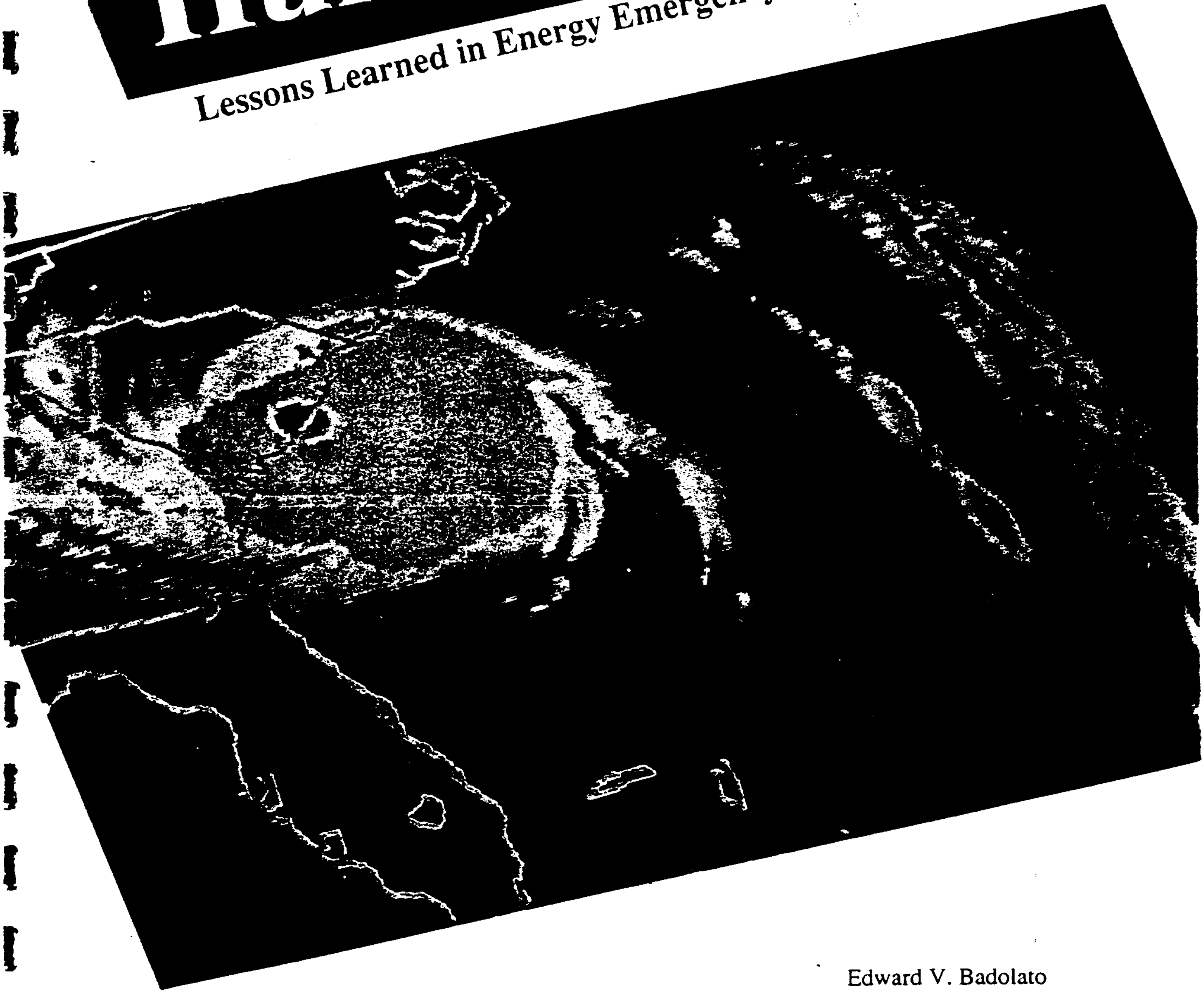
# Hurricane Hugo

## Lessons Learned in Energy Emergency Preparedness

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## PREFACE

For the past two years, the Strom Thurmond Institute of Government and Public Affairs at Clemson University has worked closely with the Federal government, the states, and the energy industry to focus increased attention on energy emergency preparedness. This has included seminars held across the nation on energy emergency preparedness, publication of reports on these seminars, and publication of *Energy Emergency Preparedness: Guidelines for State Planning* (forthcoming) in cooperation with the National Association of State Energy Officials and the U. S. Department of Energy.

Immediately after Hurricane Hugo struck the United States mainland September 21, 1989, the Strom Thurmond Institute organized a team to address lessons learned from the experience in the area of energy emergency preparedness. While the storm was regrettable, it presented a unique and timely opportunity to capture for the record lessons learned in preparedness before the storm, in coping with the storm in progress, and in subsequent restoration and recovery of the energy systems. Such opportunities to learn cannot be lost. Therefore, we felt it was important to respond in a timely fashion, while the memories of the major challenges and the efforts undertaken to overcome these challenges were still fresh in the minds of participants.

By September 25, four days after the storm, the Institute had assembled its team, designed the project, and commenced work. Courtesy of the South Carolina National Guard, the study team flew over the impacted areas in South Carolina to survey the damage. The team then met extensively over the next few weeks with state and local government officials and officials of the utilities affected by the storm. Information was also obtained from the North American Electric Reliability Council, Southeastern Electric Reliability Council, and other national associations and state and Federal agencies.

It is important to emphasize that this is a report of lessons learned in *energy* emergency preparedness, *not emergency preparedness more broadly*. However, many of the lessons learned from the Hurricane Hugo experience in energy emergency preparedness will have implications for the larger area of emergency preparedness and response to disasters like this storm. Neither does this report include specific recommendations or detailed checklists as to how to effect the lessons learned from Hurricane Hugo. Indeed, the responsible government policymakers, energy emergency planners, and those within the energy industry who deal with such crises can best determine what steps should be taken in light of these lessons learned to perfect their energy emergency plans and procedures. In official government reports and further detailed study of the Hurricane Hugo experience, there will be recommendations about the energy emergency plans implemented and responses of the respective government agencies and utilities.

For two reasons, this report should also be considered preliminary in nature. At the outset, our objective was to summarize lessons learned from this storm in the Virgin Islands and Puerto Rico, as well as on the United States mainland. However, because destruction was so extensive in South Carolina and North Carolina, it became prudent to focus in the short term on the emergency faced in these two states. Soon, we hope to extend this review to encompass lessons learned from Hurricane Hugo in Puerto Rico and the Virgin Islands. This report is also preliminary in the sense that it may suggest additional points for consideration and prompt further reflection by those directly involved in handling this emergency. An update of this report would incorporate this new information.

This effort would not have been possible without the assistance of those who took the time, although heavily involved in recovery efforts following the storm, to brief the review team, to furnish background information, and to help us better understand their roles before, during, and after the hurricane. We are especially grateful for the assistance given us by Governor Carroll A. Campbell, Jr., and the Office of the Governor of South Carolina; Major General T. Eston Marchant, Adjutant General of South Carolina, and his staff; Joseph P. Riley, Jr., Mayor of Charleston; and officials of the South Carolina Public Service Commission, the investor-owned utility companies (Carolina Power and Light, Duke Power Company, Piedmont Natural Gas, and South Carolina Electric and Gas), the South Carolina Public Service Authority (Santee Cooper), and the Electric Cooperatives of South Carolina.

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Edward V. Badolato, former Deputy Assistant Secretary for Energy Emergencies, U.S. Department of Energy, and currently President of Contingency Management Services, Inc., led the study team, assisted by Julius Bleiweis, former Executive Director of the Northeast Power Coordinating Council. Julie D. Craig, Director of Programs and Public Affairs, Strom Thurmond Institute, provided coordination and editorial support for this project. Donna Zimmerman and Joyce Bridges of the Institute staff did the word processing for this report.

To all those who gave so generously of their time and insights to our effort, we owe a debt of gratitude. The authors, however, assume sole responsibility for any errors of fact or interpretation that remain in this report.

Horace W. Fleming, Jr.
Director
Strom Thurmond Institute
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## EXECUTIVE SUMMARY

Hurricane Hugo, one of the most destructive storms in American history, struck the Carolinas September 21-22, 1989 causing extensive damage along its path from landfall just north of Charleston, South Carolina through Charlotte, North Carolina and into the interior, being downgraded to a tropical storm after passing through the Charlotte area. It moved through Virginia, West Virginia, and eastern Ohio on September 23 and was tracked for two more days while it moved into eastern Canada and out into the Atlantic Ocean.

Hurricane Hugo caused extensive damage to electric utility systems in its path and is estimated to have caused 37 deaths and approximately $6.5 billion in property damages in South Carolina and North Carolina alone. It presented to the impacted areas an unprecedented energy emergency because of the severe damage it did to electric utility systems, but management of the recovery and restoration of power was rapid, due to the careful pre-hurricane planning, coordination between and among government agencies and the energy industry, and the quick response of the affected utilities.

### Key Insights into Energy Emergency Preparedness for Hurricane Hugo

The following key insights emerge from our overall review of preparations for Hurricane Hugo and the aftermath of that storm.

**Energy is the common denominator.** In any large-scale natural disaster, energy is the common denominator. Its loss is capable of causing severe economic dislocation. On the other hand, it is essential to recovery as well. In the case of Hurricane Hugo, electric power was the principal infrastructure component that had to be rapidly restored. Because the prolonged disruption of electric power can have profound adverse effects on health, safety, and commerce and industry, emergency planners must be prepared to respond accordingly.

**Worst-case planning is required.** Planning must mesh "worst-case" considerations with an analysis of the risks involved. Emergency planners generally use "worst-case" planning for those coastal areas that are most likely to be seriously impacted by hurricane force winds and storm surge. During Hurricane Hugo, the planning horizons for the *inland* areas were found to be too limited because of the storm's unprecedented sustained force. Energy emergency planners must continue to include risk analysis and the likelihood of "worst-case" scenarios in the planning process to ensure a balanced view of their preparedness efforts and the potential risks involved.

**The Federal-state-industry energy emergency preparedness process must be coordinated at both the planning and response levels.** Dealing with the energy aspects of a severe natural disaster such as Hurricane Hugo requires effective coordination of Federal-state-industry capabilities. While other Hurricane Hugo studies at the national level will examine various additional preparedness aspects of the storm, a review of the energy emergency preparedness activities makes it clear that few states, counties, or communities in the United States possess adequate resources (e.g., emergency generators, technical personnel, and equipment) to cope independently with a natural disaster the size and scope of this storm. State and local emergency planning organizations, such as those in South Carolina, exist throughout the nation. Hurricane Hugo has shown how important it is to include energy system planning in these organizations. Federal, state, and local emergency planners must include in their planning process means to make recovery resources quickly available to stricken communities with a minimum of administrative delay.

