fires started by candles, one asphyxiation under an uprooted tree, one chain saw laceration, and six stress-related heart attacks. The article concludes with recommendations for emergency managers on how to avoid similar deaths in future hurricanes.

UTILITIES AND TRANSPORTATION SYSTEMS

Cook, Ronald A. 1991. Hurricane Hugo vs. critical lifelines. Pp. 71–78 in Benjamin L. Sill and Peter R. Sparks, eds., *Hurricane Hugo One Year Later, Proceedings of a Symposium and Public Forum.* New York: American Society of Civil Engineers.

> Except for storm surge damage on the barrier islands, the primary causes of lifeline damage during Hugo were wind and wind-blown debris, particularly falling trees. The loss of electrical supply due to downed lines caused problems with other lifelines that relied on electricity. In general, the providers of lifeline services were prepared to cope with the damage that was expected from Hugo, but the actual damages were far more severe than anticipated.

Morris, Gregory L., and J. Hari Krishna 1991. *Hurricane Hugo and its Effects on Water Supplies in the U.S. Virgin Islands and Puerto Rico.* St. Thomas: University of the Virgin Islands, Water Resources Research Center.

> This paper documents the types of damages to water supply systems caused by Hugo. The principal supply problems were the loss of the electrical power needed to operate water supply infrastructure, damage to cistern systems and contamination of cistern water by wind-blown material, and damage to the electrical components of desalination systems by hurricane-driven rain and salt spray. Operational measures taken in the aftermath of the storm are detailed. Among the recommendations for mitigation are the use of underground power cables at least for essential services, the maintenance of redundant backup generators and similar equipment, and ensuring that cistern owners (residential cisterns are required by the Virgin Islands building code) take steps to protect their water supplies from contamination during a hurricane.

Nigg, Joanne M. 1990. Lifeline disruption in two communities: Charleston, South Carolina, Charlotte, North Carolina. Paper presented at the University of Puerto Rico Conference, Six Months After Hurricane Hugo, Mayaguez, Puerto Rico, March 12-14, 1990.

> This paper reports the preliminary results of a comparison of four lifeline systems (power, telephone, water, and sewage) in one inland and one coastal community in the aftermath of Hugo. Among the conclusions are that inland communities are less likely to take preparedness measures as a result of hurricane watches and warnings than coastal communities; few lifeline companies or agencies were prepared before Hugo for the possibility of a regional catastrophe; very little attempt is made to integrate representatives from lifeline organizations into the government's emergency response planning process; and the failure of the power system has direct effects on the ability of a community to begin recovering from a hurricane.

Peña, Hernan E., Jr. 1991. A post Hurricane Hugo transportation study. Pp. 230–37 in Benjamin L. Sill and Peter R. Sparks, eds., *Hurricane Hugo One Year Later, Proceedings of a Symposium and Public Forum.* New York: American Society of Civil Engineers.

This article summarizes a study of the effects of Hurricane Hugo on Charleston's transportation infrastructure. The various transportation-related events of the storm are described, including the evacuation and recovery operations. Vehicle operating costs rose 35% in the aftermath of the hurricane, largely due to increased idling time and more stops and starts. The volume of traffic along selected arterials in Charleston increased by 20% immediately after the storm, and a 20% increase in accidents was found during the subsequent three months.

THE ECONOMY

Felts, Arthur A. 1990. The policy impacts of Hugo: the view from the lowcountry. *The South Carolina Forum* (April-June):32–33.

This brief article addresses some of the key local and state policies that were affected by Hugo's landfall in South Carolina. The biggest impact expected for 1990 was lost property taxes, because of the destruction and devaluation of a large amount of property throughout the state; the city of Charleston acted quickly to help compensate for this loss by increasing property taxes by 15% for one year. A local option sales tax was passed by the state legislature shortly after Hugo, allowing for a referendum on a local one-cent sales tax. The other principal policy issues center on coastal construction. The Beachfront Management Act was expected to receive serious challenge, and there was expected to be wide support for improved building codes and enforcement of them.

The Fontaine Company, Inc. 1991. An Analysis of the Damage and Effects of Hurricane Hugo and Status of Recovery One Year Later. Report prepared for the Governor's Office, Division of Intergovernmental Relations. Columbia, S.C.: The Fontaine Company, Inc. 200 pp.

