URS 792-2

FINAL REPORT

THE EFFECTS OF HURRICANE CAMILLE ON INDUSTRY, PUBLIC UTILITIES, AND PUBLIC WORKS OPERATIONS

Contract No. DAHC20-70-C-0284

OCD Work Unit 3325E

URS RESEARCH COMPANY
155 Bovet Road, San Mateo, California 94402

A URS Systems Affiliate

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This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

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This report describes the results of an investigation and a site inspection of the industry along the Mississippi Gulf Coast tive, Office of Civil Defense, who provided both guidance and direction. The Project Manager was William Van Horn. The survey team included William Van Horn, Robert Black and Carl Foget; the entire effort was conducted under the supervision of Myron Hawkins, Vice President and Director of the Environmental Systems Division. James Halsey and Dr. Carl Miller contributed especially through their initial survey of the Camille disaster area on August 21st and 22nd. The author also wishes to acknowledge the contributions of Ann Will, who typed the manuscript, and Allen Saltzman and Patty Wiscavage, who edited it.

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THE EFFECTS OF HURRICANE CAMILLE ON INDUSTRY, PUBLIC UTILITIES, AND PUBLIC WORKS OPERATIONS

Final Report

SUMMARY

OBJECTIVE

The devastation and subsequent reclamation and rebuilding along the Mississippi Gulf Coast following Hurricane Camille presented an unusual opportunity to study similar activities that would be necessary following a nuclear attack or other large-scale disaster.

APPROACH

Site investigations and interviews were conducted in the Gulfport-Biloxi area 1 month after the storm. Results are presented and discussed for public utilities, manufacturing facilities, food processors, and debris clearing operations.

This study analyzed the repair and restoration efforts that followed the hurricane. To accomplish this:

1. Data were collected and evaluated regarding debris removal operations
2. Recovery and restoration methods used to activate vital facilities were studied and evaluated
3. Information was collected and analyzed relating to problems of recovery and restoration of the vital functions.

FINDINGS

Restoration of Utilities

All utilities made temporary repairs where feasible in an effort to restore service as quickly as possible. Electricity was restored to 60% of the customers able to use it in 5 days, 90% in 11 days, and almost 100% in 15 days. Gas lines were repaired and service restored according to the company's predetermined hurricane plan. The telephone company reestablished long distance service within 2 days; local service to some customers was reestablished later than 5 weeks poststorm.

Restoration of potable water service was delayed until the Public Health Service officials could declare the water safe for drinking. Mains were repaired and near-normal service of potable water restored within 1 week in Gulfport and 2 weeks in Biloxi.

The Gulfport sewer system suffered only minor damage, but that in Biloxi was heavily damaged and may require the rebuilding of a significant portion. Primary treatment began in Biloxi in 19 days; secondary treatment was delayed for approximately 90 days after the hurricane due to unavailability of replacement instrumentation.

Restoration of the Manufacturing and Processing Industry

Storm damage varied considerably among the facilities. Flooding caused major damage to electrical equipment and machine bearings of low-elevation plants; other damage was caused by high winds and water-driven debris. Plants at higher elevations suffered minor wind damage to siding and roofs, which left building interiors vulnerable to wind-driven, salt-laden rain.

Generally, facilities were restored by cleaning out mud and debris and performing minor equipment repair, which was done by employees. Contractor personnel were hired to repair or replace roofs and siding and to perform the more technical repairs on equipment. In many cases the plants were ready to resume production before electrical service was restored. Notable exceptions are discussed.

Restoration of the Food Industry

Plant employees performed most of the restoration work in the food industry. The first task was to protect equipment and inventory from further damage from the weather. Plants were then cleaned and minor repairs and restoration done on plant machinery. Outside assistance was needed for roofing and electrical work.

Some food processors experienced some difficulty in retaining employees who were attracted to temporary but higher paying jobs in the debris clearance projects.

Debris Removal

Public safety and public utility emergency crews were severely handicapped by flood damage and debris obstructing or closing the major arterial streets. Therefore debris clearing aimed at opening emergency lanes began immediately after the storm subsided. Within 1 week all major access roads had been opened (in many cases only to one lane of traffic); in the first 2 weeks 338 miles of streets had been cleared and an initial 17,000 truckloads of debris dumped. Subsequently the removal of debris from the many damaged and destroyed properties was undertaken. Over a 3-month period this effort resulted in trucking over 300,000 loads to 17 emergency dump sites.

Although the Corps of Engineers, who coordinated this effort, maintained detailed records, they were not sufficiently comprehensive to add to the existing predictive procedures for debris removal.

RECOMMENDATIONS

The Office of Civil Defense should continue to support directed investigations and surveys of disasters, for they represent an important source of information on the effectiveness of civil defense programs. Each disaster should be documented by a "data bank" of all pertinent information, maps, photos, reports, etc., so that disaster and civil defense researchers can select from a comprehensive collection of materials.

Planning guidelines should be developed for future large-scale debris-clearing operations. Future debris-clearing operations should make use of these planning guidelines and should be documented by engineers well-schooled in production rate estimating. Experiments should be performed in the course of these debris-clearing operations on candidate methods for improving operational efficiency.

Existing procedures for deciding the disposition of foods that have lost refrigeration, or canned goods whose containers are damaged, should be re-examined, and if found in need of revision, new guidance on safe salvaging methods should be developed.

Methods and procedures for fully utilizing portable emergency electric generators should be developed, including those for establishing priorities for the use of generators, distributing them, announcing their availability, transporting them, and protecting them from storm and flood.

ABSTRACT

This report describes the results of an investigation and a site inspection of the industry along the Mississippi Gulf Coast following Hurricane Camille. The investigation covered public utilities; selected samples of the manufacturing, chemical processing, and food processing industries; and public works, including debris removal. The major topics covered during the interviews were hurricane plans and preparations, emergency actions during the hurricane, damage inflicted, and restoration activities.

The results are examined from the viewpoint of their relationship to civil defense and restoration efforts following a nuclear disaster. Conclusions are drawn that relate to both hurricane and nuclear disasters. Recommendations are made on measures to reduce the effects of such disasters and on subjects warranting further study.

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Section 1
INTRODUCTION

Hurricane Camille, which struck the Mississippi Gulf Coast on Sunday, August 17, 1969, just before midnight, was the greatest recorded storm ever to hit a heavily populated area of the western hemisphere. It was the most intense hurricane ever to strike the American mainland. It devastated the Mississippi coast with winds of 190 mph* and tides of 23 ft. The death toll as of August 22nd stood at 130, just in Mississippi, and total storm damage could pass the $1 billion mark (Ref. 1). Camille violently disrupted normal life, business, and industry, and brought into play emergency actions on a scale that appears to resemble what we would expect under a nuclear attack (minus the special actions necessitated by fallout and fire). In this respect Camille offered an unprecedented opportunity for civil defense research and analysis. It was because of this opportunity that OCD supported research and investigation in the Gulf Coast area following Hurricane Camille.

Early reports from the Mississippi Gulf Coast described the enormous quantities of debris that were generated by Camille. The Office of Civil Defense has studied debris formation and distribution resulting from nuclear attack (Ref. 2, for example), methods for developing a debris clearance and removal program (Refs. 3 and 4), and methods for estimating debris removal requirements (Ref. 5). The Mississippi Gulf Coast restoration activities appeared to be a possible source of information and data that could be compared to these studies.

Other news reports told of the loss of electric power and telephones because of Camille. Utilities are of course of vital interest to the Office of Civil Defense. Industry, especially those segments producing food, is also of interest. Studies for the Office of Civil Defense have covered the spectrum of events from shutdown through damage, repair, and restoration (Refs. 6, 7, and 8, for example). The Office of Civil Defense hoped that the Camille disaster would yield information that would relate to these studies.

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*Unofficial reports gave wind velocities to 205 mph.

OBJECTIVE

The objective of this research was to investigate the industrial and public works aspects of the Hurricane Camille disaster as related to civil defense. This included obtaining information on Gulf Coast restoration efforts and information on industrial emergency operations and damage to industrial facilities.

SCOPE

The area of primary interest was Gulfport and Biloxi, Mississippi. The investigative effort was spent on the study of

- debris removal
- restoration of utilities – electricity, gas, water, telephone and sewerage services
- industrial preparation, damage, and emergency operations

Little effort was spent on EOC or shelter-related activities.

APPROACH

The work focused upon analyzing the repair and restoration efforts that followed the hurricane. To accomplish this, we

1. Collected data regarding debris removal operations relating to restoration of community functions and critical facilities and evaluated those operations
2. Studied and evaluated recovery and restoration methods used to activate vital facilities, e.g., power, water, gas, sewage, and an oil refinery
3. Collected and analyzed information relating to a specific community problem of recovery and restoration of the vital functions

Information was derived from interviews between September 17 and October 6, 1969, with industrial managers, civil officials, and military leaders; from plant visits; from touring the area, and from reviewing the few after-action reports that have been made available to us. Very little meaningful quantitative information is available at this time. Therefore results and conclusions are mainly based on qualitative information.

A site inspection was conducted in Gulfport, Biloxi, Ocean Springs, and Pascagoula. It included all utilities, samples of manufacturing industry, samples of food industry, and all groups responsible for debris clearance. All available data, including several pertinent reports on Hurricane Camille, have been gathered and reviewed.

Significant findings were identified, discussed, analyzed, and then conclusions developed through small debriefing seminars and conferences of the project staff.

HURRICANE CAMILLE

The U.S. Weather Bureau gave extensive warning to the Gulf Coast on Camille. The first advisory recognizing Camille as a tropical storm southwest of Cuba was issued on Thursday, August 14, 1969. By 9 a.m. Friday, she was declared a hurricane, and by midnight, "dangerous." On Saturday evening tides to 12 ft and winds to 150 mph were predicted, but the path of the eye of the hurricane was not predicted, except generally. This was less than a day and a half before the coast was hit, and many establishments had committed themselves to their established plans. Then at 3 p.m. on Sunday, when Camille was less than half a day from the coast, the unprecedented intensity of 190-mph winds, tornadoes, and 20-ft tides were predicted. Table 1 lists these and other important developments in Camille that were reported by the Weather Bureau on the Gulf Coast (Ref. 9).

Camille's path is shown on Fig. 1; Camille crossed the Gulf in just two days and, contrary to expectations, did not "hook" and head for the middle of Florida.

Table 1

CAMILLE CHRONOLOGY

Thursday Aug 14	Camille was first detected as a tropical storm southwest of Cuba. At 9 p.m. EDT, the weather bulletin warned that "conditions favor some intensification" of this tropical storm.
Friday Aug 15	By 9 a.m., Camille was declared a full-fledged hurricane with conditions favorable towards some further intensification. No prediction as to the course of Camille had yet been made. By 6 p.m., the Weather Bureau advised everyone along the eastern Gulf of Mexico to remain in close touch with future weather reports. By midnight, Camille was reported to be a dangerous hurricane.
Saturday Aug 16	Small craft along the northwest Florida coast and as far west as Mobile were advised to seek safe harbor and conditions were reported to be favorable for an increase in Camille's intensity. At noon, tides 5 to 10 ft and winds to 115 mph were predicted, but the Weather Bureau noted that conditions were still favorable for some further increase in intensity. By 6 p.m., Camille was declared very intense with predicted tides to 12 ft and highest winds at 160 mph. Small craft from Pensacola to Cedar Key were advised to seek harbor. At midnight, the Weather Bureau predicted tides up to 15 ft and winds up to 160 mph. The hurricane watch was set from Fort Walton to Biloxi.
Sunday Aug 17	At 6 a.m., gale warnings were extended westward to New Orleans and hurricane warnings were in effect from Biloxi to St. Marks, Florida. By 4 p.m., the Weather Bureau predicted tides to 20 ft, winds to 190 mph, and tornadoes. At 7 p.m., hurricane force winds were reported occurring at the mouth of the Mississippi River. Tornadoes were considered likely up to 100 miles inland and heavy local rains of 8 to 10 in. were predicted.
Monday Aug 18	By 4 a.m., Camille had begun to weaken. Highest winds were estimated at 120 mph. Camille had crossed the coast and was centered about 20 miles from Hattiesburg, Mississipppi. At noon, Camille was about 50 miles north of Jackson, Mississippi. Highest winds were about 50 mph and tides along the coast were falling.