**Pre-emergency energy planning should be continued and sustained to maintain readiness.** The energy industry has historically developed and maintained, prior to their need, energy plans to be instituted at the time of an emergency. The industry should continue to review their plans in a timely manner and keep them at a high level of readiness . The extreme emergency created by Hurricane Hugo made it abundantly clear that the electric power systems have the expertise to cope with such emergencies. The hurricane also clearly showed how critical the pre-emergency planning process is during energy restoration. Dealing with electric system emergency matters and restoration of service should continue to rest with the industry. The general planning that is routinely conducted at the state and local levels for natural disasters should take into account industry's response capabilities. Critical national and regional energy response resources—such as those available to the Federal government (including the Federal Emergency Management Agency and the military)—should also be the subject of detailed advanced planning. Many state energy offices already have energy emergency management teams that share energy planning information, develop energy emergency coordinating procedures, and conduct training and exercises. A close working and planning relationship between these energy emergency management teams and the state emergency preparedness organizations should benefit the overall energy response to natural disasters. Further, industry and government should coordinate their respective efforts recognizing their separate responsibilities while building upon the capability and authority of each.

**During a severe natural disaster, an energy emergency coordinating group is needed at the state and local levels.** While states already have emergency response organizations (usually the State Adjutant General or the Emergency Preparedness Division), the complexity of dealing with severe energy response and recovery operations such as encountered in Hurricane Hugo requires a level of technical, legal, and economic expertise that does not normally exist in those emergency organizations. The civilian executive leadership in charge of the state's energy response and recovery should have a coordinating body available during the emergency with appropriate membership from government and industry to provide energy-related information and support. This coordinating group should have adequate communications and functional facilities that would allow it to provide an interface with local officials and the energy industry during the emergency and to expedite the removal of impediments to the rapid recovery of the state's energy systems.

**Industry responded capably and professionally.** Hurricane Hugo demonstrated that the energy industry response to natural disasters and emergencies is capable, responsive, and professional. However, government-industry emergency planning should be strengthened through improved interface, planning, and exercises.

**The role of the military should be better understood and coordinated.** The role of the military in severe natural disasters must be clearly understood and coordinated. The military has critical resources which are vital to the restoration process (e.g., field kitchens, medical facilities, fuel and water tankers, bulldozers, trucks, radios, helicopters, and tracked vehicles) and which can be quickly brought to bear to take some of the initial pressure off already-overtaxed local resources in the restoration process. Regarding the energy infrastructure, the military can play a very important role in restoration, but this role must be planned, exercised, and coordinated with the energy industry. Additionally, national security planning officials should review the energy impact that a storm the size of Hurricane Hugo can have on military bases in the storm area and on national security emergency preparedness.

**Communication systems are vital.** Communications systems are vital to effective emergency operations and the energy infrastructure. Without communications, there can be little or no effective electric power system operations. Survivability, redundancy, and effectiveness of voice emergency coordination and control networks should be examined. The news media should be used to keep the public informed of the progress in the restoration procedure. Use of emergency radio and television emergency broadcast systems should be strengthened as a means of communicating with the public.

**Government-industry public awareness programs are critical.** Public awareness, outreach programs, and information programs on natural disasters (e.g., hurricanes, severe storms and flooding), similar to those conducted by the National Weather Service and the South Carolina Emergency Preparedness Division, should be an on-going part of government-industry energy emergency cooperative efforts to inform the public. Much is being done at present, but it is obvious from the Hurricane Hugo experience that more needs to be done. Public education on such topics as the hurricane warning system, home safety, potential evacuation routes, proper use of portable generators, and personal emergency preparedness checklists are very important for the general public and should be undertaken before a crisis occurs.

**Use of portable emergency generators and safety in their operation are major considerations.** Availability and operation of portable power generators in times of emergencies are major considerations in energy emergency preparedness planning for natural disasters. Generators ranging from large capacity models to small house-sized units proved invaluable during Hurricane Hugo in maintaining health, safety, and security. Portable sources of power during an emergency of this kind are particularly important to those retail establishments in rural communities that must provide milk, ice, food, gasoline, and other such goods during recovery. Portable emergency generators are also essential for life support equipment in the home and on dairy and poultry farms. However, the public must be educated on the proper operation of these small, portable generators so as to prevent property damage and serious personal injuries that can be caused by inadvertently energizing the larger electric power system.

**While more data must be collected, available figures indicate that human casualties during this hurricane were less than during previous storms due to better forecasting, evacuation, and preparation.** However, with the majority of casualties occuring during the post-storm restoration period from such accidents as electrocution, fires, stress-related heart attacks and tree-clearing incidents, increased emphasis should be placed on post-storm safety procedures. For example, one-half of the post-storm fatalities during Hurricane Hugo were energy-related, resulting from house fires caused by using candles for light and electrocution from downed wires and portable generators.

## Lessons Learned: A Summary

The following points constitute the essence of energy emergency preparedness lessons learned and observations resulting from the response to Hurricane Hugo before, during, and after that storm.

### Emergency Preparedness Plans

Prior planning and preparedness are the keys to successful response. All of the electric utility systems impacted by Hurricane Hugo had in place emergency plans upon which to base their procedures and actions before, during, and after the storm. As the storm approached, these plans and procedures were reviewed by the utility systems and discussed with the applicable government agencies.

*Lesson learned: Prior planning and preparedness are the keys to successful energy responses to a natural disaster.*

### Equipment and Material

In all cases, estimates of material and equipment needs (in addition to existing inventory) were prepared in advance of the storm. Spare parts, equipment, and other material needed were ordered prior to assessments of storm damage.

In many instances, decisions on the use of material and equipment accepted from the manufacturer but not completely in accordance with specifications were left to engineers in the utility companies. This delegation of authority and flexibility expedited restoration efforts.

In some cases, utility systems outside the storm area surrendered their places on manufacturers' production lines, thereby giving priority to the systems affected by the storm. Some also surrendered their stocks (held by manufacturers) to those systems affected by the storm, with the understanding that the material or equipment in question would be replaced as soon as possible after the emergency.

*Lesson learned: A thorough estimation of energy infrastructure post-storm material and equipment requirements prior to the emergency is very useful for organizing support from manufacturers and other utility systems.*

### Storm Tracking

Most of the utility systems (including all of the private electric utility companies) had their own meteorologists tracking the storm, using the latest information from the Local National Weather Service station (located at the Columbia, South Carolina airport) and the National Hurricane Center. Advice from their meteorologists indicated that, due to the counterclockwise rotation of the hurricane winds, the most severe damage would be in the northeast quadrant of the storm. They were correct in their assessments, and this assisted in preparedness efforts.

*Lesson learned: Dedicated meteorological support and storm tracking were extemely valuable in formulating energy infrastructure preparedness and response plans.*

## Communications

In most cases, communications were lost as soon as the major force of the storm hit, and those commercial circuits that remained in service were quickly overtaxed by public use. The Emergency Broadcast System, particularly vital to the general public, was lost hours before the storm, suggesting that this system should be reevaluated (especially the installation of emergency generators) in order to ensure continued broadcasting in anticipation of future disasters of this type.

Particularly effective before and after the storm were cellular telephones (used extensively by the utility companies and government personnel) and the South Carolina Law Enforcement Division (SLED) statewide FM radio net with its system of automatic repeaters.

In the aftermath of the storm, FAX machines proved especially useful as means of organizing distant crews, making arrangements for their accommodations, ordering needed spare parts, and generally aiding management of the restoration effort.

*Lesson learned: Normal communication systems, telephones, radio and commercial [illegible] broadcasting are vulnerable to severe storm action, but Hurricane Hugo demonstrated the value of cellular phones, a resilient statewide emergency FM net and FAX machines.*

## Repair Crews

The utility systems quickly evaluated the need for assistance from their own work crews, from contractors, and from utilities outside the stricken area. They estimated the number of outside crews they could support efficiently. The support of their own crews and outside crews was exceedingly difficult because of the following factors.

- **Lodging.** Local sleeping accommodations were needed relatively close to the crews' work sites.
- **Laundry.** In most instances, laundry facilities were not available because of the shortage of water and lack of power for the electrically-driven pumps.
- **Food.** Because of the electric power outage, there was a need for field kitchens.
- **Water.** Until electricity was restored, water had to be provided by tank trucks. In many instances, military tank trucks were used. In a few cases, milk tank trucks were converted and put into service to transport water.
- **Gasoline.** The inability to pump gasoline—again, because of the electrical outage—was a major factor in the first few days after the storm.

- **Length of work day.** The work day had to be limited to daylight hours, except for critical needs. The work day was also limited to an average 16 hours because of concerns that crew fatigue would compromise safety.
- **Security of repair trucks.** In most cases, utility repair trucks were left in a guarded staging area for the night (usually in shopping center parking lots), and repair crews were bussed to meals and to their sleeping quarters. Night-time hours were used to restock trucks with materials and equipment for the next day's work.

Several outside crews brought with them, in support roles, their own mechanics and portable garages for repair work, engineers, accounting personnel, inventory clerks, and other key support staff.

The host utilities provided guides in the areas where the outside crews were working for purposes of providing directions and safety advice to these crews and to familiarize them with company construction practices and design of the systems on which they were working. In the case of the electric cooperatives, crews drawn from other cooperatives needed a minimum of briefing since standard designs are used by all such electric cooperative systems. This expedited restoration of the cooperatives' systems.

*Lesson learned: Planning for the operational use and upkeep of outside work crews during the restoration phase is a major logistical consideration.*

## Restoration

All of the electric utility systems had already adopted restoration plans. Under these plans, the restoration priorities, in general, were:

- nuclear generating plants,
- other generating plants and critical transmission lines,
- other transmission lines,
- distribution primary feeders,
- tap lines, and
- individual service.

Exceptions to be identified in the storm plan include (but were not limited to):

- customers on life-support systems,
- water and sewage services,
- hospitals,
- law enforcement centers,
- major telephone communications centers,
- fire stations, and
- other services needed for the general welfare.

*Lesson learned: The use of pre-existing restoration plans along with their priorities for restoration enhanced the response effort.*

### Generating Stations

For the most part, there was no damage to the generating stations. However, the cooling towers of one station were damaged so that the station was rendered inoperative. The affected system requested from the local environmental protection office permission to operate the plant without the cooling towers, and permission was granted.