This study analyzes the damage and effects of Hugo and the status of the recovery one year later in the 24 counties that had Presidential disaster declarations as a result of the storm. The work entailed collecting data and coordinating already-existing data, analyzing damages and recovery and economic forecasts of the area's economy with and without the storm, and making recommendations to facilitate economic recovery and development with regard to the economy itself, infrastructure, natural resources, housing, environment, and solid waste. Of the total $6.4 billion in physical damages in the state, it was calculated that all but $3 billion was "reimbursed" through insurance payments, public assistance, and salvage. Of the unreimbursed losses, about half was shouldered by residences, a problem that will affect the state's economy over the long run. The other half was accounted for by the forestry and agriculture sectors. Forestry was the big loser overall; of the estimated $1.2 billion in damages to timber, only about $150 million was recovered. Numerous recommendations are made for various sectors of the economy, including that long-term effects on the state's economy continue to be analyzed; that infrastructure within the disaster areas be monitored for long-term impacts; that state and local officials initiate a wildlife census in the disaster

counties; and that the state make local participation in state-funded projects contingent upon local passage of minimum building codes, particularly for manufactured housing.

Lord, J. Dennis, and Lee W. McConnell 1991. Property damage and retail sales impacts of Hurricane Hugo. *Area* 23.3:229–37.

The researchers tracked the sales of a do-it-yourself retail chain with stores both inside and outside the storm corridor and compared 1989 sales with those for the same months of the previous year. They also examined the geographic pattern of disaster aid paid by the Federal Emergency Management Agency to state and local agencies across the Carolinas. Both sets of data illustrated the path and relative intensity of the hurricane, with high per capita damage payments in the three Charleston area counties, a decline in damage payments inland, and a decrease on either side of the path of the storm's eye; damage extended much farther east of the path of the eye than to the west of it. Stores along the path of the eye experienced the largest increases in sales (some coastal stores had 200% or more increases for October and November after the storm) with the magnitude of the increases declining inland.

IMPACTS ON NATURAL SYSTEMS

Bush, David M. 1991. Impact of Hurricane Hugo on the rocky coast of Puerto Rico. *Journal of Coastal Research* SI(8):49–67.

> In contrast to the entirely sandy and gently sloping coast of South Carolina, Puerto Rico's coastline is a series of sandy stretches separated by rocky stretches or headlands, with coastal lowlands that are narrow and relatively steep. Because Hugo was about the same intensity when it made landfall at both locations, a comparison of the response of both coastal types can be made. Intense damage in Puerto Rico was largely restricted to sand overwash, wave damage to structures on sandy beaches, and wave damage to structures at low elevations on rocky stretches of the coast. The steepness of the coastal areas limited the extent of inland penetration of the surge, and the rocky portions of the coast provided armoring and elevation. Poor construction and overcrowding of the coastal lowlands increased damage by putting large numbers of poorly built structures at risk.

Cely, John Emmett 1991. Wildlife effects of Hurricane Hugo. *Journal of Coastal Research* SI(8):319–26.

> Before extensive human settlement, hurricanes probably had only localized effects on wildlife populations. It is apparent from Hugo that, because the modern landscape consists only of isolated and fragmented pockets of wildlife habitat, unique, rare, and endangered species are at increasing risk from natural disasters. This study concluded that Hugo's dramatic alterations to coastal and forested habitats will be its primary effects on South Carolina wildlife. Much of the damaged habitat will require decades to recover, slowing repopulation by some species, especially gray squirrels and songbirds.

Gardner, L. R., W. K. Michener, B. Kjerfve, and D. A. Karinshak 1991. The geomorphic effects of Hurricane Hugo on an undeveloped coastal landscape at North Inlet, South Carolina. *Journal of Coastal Research* SI(8):181–86.

> In spite of its intensity, Hurricane Hugo had only a modest impact on the geomorphology of the undeveloped coastal landscape at North Inlet, South Carolina. Pre- and post-Hugo aerial photographs showed no change in the salt marsh creek network or the size or shape of sand bars. The changes were limited to the creation of several new, small washover fans around the inlet. The absence of significant impacts was probably due to the storm's perpendicular approach, the relatively light precipitation, and the fact that natural barrier systems are meant to cope with the wind and wave forces associated with severe storms.

Janiskee, Robert L. 1990. "Storm of the century": Hurricane Hugo and its impact on South Carolina. *Southeastern Geographer* 30(1):63–67.