Source: ESSA (Ref. 9)

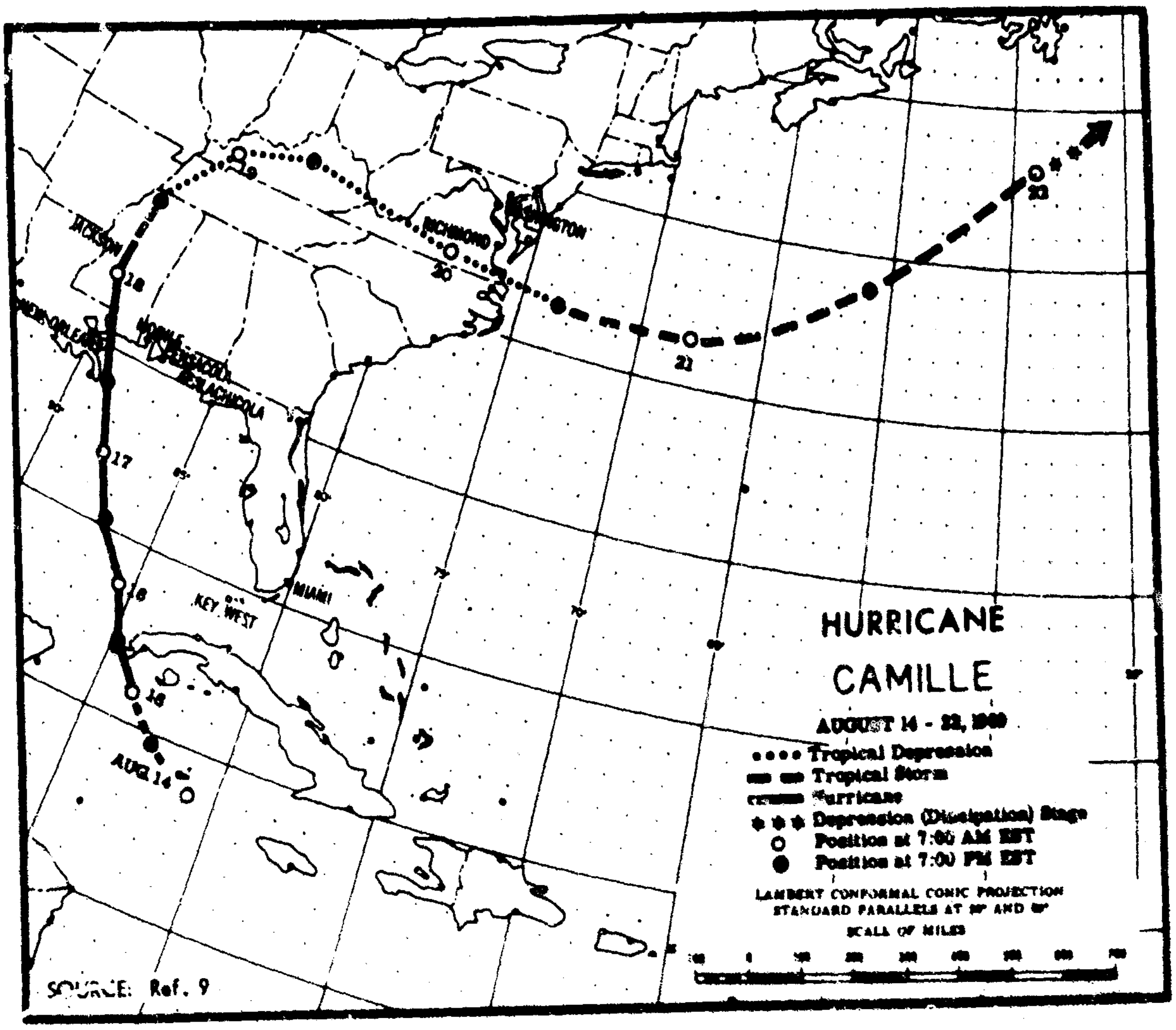

Fig. 1. Path of Hurricane Camille, Aug 14-22, 1969

The damage and destruction from Camille is mapped in Fig. 2. The heaviest destruction occurred on the coastline, especially in low-lying areas. Much of this was attributed to the wind-whipped tides flooding these areas, augmented by the full fury of the winds. The intensity and extent of damage diminished considerably immediately above the high-tide line. Then wind damage gradually diminished as Camille spent itself while moving northward across land.

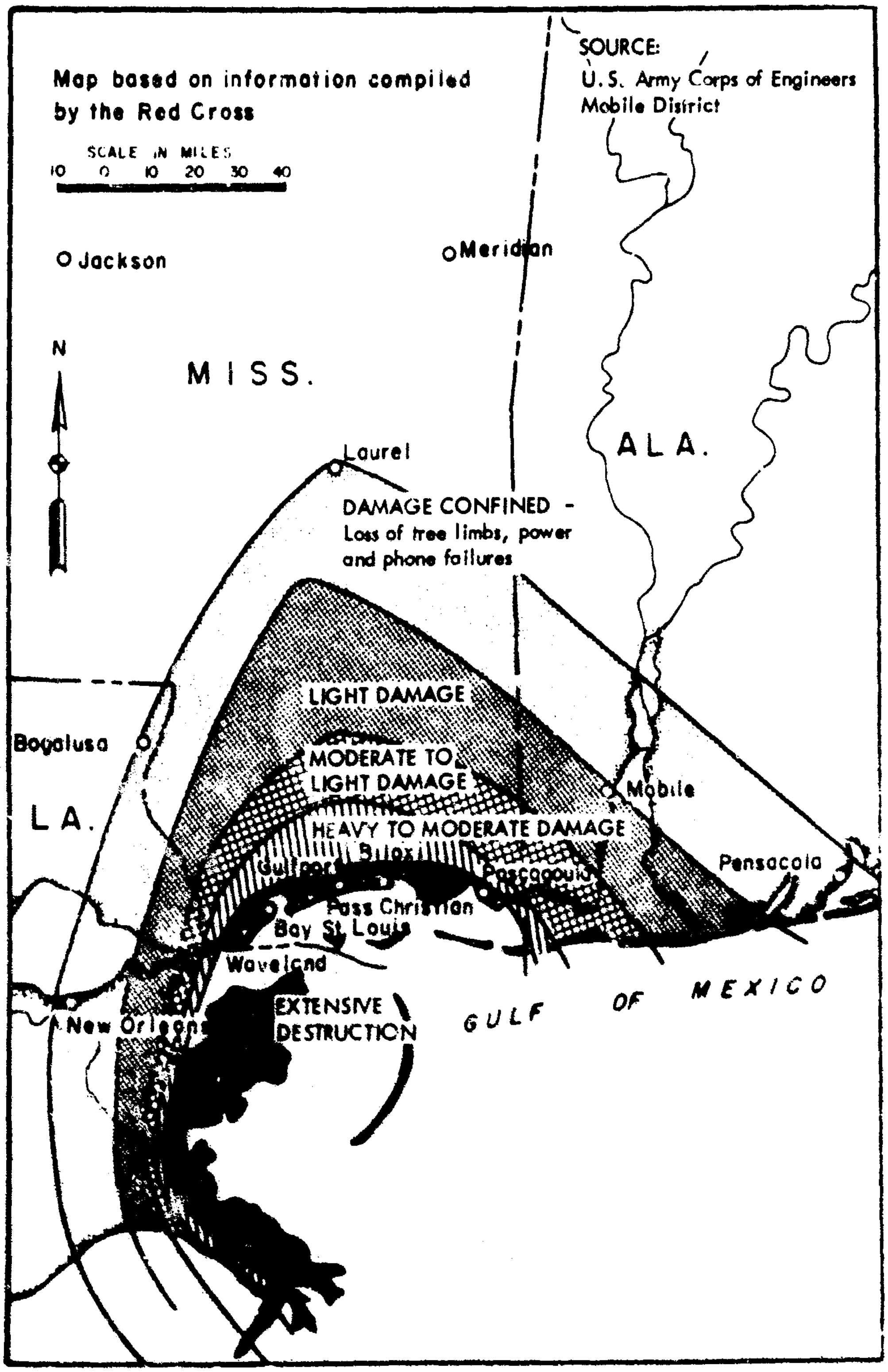

Fig. 2. Map of Damage and Destruction Levels

Section 2
FINDINGS

The interview findings are grouped by industry class (under the headings of "utilities," "manufacturing and processing industry," "food industry") and under the general heading "debris clearance."

UTILITIES

All major utilities in the Gulfport-Biloxi area were covered by interviews. These included the electric power company, the gas distribution company, the telphone company, and the Gulfport and Biloxi water and sewer companies.

The electric, gas and telephone utilities had hurricane plans and implemented these plans upon receiving warning that the hurricane was forming southwest of Cuba, even though this was more than 600 miles away and the expectation was that it would cross the coast at Florida, not Mississippi. All of these companies set up plans for calling in repair crews from distant parts of the system or from affiliated companies in the South. All utilities used temporary repairing techniques, where suitable, for the preservation of surviving equipment and the early restoration of service (Fig. 3).

The gas and water companies attempted to maintain some positive pressure in the distribution system mains in order to reduce or avoid their contamination. As a result of this policy, these companies had an immediate post-storm high workload of plugging leaks and isolating destroyed sections. The electric and telephone utilities did not have this problem.

The rate of restoring service was limited more by the availability of technically trained repair manpower than it was by the availability of repair materials. This appeared to be the case even though repair manpower was drawn

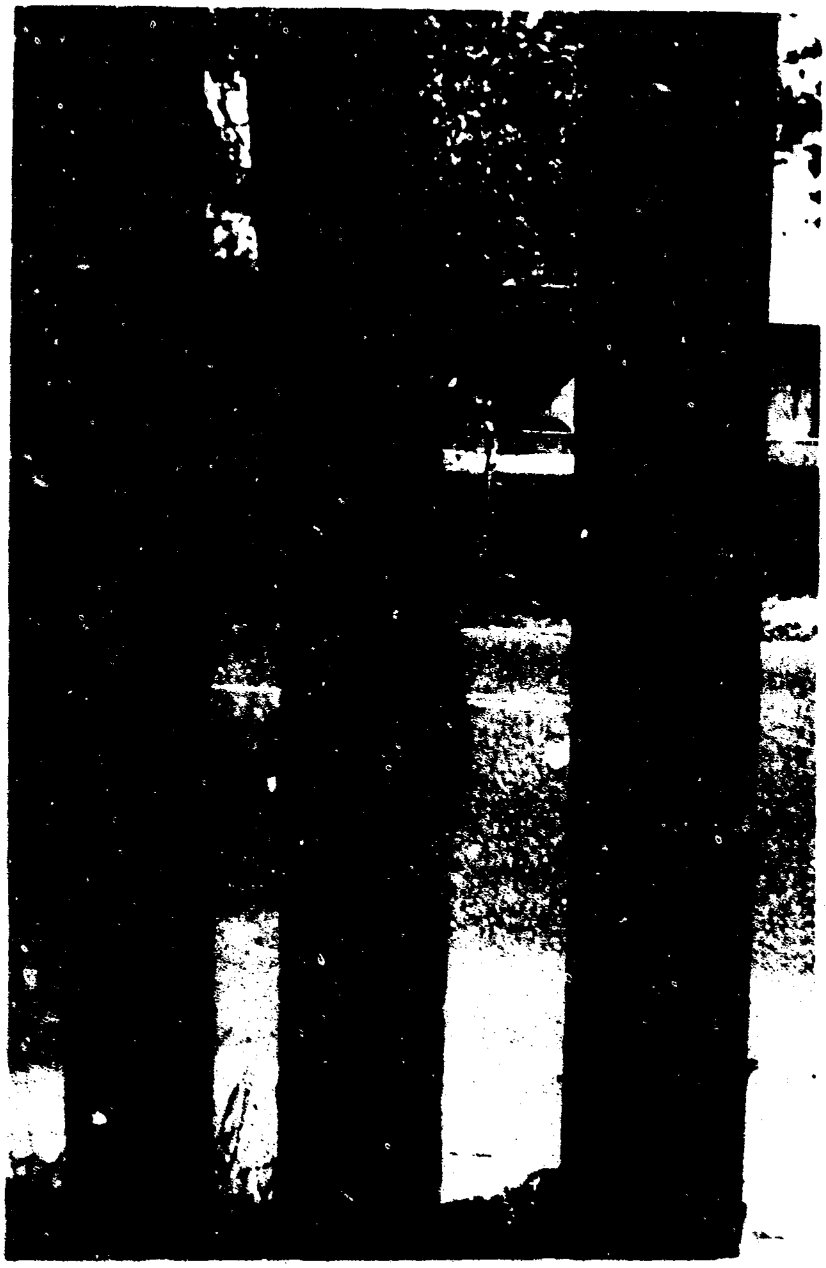

Fig. 3. Temporary Repair of Electric Power Distribution System: Stubbed Pole (Sept 1969)

from a very large area of the South. However, in order to keep well ahead of the demand, massive quantities of repair materials were shipped into the disaster area from all over the country. Planning for the restoration of service was uncomplicated, i.e., we found no evidence that any planning group made detailed or sophisticated resource allocation evaluations and decisions. We believe that such evaluations were not made by them because the massive support from outside the disaster area made such evaluation apparently unnecessary despite the magnitude of the destruction.

The distribution systems of the utilities were severely damaged. Repair crews required mobility and access to damaged parts of the distribution system. Light debris on roads seriously hampered mobility by causing flat tires on repair trucks. This problem was alleviated somewhat by a tire repair company that repaired tires in a shop, loaded them on a truck, and delivered them to the field where they were needed, trading repaired tires for punctured tires, then repeating the process.

Traffic along those routes that were open was unusually dense. Since traffic signals were inoperable, the result was severe congestion, which impeded the movement of repair vehicles and slowed the progress of repair and restoration. These conditions improved when the National Guard controlled traffic into the affected area and after the public works department and private contractors opened additional routes by clearing debris.

Had repair crews from outside the area not been available, the rate of restoration of service, it is estimated, would have been reduced to one-half to one-tenth the rate that was achieved.

These comments apply generally to all of the utilities. Comments regarding specific companies are given below.

Mississippi Power Company

The Mississippi Power Company is a subsidiary of the Southern Company. As a part of its hurricane plan, it distributed equipment and supplies from the central warehouse to local repair yards, where they would be more available at the expected point of need and where they would be less vulnerable to a freak accident. As another preparatory action, repair crews from affiliated power companies were mobilized so that they could be sent into the Gulf Coast area as soon as winds subsided.

As Camille crossed the coast and moved northward, power poles and power lines were blown down by the wind and knocked down by falling trees. Service deteriorated rapidly, and by about 2 a.m. August 18, the Mississippi Gulf Coast was virtually without electric power. The failing power lines started several fires, but these were apparently minor and of little consequence.

Southern Services, Inc., Birmingham, the Southern Company's service organization, was contacted early Monday morning, August 18, for help in securing additional line crews from Mississippi Power's sister companies in Alabama, Georgia, and Florida. This enabled Mississippi Power Company personnel to concentrate on immediate repair problems.