*Lesson learned: During Hurricane Hugo, power generation plants were not particularly vulnerable to storm damage.*

### Transmission

The transmission system voltages in North Carolina and South Carolina are 500 kv, 230 kv, 138 kv, 115 kv, 100 kv, and 44 kv (which may be considered subtransmission); 500 kv and a portion of the 230 kv are steel tower construction, with the remainder of the 230 kv, 100 kv and 44 kv wood pole construction.

There was essentially no damage to the 500 kv steel tower system.

The extent of damage to the remainder of the transmission system depended upon its location with respect to the South Carolina coast, where the damage was most severe.

*Lesson learned: Steel transmission towers were relatively undamaged, but there was damage to the wooden pole transmission towers, mainly in the coastal areas.*

### Distribution

In practically all instances, distribution systems needed to be *rebuilt* rather than *repaired.*

Underground distribution in many residential subdivisions was affected due to cable and splice failures resulting from moisture. The distribution system voltages, depending on the company, are 24 kv, 12 kv and 4 kv.

*Lesson learned: Above-ground electric distribution systems can expect very heavy damage from a storm of Hurricane Hugo's severity.*

### Temporary Restoration

In order to expedite restoration of the electrical system, initial temporary actions were begun immediately with permanent repairs to take place as soon as practicable. In several areas, restoration was considered to be temporary because of equipment or material considerations. Permanent restoration is now complete in most areas.

*Lesson learned: Rapid restoration of electric service may require that less than standard equipment and material be used initially for repairs with replacement and permanent restoration to begin as soon as possible thereafter.*

### Emergency Generators

Planning, safe operation, and the creation of emergency generator stockpiles and data bases are critical elements of the emergency generator program. Utility systems advised customers not to use emergency generators unless the utility companies were notified, because incorrect connection could cause safety hazards in the systems.

The South Carolina National Guard provided approximately 120 emergency generators of varying sizes from 1.5 kw to 100 kw, totaling nearly 1,900 kw. Priorities were established as to where these units were connected.

*Lesson learned: Emergency generators are the most important pieces of equipment used during the restoration process, but careful planning is necessary to ensure their availability and safe operation.*

### Construction Equipment

In some instances, the tracked equipment used by external contractors was not adaptable to use in the low-lying, swampy terrain found in the coastal areas of South Carolina.

*Lesson learned: Heavy repair equipment brought into storm areas to help with restoration may not be suitable for the local terrain.*

### Transmission Substations

Most are operated remotely and therefore were unattended. These substations suffered essentially no damage.

*Lesson learned: There were little or no equipment damage and no personnel casualties at the transmission substations.*

### Media and Public Relations

The electric utility companies made extensive use of the public media. Because cable television was knocked out by the storm, the utilities relied especially on radio to broadcast daily updates on the progress of their crews in restoring power. Battery-powered radios became the most reliable means of communicating with the public in the storm areas.

Just prior to the storm and when it became apparent what areas would be damaged by it, the utilities withdrew their other advertisements from radio and television and substituted safety ads in their places. Many of these safety ads were specifically tailored to the unique characteristics of damage caused by hurricanes and the damages expected from Hurricane Hugo.

The companies enjoyed an excellent working relationship with the media due, in large part, to good preparation beforehand.

*Lesson learned: The news media can play a very important role by informing the public about the emergency situation before, during, and after the storm.*

### Road and Right-of-Way Clearing

Clearing debris is an important operational consideration in the restoration process. National Guard units cleared roads of fallen trees and large debris to permit line crews to restore electric service. The utility companies also used their own right-of-way workers, where available, to clear roads.

*Lesson learned: Detailed planning and coordination of debris clearing operations are key elements of the electric power restoration process.*

### Traffic Control

Where required, National Guard personnel performed traffic- and people- control to permit line crews to perform their tasks more efficiently and safely.

*Lesson learned: Power and gas restoration operations require significant control of traffic and population by designated security forces.*

### Other

Utility companies owning buses provided free bus transportation prior to the storm for the purpose of evacuating certain residents (especially in the Charleston area) and for evacuating patients from hospitals and other special care units, including convalescent homes.

One utility company also provided substantial quantities of free dry ice, anticipating the public need for it to make up for inoperative refrigerators after the storm.

*Lesson learned: Utility companies have internal capabilities for the provision of specific community services that can make significant contributions to the public preparedness and recovery processes.*

## THE STORM

Hurricane Hugo ranks among the most destructive storms in American history. It began as a tropical depression southeast of the Cape Verde Islands, off the west coast of Africa, on Sunday, September 10, 1989. It moved westward at 18 knots across the Atlantic Ocean, becoming a tropical storm on Monday, September 11. By Wednesday, September 13, it attained hurricane status with 140 mph winds and was located at that time about 1,100 nautical miles east of the Leeward Islands in the Caribbean.

Over the next three days, Hurricane Hugo turned to the west-northwest and decelerated slightly. On Sunday, September 17, the hurricane's eye crossed the mid-section of Guadeloupe, with winds of up to 150 mph. It caused 11 deaths on Guadeloupe and left an estimated 15,000 residents homeless.

On the 18th, Hurricane Hugo hit the British island of Montserrat and the U.S. Virgin Islands. On Montserrat, it killed nine people and caused over $100 million in property damages. Six persons were killed on St. Croix, nearly all of the houses on that island were damaged or destroyed, and most of the 53,000 residents were left without shelter. There was also severe damage to the electric power distribution system, and the huge Amerada Hess oil refinery was put out of operation for an extended period, eliminating its 545,000 barrel per day production.

The hurricane gathered forward speed and on Monday, September 18 at 8:00 a. m., it clipped the northeast corner of Puerto Rico, killing 12 persons, leaving 30,000 people homeless, and causing $300 million in property damage. The hurricane then moved slowly across the open ocean for the next three days, but its winds regained strength and its forward speed suddenly increased, which cost nearly one full day in preparation time on the part of government officials on the U.S. mainland.

By Tuesday morning, September 19, Hurricane Hugo was north of Puerto Rico and moving north-northwest at a forward speed of approximately 20 mph. Two days later, it was off the east coast of Florida and had begun to accelerate and turn gradually to the north.

At 10:00 p. m. EDT on Thursday, September 21, the leading edge of Hurricane Hugo hit the South Carolina coast near historic Charleston. The full force of the storm struck around midnight, with winds of 135-139 mph and a forward speed of approximately 25 mph. The total storm imprint area was estimated to be 600 miles in diameter. The storm surge was 8-15 feet above normal tide from Charleston to Myrtle Beach but much less south of Charleston. It was measured at 20.3 feet in the vicinity of the coastal fishing village of McClellanville, South Carolina. The combined effect of the storm surge and tide resulted in a maximum water level of approximately 20 feet in the Bull's Bay area, north of Charleston.

Moving inland, the storm center passed between Columbia, South Carolina and Sumter, South Carolina, proceeded north-northwest, and passed just to the west of Charlotte, North Carolina in the early morning hours of Friday, September 22. It continued its northward trek across western Virginia, West Virginia, and eastern Ohio and became an extratropical storm as it moved into the Erie, Pennsylvania area early Saturday, September 23. The storm was tracked for two more days as it moved into eastern Canada and then out into the Atlantic Ocean. In Figure 1, we show the path of Hurricane Hugo to the mainland United States. In Figure 2, we show