> Hurricane Hugo's impacts on tourism, forestry, wildlife, and coastal resources management in South Carolina will be long term. This article summarizes damages and projects the impacts of Hugo on the state's economy, lumbering, agriculture, endangered species, fishing industry, and beachfront development. It concludes that the test of South Carolina's relatively new Beachfront Management Act posed by Hugo's destruction may be the most telling and far-reaching of Hugo's impacts.

Knott, David M., and Robert M. Martore 1991. The short-term effects of Hurricane Hugo on fishes and decapod crustaceans in the Ashley River and adjacent marsh creeks, South Carolina. *Journal of Coastal Research* SI(8):335–56.

> Trawl sampling in the Ashley River and lower Charleston Harbor after Hugo revealed that hurricane damage to the nektonic communities of the river channels and marsh creeks was severe and immediate, but short-lived. Hypoxia and salinity reduction resulted in extensive mortality along distinct geographic gradients, with the greatest impacts upstream. Organisms that did not succumb to the initial oxygen depletion migrated downstream. The most severely affected areas were repopulated within two months.

Marsh, Christopher P., and Philip M. Wilkinson 1991. The impact of Hurricane Hugo on coastal bird populations. *Journal of Coastal Research* SI(8):327–34.

> Large numbers of birds apparently were killed during Hugo, but this did not appear to reduce local shorebird populations drastically. The hurricane's impact may have been much greater on weaker flying species. The most obvious effect on local birds was the alteration of habitat. Three important nesting islands were seriously eroded.

Nelson, Douglas D. 1989. Factors effecting beach morphology changes caused by Hurricane Hugo, northern South Carolina. Unpublished paper. 45 pp. Copies available from author, Center for Marine and Wetlands Studies, Coastal Carolina College, P.O. Box 1954, Conway, SC 29526, (803) 347-3161.

> Hurricane Hugo caused beach erosion of two distinct styles within the area studied. The fine sand beaches of North Myrtle Beach did not change slope as a result of the storm, but eroded downward uniformly along the entire profile. Coarser sand beaches showed a decrease in beach slope and more washover deposition of sand. During the hurricane, littoral transport energy apparently overpowered the deleterious effects of seawalls and positive effects of local sources of sand. Erosion moved the high tide line an average of 10.4 meters landward. However, localized accretion also occurred near the inlets. Pre-hurricane beach surveys revealed that long wavelength waves generated by the approaching storm facilitated berm sedimentation and beach accretion throughout the study area for several days before the hurricane made landfall.

Remion, Michael C. 1990. Assessment of Hurricane Hugo damage on state and private lands in South Carolina. Pp. 41–47 in J. D. Greer, ed., *Third Biennial Conference on Remote Sensing Applications*. Bethesda, Md.: American Society of Photogrammetry and Remote Sensing. 488 pp. Reprints available from author, South Carolina Forestry Commission, P.O. Box 21707, 5500 Broad River Rd., Columbia, SC 29221.

> Over 18,000 miles of roads and highways were blocked by downed timber in South Carolina as a result of Hurricane Hugo, and the amount of timber destroyed was enough to build 660,000 new homes. A forest disaster was officially declared in the state. Besides the need for massive reforestation (1.3 million acres were totally destroyed), foresters must plan for invasions of damaged timber by insects and disease-causing organisms and for forest fires. Infrared aerial photography has been invaluable in helping private landowners, forest managers, and public agencies assess, analyze, and cope with various aspects of the hurricane's impact.

Shelfer, Richard B. 1990. Hurricane Hugo damage on the Francis-Marion National Forest. Pp. 33–40 in J. D. Greer, ed., *Third Biennial Conference on Remote Sensing Applications*. Bethesda, Md.: American Society of Photogrammetry and Remote Sensing. 488 pp. Reprints available from author, U.S. Forest Service, Francis-Marion Sumter National Forest, R8, 1835 Assembly St., Room 333, P.O. Box 2227, Columbia, SC 29202.

> Hugo caused more damage to the Francis-Marion National Forest in South Carolina than has ever been experienced by any forest in the nation's system. This paper documents some of the events that occurred during the storm, and describes plans for the forest's recovery. Remote sensing techniques and a geographic information system have been useful to the U.S. Forest Service in assessing the storm's impacts and setting priorities for future work. The post-Hugo status of the forest is compared to its cut-over, altered condition when it entered the national forest system in the 1930s. An interesting result of the storm is that, now that the forest canopy has been removed, evidence of previous land uses in the form of rice dikes, fence rows, and shell mounds is now visible in air photos.