The extent of damage and status of the power distribution system on Monday morning, August 18th, as described in Ref. 10, are shown in Fig. 4 and tabulated below. The Jack Watson power plant, the largest on the

Table 2

ELECTRIC POWER SYSTEM TRANSMISSION LINE DAMAGE

Transmission Line	Percentage Out of Service	Structures Down
230 kv	35	67 towers
115 kv	65	51 H-frames
46 kv	77	56 poles

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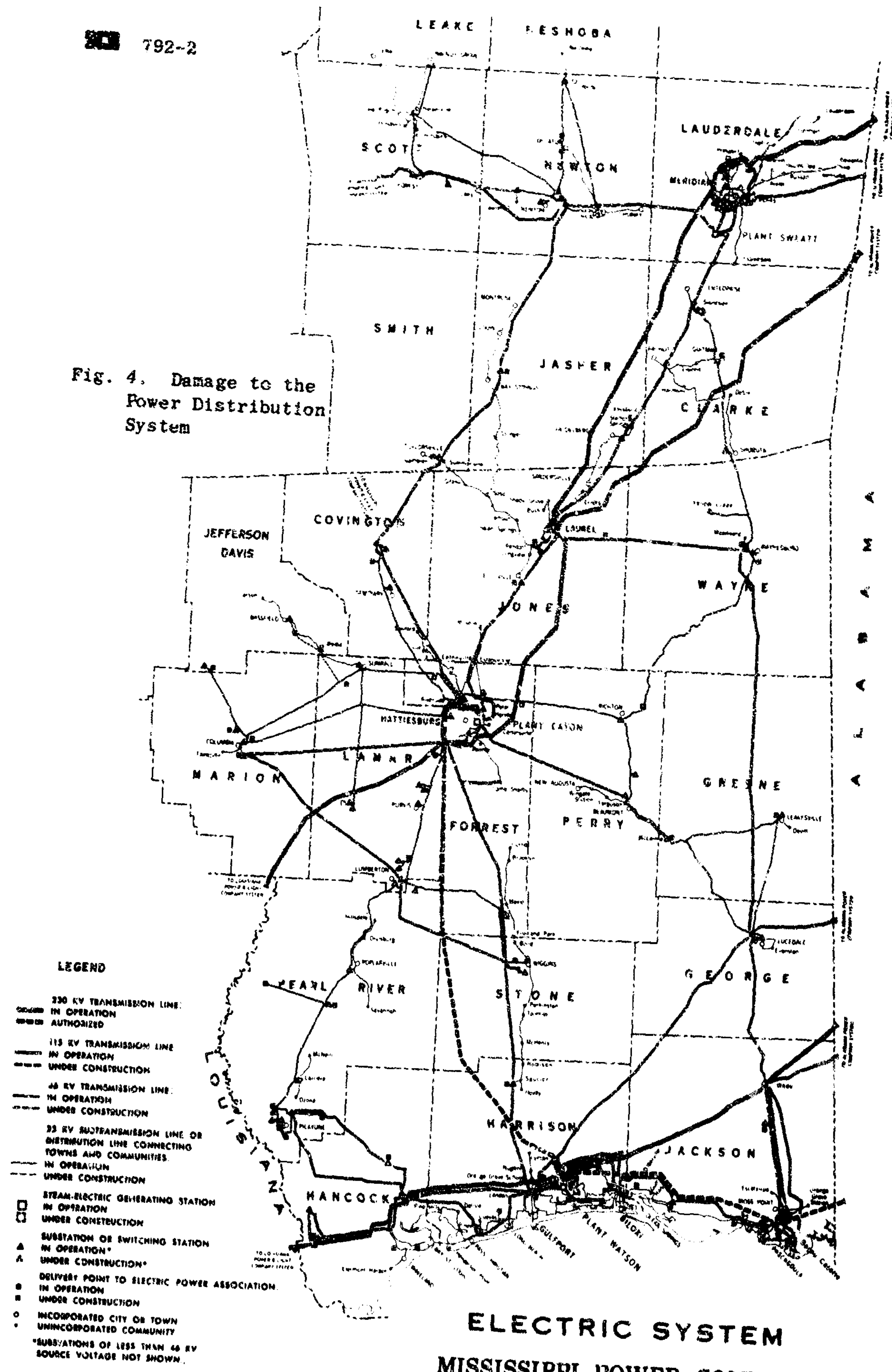
Fig. 4. Damage to the Power Distribution System



The extent of system interruptions as a result of Hurricane Camille is graphically shown on this map in black. Lines printed in red remained in service during the storm.

Mississippi Gulf Coast (Fig. 5), suffered only minor damage, but the 230-kv transmission line (Figs. 5 and 6) was extensively damaged.

Approximately 1600 specialists were brought in from affiliates during restoration operations. On the peak day of activity, approximately 1350 line personnel (the equivalent of 300 crews) were working in the area. The normal complement of repair specialists is about 100.*

The estimated rate of restoration of service, based on available data, is shown in Fig. 7. Several thousand pre-storm electric customers sustained severe damage and were unable to accept service within a month after the storm. However, within 5 days after the storm, the power company was able to re-energize 60% of those needing power and almost all others within 15 days.

Repair crews worked on an area-wide basis according to a pre-planned set of priorities. This method of operation greatly simplified supervision and management problems and also diminished the need for centralized communication.

Distribution system restoration priorities are prescribed in the established Hurricane Bulletin under "Work Assignments." The sequence of restoration is as follows:

1. Necessary sub-transmission feeders
2. Substations
3. Essential service customers
    - Hospitals and clinics
    - Waterworks
    - Sewerage facilities
    - Food processors and distributors
    - Ice plants

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*The feeding and lodging of this large number of persons would have been difficult under the best of circumstances. This problem was magnified following Camille because such a high percentage of the restaurants and the motels were destroyed by the hurricane; hence lodging and eating facilities were critical items and will be included in revised hurricane plans.

Fig. 5. Plant Jack Watson, Principal Gulf Coast Steam Electric Generating Station, and 230-kv Transmission Line

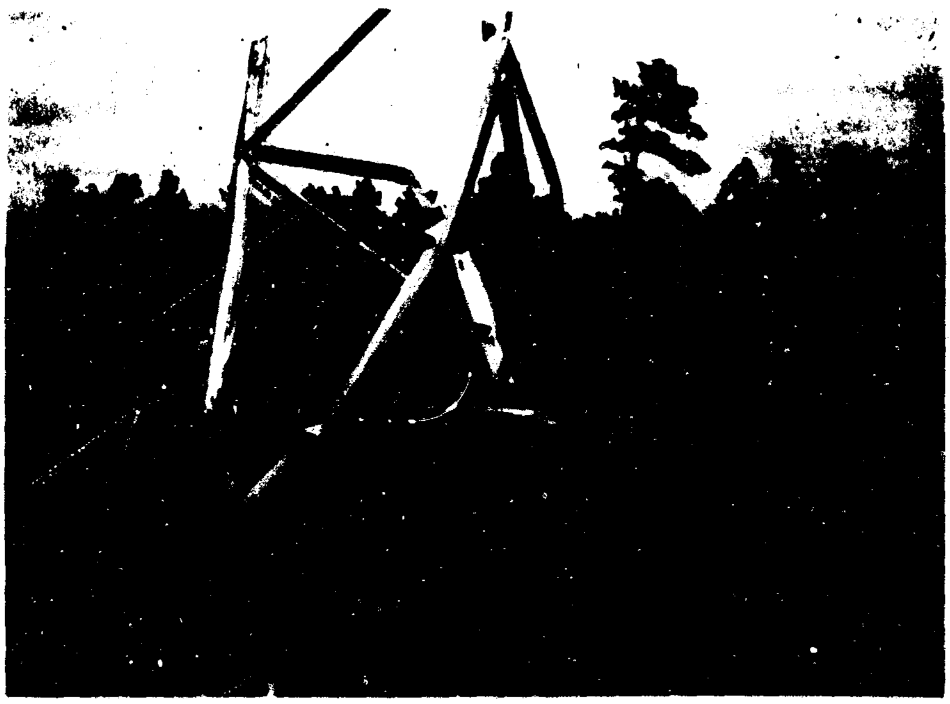

Fig. 6. Collapsed 230-kv Transmission Tower

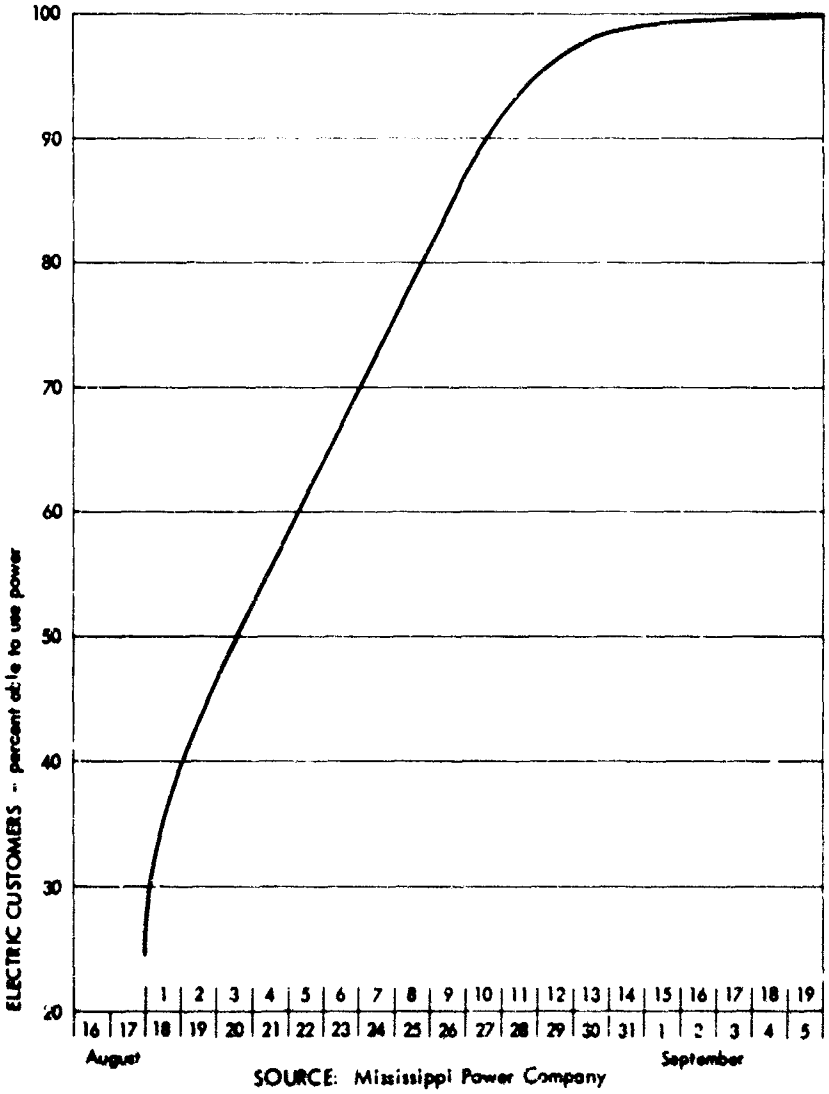

Fig. 7. Mississippi Power Company's Recovery from Hurricane Camille

4. Feeders
   - Individual customers served by undamaged line from feeders
   - All customers having service entrance wiring in adequate condition
   - Other customers
5. Undamaged primaries (fuse replacement only)
6. Damaged primaries
7. Secondaries
8. Services
9. Street lights

Downed power wires represented a potential hazard to the populace, so the power company periodically issued safety bulletins to radio, television, and newspaper throughout the day. There were no reports of electrical injuries to citizens from these downed wires.

<u>United Gas Distribution Company</u>

Hurricane plans were implemented. This included shutting off service to customers on the south side of U.S. Highway 90 along the beach. Service to the city of Pass Christian was shut off after the hurricane due to the magnitude of the damage to the homes and businesses in that area. Service to the balance of the system was maintained.

System damage was confined mostly to the beach area and resulted chiefly from structures tearing loose from their foundations and gas connections. Some uncovering of gas mains resulted from water wave action, as indicated in Fig. 8.

The 32 service and construction employees and approximately 25 vehicles normally working in the Biloxi-Gulfport area were augmented by additional company personnel from other operating areas of the company in Mississippi, Louisiana, and Texas, increasing this work force to 127 men and 68 vehicles. In addition, 30 to 40 contractor personnel assisted in restoration work.

Both plugging of severed lines and service restoration work were performed mainly on a block-by-block basis, with additional manpower in reserve for on-call work.

Small severed lines were plugged by driving wooden pegs into pipe ends or by the use of expansion stoppers as temporary repair, followed by permanent repair later. Larger lines were shut off by pipe squeezers and by welding the

Fig. 8. Damage to Gas, Water, and Sewer Mains Near the Beach (Sept 1969)

ends closed. In spite of extensive damage to United's distribution system, there were no fires, explosions, or injuries as a result of gas leakage. This is in part attributed to the fact that natural gas is primarily methane, which is lighter than air, and that winds were strong enough to dilute the gas below the explosion point.

Repair crews and others who came into the Gulf Coast area from other locations were hampered in their local travel by the fact that street signs had blown down during the hurricane. Wherever possible local non-technical personnel, such as company salesmen, were assigned to one or more repair crews to act as guides.

The hurricane plans for United Gas Distribution Company were judged by the company officials to be sufficient for preparing for and recovering from Hurricane Camille.

South Central Bell

The South Central Bell telephone system provides service to the states of Mississippi, Alabama, and Louisiana. As a part of its hurricane preparations, the telephone company alerted crews from northern districts and affiliated companies well in advance of the storm. Then a "hot" line to Jackson was established from the Gulfport-Biloxi area. At midnight on August 17th the hot line was used to call the crews into the Gulfport area.

Traffic managers of South Central Bell made 15-minute checks on circuit traffic beginning many hours before the storm. Limiting devices were installed primarily on long distance circuits so that outgoing long distance telephone calls would have a degree of preference over incoming long distance calls. Some of this limiting action was required pre-storm, but the heaviest limiting occurred after the storm.