Figure 1

**Path of Hurricane Hugo**

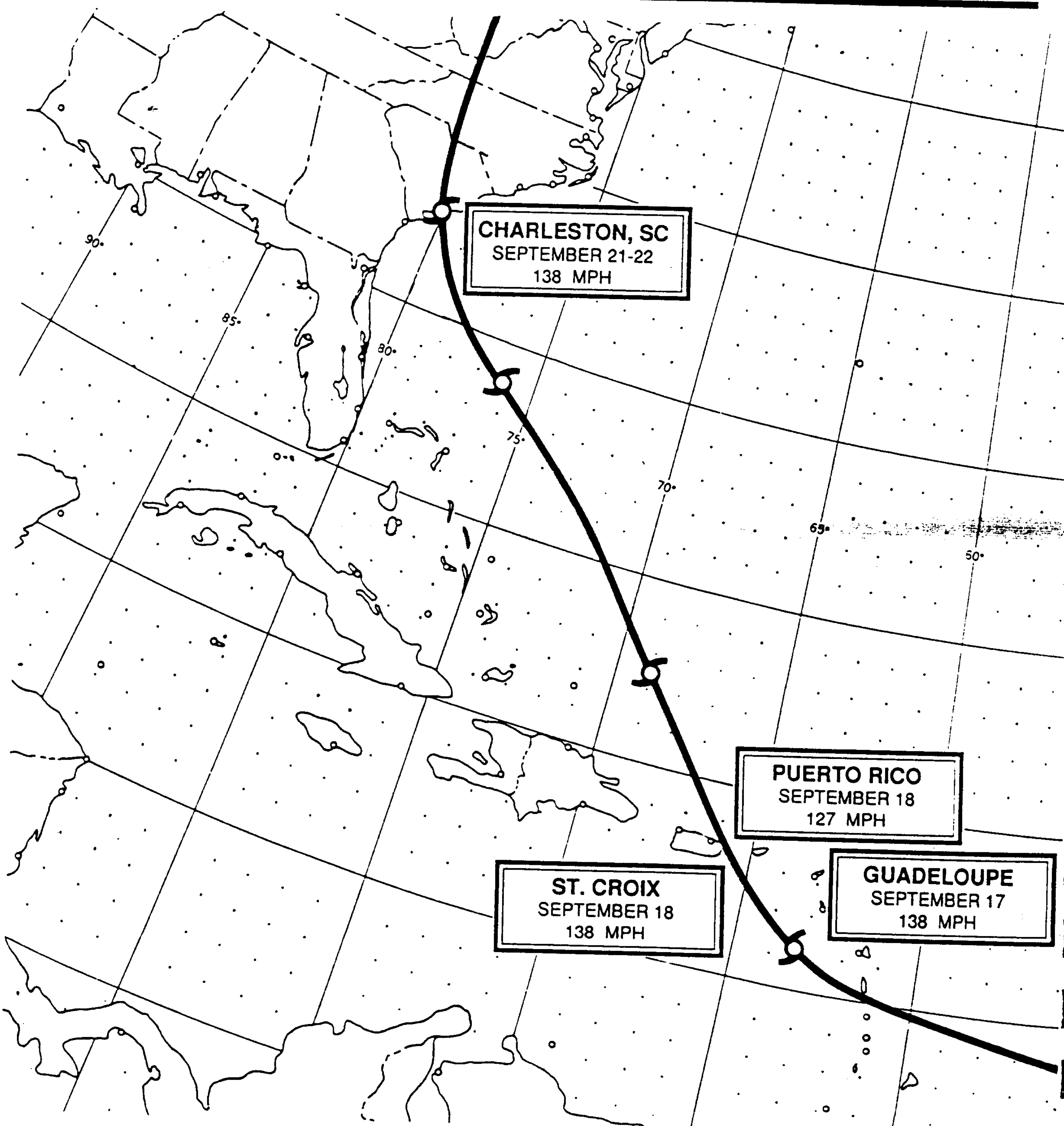
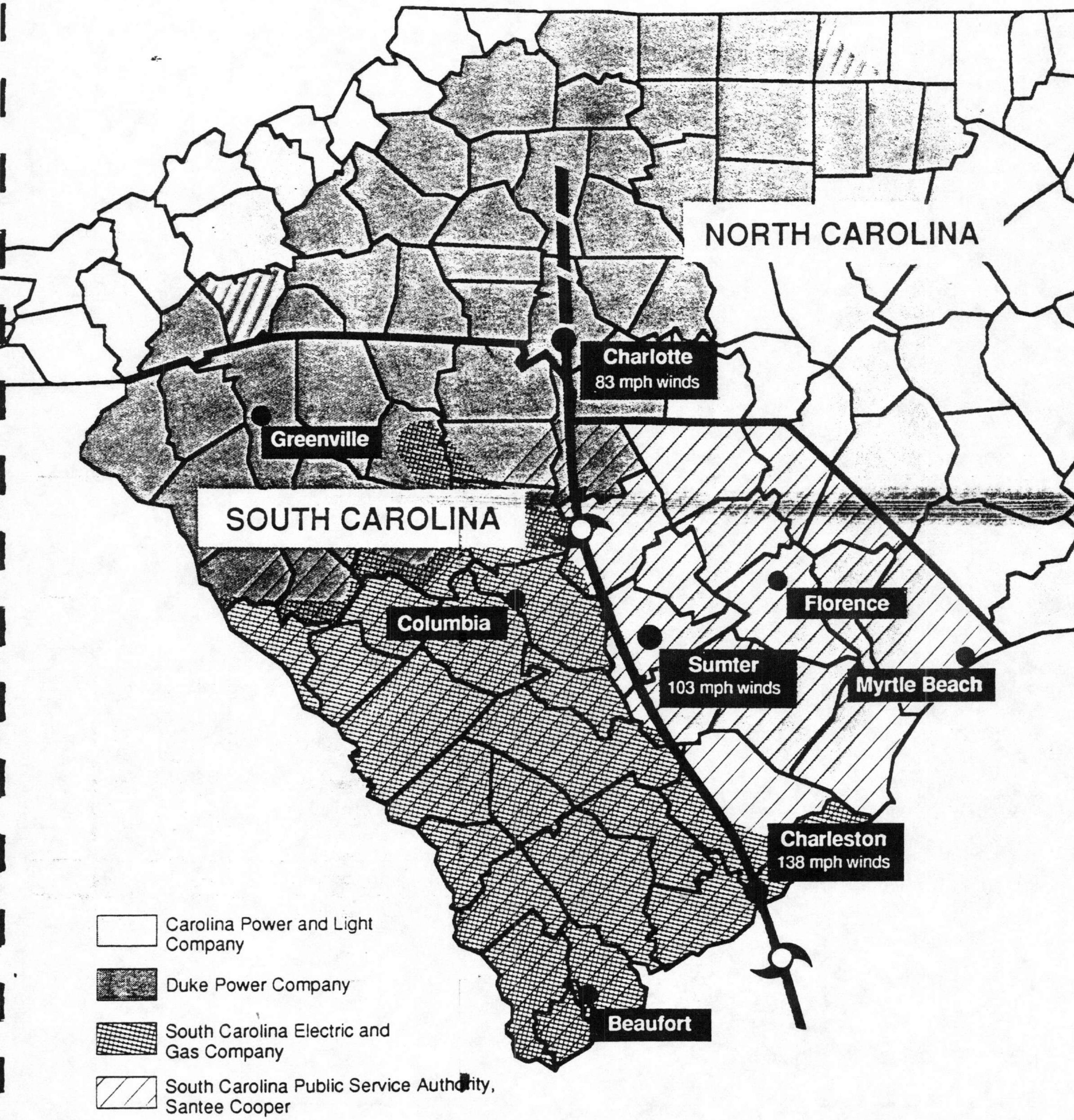


Figure 2

Investor-Owned Electric Utilities and Public Service Authority Affected by Hurricane Hugo



its path across the affected investor-owned electric utilities and public service authority and, in Figure 3, across the service areas of the electric cooperatives in South Carolina. In Table 1, we show the storm's characteristics.

Because of its sustained strength as it moved inland, Hurricane Hugo was the most severe hurricane to penetrate the South Carolina coastline in modern times. Forecasts of Hurricane Hugo's path were quite accurate although the forward speed of the storm accelerated as it neared South Carolina. The increased forward speed of the hurricane, plus the strength of the storm as it penetrated the coastline, kept wind speeds to above hurricane strength as far inland as York and Lancaster counties. Since a hurricane of this magnitude had not moved across South Carolina in recent history, commercial and residential areas were not equipped to handle winds of Hurricane Hugo's force. While there had been extensive preparation in coastal areas, the inland population and smaller communities had never experienced a storm of this strength.

Considering the size and strength of the storm, it is likely that had the Governor of South Carolina not ordered the evacuation of the barrier islands loss of life in these and other low-lying areas near the coast hardest hit by the storm would have been much greater.

Hurricane Hugo caused 82 deaths: 41 on the U.S. mainland, 12 in Puerto Rico, and 6 in the U.S. Virgin Islands. An additional 23 deaths are estimated elsewhere in the Caribbean. Thirty-five (35) deaths in South Carolina and 2 in North Carolina were attributed to Hurricane Hugo; 15 of these deaths occurred during the passage of the storm. While more data must be collected, figures indicate that human casualties during this hurricane were less than during previous storms due to better forecasting, evacuation, and preparation. However, with the majority of casualties occurring during the post-storm restoration period from such accidents as electrocution, falls, and tree-clearing incidents, increased emphasis may need to be placed on post-storm safety procedures.

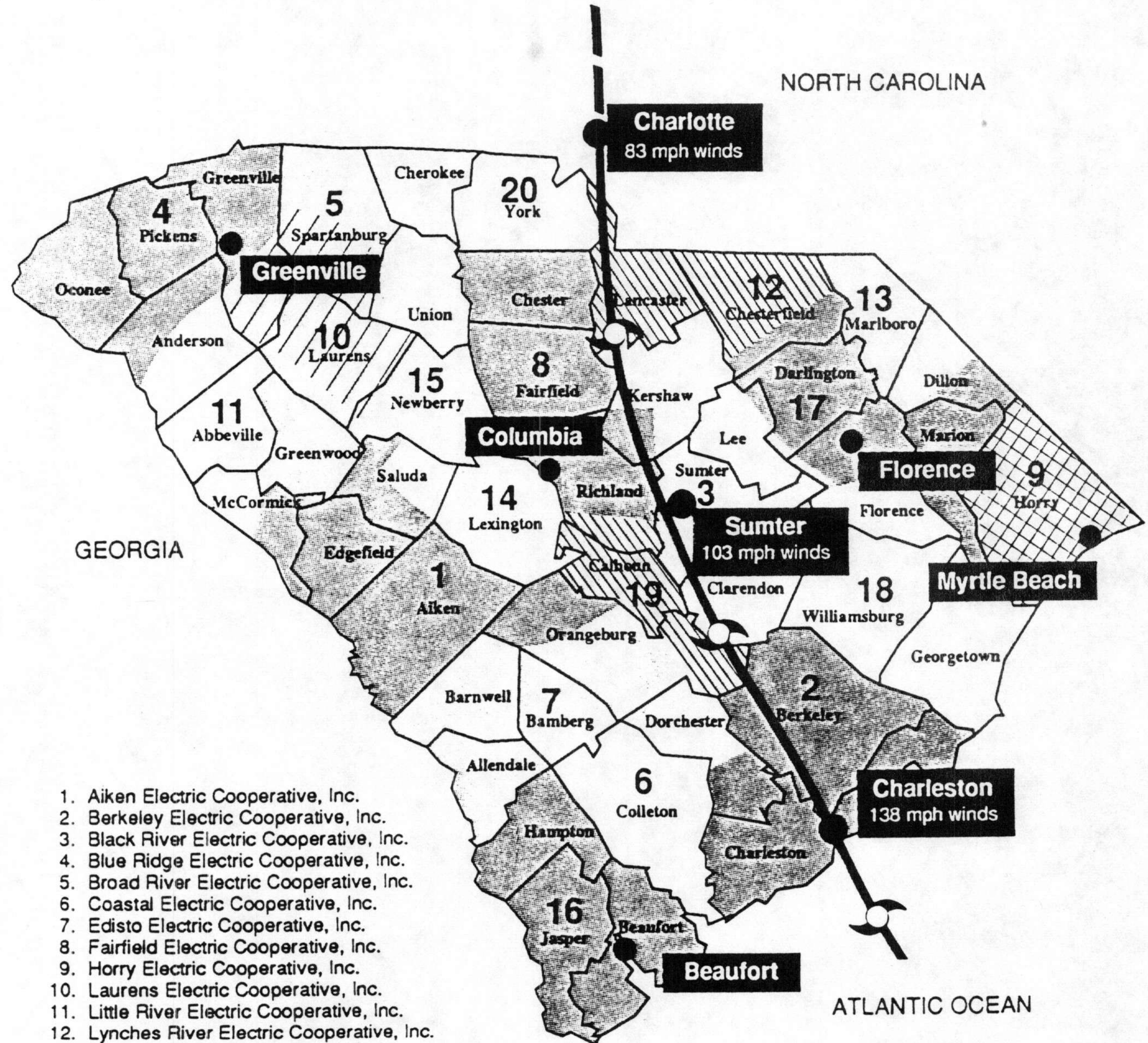
Hurricane Hugo is considered the most economically destructive storm in U.S. history. Initial estimates exceed $6 billion in property damages in South Carolina alone. Another $400 million in damages were caused in North Carolina and an estimated $2 billion in damages in the Caribbean. Estimates for past storms have often been two to three times the amount of insured property damage. Consequently, it is possible that Hurricane Hugo's total damages the length of its path will exceed $10 billion.