Stauble, D. K., W. C. Eiser, W. A. Birkemeier, L. Z. Hales, and W. C. Seabergh 1990. Erosion characteristics of Hurricane Hugo on the beaches of South Carolina. *Shore and Beach* 58(4):23–36.

> Hurricane Hugo caused severe erosion of the beach and dune system along over 150 miles of the North and South Carolina coasts. Much of the protective dune disintegrated and several breaches in narrow barrier islands occurred as overwash inundated the low coastal areas. The mostly flat, fine-grained beaches were eroded down to old marsh surfaces in many locations. Many of the coastal protection structures were completely destroyed because they were not designed to withstand such an extreme event, especially smaller wood and concrete seawalls and stone revetments. Most inlet jetties were damaged at their seaward ends but maintained structural integrity.

Stauble, Donald K., William C. Seabergh, and Lyndell Z. Hales 1990. The initial impact of Hurricane Hugo on the beaches, dunes and inlets of South Carolina. Pp. 362-77 in Lawrence S. Tait, comp., *Beaches—Lessons of Hurricane Hugo, Proceedings of the 1990 National Conference on Beach Preservation Technology*. Tallahassee, Fla.: Florida Shore & Beach Preservation Association. Reprints available from authors, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

> Hurricane Hugo made a lasting impact on a 140-mile stretch of the South Carolina coastal mainland, barrier island beaches, dunes, and coastal community infrastructure. Almost the entire primary dune line was eroded to base level. There was less damage to upland structures in the few areas where the dune survived. Beaches along the entire area suffered erosion of the subaerial beach. Eroded material was transported inland as overwash, offshore into a storm bar, and alongshore. Several breaches were cut across narrow sections of barrier islands and spits in the lower Grand Strand and Cape Romain areas. Within one week after the hurricane, sand was beginning to return to the lower foreshore, particularly along beaches that had been recently nourished.

Stauble, Donald K., William C. Seabergh, and Lyndell Z. Hales 1991. Effects of Hurricane Hugo on the South Carolina coast. *Journal of Coastal Research* SI(8):129-62.

> The combination of wind, waves, and surge from Hugo resulted in beach and dune erosion along a large portion of the central and northern coastal segments of South Carolina, including a wide variety of coastal morphologic types. Most dunes were reduced to a flat surface, while others were severely eroded. Most shore protection structures were seriously damaged or destroyed—only the largest remained intact. With the loss of the dunes and the protective structures, damage to coastal buildings was severe. Low-lying areas were overwashed during the height of the storm, and water, sand, and debris were carried up to 600 feet inland, in some cases completely over narrow barrier islands and spits. Numerous breaches were formed, creating cuts and new inlets. Existing inlets and associated navigation structures received only minimal damage, but all ocean fishing piers were demolished.

Thieler, E. Robert, and Robert S. Young 1991. Quantitative evaluation of coastal geomorphological changes in South Carolina after Hurricane Hugo. *Journal of Coastal Research* SI(8):187-200.

> Pre- and post-storm aerial videotape surveys were made of 51 kilometers of the barrier island coast of South Carolina from Garden City to Folly Beach. As a result of Hugo, the geomorphological classification of the coast changed from mostly dune fields and dune ridges to washover sheets. The study's conclusions about the protective effects of dunes provide a basis for predicting damage in other developed coastal areas in future storms. Among the findings are that the minimum width required for a dune field to survive Hugo and thereby protect buildings (providing it was not submerged) was 30 meters; 50% of all buildings completely destroyed or removed from their foundations were fronted by a "deadly" combination of dry beaches less than 3 meters wide and dune fields less than 15 meters wide.

U.S. House of Representatives 1990. Effects of Hurricane Hugo on Forest Resources. Hearings before the Subcommittee on Forests, Family Farms, and Energy of the House Committee on Agriculture. U.S. House of Representatives, 101st Congress, 1st session. November 6, 1989, Moncks Corner, S.C.

This is the formal record of hearings to review the effects of Hugo on forest resources in the Southeast. Prepared statements and question-and-answer sessions are included from the more than 30 witnesses. The materials describe the experiences of people affected by the storm's impact on forests, their activities to cope with damages, and their plans for restoration. Opinions and position statements were submitted by state and federal foresters and rangers, lumber companies, salvage companies, soil and water conservation districts, politicians, the National Wildlife Federation, and private citizens.