The telephone company lost about 80% of its Gulf Coast long distance circuits, more than 80,000 public and domestic telephones (or about three-fourths of the pre-storm total), and about 700 poles. The long distance submarine cable across Bay St. Louis, which carried about 800 circuits, was lost.

Several types of temporary repairs were made. The Bay St. Louis long distance submarine cable was replaced with a cable laid on the railroad trestle across the bay; this action was completed within a week after the disaster. Supplementary long distance circuits were provided by portable microwave units set up in downtown Gulfport. Temporary telephones, both long distance and local, were set up on plywood panels at prominent locations in Gulfport, Biloxi, Pass Christian and Bay St. Louis.

After the storm subsided, telephone company engineers performed a "broad brush" survey in about 3 days to identify the locations and extent of major damage to the system. Detailed planning for reconstruction and repair was held to a minimum by repairing lines according to a pre-established set of priorities. An estimating crew would precede the construction crew, usually by a few days, to make a detailed survey of a damaged section of the system. This survey included a complete listing of all parts and equipment required for restoring that portion of the system to pre-storm conditions as specified by blueprints that were available. The materials were drawn from stores and put on the repair trucks; the construction crew then proceeded to rebuild the system to original specifications.

Cable troubles were among the more serious disorders; 2900 were reported in the service area, mostly along the Gulf Coast. Both aerial and (to a lesser degree) underground cables, containing perhaps several hundred telephone pairs (one pair per circuit), were torn, severed, and otherwise damaged. Often moisture leaked into damaged cables and seriously degraded signal quality. Restoration, splicing, or replacement of a multiconductor cable is a tedious, labor-consuming task.

Miraculously none of the central offices (there are about eleven in the Mississippi Gulf Coast area) was seriously damaged. The central office in Pass Christian was saved by the employees who sandbagged the low openings and effectively prevented flooding by seawater. On the other hand, thirty-seven private switchboards (PBX) were completely destroyed and nine partly destroyed. (Some of these were not needed post storm because the businesses they served had been lost.)

A problem peculiar to the telephone company became evident. When a station that had been severed from the line was called, the caller heard a normal ringing sound, leading him to believe that the station was functioning normally. The caller was thus prompted to continue ringing and wait for his connection to be completed. This peculiarity in the system resulted in incoming long distance calls tying up the lines for extended periods. The problem was alleviated through the tedious procedure of manually identifying stations on severed lines and then installing intercepts* on each line.

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*An intercept is a recorded message stating that the station called is temporarily out of service.

Water and Sewer

The cities of Gulfport and Biloxi each have independently functioning water systems and independently functioning sewage systems. They are operated under each community's Department of Public Works.

Water

The Gulf Coast area has abundant water available from shallow wells. It is drawn from these wells by electrically powered pumps. Some storage capacity and hydrostatic head is maintained by water towers. Several of the pumps have standby diesel for emergency power.

The Gulfport water system has blocking valves so that portions of the system can be isolated selectively. Further, this system has standby gasoline or diesel motors on three of its pumps. The Biloxi system has no blocking valves.

Pre-hurricane preparations included topping off the Gulfport 850,000-gallon tower to give it stability against the winds and then valving it off to provide an emergency source of water for fighting fire. In addition, electricians and well-maintenance crews in Jackson were alerted.

Post-hurricane survey revealed that 25 percent of the Gulfport water distribution system was damaged and normal power was lost to all pumps. After the hurricane, damaged parts of the system were isolated with the blocking valves and at three locations diesel-driven pumps were activated to maintain pressure. The Gulfport system never fully lost positive pressure. On the other hand, the Biloxi system, which also lost power to all pumps, had breaks which were not all sealed for 3 days and therefore it did lose all positive pressure and was contaminated.

The State Board of Health suspected all Gulf Coast water supply systems, from Waveland to Biloxi, to be contaminated, and issued warnings to the public, via loudspeaker trucks, against drinking untreated water (Ref. 11). Some information sources indicated that tests of Gulfport water never did show contamination, but the Board of Health reported contamination. The Gulfport water supply was cleared of contamination on August 22, 4 days after the hurricane (Ref. 11). It was reported to be approved for drinking about a week after the hurricane. Tests showed that Biloxi water was heavily contaminated. The Biloxi water system was superchlorinated and was clear of contamination on August 28, 10 days after the hurricane (Ref. 11), and reported to be approved for drinking 2 weeks after the hurricane. These delays, 1 week for Gulfport and 2 weeks for Biloxi, in restoring running water of potable quality worked a considerable hardship on the population.

In Pass Christian (which has its own water system), some residents objected to the heavily chlorinated water when the system was restored and so they reactivated some old wells which gave them good-tasting (but untested) water. Subsequently many of these people became ill, presumably from contaminated well water.

Hurricane preparations are being changed as a result of the experience gained from Camille. The blocking system is being realigned and two additional standby engines will be purchased. The well equipment that needs rebuilding will be constructed more sturdily.

Sewer

The Gulf Coast area is barely above sea level. Therefore sewage flows by gravity from the source to sumps at lift stations, where it is raised by electrically driven pumps or eductors and then flows by gravity to the treatment plant, where it is given primary and secondary treatment (some of the sewage might be lifted in two stages). The Gulfport and Biloxi systems are substantially the same. The main difference is that the Biloxi sewage system is generally at a lower elevation than the Gulfport system. The only preattack preparations taken were that several of the lift-station electric motors in the Biloxi area were removed and stored on high ground at the sewage treatment plant. This effort proved to be fruitless as the motors were flooded by the unanticipated extra-high tide.

After the hurricane, limited service was restored in the Gulfport system by pumping out the sumps of the lift stations by means of cesspool cleaning trucks. Three of the stations were inundated and the motors soaked with saltwater. Many service connections along the beach were broken. There was no electric power for the lift station pumps. Lack of city water, because of the impaired water distribution system, helped the sewerage system because less water was used, and therefore less sewage lifting capacity was required. Consequently, the cesspool cleanout trucks were able to keep up with the load.

Both Biloxi and Gulfport baked the electric motors to dry them out. The city of Biloxi re-installed these motors even though it was recognized they were not suitable for permanent service. This was done under the assumption that replacement motors for the pumps would be obtainable from outside the Gulf Coast area in time to maintain a continuous service. These motors operated satisfactorily for a while, but eventually they overloaded and shorted out and were severely damaged. Nevertheless, the city considered this tactic for rapidly restoring service was justified for public health reasons.

Sections of Biloxi were underwater during the height of the storm. The sewage system filled with water, and when the tide subsided it was left with a positive head of water. Further, because the pumps were damaged and without power, this positive pressure could not be relieved. As a result, there was a very unusual "domino" effect of damage. The positive pressure inside the sewer eventually blew out many of the joints and, since these sewer pipes are buried in fine sand in many parts of the town, the sand began to sift through the leaks in the joints and into the sewer. This in turn left voids under the pavement of city streets in many places. Subsequent heavy traffic on the city streets broke down the pavement, exposing potholes. The resulting damage to the street system and to the sewer system was so serious that the city is contemplating replacing large portions of the sewage system.

The Biloxi sewage treatment plant was inundated and all controls were flooded with saltwater. The following table indicates the restoration of sewage service for Biloxi.

Days After Hurricane	Date	Event
0	8/17	Hurricane Camille hit Gulf Coast
8	8/25	Two sewer lift stations were partially operable
12	8/29	Manual chlorination of sewage begins
13	8/30	Two eductor stations in operation
19	9/5	Primary sewer systems serving 100% of the people
approx 90	approx 11/18	Secondary treatment begins

Primary treatment was begun after 12 days by manual operation of the plant. However secondary treatment was delayed for an extended period because critical electronic instruments and controllers were unavailable even though a nationwide search was initiated for them.

MANUFACTURING AND PROCESSING INDUSTRY

Almost all industrial establishments took heed of the hurricane warning and made preparations for the high wind and high tides. Most establishments shut down (many shut down routinely over the weekend anyway), cleaned up, and secured all the gear that might be blown about by the high winds. Plants were then either evacuated or staffed by security guards. Those facilities that could not shut down completely — mostly because of high-temperature furnaces requiring more than 3 days to cool — recruited emergency crews for maintaining the plant equipment on a standby condition.

Storm damage varied considerably among the facilities. Low-elevation plants suffered water damage, especially to electric motors, electrical controllers, electrical terminal boards and the bearings of rotating machinery. Some of these also suffered damage from water-driven debris (Fig. 9). The plants at higher elevations suffered minor wind damage to siding and roofs, which in turn left the interior of the plants vulnerable to wind-driven rain and saltwater. This water damaged electrical equipment.

Plants were restored by cleaning them up, repairing damaged siding, and by cleaning and repairing or replacing electrical equipment and bearings that

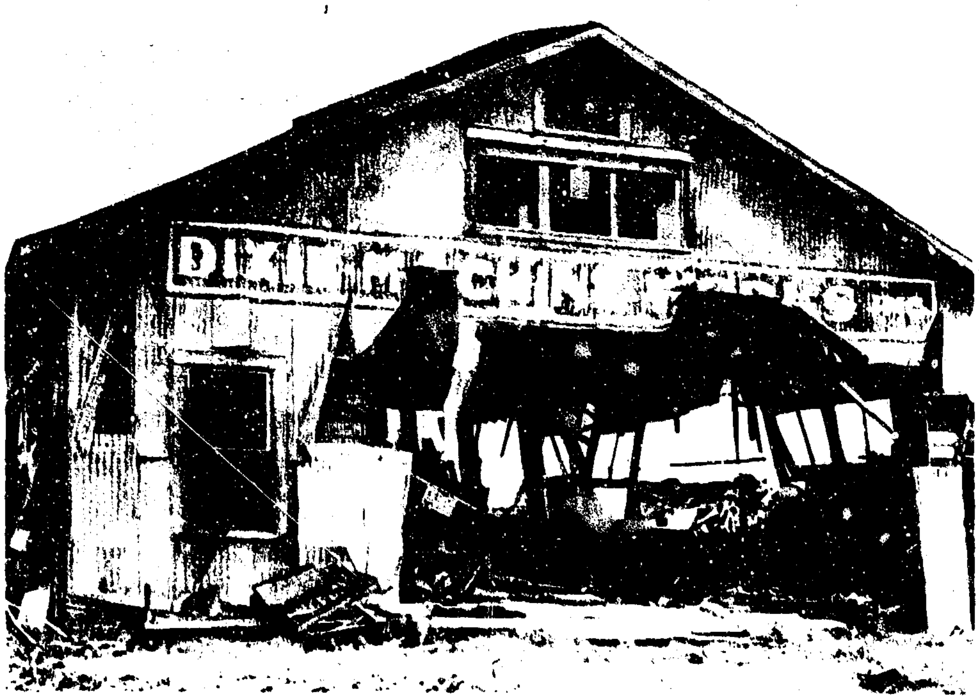


Fig. 9. Small Machine Works Badly Damaged by Debris-Laden Tide (Sept 1969)

had been damaged by water. In all but a few cases, the damage was minor and the plant staff assisted materially in restoring the plants. The plant staff in general was able to clean out debris and mud and to clean and refurbish electric motors and electrical terminals, etc. Contractor personnel were brought in to repair building siding and roofing and to perform the more technical repairs and refurbishing. In many cases the plants were restored and ready for production before electrical service was restored. Notable exceptions are discussed in the following paragraphs.

Standard Oil of Kentucky

This petroleum refinery is located in Pascagoula, Miss., and has a normal capacity of about 135,000 bbl a day (Fig. 10).

The plant has three types of shutdown, a crash down taking 2 hours but possibly causing severe damage to some operating units; a safe shutdown taking about 12 hours and much less harmful to equipment, and an orderly shutdown which takes 48 hours and does not apply unusual stress to equipment. With any type of shutdown, the plant normally maintains operation of its steam plant so that steam-traced lines may be heated and stand-by pumps operated. This open-air plant has found that it cannot safely operate with winds in excess of 50 mph because of the hazards to personnel from flying debris. Therefore the management elected to proceed with the orderly 48-hour shutdown and to evacuate the plant except for a small security force.

During the storm, the steam plant and all emergency power were incapacitated by the tide flooding the plant to a depth of about 4 ft — which was also the major source of damage. Electrical items and the bearings of rotating machinery were damaged. The total damage ran into the millions of dollars.