Twenty-four (24) of South Carolina's 46 counties and 29 of North Carolina's 100 counties were declared disaster areas in the aftermath of the hurricane.

In Table 2, we compare Hurricane Hugo with similar storms. By all measures, Hurricane Hugo has earned its reputation as one of the most dangerous and costly storms ever to hit the U.S. mainland, Puerto Rico, and the Virgin Islands.

Figure 3

Electric Cooperatives in South Carolina Affected By Hurricane Hugo




1. Aiken Electric Cooperative, Inc.
2. Berkeley Electric Cooperative, Inc.
3. Black River Electric Cooperative, Inc.
4. Blue Ridge Electric Cooperative, Inc.
5. Broad River Electric Cooperative, Inc.
6. Coastal Electric Cooperative, Inc.
7. Edisto Electric Cooperative, Inc.
8. Fairfield Electric Cooperative, Inc.
9. Horry Electric Cooperative, Inc.
10. Laurens Electric Cooperative, Inc.
11. Little River Electric Cooperative, Inc.
12. Lynches River Electric Cooperative, Inc.
13. Marlboro Electric Cooperative, Inc.
14. Mid-Carolina Electric Cooperative, Inc.
15. Newberry Electric Cooperative, Inc.
16. Palmetto Electric Cooperative, Inc.
17. Pee Dee Electric Cooperative, Inc.
18. Santee Electric Cooperative, Inc
19. Tri-County Electric Cooperative, Inc.
20. York Electric Cooperative, Inc.

Table 1

Storm Characteristics at Landfall

| | Position | Pressure (millibars) | Pressure (inches) | Windspeed (knots) | Windspeed (mph) |
|---|---|---|---|---|---|
| Guadeloupe September 17, 1989 | 16.3N 61.3W | 941 | (27.79) | 120 | 138 |
| St Croix September 18, 1989 | 17.1N 64.8W | 940 | (27.76) | 120 | 138 |
| Vieques, Puerto Rico September 18, 1989 | 18.2N 65.5W | 945 | (27.91) | 110 | 127 |
| Fajardo, Puerto Rico September 18, 1989 | 18.3N 65.6W | 946 | (27.94) | 110 | 127 |
| Charleston/Sullivan's Island, SC September 21-22, 1989 | 32.8N 79.8W | 934 | (27.58) | 120 | 138 |

*Source:* South Carolina Water Resources Commission, Office of the State Climatologist.

Table 2

**Hurricane Comparisons**

| Year | Name | Landfall | Category | Casualties & Damages |
|---|---|---|---|---|
| 1893 | Unnamed | South Carolina | Category 2 | 2,000 deaths; $10 million damages |
| 1900 | Unnamed | Texas | Category 4 | 6,000 deaths; $20 million damages |
| 1954 | Hazel | South Carolina & North Carolina | Category 4 | 95 deaths; $27 million damages |
| 1969 | Camille | Mississippi | Category 5 | 320 deaths; $1.5 billion damages |
| 1972 | Agnes | Florida | Category 1 | 122 deaths; $2 billion damages |
| 1979 | David | South Carolina & Georgia | Category 1 | 15 deaths; $2 billion damages |
| 1983 | Alicia | Texas | Category 3 | 21 deaths; $2 billion damages |
| 1989 | Hugo | Virgin Islands, Puerto Rico, South Carolina | Category 5* | 82 deaths; estimated $10 billion damages |

*Maximum strength during storm history. Was Category 4 when struck South Carolina.

*Source:* Press reports; National Weather Service reports; South Carolina Water Resources Commission, Office of the State Climatologist.

## PRE-HURRICANE PLANNING AND PREPARATION

At the 42-hour mark, the greatest probability of landfall was between Jacksonville, Florida and Savannah, Georgia. A hurricane watch was, therefore, instituted for this area along the coast, and the tempo of emergency planning and preparations picked up. The utilities' corporate weather stations and the National Hurricane Center operated by the National Oceanic and Atmospheric Administration (NOAA) in Florida were used to locate, track, and provide information on the hurricane.

At noon EDT, September 20, it was estimated that Hurricane Hugo would make landfall somewhere between Savannah, Georgia and Charleston, South Carolina. The Governor's staff, the Public Service Commission, and the utilities had expert weather advice to keep abreast of the situation and upon which to base their storm planning decisions. The Charleston regional Emergency Operations Center (EOC) and the forward EOC of South Carolina Electric and Gas (SCE&G) now augmented their staffs to include Crisis Public Communication Centers. Approximately 600 key utility operations personnel from SCE&G were dispatched to Charleston and outlying areas to be ready to assess and plan for restoration as soon as the storm passed.

As the threat of Hurricane Hugo to South Carolina developed, Federal, state, and local government agencies and energy industry groups intensified preparations.

### State and Local Government Responses

The Governor's Office reviewed the state's emergency response capability and available resources, including the National Guard, state and county emergency services, law enforcement agencies, and the electric power industry. Surveys were made of potential requirements and the types and numbers of electric power generators available in the state. Discussions were also held with neighboring states to determine the additional emergency generators and other support that could be made available.

**Plan Review and Coordination.** Priorities were set by the governor, and involved planning for the evacuation of the coastal areas likely to be hit hardest by the hurricane, keeping the roads open, and maintaining electric power to critical facilities such as hospitals, communication facilities, and water pumping stations.

Planning sessions were held to develop strategies for setting response priorities and for staging emergency response personnel and equipment so that they would be readily available for assistance to the impacted area.

As Hurricane Hugo increased in intensity, there were special meetings of emergency preparedness officials at the state and local levels. Some utilities recalled retirees to assist with their operations. Storm-related safety advertisements were sponsored by the utilities on radio and television. Hospitals, convalescent centers, and nursing homes in vulnerable areas were given special attention in planning for the evacuation effort because of their unique transportation needs.

Concurrently, the South Carolina Public Service Commission directed its staff to review the emergency response procedures contained in the utilities' storm plans which the Commission had on file. The Commission also received briefings from utility officials on their overall preparedness and steps the utilities were taking to prepare for the hurricane. It is worth noting that after a severe ice storm in South Carolina in 1978, the Public Service Commission requested the electric utilities to share with the Commission copies of their emergency response plans for severe storms. The Commission staff cites these plans as a major factor in the overall high state of emergency response preparedness of the South Carolina utilities.

**Activation of the National Guard.** The Emergency Preparedness Division of the State of South Carolina is functionally a part of the Adjutant General's office, and the National Guard played a significant role in these early emergency planning efforts.

Two days before the storm hit, the Governor authorized the Guard to activate units along the coast and other key support units across the state and to take preparatory actions such as pre-loading heavy equipment (bulldozers and front-end loaders) on transporters, performing operational checks of communications units, checking fuel storage and handling units, and deploying electric generators. The National Guard had approximately 214 generators varying in capacity from 1.5 kw to 100 kw and, with loans from other states, the total number of generators available—with trained operators—was 250. During the preparatory phase, there was some re-positioning of emergency generators that had been permanently placed in areas that were subject to flooding, such as the first floors of hospitals and low-lying areas near emergency communication centers. The assignment of a National Guard liaison officer to the Governor's emergency staff and to each affected county helped to facilitate these actions.

As they prepared for the storm, state and local officials were in touch with members of the South Carolina Congressional Delegation, especially the offices of the U.S. Senators. In the aftermath of the storm, this proved beneficial, since these offices were prepared to help the local response effort in expediting Federal government assistance to the scene.

**Alerting the Public.** Hurricane Hugo demonstrated that, even though we live in the "age of television," television may not be a reliable primary broadcast source during a severe natural disaster. Two of the three Charleston VHF channels were out of service hours before the eye of the storm arrived. The South Carolina statewide educational television network was also put out of service with damage to its transmission tower. At the receiver end as well, electric power outages denied viewers the use of their televisions unless they were fortunate enough to have a battery-powered set. With the increased use of cable television, the loss of overhead lines resulted in the loss of transmission signals to a large segment of the public affected by the storm. In Charlotte, North Carolina, for instance, 95 percent of cable television subscribers lost cable service, and a total of 125 miles of cable had to be repaired or replaced. By October 6, approximately 62 percent of cable service had been restored, and service was completely restored two months after the storm.

In contrast to television, there were thousands of portable radios, car radios, and "walkman" radios that were available and operational throughout the storm. However, the reception suffered as, one after another, radio stations went silent because they lost major equipment or power.

The performance of the Emergency Broadcast System during the storm presented problems. Early on, most of the radio and television stations in the path of the storm were either damaged or they lost electric power and were unable to transmit for several days. In the immediate storm path, only one AM station was able to maintain service because it had its own emergency power generator. Most of the stations still operating in South Carolina either were too distant from the affected area to be helpful or were operating at levels of power transmission too low to be very effective. Out-of-state high-powered transmissions from radio stations in Jacksonville, Florida and Atlanta, Georgia were also used by many in the hurricane's path to obtain news and weather information.

The ability to provide emergency broadcast information during a severe natural disaster is a critically important function that needs serious review. The emergency broadcast situation during the hurricane should be examined carefully by the various regional groups such as the broadcasters associations and emergency broadcast committees because of its implications in the event of a regional or national catastrophe producing widespread electrical outages.

**Communications Systems and Equipment.** There were also sporadic problems with some of the local governments' radio systems and with back-up systems, including the National Guard's tactical field radios when they were operated at the limit of their range. In these cases, the National Guard switched over to the South Carolina Law Enforcement Division's (SLED) statewide FM radio net. The SLED net with its long-range automatic repeaters strategically placed around the state is credited with being the most reliable emergency communications link between the state EOC and outlying areas affected by the storm. There is general agreement among emergency response officials that the SLED net provided superb support throughout the storm and that local amateur radio operators also performed well.

**Evacuation of Coastal Areas.** The day before the storm hit, the Governor of South Carolina ordered evacuation of the vulnerable barrier islands. This proved to be one of the most important pre-storm decisions. Prior hurricane experience has shown that the majority of human casualties in hurricanes results from storm surge and coastal flooding. Evacuation of coastal areas, however, can be an expensive undertaking. The National Weather Service estimates that it costs the economy $50 million to evacuate 300 miles of coastline. In retrospect, it is clear that state and local officials were right in evacuating these areas.

Mandatory evacuation orders were issued by the Governor on Wednesday evening, September 20, and by the Mayor of Charleston on Thursday morning, September 21. There were tremendous coordination problems to be overcome with this evacuation. First of all, more than 150,000 people began evacuating the coastal areas of South Carolina in advance of Hurricane Hugo, causing heavy traffic as thousands of cars jammed highways leading inland. Second, to speed the evacuation, all four lanes of the interstate highway leading out of the area had to be used for outbound traffic. Third, the South Carolina Highway Patrol had to coordinate with officials of local towns and jurisdictions adjacent to the evacuation route to close access ramps onto the interstate highway to ensure the safe use of all four traffic lanes. Fourth, there was a run on gasoline supplies as thousand of vehicles were "topped off." Finally, those evacuating the coast crowded inland areas, placing additional demands on available accommodations, which eventually would also lose power.

The effective evacuation operation during Hurricane Hugo provided some useful lessons in evacuation procedures, several of which (such as fuel availability and the safety shutdown procedures taken prior to evacuating homes and businesses) affect the energy sector. There are particularly important considerations in mass evacuations of *coastal* areas, such as what areas are threatened by the storm surge, who needs to be evacuated, where they can go, traffic flow, and the security and maintenance of the evacuated areas. Throughout the United States, evacuation of heavily-populated coastal areas threatened by hurricanes requires hard decisions by those officials charged with this responsibility. And even after the decision is made to evacuate, problems can still arise.

Two valuable resources exist for government officials undertaking such an evacuation. The first is a data base available to coastal counties from the Federal Emergency Management Agency (FEMA) for use in their planning. This data base shows evacuation routes, traffic capacities, and related information. The second is storm surge maps produced by the South Carolina State Climatology Office and the National Oceanic and Atmospheric Administration (National Weather Service) and funded by FEMA, the South Carolina Emergency Preparedness Division, and the South Carolina Coastal Council. Both of these resources were available to officials in South Carolina in this instance.

## The Utilities' Responses

The electric utilities in the areas affected by Hurricane Hugo consist of electric cooperatives, the state public service authority (Santee Cooper), and investor-owned systems all operating within the Southeastern Electric Reliability Council (SERC). Lists of these utilities appear as Figures 2 and 3, which depict the path of the hurricane from landfall near Charleston, South Carolina through Charlotte, North Carolina.

**Plan Review and Coordination.** All of the utilities affected had emergency preparedness and restoration plans, although in retrospect none of these plans or the senior emergency response officials had anticipated the strength of the storm and the destruction that it would cause to the electric power infrastructure.

As soon as it became apparent that Hurricane Hugo would make landfall along the South Carolina coast, each utility company reviewed its storm plan, identified and assembled key staff, and began detailed preparations. These early actions are considered critical to the overall effectiveness of the subsequent response. The detail and the depth of the utilities' emergency planning documents provided an orderly approach to preparing for the storm, and additional simplified planning material was very useful at the operational level.

**Implementing the Plans.** As key staff were assembled and storm plans were reviewed, the electric utilities took the following preparatory steps:

- cut back non-essential repair and maintenance activities,
- inventoried critical spare parts,
- estimated material and equipment needs in excess of inventory,
- performed operational checks of emergency generators,
- filled fuel storage tanks and inspected vehicles,
- checked battery and generator power sources for remote communication sites,
- arranged for housing, food and services for repair crews,
- scheduled storm preparedness staff meetings (Some utilities went to twice-a-day meeting schedules as the storm neared.),
- printed thousands of maps of the distribution system,
- monitored storm progress with company meteorologists and the National Weather Service, and
- requested repair crew personnel to report to work on September 22 and be prepared to travel.

Investor-owned utilities also contacted the South Carolina Public Service Commission to brief the Commission on their planning and preparations. (The Commission has no jurisdiction over the preparedness and restoration plans of the cooperatives and the state authority.)

Externally, the utilities:

- coordinated with other utilities and cooperatives in the area for possible mutual assistance,
- coordinated with local emergency preparedness personnel,
- arranged for out-of-state repair crews to be put on standby,
- ordered ice (both wet and dry), and
- contacted manufacturers for spare equipment and repair items, and requested them to hold available stocks for possible use in making repairs. (Certain other power systems outside of the storm's path contacted manufacturers and released their stocks to the utility systems affected by Hurricane Hugo.)

Out-of-state repair crews lending assistance after the storm are listed in Table 3.

**Prepositioning of Recovery Teams.** Having a cadre of technical staff prepositioned in forward areas where they could respond in a decentralized manner proved to be a wise decision on the part of the utility companies since these persons could proceed quickly after the storm with restoration activities. However, the unexpected force of the storm rendered the "non-hurricane-proof" EOC buildings inadequate for forward operations. The roof of the building housing the Charleston regional EOC staff was blown off, and the staff had to relocate as the eye of the hurricane passed over the city. Additionally, staffing of state and local emergency preparedness offices and the electric power utility storm response teams fluctuated from first-tier to second-tier and sometimes to third-tier personnel. This in itself was not a problem because the teams responded quickly and effectively, but it does point out the necessity for a program to properly cross-train and prepare all members of the various emergency staffs on storm procedures.

Local managers of the utility systems took the precautions of getting supplies safely under cover or moved to less vulnerable areas, getting equipment and vehicles topped off with fuel, and making sure that all equipment that would be out in the storm was properly secured against the severe hurricane winds. Communications systems were tested, and key utility officials had radio equipment installed in those vehicles not previously so equipped. Where direct communication lines between critical emergency management centers did not already exist, they were installed, and existing lines were reinforced. Cellular telephones were also made available for use.

**Estimating Equipment and Material Needs for Recovery.** Estimates of equipment and material needs were made in advance of the storm. In some instances, replacement equipment

## Table 3

### Power Systems and Electrical Contractors Providing Assistance

| Electric Cooperatives of South Carolina | Carolina Power and Light | Duke Power | South Carolina Public Service Authority (Santee Cooper) | South Carolina Electric and Gas |
|---|---|---|---|---|
| Alabama | Appalachian Power Co. | Alabama Power Co. | Amp Systems, Inc. | Alabama Power Co. |
| 7 Cooperatives | Asplundh Tree Expert Co. | Appalachian Power Co. | R. H. Bouligny, Inc. | Arkansas Power & Light Co. |
| Delaware | Davey Tree Expert Co. | Asplundh Tree Expert Co. | Dillard Smith Const. Co. | Asplungh Tree Expert Co. |
| 1 Cooperative | Floyd S. Pike Electrical Contractor, Inc. | Y. C. Ballenger Electrical Contractor, Inc. | Georgia Power Co. | Y. C. Ballengher Electrical Contractor, Inc. |
| Florida | Haynes Electric Utility Corp. | Baltimore Gas & Elec. Co. | Heart Utilities Const., Inc. | Baltimore Gas & Electric Co. |
| 7 Cooperatives | Heatleys Line Const. of Maine, Inc. | Bartlett Tree Expert Co. | Holley Electric Const. Co. | R. H. Bouligny, Inc. |
| Georgia | Line Construction Co. | R. H. Bouligny, Inc. | Jacksonville Electric Auth. | Burke Contracting, Inc. |
| 27 Cooperatives | L. E. Meyers, Inc. | Cincinnati Gas & Elec. | River City Const. Co. | Clay's Const. Co. |
| Maryland | Richardson-Wayland Electrical Corp. | Columbus Southern | Sumter Builders, Inc. | The Davey Tree Expert Co. |
| 2 Cooperatives | Stackhouse, Inc. | Davey Tree Expert Co. | Utilities Const. Co. | Dillard Smith Const. Co. |
| Mississippi | Sumter Builders, Inc. | Jessie B. Davis | Williams Electric Co. | Eastern Utility Const. Co., Inc. |
| 1 Cooperative | Utilities Const. Co., Inc. | Delmarva Power | C.W. Wright Const. Co. | Ertel Construction Co. |
| North Carolina | Virginia Power Co. | Dillard Smith Const. Co. | | Fitton & Pittman Contractors |
| 6 Cooperatives | Weeks Construction Co. | EMC-Jasper (GA) | | Florida Power & Light Co. |
| Tennessee | Wilson Tree Co., Inc. | E.R.S.C., Inc. | | Florida Power Corp. |
| 10 Cooperatives | | Davis H. Elliott Co., Inc. | | Gambrell Electric Co. |
| Virginia | | Farren S. Tree Surgeons | | Georgia Power Co. |
| 7 Cooperatives | | Florida Power & Light Co. | | N. G. Gilbert Corp. |
| Other Power Systems | | Georgia Power Co. | | Gulf Power Co. |
| CP&L | | N. G. Gilbert Corp. | | Guyton Electric Co. |
| City of Georgetown | | Gulf Power Co. | | Bob Hammond |
| City of Fayetteville | | Henkles & McCoy, Inc. | | Illinois Power Co. |
| Santee Cooper | | Kentucky Power | | Knoxville Utilities Board |
| Air 1 Mechanical | | Mississippi Power & Light Co. | | Louisiana Power & Light Co. |
| Allied Tree Services | | L. E. Myers Co. | | J. L. Malone & Assoc., Inc. |
| Asplundh Tree Expert Co. | | Nantahala Power | | Marable-Pirkle Services, Inc. |
| Baker Timber Co. | | New River Electrical Corp. | | Mayfair Contracting, Inc. |
| Bayles, William | | Floyd S. Pike Electrical Contractor, Inc. | | Mississippi Power & Light Co. |
| Blue Ridge Electric Cooperative, Inc. | | | | |
| Broad River Electric Cooperative, Inc. | | | | |

## Table 3 (continued)

### Power Systems and Electrical Contractors Providing Assistance

| Electric Cooperatives of South Carolina | Carolina Power and Light | Duke Power | South Carolina Public Service Authority (Santee Cooper) | South Carolina Electric and Gas |
|---|---|---|---|---|
| Delta, Inc. | | Potomac Electric | | Moody & Sons Inc. |
| Ellason Tree Service, Inc. | | Richardson-Wayland Electrical Corp. | | J. E. Oswalt Housemoving, Inc. |
| Davis H. Elliot Co., Inc. | | Riggs-Distler Co., Inc. | | Floyd S. Pike Electrical Contractor, Inc. |
| Farrens Tree Surgeons, Inc. | | River City Const. Co. | | Robert O. Porth |
| Ford, Ralph E. | | Stackhouse, Inc. | | Potomac Edison Co. |
| Gay Electric | | Tampa Electric Co. | | Richardson-Wayland Electrical Corp. |
| Hall's Pole and Pile Service | | Triangle Electrical Corp. | | Savannah Electric & Power Co. |
| Laurens Electric Cooperative, Inc. | | US Utility Contractor Co. | | Southeast Power Corp. |
| Mitchum & Son Timber Co. | | Virginia Power Co. | | Sox & Freeman Tree Expert |
| Mixon, Billy | | Wilson Tree Co., Inc. | | Stackhouse, Inc. |
| R. D. Moody Const. Co. | | C. W. Wright Const. Co. | | Stanly Line Const. Inc. |
| A. D. Musgrove Const. Co. | | | | Sumter Builders, Inc. |
| Over and Under Contractor | | | | Tampa Electric Co. |
| Powerline Clearing Contractors | | | | Town of Winnsboro, S.C. |
| Floyd S. Pike Electric Contractor, Inc. | | | | Utilities Const. Co., Inc. |
| Red Simpson, Inc. | | | | Wilson Tree Co., Inc. |
| River City Const. Co. | | | | |
| Saluda River Electric Cooperatives, Inc. | | | | |
| Dillard Smith Contractor | | | | |
| Stackhouse, Inc. | | | | |
| State Tree Service | | | | |
| Sumter Builders, Inc. | | | | |
| Trees, Inc. | | | | |
| Umphlett Const. | | | | |
| Utilco | | | | |
| Utilities Const. Co., Inc. | | | | |
| Williams Electric Co. | | | | |
| Williams Tree Service | | | | |
| Wilson Tree Co., Inc. | | | | |

*Source:* Utility systems listed above

and materials accepted from manufacturers were not in accordance with specifications. In such cases, company engineers were given authority to approve their purchase. Certain utilities unaffected by the pending storm surrendered their places on manufacturers' production lines to give priority to those systems gearing up for the storm and also surrendered to the affected utilities stocks held by their manufacturers, with the understanding that these stocks would be replaced as soon as possible after the emergency.