Restoration of the plant would have been impossible without supplies and parts obtained from outside the area and, in many instances, from great distances. Bearings and electrical parts were the most critical items. The plant's own work force was augmented by 80 refinery men imported from affiliated

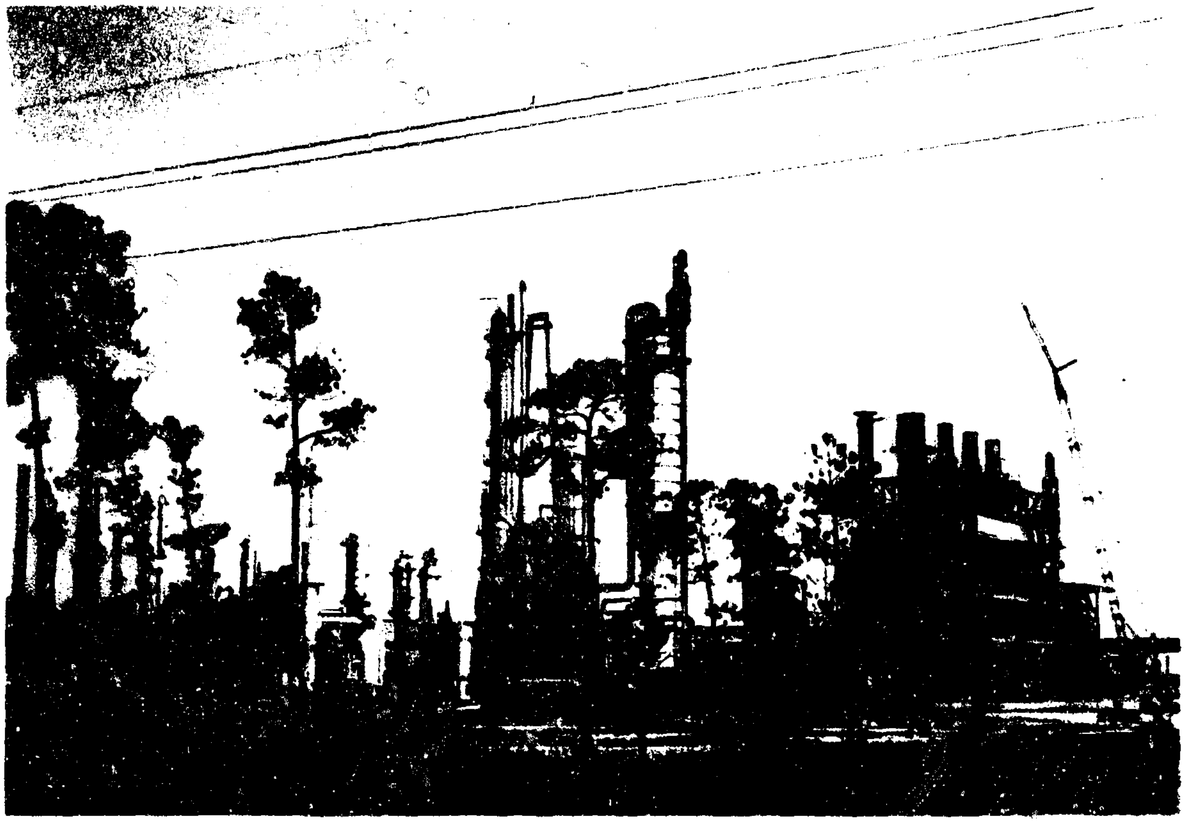


Fig. 10. Standard Oil of Kentucky, Pascagoula Refinery (Sept 1969)

companies across the United States and by 400 contractor personnel not accustomed to working in oil refineries. (They appeared to work at about 50% of the efficiency of the oil refinery men.) In addition, 650 electric motors were sent out for repair. Electrical power service was restored within 2 days. The plant was restored and ready for production after about 1 month. Without the imported help, the plant would have been out of service two to three times as long.

The amount of damage to this oil refinery by flooding is very dependent upon the depth of floodwater. Had the water depth been 3 ft less (that is, just 1 ft), damage would have been almost insignificant. However, had the depth been 2 ft greater (that is, 6 ft), instruments and controllers would have been submerged and the amount of damage would have been enormous. The management of this plant is now considering diking, either a peripheral dike or dikes around individual units.

Olin Aluminum

This establishment manufactures extruded aluminum shapes and has about 178 employees.*

The plant has a shutdown plan to be executed in the event of hurricane both to protect personnel and to protect the aluminum furnaces, which if "crashed down" could take as long as 5 months to refurbish. The hurricane plan was in force 36 hours prior to the expected time of the hurricane's arrival. The casting house was shut down 24 hours prior to the storm. Then, on Sunday, the mill was shut down, which took about 5 hours.

After the storm, an equipment damage survey was performed in about 3 hours by one experienced man. Significant equipment damage was limited to one 60-hp motor, which is considered minor for this plant. However, obtaining a replacement motor was very difficult. During the restoration period, absenteeism was minor and did not hinder the progress of restoration. Electric power was restored within 2 days (the plant is a large consumer of electric power), and production was resumed in 8 days.

Glenbrook Laboratories

This plant manufactures milk of magnesia and has a large pharmaceuticals warehouse. The establishment has approximately 85 employees.

The plant (except for the chemical processing area) is routinely shut down on weekends and offers no significant shutdown problem. It has its own well and a 75,000-gal standpipe. A portion of this capacity (50,000 gal) is reserved for firefighting and leads directly into the fire protection system.

*Workforce data derived from the following sources: "Principal Manufacturing and Processing Plants, Gulfport, Mississippi," prepared by the Gulfport Chamber of Commerce and "Community Audit for Biloxi," prepared by the Director, Biloxi Port Commission.

The chemical processing plant was shut down prior to the anticipated arrival time of the hurricane, and a number of employee's families sought shelter in the plant. The plant suffered little damage.

Electric power was restored 4 days after the storm and production was resumed in about 7 days.

The emergency plan for the facility is being revised to include emergency power for lighting.

Gulfport Glass

This establishment manufactures glass bottles. It is located adjacent to Glenbrook Laboratories. It is the source from which Glenbrook obtains all its bottles. Gulfport Glass has about 172 employees.

The plant's hurricane plan includes shutting down production and stopping the pouring from most furnaces. However, a few of the furnaces must keep pouring slowly or the pour throats will freeze, and unblocking is a tedious process. The plant has a 125-kw emergency electric generator, which is sufficient to maintain the minimum required forced draft to the furnaces that must keep pouring.

When the hurricane plan was put in effect, plant production was shut down, the generator was tested, and an emergency crew to maintain the furnaces was recruited (23 men volunteered). The events of major significance to this plant are tabulated below.

Time After Hurricane	Event
2 hr	Roof leaked and rainwater shut down the emergency generator
5 hr	Generator was returned to service
5 hr	Insufficient water pressure to supply glass cooling water. Pouring throats froze
2 days	Electric power was restored
2 days	50% of work force reported for duty
5 days	Pouring throats cleared
8 days	Water pressure was restored
10 days	Production resumed.

The plant suffered little damage from the storm. However loss of some weather protection allowed rain and saltwater to blow into the facility, drowning the electrical controller and causing the emergency electric generator to shut down. Gas to the furnaces was still available, and the generator was restored to service in time to keep the furnace pouring throats from freezing. However glass cooling water (from the municipal water supply) was lost and pouring was stopped to prevent the buildup of intolerable heat. The pouring throats froze at this point.

The plant was ready to begin production 8 days following the hurricane. However, water pressure was still low and the plant might have consumed so much water during production that neighboring residences would have been deprived of sufficient water. Therefore the management elected to delay the restarting of production until 10 days after the storm, when sufficient water pressure was available.

The plant must have outside utility support of gas and water in order to maintain furnace operations during an emergency. A mutual aid agreement between this establishment and Glenbrook Labs would be worthy of exploration. Perhaps Glenbrook Labs could supply water to Gulfport Glass for an emergency period.

However, if the minimum flow rate required by Gulfport Glass would significantly deplete Glenbrook's reservoir, then Glenbrook would need additional emergency electric power capacity in order to operate pumps to replenish its reservoir.

Gulfport Glass is in the process of building a new warehouse. The specifications for this new warehouse will include additional strengthening so that the warehouse can withstand severe wind loadings.

H.K. Porter Co., Inc.

This moderate-sized plant extracts magnesium oxide from seawater, combines it with chromium oxides, and fires the mix to form refractory bricks. The market is in the steel industry, primarily in Chicago, Ill., Pittsburgh, Pa., and in Birmingham, Ala. The critical portion of this plant includes two tunnel furnaces at ground level maintained at 3000°F and 3200°F.

The furnaces require a cooling period of 8 days and no preparations were considered feasible to protect them. However a small security force stayed at the plant. During the hurricane, as the tide came in and hit the hot furnaces, a tremendous volume of steam was generated, which eventually forced the crew to evacuate the vicinity of the furnaces and seek refuge in an elevated place well away from the furnaces. No corrective action was possible.

Miraculously the furnaces were not seriously damaged or collapsed by the water. Apparently the furnaces were so hot and the duration of the high tide so short that the water did not cool the furnaces unduly. On the other hand, other damage and losses amounted to more than $1.5 million, mostly through damage to electrical items and rotating machinery. In addition roofs and siding of buildings were damaged.

Many blueprints of the plant were damaged or lost. Although some of the damaged prints were recoverable, the unavailability of many others was quite detrimental to the restoration effort.

The first priority for restoration was the emergency power plant. Commercial electric power was unavailable for several weeks, therefore the company's own power plant materially aided the reconstruction effort.

Most restoration effort was supplied by plant personnel. The plant received good cooperation for manufacturers and suppliers of replacement parts and instruments. However even after more than 30 days following the hurricane, production still had not been resumed.

In its future emergency planning, this plant may consider duplicating — or microfilming — vital blueprints for vault storage.

Coastal Chemical Corporation

This small plant manufactures ammonia (500 tons/day) and phosphoric acid, sulfuric acid, and diammonium phosphate. The plant operates continuously.

Shutdown in preparation for the hurricane began 4 days before its expected arrival. The plant could have been shut down safely more rapidly if necessary.

The pneumatic instrumentation used in this open-air plant, which was exposed to the rain and saltwater, was virtually undamaged by the storm. However electrical equipment was damaged.

Almost all cleanup and restoration was done by plant personnel aided by repairmen from Westinghouse Corp. Electric power was restored in about 4 days. The lack of electric power for lighting was a major problem initially, and the plant obtained several emergency electric power generators for illumination and for refrigeration of the liquid ammonia (to reduce product loss).

Partial production was begun within 2 weeks and full restoration of production achieved in 3 weeks.

The plant emergency operating procedures will probably be revised to include emergency power. However the facility is designed to fail safe so that loss of the electric power does not give rise to safety hazards.

Resin Manufacturers

Three small plants produced condensation-type resin (poly-type resin) from petroleum fractions by polymerization. These resins are commonly used for coating paper and for making phonograph records. Chemfax Company, with 33 employees, operates on a batch process, as does the Alpine Division of Masonite Corporation. Delta Division of Reichhold Chemical Corporation (Fig. 11), with 50 employees, operates in a step-wise continuous process.

Orderly shutdown of these plants requires about 8 hours maximum. A crashdown in less than 2 hours would not leave time to empty and clean the reaction vessels and the resins would set up in them, creating a major clean up problem and perhaps a fire and explosion hazard.

The two batch process plants were shut down for the weekend as a normal course of action; later, electric power was disconnected at the mains. The continuous process plant was shut down in an orderly manner. All three plants were left unattended.

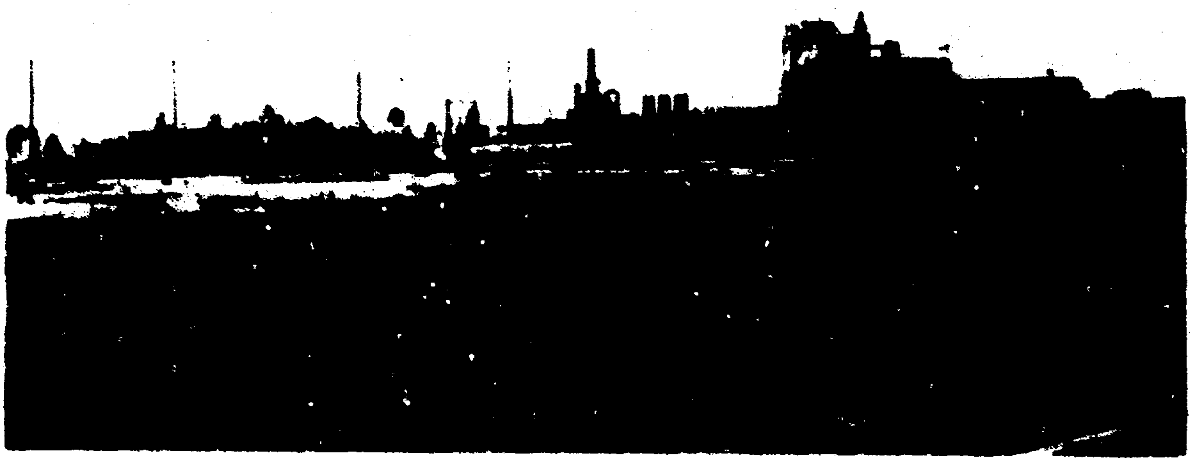


Fig. 11. Reichhold Chemical Corporation, Gulfport (Sept 1969)

The hurricane damage was limited to direct wind damage and damage caused by wind-driven debris. These plants were all above the maximum level of the tides.

One of the three plants had a storage yard containing several hundred empty metal drums. These could not be fastened down or removed before the storm. The wind scattered these drums, causing heavy damage to the siding of several buildings.

Another of the plants was designed for 100-mph winds. It suffered very little damage (fortunately, there was no loose material in the yard to cause damage).

Following the hurricane, plant personnel performed almost all of the restoration work. Electric power was restored in 2 days to 2 weeks; telephone communications for one plant was out for over 5 weeks. The plant that received the power within 3 days was able to restore two-thirds of its operations in 4 days. Production was limited by continued shortage of personnel.

None of the plants had emergency electric power. As a result, a sudden and prolonged loss of commercial electric power would constitute an unexpected crashdown, causing resins to set up and producing damage to equipment. Two of the plants had water pumps driven by prime movers to supply cooling and firefighting water.

Hurricane and disaster plans for these plants, when they are revised, will probably take into account procedures for the storage of loose equipment, crashdown procedures and fire protection procedures.

Gulf Publishing Company

This establishment publishes the Daily Herald, which is the major daily newspaper of the Mississippi Gulf Coast. It employs approximately 90 persons.

The company prepared for the storm by boarding up the many large plate glass windows and by placing plastic tarps over some of the equipment (even though the equipment was inside the building). Then the plant was secured. Some people remained in the building overnight to gather the news. This was dispatched to Columbia, South Carolina, as long as telephone communication was available.

During the storm the plant was flooded with about 18 in. of water, which brought in large quantities of mud. This mud fouled electric motors and other equipment located on the floor.

After the storm, employees cleaned the plant. An electrical contractor (who normally maintains the plant's electrical equipment) was hired to service motors; the company had no problem in securing his services. Cleanup of the plant and electrical repairs were actually completed by the end of the third day following the storm; coincidentally, electric power was restored to the plant. At the beginning of the fourth day, the plant was in full operation, and the paper was published in Gulfport that afternoon.

Every edition of the Daily Herald was published. While the Gulfport plant was out of service, an abbreviated version of the paper was published in Columbia, South Carolina, then flown to Gulfport, where it was distributed free to the Gulf Coast residents.

Timber Industry

The pine forests of southern Mississippi were very badly damaged by the hurricane. This damage was almost entirely the result of wind stressing the wood beyond its elastic limit, causing internal splintering and subsequent death of the tree (Fig. 12). Dead trees are rapidly attacked by insects and

Fig. 12. Damage to Timber by Wind, Near Waveland, Mississippi

subject to "staining" (a form of mold or mildew). Such timber grades out lower than prime timber, and if the attack is serious enough, the timber is worthless. Between 35 and 50 million board feet of timber was downed in the 101,000 acres of national forest. Total amount of downed timber in the state was estimated at 1.8 billion board feet. The estimated potential value of the downed timber was $50 million. The forestry commission estimated that the timber could start staining within 6 weeks under adverse conditions but under favorable conditions might last through winter safely.

Most timberland is farmed by landowners who contract for timber grading, cutting, hauling and shipping services. Their choice of action is therefore dependent upon the availability of these contract services. Further, the price of timber is somewhat subject to the laws of supply and demand as well as the ability of the sawmills and pulp mills to handle the volume of the material.

To avoid flooding the market or overtaxing the transportation network, the possibility of cutting and storing the damaged timber was explored. Sprinkled timber or timber floated in ponds can be stored without damage for extended periods of time. This alternative method of handling timber is limited by the amount of contract labor available to build ponds and the amount of labor and materials available to erect sprinkling systems. Further, these storage methods add cost to the timber. Also there were demands for these contract services from outside the timber industry.

This situation, with its numerous interrelated influences, appeared to afford the opportunity for a detailed resource allocation evaluation. Such an evaluation was not performed for a number of reasons, among which were:

- The possible economic payoff was not clearly presented
- State officials did not have ready resources for making such an evaluation
- The means for implementing such a plan were not evident
- Time was deemed to be too short

In short, the State Forestry Commission representatives felt that the economic situation could not be materially improved because all available resources and services were being fully used.

FOOD INDUSTRY

Sample facilities of the food industry were selected for study, including a fish cannery, a pecan sheller, a bakery, a bottling plant, a meat packer, a milk distributor, and the dairy association. Most of these establishments are small, employing between one and two dozen people.

The food industry establishments away from the beach had no hurricane plans. Only the dairy association took steps to protect itself against loss of electric power. Most food plants can shut down and clean up their operation fast enough with normal hurricane warning.

Emergency repair work was commonly done by plant employees and was aimed at protecting equipment and inventory from the weather. Then plant employees cleaned the plant and did minor repair and restoration work on plant machinery.

The most common types of outside assistance requested were roofing contractors and electrical contractors. Roofing contractors were the most urgently needed to assist in making temporary repairs of roofs to protect equipment from possible future rain damage.

After the hurricane, some food processors had difficulty in retaining their work force because local temporary high-paying jobs attracted their common laborers.

Seafood Cannery

The seafood industry, mostly at Biloxi, was hit especially hard. The most severe damage appeared to be caused by the high tide, waves, and water and wind-driven debris. There were indications that, in some cases, extensive damage was caused by the tornado-like winds that struck before the water waves hit. Of the 14 plants, 12 were still out of operation 1 month after Camille. Figure 13 shows the typical appearance of the industry's structures at this time.

Mavar Shrimp and Oyster Co., Ltd., which is located on the Gulf waterfront, employs about 100 persons, and normally cans seafood as pet food all year, and seafood for human consumption during the summer. Hurricane precautions began Friday, more than 60 hours before the hurricane struck. These precautions included, among other things, removing electric motors

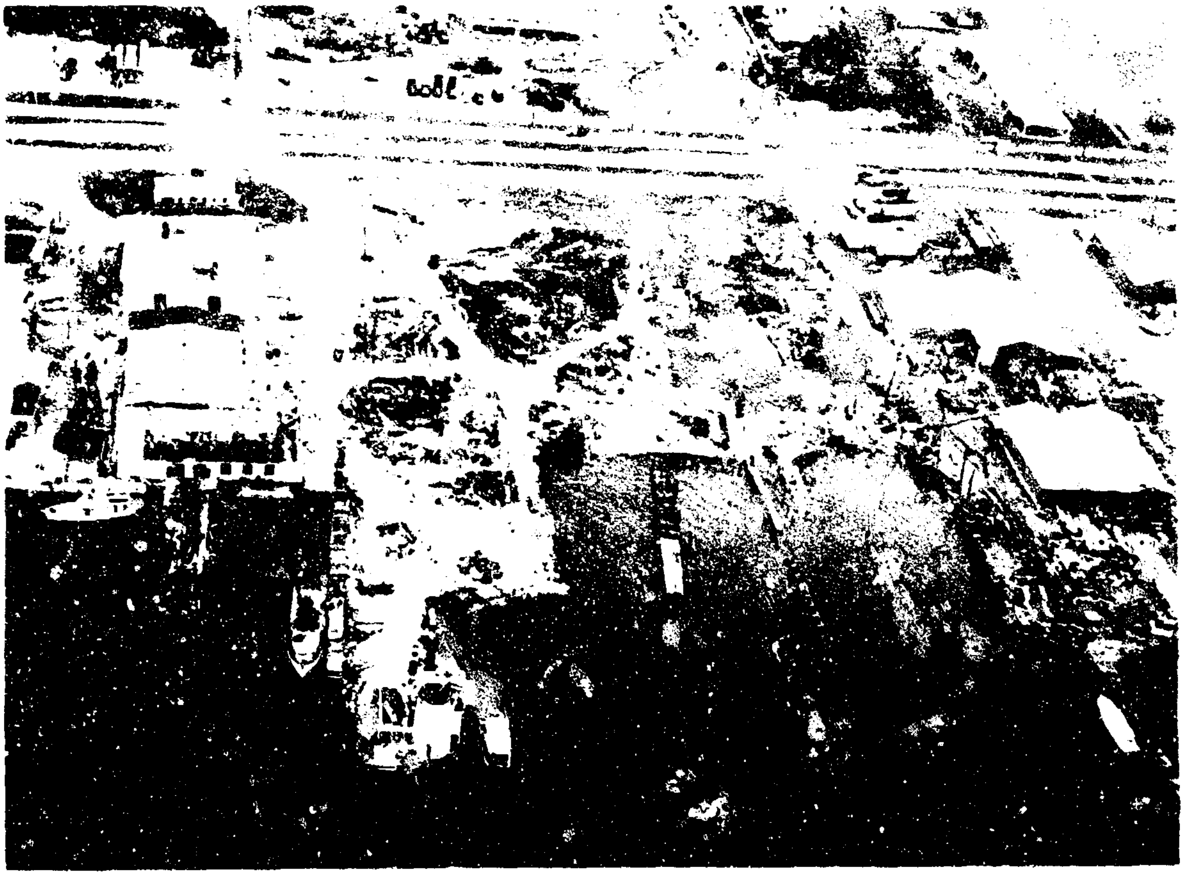


Fig. 13. Cleanup and Rebuilding of Fish Canneries on Gulf Side of Biloxi (Sept 1969)

and taking them to high ground, tying down all loose equipment that could be secured, and moving product inventory to high ground. More precautionary actions were planned than could be accomplished during the 3 days available.

During the course of the storm the facility structures were extensively damaged; much of the building siding and processing equipment was destroyed. This cannery can be seen on the left of Fig. 13. The worst aspect of the water damage was that the tide was higher than anticipated and inundated the high ground where the motors and the product inventory were stored, thereby nullifying much of the storm preparation effort.

Bottling Plant

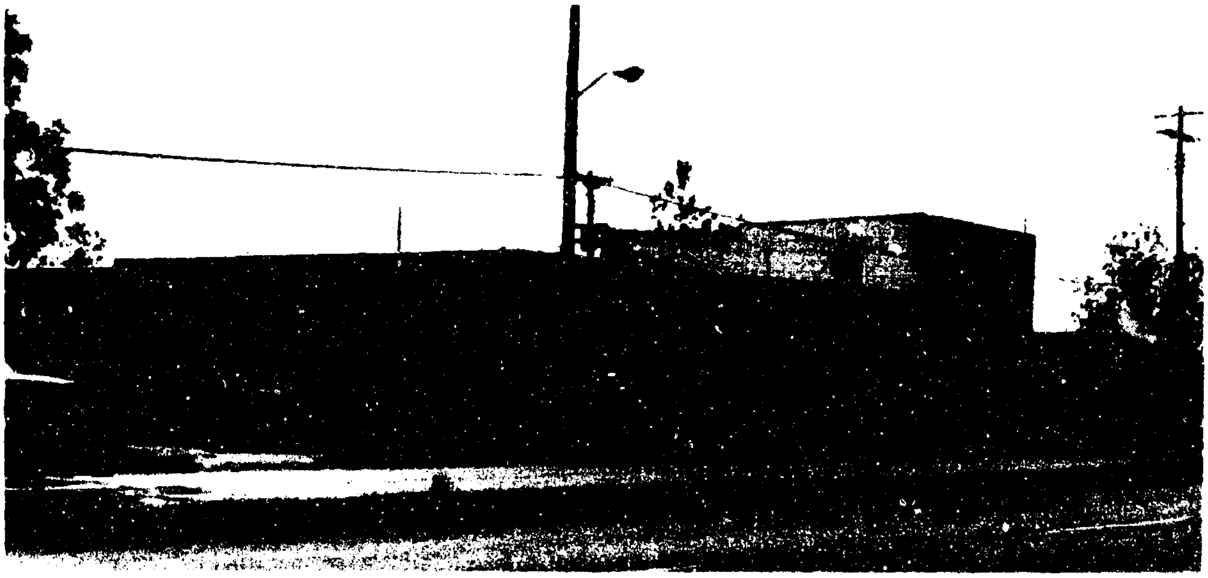
The Seven-Up bottling plant (Fig. 14a) with 15 employees produces soft drinks in both returnable and non-returnable bottles. This plant uses water from its own wells and imported syrups and extracts. Products sold in cans are purchased from out of town contract canners, distributed on a franchise basis but not produced locally. The building suffered moderate damage, mostly to siding, doors, and roofs. Equipment damage was minor, but the plant did sustain some damage to inventory. Temporary repairs to the structure and permanent equipment repairs took a total of 2 man-months. Half of this effort involved plant personnel; local carpenters did the rest. The plant was ready for operation in 1 week.

Thirty percent of the plant's customers were beach establishments which were lost. Also lost along the beach were vending machines valued at $35,000, as well as approximately $30,000 inventory of bottles, cases, and illuminated electric trademark signs. In the absence of telephone service, delivery routes were re-established through personal contact by salesmen. It took about 4 weeks to fully restore the routes, excluding the establishments that were destroyed.

Pecan Sheller

Williams Pecan Products Co. has about 30 employees. This company purchases pecans grown in the Mississippi Gulf Coast area, shells and grades them, and sells the meats to markets generally outside the area.

The tides from the hurricane did not reach the plant, and from the street the building appeared almost undamaged (Fig. 14b). However, the roof had suffered enough damage so that substantial wind-driven rain and saltwater was blown into the building. This roof damage was not visible to an untrained observer scrutinizing the 1:10,000 scale aerial survey photographs.



A. Seven-Up Bottling Plant. Significant-appearing exterior damage but equipment damage was easily repaired

B. Williams Pecan Products Co. Exterior damage appeared insignificant but equipment and inventory was severely damaged.

Fig. 14. Typical Appearance of Plants Inland of Gulfport, One Month After Camille

The major equipment damage was due to airborne water (which contained an appreciable quantity of salt) which penetrated through the damaged roof. This water got into the refrigerator (which had lost power) and contributed to the mildewing; subsequently the Food and Drug Administration condemned over 1 week's finished production. The water also rusted much of the machinery and damaged beyond repair most of the electronic grading equipment. Replacement grading equipment was not available locally and required 7 to 8 weeks for delivery. Temporary repairs to the structure and permanent restoration of production equipment was accomplished by plant personnel in 8 to 9 weeks.

Grading adds about 3% to the value of the product. Production of ungraded nutmeats could have begun in about half the time actually required, using self help and a local roofer. Further, in an emergency, the mildewed product probably could have been salvaged for human consumption.

Bakery

This small downtown bakery produces rolls and cakes for local trade. Although the bakery suffered very slight physical damage, putrefaction caused serious problems. The proprietor did not take the precaution of cleaning up thoroughly Sunday after work. The next day, electric power was unavailable and the proprietor still could not clean up because the interior of the bakery was unlighted. As a result, all loose flour molded and the required cleanup took several days.

Eighty percent of the bakery's normal trade — beach resort — was lost, but enough retailers inland were picked up as customers to almost compensate for the loss.

Meat Packers

Dedeaux Packing Co., with about 35 employees, is a rather small facility and depends primarily on hand labor. Electric power was lost and minor structural damage occurred. Electrical power was supplied through a Civil Defense portable generator to keep the refrigeration units going, thereby preserving inventory in the freezers. Commercial power was off for over 2 weeks.

Restoration of production was hampered by labor shortages. On the other hand, the demand for meat products increased for a short time from 3 head per day to 20 head per day.

Milk Distributor

Barber Pure Milk is a distributor that has plants at scattered locations over two states. The local distributor employs about 25 persons. The operation is sufficiently integrated that plants can double up to compensate for lost plants. The operation includes a number of trucks and drivers.

The facility, used mainly as an office and for storage, suffered only superficial damage and power outage. Route service was somewhat impaired because of street and traffic conditions.

Response to the emergency was prompt. It included transporting ice into the area to preserve milk stocks at retailers, and bringing in packaged water within 12 hours after the hurricane and distributing it as needed.