## ACTIONS DURING THE STORM

When Hurricane Hugo made landfall on Thursday evening, September 21, the Governor's Office was closely monitoring the situation and had been receiving periodic updates through the Emergency Preparedness Division's EOC. Winds were clocked at 135-139 mph. Hurricane Hugo was a Category 4 hurricane with a 600-mile imprint. The storm almost immediately knocked out Charleston's regional EOC and SCE&G's 80-person forward EOC, both located in the center of the city. These losses temporarily affected the ability to assess the storm action.

By 11:00 p. m. EDT, September 21, the storm was in its full fury along the South Carolina coast, and parts of the electric power distribution system were being destroyed. Calls for assistance from local officials in the area affected by the storm were being received in the state's EOC in Columbia and relayed to the National Guard Command Center also located in Columbia. Most were requests for generators, and it was apparent that to provide the correct generator support in the aftermath of the storm, the National Guard needed better technical information on the types and sizes of generators needed. As the requests for generators increased, the National Guard developed a checklist of information needed to determine specific generator requirements. This avoided the initial confusion caused by poor communications and lack of knowledge about the technical specifications on the part of those requesting the generators.

## RESTORATION AND RECOVERY

When the storm had passed, it was clear that there had been extensive damage to the electric power system in South Carolina and North Carolina. It was also apparent that Hurricane Hugo had caused an electric power emergency of unprecedented proportions. By comparison, the natural gas utilities had not been as severely damaged.

## Setting Priorities

The Governor's Office was heavily involved in sorting out numerous problems presented by the storm and setting priorities among the many requirements received. Because the Governor set overall priorities and closely monitored the progress of electric power restoration, recovery and restoration efforts were facilitated.

The South Carolina Public Service Commission quickly met in full committee with the regulated utilities—Carolina Power and Light, Duke Power Company, SCE&G, and Southern Bell Telephone Company—to be briefed on the total outage, estimated damage, and plans to restore the systems. Thereafter, the Public Service Commission staff attended the utilities' restoration briefings and prepared daily reports of the situation to keep the Commission current on the utilities' progress in rebuilding the system.

The National Guard was immediately involved with its helicopters flying missions to assess damage, perform search-and-rescue missions, and ferry work crews and officials to the barrier islands and other outlying areas. National Guard engineers and support units were clearing roads, limiting access to damaged areas, directing traffic, and assisting with the cleanup effort, as well as installing portable generators to get lights back on, water pumping, and sewage facilities operating again.

The Mayor of Charleston focused his attention primarily on restoring electric power to that city and its environs. Early estimates of four-to-six weeks to get the power restored could have had serious consequences for a city the size of Charleston, and the Mayor worked closely with SCE&G officials to expedite the recovery process. To everyone's credit, service to some customers in the city was restored within four days, with the restoration of SCE&G's entire system taking only 18 *days*, a great improvement over the initial estimate of four-to-six *weeks*. This type of support and cooperation between government and industry may account for the relatively few complaints voiced by the public about the reconstruction effort.

## Damage Assessment

By daybreak on Friday morning, September 22, assessment of the damage to the electric power system was underway. In six hours, a swath from Charleston to Charlotte, North Carolina had received tremendous damage. The damage in South Carolina was extensive and affected *all* aspects of the electrical power systems. In Charlotte and the surrounding area, there was major damage primarily to the electric power *distribution* system.

The devastation and scale of damage to the electric infrastructure in both states was so extensive that it was difficult to conduct an accurate, rapid damage assessment in the early hours after the storm. Communications and transportation difficulties contributed to this problem. Downed trees made roads impassable. Helicopters arranged by the utilities for damage assessment and staged in what were considered to be safe areas some distance from the projected impact area of the storm were unusable because they were damaged by the far-reaching hurricane winds. At the Charlotte airport where certain of these helicopters were staged, winds reached 83 mph.

Right after the storm, there was essentially no electric power east of Interstate 95 in South Carolina. One company had 400 transmission structures down; 5,000 poles down; 570 miles of transmission lines destroyed; 15,000 service drops and 1,200 transformers destroyed. Another system experienced 1,670 miles of transmission lines out-of-service with 905 poles damaged; 1,500 miles of distribution lines out-of-service with 200 miles damaged; 709 poles in need of replacement; 382 transmission structures damaged; and 659 transmission structures leaning. Customer outages are shown in Table 4.

None of the electrical utilities in South Carolina had previously suffered anything like the extent of damages to transmission lines as that caused by Hurricane Hugo. In 1984, a series of tornadoes in this same area had taken down 30 transmission lines of one of the electric utilities, compared to 198 that were brought down by this storm. As one utility executive explained, referring to the aftermath of Hurricane Hugo, "It was not a question of *repairing* the distribution system; it was a matter of *rebuilding* in *days* a system that had taken us *80 years* to create and then restoring power to all our customers."

Overall, there was little to no damage to the electric power *generation* system, but there was considerable damage to the *transmission* system and almost total destruction of the *distribution* system. Damage to the *generation* system consisted of wind damage to the cooling towers of one facility in South Carolina. The affected utility requested permission from the local environmental protection office to operate the plant without the cooling towers, and permission was granted.

The damage to *transmission* was to that part of the system constructed on wood poles (i.e., 100 kv, 44 kv, and a portion of the 230 kv system). South Carolina's transmission system consists of 500 kv, 230 kv, 100 kv, and 44 kv (which in some instances is considered subtransmission).

In practically all cases, overhead *distribution* systems had to be rebuilt. Underground distribution in many residential subdivisions was also affected due to cable and splice failures from flooding. Distribution voltages vary depending on the system (e.g., 24 kv, 12 kv, 4 kv).

It is worth noting that every utility official interviewed for this study remarked that, even though they had restoration plans, the damage was greater than anything they had anticipated in their contingency plans. At first glance, the emergency response system would appear to have been overwhelmed, but the electric power utilities had certain advantages. First was the general understanding of the monumental challenge facing them and the total support provided by all of the elected officials from the Governor through the state agencies and local levels of government. Second was the public support and awareness of the herculean effort required to restore power. Third was the superb conduct of the reconstruction operations by the utilities themselves. Finally, utility officials found that there were more resources, personal initiative, and talent available from within their companies than they had initially thought for coping with the myriad of problems they faced.

## Coordination of Recovery Activities and Resources

Early in the recovery period, the Governor's priority of restoring the electric power system was the common goal of the utilities, local officials, the National Guard, and the regular military units that arrived in the area.

Some electric power officials feel that there should have been a closer working relationship between the military and the utility companies. For example, certain military units were assigned to perform transmission right-of-way clearing tasks without coordinating with the appropriate utility company. While the utilities were grateful for this assistance, utility company officials had no way of judging the technical competence of these military units to perform these tasks consistent with their (the utilities') safety procedures or if they would be working at cross-purposes. In some instances, military crews cleared trees and debris from the roads and placed them in the power line rights-of-way, thus hampering—and, in some cases, even preventing—repair crews from reaching downed transmission lines.

Because of incidents like these, some utility officials have suggested that a Standing *Energy* Emergency Preparedness Committee be formed at the state level *under the existing preparedness structure* to establish a dialogue and a means of coordination between government and industry for the sake of better understanding each other's roles in emergency recovery efforts. This committee could build on the existing government-industry planning and cooperation that exists between the nuclear power industry and the state for evacuation and emergency preparedness. It could also encourage an *ad hoc* network of those individuals and agencies who would play key roles in future energy emergencies.

## Organization and Management of Repair Crews

Several thousand crew members assisted the affected utilities in recovery and restoration efforts. (See Table 3.) Staging, briefing, supplying, feeding, and housing these crew members would have been exceedingly difficult even under normal circumstances. However, without water and power and with most hotels and restaurants closed or damaged by the storm, supporting these crews required a major effort.

A central theme that came out of discussions with utility officials about their crisis management organizations was the merit of "flattening out" the normal organization's chain of command during such emergencies so that those assigned specific emergency response tasks could carry out their responsibilities and make significant decisions (including financial commitments) without having to go through a long approval process. For example, one individual should be in charge of food, another accommodations, and another resupply of equipment, fuel, spare parts, and the like.

The size, equipment, and makeup of the repair crews were mentioned numerous times by utility company officials in the course of this review. They noted that some of the larger crews came completely task-organized, as self-contained teams with their own supervisors, portable garages, shop units, administration and accounting support. Crews from Alabama Power Company, Baltimore Gas and Electric, and Georgia Power Company were good examples of this, and there is interest in similarly reorganizing some of the North Carolina and South Carolina response crews in the future.

Field crews followed strict safety procedures. First of all, they generally worked only in daylight, with 16 hours on and 8 hours off, and there was a continuous and rigorous safety monitoring program. Secondly, before a repaired or rebuilt section of line was connected to the system, fuses, disconnect switches, circuit breakers, and other applicable devices were checked before approval was granted to energize the line. In some cases, a decentralized system was used, allowing those who knew their local systems best to work restoration in their own assigned sectors. However, an overview was maintained at a central control point for coordination between sectors.