Dairy Association

The Gulf Coast Dairymen's Association provides marketing service for the raw milk of 60 dairies and has about $3 million in sales per year. The dairy operations in this locale generally are highly mechanized. Cattle feeding, milking, and milk processing are done by machine.

Power loss affected all dairies and lasted from 1 to more than 16 days. This was the most serious consequence of the hurricane because every phase of milk production, including storage, depends on electrically powered equipment. Milking by hand was limited by the shortage of trained personnel.

Several types of emergency action were taken to maintain milking operations. A 35-kw Civil Defense generator was mounted on a truck and moved among four dairies to supply power for milking cows and refrigerating the milk. This action was highly successful. No other portable generators were available immediately following Camille. Some milking machines are vacuum actuated; these were attached to the intake manifold of gasoline engines. This mode of operation was satisfactory but very slow. The milking rate was reduced to a bare minimum. Fresh cows were milked once a day instead of twice, and the cows which were drying up were not milked at all. Teat dilators (a device that dilates the duct in the teat sufficiently to allow milk to flow) were used as a last resort with disastrous results; about 20 to 25 (or 50% of those so treated) became infected and had to be destroyed. Altogether, about 8% of the cows were lost for milking and were sold for beef.

All dairy farms but one had a loss in production because of Camille. The most important reason was lack of electric power. Figure 15, derived from information supplied by the dairy association, shows the restoration of production and the restoration of dairies following Camille. This figure

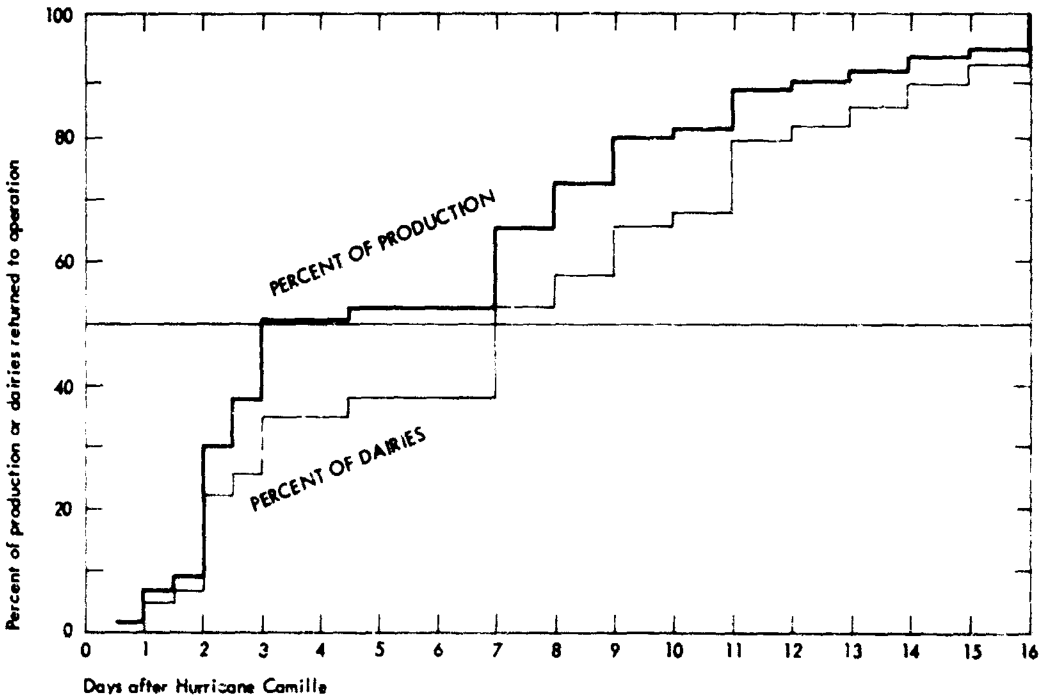


Fig. 15. Recovery of Dairies Following Camille

shows that, in general, power was restored to the larger producing dairies quickly (within 3 days, production was back to 50% from 35% of the dairies). The total milk production lost is equivalent to about 4.7 days' full production.

The Gulf Coast Dairymen's Association is now preparing a disaster plan. In addition, about one-third of the dairies have purchased emergency power generators.

DEBRIS CLEARANCE

An enormous amount of debris was created by Hurricane Camille. Apparently most of this debris was caused by the action of the waves coming in on the rising tide. These waves pounded structures to pieces, uprooted trees, and washed floating debris inland to the approximate location of the high-tide line. Masonry debris and other heavy debris was moved for shorter distances. Consequently, most of the debris that blocked roads and streets was low-density debris, primarily wood in some form. In addition, the high winds felled many trees over a very large area of the Mississippi Gulf Coast; many of these fell across roads. Occasionally, tornado-like winds moved entire houses off their foundations and into the streets, partially blocking them, or demolished structures and scattered the debris into the streets.

Other storm action disrupted highways and bridges. The main highway, US 90, a four-lane highway which runs along the coast from Bay St. Louis to the Bay of Biloxi, was badly battered by the storm. The highway bridges over the Bay of St. Louis and the Bay of Biloxi were both thrown out of alignment by the battering action of the waves so that they were virtually impassable by auto. The highway between these bridges was choked by debris in spots and undercut both by wave action and by the receding waters, so that large portions of it collapsed and were impassable. Emergency transportation operations were severely curtailed because of the loss of this important highway.

<u>Five-Step Program</u>

Debris clearance proceeded in five steps:

1. Opening all roads to emergency vehicles
2. Opening all roads to two-way traffic
3. Roadside debris collection
4. Cleanup of condemned property
5. Beach cleanup

The manpower, equipment, management, and funding which contributed to the debris-clearance operation came from many sources. The first step was accomplished by the local Public Works Departments with support from the Naval Construction Battalion Base and local contractors. The second and third steps were started by Army Engineer units and continued (together with the fourth and fifth steps) by private contractors from a six-state area under the management of the Army Corps of Engineers (Mobile District) by the direction of the Office of Emergency Preparedness (OEP).

Step 1. Opening Roads to Emergency Vehicles

The day after the hurricane, work began on opening a single lane for emergency vehicles. Two miles of lanes for fire engines and ambulances were opened in three days. Debris was moved aside to clear a path for vehicles. The Public Works Departments had 20 to 30 chain saws and 3 front end loaders for this work. The Navy Sea Bee Base supplied two battalions to civil authorities and portions of these construction units helped open roads. Local private contractors also contributed bulldozers, etc., and operators. We gather that efforts were concentrated on the most restricted parts of the important arterial streets.

Step 2. Opening Roads

Other streets and roads were similarly opened for two-way traffic during this step in order to provide access to all parts of the stricken areas and to clear utility rights of way, thereby permitting access by utility crews for the restoration of utility services. Debris was moved off to the sides of the highways, roads, and streets into windrows and heaps so that traffic could resume. Much of the street-blocking debris was in the form of fallen trees and water-driven building debris. The trees were frequently cut into manageable lengths with chain saws to facilitate their removal from the traffic lanes.

This work, under the Army Corps of Engineers, was designated "Phase I." Five civilian contractors, working for the Corps, began opening roads by the third day following the hurricane. These contractors had a total peak force of 121 men, 84 pieces of heavy equipment, and 26 chain saws. They had opened all major access roads after 1 week of work.

Two groups of Army Engineers, totalling 920 men and their equipment, arrived within a week after the hurricane and, under the general direction of the Corps of Engineers, in 2 weeks cleared 338 miles of streets and disposed of 17,000 truckloads of debris.* By this time enough civilian contractors were operating so that Army assistance was no longer critically needed. The Army units were then withdrawn.

Step 3. Roadside Debris Collection

This step included collecting the windrowed debris from Step 2 (Phase I of the Corps work) along the sides of streets and transporting it to designated disposal areas north of each city along the Gulf Coast. Clearing operations extended to 10 ft beyond the street edge in order to pick up as much debris as possible from private property without going onto the private property.

This operation required three passes. The first was primarily street debris. Because property owners were encouraged to remove debris from their property and set it at the side of the road, the second and third passes were primarily trash and debris from private property. The first pass accounted for about 75% of the debris; the second pass, 15%; and the third, 10%.

The Corps of Engineers organized the disaster area into 20 parcels of about 5 square miles each and designated a dump site for each. Then contractors were selected for working each of the parcels. This operation was designated by the Corps of Engineers as "Phase II."

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*From briefing notes prepared by U.S. Army Corps of Engineers, Mobile District, 8 Sept 1969.

Dump areas were chosen that would be as far removed as possible from residences, but the attempt was made to minimize hauling distances (Fig. 16). Existing dumps were used where possible. Some dumps were designated for burning, others for filling and covering, still others for dumping. The smoke from one dump designated for burning became very objectionable to nearby residents; the fire was extinguished only after several weeks and great expenditure of effort.

The Phase II operation included hauling about 70,000 loads of debris during the three passes. The debris had been scattered nonuniformly over the 740 miles of roads, being entirely absent over many miles and extremely

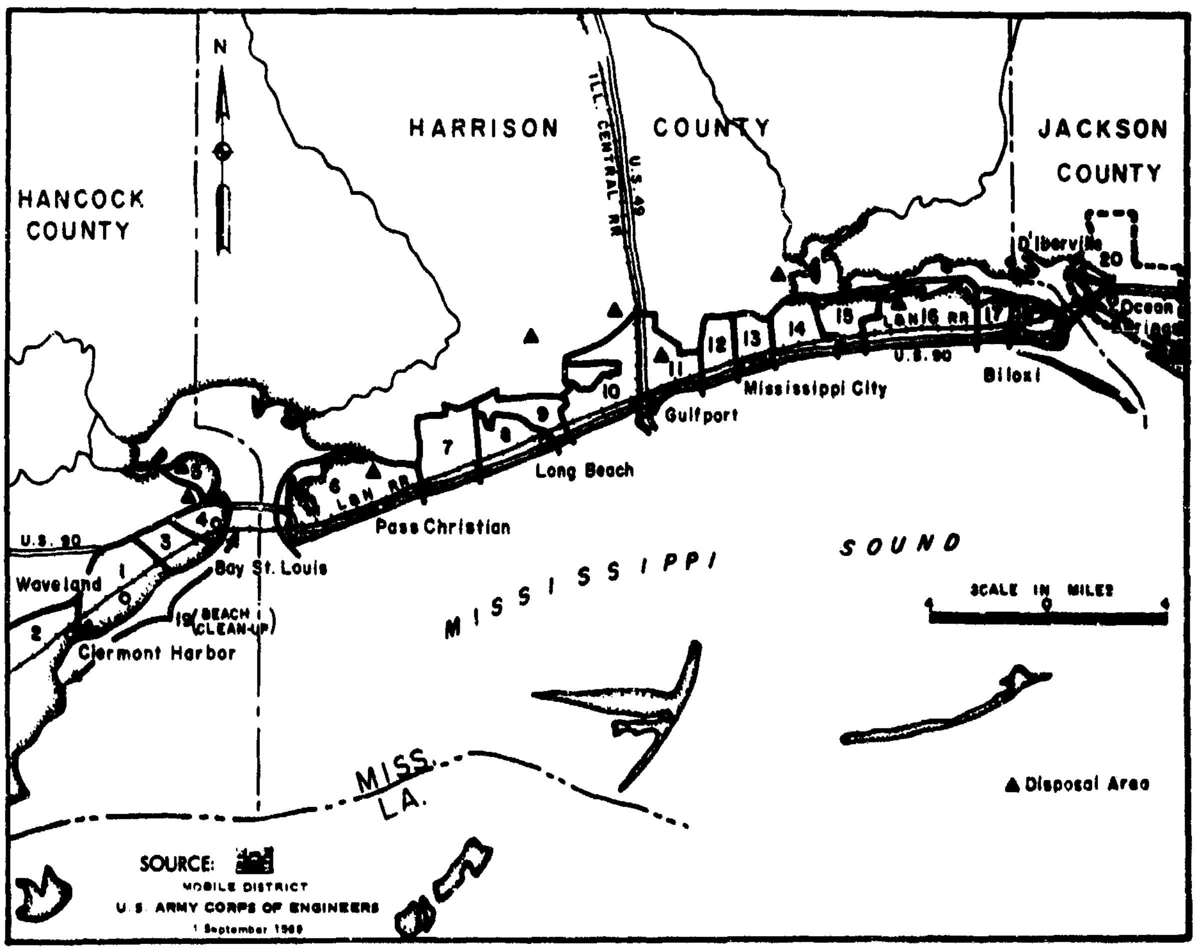


Fig. 16. Contract Parcels, Mississippi Cleanup Operations

thick over others. Uniformly distributed, the amount collected would have constituted a 3-ft-wide windrow, 1 ft deep, on each side of the 740 miles of road.*

Step 4. Cleanup of Condemned Property

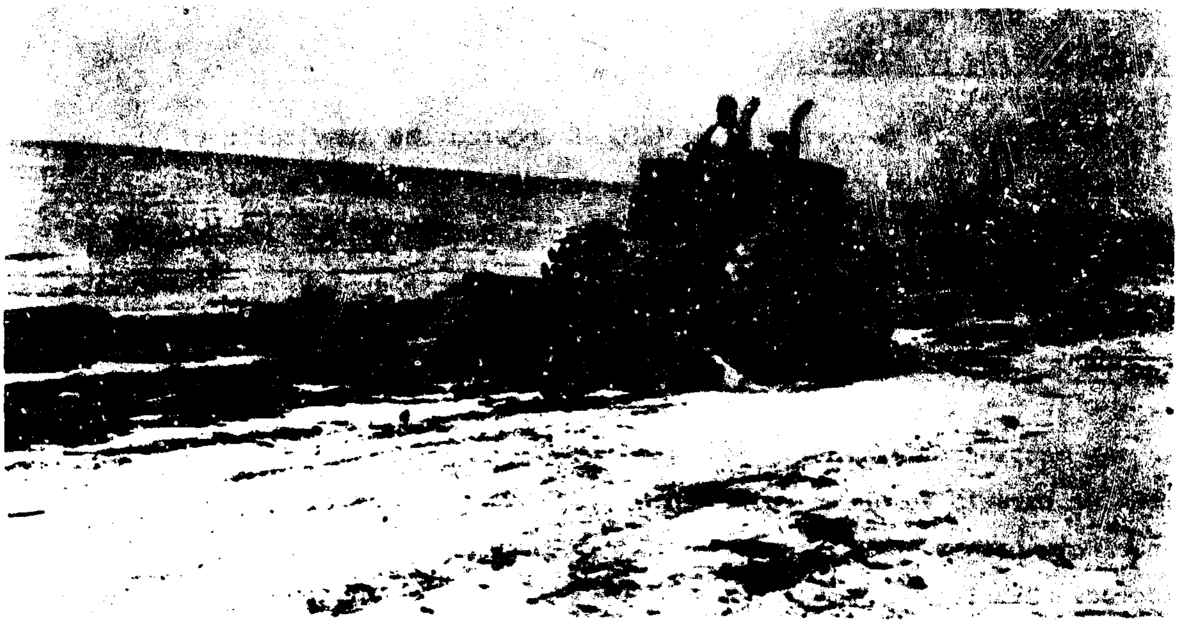
This step included debris removal and building demolition from private property in the interest of public health and safety at the request of the U. S. Public Health Service. The work was managed by the Corps of Engineers and was designated "Phase III" by them. The Corps of Engineers obtained the necessary liability releases from property owners for this work so that contractors could operate on private property to clear all debris from the property.