In the case of the electric cooperatives, there is a regional "closeness" in their industry based on cooperation, coordination, familiarity with each other's operations, close personal networking, common supply contacts, and exchanges of emergency response resources. Each cooperative has an internal emergency plan that includes mutual assistance agreements with cooperatives in other states. The similarity of training, operating procedures, and equipment standards ensures that crews from out-of-state cooperatives have little difficulty working on repairs to assemblies and equipment.

Facsimile (FAX) systems proved to be extremely useful in preparations for Hurricane Hugo and in its aftermath. By FAX, operating procedures were exchanged by the utilities between each sector's responsible supervisor so that technical problems could be avoided. The utilities also used FAX machines to communicate with out-of-state utilities for the purpose of describing their needs for repair crews, arranging contracts, and exchanging information on equipment, spare parts, and other assistance needed.

## Staging the Recovery and Restoration Teams

The investor-owned utilities, the state public service authority, and the electric cooperatives relied on good preparation and innovative support techniques to organize and support the thousands of outside crew members that assisted them in rebuilding their electric systems. They are justifiably proud of their operational response and the ingenuity of their staff members.

One innovative technique was the use of shopping center parking lots prior to the storm as material staging areas with security, supply, and transportation personnel manning the site in what became in effect a temporary staging and supply depot. Utility trucks were left in these staging areas at night for refueling and resupply, and the crews were bussed to central points for meals and then on to their hotels and motels. But even this well-coordinated plan presented major problems, with one utility alone using 2,600 outside crewmen, serving them 10,000 meals a day, and providing 12,000 gallons of fuel per day for their service vehicles. Water and electric power had to be provided, and some electric and water systems had to be repaired quickly to supply the restaurants feeding the repair crews and the 1,800 hotel and motel rooms where the crews were housed. Laundry facilities also had to be provided, and gasoline had to be pumped into service vehicles.

Due to the extremely heavy rains in the days immediately following Hurricane Hugo, some resupply and staging areas had to rely on large funeral-style tents to keep supplies dry. In another instance, a company arranged with a local cafeteria to open several hours early and close late (before and after curfew) in order to feed hundreds of its crew members, bussing them directly from the staging areas and their living quarters. Some crews used gas barbeque grills to prepare their own meals until electricity and gas service could be restored.

There were other major support problems. Because of a sudden cold snap, crews from Florida had to be provided 600 sweat shirts so they could withstand the cold temperatures. And because of the lack of power to operate the sewage system, hundreds of portable toilets had to be provided until the sewage systems were operational.

Another consideration was security. Not only was there a need for extra security for the trucks, equipment, and fuel in the utility staging areas and for the corporate buildings and supply facilities, but some repair crews were working in areas where there were curfews and restricted access. For purposes of identification and ease of access to these areas, the utility companies had to provide the crews with easily recognizable and standardized hats, badges, and shirts, as well as magnetic signs that could be attached to their vehicle doors.

## Use of Generators

The Hurricane Hugo experience demonstrated that the availability and operation of emergency electric power generators are major considerations in the energy emergency preparedness planning for natural disasters. Critical factors in the use of generators involve the need for an accurate data base for use in setting priorities and allocating equipment. Technical checklists should be available before the emergency and used to ensure that generators of appropriate type and size are provided. Government and industry should coordinate the strategy for placing and operating emergency generators. The security of loaned generators must be considered, and attention must be given to safety concerns when operating generators under emergency conditions in an environment such as the post-Hugo recovery period. All sizes of generators proved invaluable during the hurricane for maintaining health, safety, and security operations. Especially in rural communities, the value of a portable source of power during an emergency to operate small retail facilities to provide milk, ice, food, gasoline, and the like cannot be overestimated.

When responding to the high priority accorded to hospitals, some interesting problems were encountered. For example, the Medical University of South Carolina Hospital in Charleston used its backup generators as the city lost power, but the backup generators were water-cooled. When the city was forced to shut off water because of damage to its distribution system, the hospital was faced with a loss of its emergency power. While a replacement was being urgently sought, the National Guard kept the generator going by manually pumping water through the cooling system. Fortunately, the Governor's command post found replacement generators in Florida and, with the assistance of the South Carolina Highway Patrol and the National Guard, the replacements were installed that same day.

Another problem related to the use of larger generators was the lack of standardization and compatibility of the generator plugs and receptacles. In some cases, electricians had to rewire the plugs, consuming precious time where restoration of power was critical.

Even though they were a critical piece of equipment, small portable generators presented a considerable safety problem after the storm. For utilities, safety considerations for the repair crews and the public were paramount. Downed trees, broken wires, leaking gas, high water, and destruction to homes all contributed to a high level of concern for safety. Especially alert to the dangers posed by uninformed and indiscriminate use of small generators, and not knowing where they were in use, repair crews took the added precaution of listening for the sounds of these generators when entering damaged areas.

The utility companies used radio and newspapers to point out to the public the hazards of portable generators. Many individuals using portable electric generators to obtain temporary power for their homes and businesses were not aware of the safety problems and dangers, especially to the repair crews. The most serious electric safety accidents following Hurricane Hugo in South Carolina and Puerto Rico involved backfeeding current from portable generators through downed lines, injuring several repair crewmen and killing at least four crewmen. There is a definite need in planning for such disasters to educate the general public on the proper use of generators through the manufacturers' operating manuals and other specially-prepared materials.

## Need for Tracked Vehicles

Hurricane Hugo demonstrated the importance of having available tracked equipment for use by crews operating in swampy areas. In some cases, wheeled repair vehicles had to be pulled into position by bulldozers. In other cases, the tracked vehicles provided by out-of-state contractors were not suitable for wetland operations. There is considerable interest among the electric utilities in North Carolina and South Carolina in creating a regional tracked vehicle data base to expedite the sharing and use of such equipment during an emergency.

## Restoration of Power

Reenergizing the electric power system proceeded in a coordinated manner based on restoration priorities previously established. Restoring service to nuclear generating plants was the first priority, but in the case of Hurricane Hugo, nuclear plants were not affected. Next in priority were:

- critical transmission lines and other generating plants,
- other transmission lines,
- distribution primary feeders,
- primary lines,
- tap lines, and
- individual services.

A list of exceptions was developed:

- customers on life support systems,
- water and sewage services,
- hospitals,
- law enforcement centers,

- fire stations, and
- other services needed for the welfare of the general public. (For example, after the first week, the reopening of schools became a priority.)

## Natural Gas Utilities

While Hurricane Hugo did severe damage to the electric power systems, there were also severe but localized problems with the natural gas distribution system in the coastal areas of South Carolina. Like their counterparts in the electric power industry, the gas utility emergency planners had corresponding storm plans, emergency operations centers and emergency procedures for restoration of service, repair crew augmentation plans, and equipment and material resupply arrangements.

In the coastal areas of Charleston, Folly Beach, Georgetown, and Myrtle Beach, South Carolina there was considerable erosion damage to gas lines. Some were left exposed and visible; others were broken. Additionally, sand and salt water had infiltrated the lines, and these lines had to be purged before operations could be resumed. Service also had to be shut down in some areas while large sections of gas lines, damaged by water and other factors, were replaced. To ensure the integrity of the system, a leak survey was conducted in the Charleston, Myrtle Beach, and [illegible] Summerville areas during restoration.

With customers clearing their property and numerous repair excavations underway, gas leaks were a continuing problem. As seasonal temperatures begin to drop, more hurricane-related problems with the gas distribution system are expected. For example, water in regulators will freeze, appliances will rust, sand and debris will clog burners, and the salt water remaining in the lines may eventually cause a number of appliance malfunctions.

In the inland or piedmont areas, which were far from the coastal storm surge, there was minimal damage to the gas system. The most serious problem was the roots of wind-felled trees pulling up residential gas lines as the trees fell. However, these incidents were isolated and easily handled by the local repair crews.

One interesting gas-related aspect of the emergency was the heavy use of bottled propane gas for lights, cooking, and heating as a temporary substitute while gas and electricity services were being restored. Large amounts of propane supplies were provided to customers by the utilities as an emergency service. SCE&G used a particularly innovative program where thousands of full portable propane tanks were rapidly exchanged for empty tanks from the backs of trucks in some neighborhoods.

### Petroleum

The main problem faced in the petroleum industry in North Carolina and South Carolina as a result of Hurricane Hugo was brought about by a loss of electricity so that gasoline and diesel fuel could not be pumped. There was also a localized need for more gasoline and diesel fuel in the hardest hit areas to operate recovery vehicles. Additionally, there was a significant increase in demand for two-cycle oil to operate small engines such as chain saws and portable generators. Sufficient supplies of gasoline, diesel fuel, and special lubricants were quickly moved into the affected areas to satisfy these demands.

During the recovery period, the South Carolina Petroleum Council unexpectedly became a clearinghouse for the petroleum industry and those who needed assistance with additional supplies of gasoline and related needs. Where spot shortages occurred, the Council put dealers and customers in touch and assisted in rerouting products.

In South Carolina, the major oil companies made specific allocations of gasoline and diesel fuel to the affected local governments. Some also donated quantities of diesel fuel, gasoline, and motor oil, made cash contributions and contributions of building supplies and food to local relief funds and charitable organizations, and extended the credit given to their credit card customers. Others loaned generators and provided volunteers to work in the relief effort.

As noted above, the greatest problem overall for the petroleum industry caused by Hurricane Hugo was the loss of the electric power needed to pump gasoline and supply their customers. Power was restored relatively quickly, and gasoline distribution proved to be a short-term problem. In many cases, it was more of an inconvenience than a crisis for consumers.

## CONCLUSIONS

Hurricane Hugo taught valuable lessons in energy emergency preparedness, many of which have implications for those involved in the broader area of emergency preparedness planning. While this report summarizes the primary lessons learned from review of the Hurricane Hugo experience, there will be additional insights revealed through other studies and the official reports to follow. This report is, therefore, preliminary in nature and presented as such.

The main lesson learned from Hurricane Hugo is that it is possible for government and industry to work together efficiently and effectively to mitigate the effects of such a massive natural disaster. Indeed, those involved in planning for and recovery from this hurricane can take pride in their performance in responding to the widespread devastation caused by this storm.

However, there should be continuing review of this experience and the lessons learned from it in order to improve coordination between and among Federal, state, and local government agencies and the energy industry in planning for and coping with disasters of this type and magnitude.

*Cover*: Hurricane Hugo, 12:00 a. m. EDT, September 22, 1989. Photograph courtesy of the National Oceanic and Atmospheric Administration and the South Carolina Coastal Council.

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