Those portions of parcels that were designated for Phase III debris clearance were subdivided into 300 by 300 ft squares. This unit area was chosen because it could be readily visualized and provided a useful increment for measuring daily progress. The Corps estimated that the average square could be cleared by removing about 70 truckloads of debris.

Step 5. Beach Cleanup

The beach cleanup operation was somewhat similar to the Phase III operation, except that, because the beaches are generally not private property, liability releases were not required. Further, the techniques of beach cleanup were readily mechanized (Fig. 17).

*This estimate assumes trucks carrying one-fourth of their cubic capacity.



A. Scraping Debris into Heaps

B. Debris Heaps Ready for Removal to Dump

Fig. 17. Beach Debris Cleanup Operation (Sept 1969)

Contracting for Clearance

The Office of Emergency Preparedness ordered the Army Corps of Engineers into action on Tuesday, August 19. An emergency area office was established in Gulfport on that day. This office grew to a complement of 17 officers and 44 civilians who assessed the clearing problem, determined priority for clearing operations, prepared bid requests, evaluated proposals, and awarded contracts to civilian heavy-equipment operators.

As mentioned, the Gulf Coast area was divided into 20 separate contract areas or parcels as shown in Fig. 16. Each parcel was the subject of a separate contract to be awarded on the basis of successful competitive bidding. Bidding was initiated soon after the storm, and within 2 weeks, contracts costing $2.7 million had been awarded for the Phase II operation, which was scheduled for completion within 45 to 60 days.

The Phase III operation was initiated shortly after the Phase II contracts were let, mostly using the same contractors. Thus the Phase III operation was largely an extension of the Phase II work. The Phase III operation was expected to continue for several months.

Contracts were let on a labor and equipment-time basis. Other alternatives that were considered were fixed price and cost plus fixed fee. The latter methods require preparing an estimate of the work to be done prior to the awarding of the contracts. This estimating could not be performed fast enough to allow prompt commencement of the work. Further, a fixed-price contract was considered infeasible because of the large number of litigations that could arise as a result of differences in opinion concerning necessary contract variances in the course of work.

As a result, all contracting was done on a manpower and equipment-time basis. Contracts ran for 30 days, at the end of which they could be terminated or renewed. Further, contractors were given about 10 days to get their equipment together and to get their operations organized; the Corps of Engineers retained the option of terminating a contract 5 days later (15 days total) if a contractor showed he was obviously unable to get his operation underway. The Corps did not feel it necessary to terminate any contracts after 15 days; however, one contract was not renewed after the 30-day period.

Debris Clearing Operations

Debris clearing consisted of a series of separate operations that included gathering, loading onto trucks, hauling, and dumping. Often the "gathering" required cutting pieces to a manageable size and demolition of hazardous structures.

A military team for debris clearance included:

5 dump trucks (10 cu yd capacity)
1 bucket loader
2 chain saws (22 in.)*
1 saw file
8 men (minimum)

These crews operated on an 11-hour day, each truck making approximately 10 round trips to the dump site.

Civilian heavy-equipment teams were similarly organized, using three or four dump trucks per loader. However, the dump trucks had capacities of 10 to 26 cu yd and the loaders available to the civilian contractor were of assorted types, most of which were considered less efficient, for the type of debris present, than those used by the Army. Civilian teams managed about 8.5 loads per day per truck.

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*A 36-in. chain saw would have been a better choice had it been available.

Table 3 shows statistical data for the debris-clearing operation as gathered by the Army Corps of Engineers from 9 contractors working the 20 parcels. Table 4 shows how the effort and progress varied for one parcel over 9 days.

Many different types of equipment were used for loading debris onto trucks. The front end loader with a standard bucket was almost useless for clearing brushy debris because it could not hold onto large pieces while maneuvering them onto the trucks. The types of equipment that had grapplers were effective in loading debris onto the trucks. The "Prentiss" type loader was by far the most versatile loader. However, for specific debris clearing tasks, other types of loading equipment were more useful (Ref. 13). For example, cane loaders were especially useful for very bulky and lightweight debris, but they were less effective on large pieces of heavy debris. The standard 4-in-1 loader as used by the Army was also highly satisfactory for loading bulky debris onto trucks.

The tailgates of trucks were removed for the debris-hauling operations so that trucks could be dumped more quickly (Fig. 18). Although this mode of operation facilitated dumping, it had several disadvantages. Trucks could not be loaded to more than about one-half their capacity, and debris very often bounced off the backs of trucks during transport, thereby littering the streets and creating minor road hazards. Trucks usually appeared to be hauling only about one-fourth their cubic capacity, but this estimate is based on casual observation and not on a statistical sampling at a control point. Trucks were often forced to queue at the entrance to dumps, which was wasteful of equipment time.

Table 3

ARMY CORPS OF ENGINEERS DEBRIS-CLEARING OPERATIONS

Item		Typical Day*	Totals to Sept 15
PERSONNEL AND EQUIPMENT			
Contractor Personnel Working**		2239	
Total Pieces of Equipment Working			
Loaders	177		
Dumps Trucks, Phase II	509		
Miscellaneous Equipment	517		
		1421	
WORK ACCOMPLISHED			
Truck Loads Delivered		6309	70,215
Phase II Operation			
Miles cleared Pass 1		39	678
Pass 2		36	440
Pass 3		24	73
Total miles to clear			740
Phase III Operation			
300' squares cleared		27	60.5

*Sept 15, 1969 **9 contractors working 20 parcels

Table 4

NINE DAYS' OPERATION ON PARCEL 6

Date	Total Personnel	Total Equipment	Trucks: Phase II	Trucks: Phase III	Trucks: Total	Loaders	Ratio of Trucks to Loaders	Loads Hauled	Performance: Phase II Miles Cleared	Performance: Phase III 300' Squares Cleared
Sept 8	177	91	57	0	57	13	4.4	508	5	0
9	366	166	99	0	99	26	3.8	[illegible]	1	0
10	372	190	96	0	96	40	2.4	[illegible]	3	0
11	397	196	107	0	107	28	3.8	911	10	0
12	341	214	114	0	114	22	5.2	[illegible]	8	0
17	347	228	11	80	91	25	3.6	614	7	10
18	371	244	19	77	96	26	3.8	627	8	9
19	[illegible]	311	20	74	94	30	3.1	611	7	10
20	366	---	19	76	96	21	4.5	629	7	10

A. Heavily Loaded Truck Headed for the Dump. Note that the load overhangs the truck bed.

B. Loaded Trucks Awaiting Entrance to Dump

Fig. 18. Debris Hauling

MISCELLANEOUS OBSERVATIONS AND FINDINGS

While conducting interviews and site inspections in the disaster area, several items of civil defense and emergency operations interest, but not directly related to the objectives of this study, were noted.

Military Support

The Navy Mobile Construction Battalion located at Gulfport and the Air Force unit located at Keesler AFB, Biloxi, both offered assistance to the local government following Camille. The Navy SeaBee's had training and equipment that were of great immediate benefit. They contributed 2 battalions (about 1500 officers and men) for 2 days following the hurricane. These battalions performed rescue work and debris clearance and assisted the public utilities. In addition, the SeaBee base loaned the Civil Defense Director many portable emergency power generators. The Air Force generously supplied manpower and vehicles. The National Guard was mobilized and acted immediately to maintain law and order, to restrict the flow of sightseers into the area, and to help direct traffic in the downtown areas where traffic lights were not operating and congestion was severe. Then the Army Engineers arrived for debris clearance, as discussed earlier. All of this military support was an important contribution and was appreciated by the Gulf Coast residents. Reference 1 describes details of these and other Federal actions.

Remedial Movement

A remedial movement operation occurred during the height of the hurricane at the SeaBee base. The SeaBee headquarters learned, through radio communications with the occupants of warehouses used as shelters, that the windward walls of four warehouses were coming apart and exposing the interior of these warehouses to the fierce debris-laden winds. These four warehouses held between 800 and 1200 men and officers. The warehouses had to be evacuated. The question was only how to effect the move most quickly and safely.

A nearby warehouse (about 1/8 to 1/4 mile away) was already housing a large number of military dependents. Eight amphibious tractors were mobilized for assistance. The relocation operation took 30 to 40 minutes. Only about 12 men were injured, a very small number in view of the debris-laden winds (over 100 mph). Further, the injuries were not serious. The men were treated and released. During the move, discipline was maintained to an acceptable level.

The receiving warehouse, consisting of three 200-ft by 200-ft bays, eventually sheltered about 3,000 people. One of the bays similarly became uninhabitable and the shelterees then crowded into the remaining two bays containing heavy equipment and supplies. As the building became more crowded and the possibility of collapse increased because of ever-increasing wind intensity, people took refuge under the heavy equipment for additional protection. An excellent level of self-discipline was maintained throughout this extremely hazardous period.

Civil Defense Coordination

The Harrison County Civil Defense Director, Wade Guice, had a hurricane plan (Ref. 12) that was activated on first warning of the Weather Bureau. During the entire period, from warning until the emergency had subsided, the CD headquarters operated as an effective communication, information, and coordinating center, through which resource acceptance and distribution was coordinated.

The National Warning System (NAWAS) provided an invaluable communications link. The NAWAS circuit is a land line voice communications and is linked to Civil Defense and Police Departments in Pascagoula, Ocean Springs, and Biloxi, to Harrison County Sheriff's Department, the Gulfport Highway Patrol, and Gulfport and Harrison County Civil Defense, as well as the State Civil Defense Office. NAWAS was the only 100% operational communications for many days between these agencies.

Civil Defense rescue trucks were deployed and operating during the hurricane. One truck was trapped by rising tides and was lost. The many others made a substantial contribution, especially in rescue work and in plugging gas leaks.

Volunteer Supplies and Services

Many companies and individuals rushed supplies and assistance to the Gulf Coast area. Many of the Gulf Coast businessmen made their resources available.

Giant Foodstores, Inc., and Delchamp Foodstores provided more than 43 truckloads of food to the Civil Defense authorities. This food was placed in 12 distribution centers located in churches and schools throughout the area. Food was offered free in 1-day rations. These distribution centers, which operated for about 10 days, also supplied clothes and bottled drinking water.

After the 10-day period of operation of the 12 food distribution centers, the Red Cross arrived and re-oriented the distribution center system. The 12 centers were replaced by one large distribution center, which enabled much better control over distribution and reduced the cost of distributing food to the population. Many people who needed food, however, lack the transportation to get to this distribution center and therefore were hindered in their effort to obtain aid.

Packaged water was supplied by soft drink bottlers, breweries, and milk distributors, and bulk water was brought in by milk tankers for a period of about 2 weeks, while locally supplied water was of questionable safety.

Clothing poured into the area from all over the nation. However, it was not as critically needed as were water and food. Further, it was unsorted, and therefore any distribution that would not have been wasteful would have consumed much labor for sorting.

[redacted] 792-2

A railway car of chain saws was located in the vicinity of Gulfport. The owner or consignee was quickly located. He authorized re-routing of the car to Gulfport so that this equipment could be used to help clear the streets.

The ice industry in the outlying areas shipped much ice into the disaster area to preserve perishable products (especially milk) that were without refrigeration. Ice was also critically needed by the morgue.

The surviving hotels and motels often allowed repairmen to use their rooms free.

A Humble Oil Co. truckdriver, upon hearing of the scope of the disaster, drove his gasoline tanker into Gulfport and located it across the street from the Civil Defense headquarters. He then dispensed gasoline to emergency vehicles for the next 3 days without charge and did this despite a severe attack of influenza. This service was especially valuable, for although there was much gasoline stored underground at service stations, this gasoline was largely unavailable because of loss of electric power for pumping the gasoline.

FDA and PHS Involvement

The safety of the public and the possible danger to public health arising out of the disaster spurred Food and Drug Administration and Public Health Service officials to speedy action. They very quickly issued warnings not to drink water from the public water supply until test results had indicated the water was safe and also quickly condemned and ordered destroyed frozen meat that had lost refrigeration. This latter action caused a ripple of dissension. The Sheriff's Department had to supply men to guard such "suspect" meat until it was removed from the cold storage area and moved out to the dumps, where it was destroyed.

Street-Signs

Many street-signs were destroyed as Camille crossed the coast. This was of minor consequence to the local citizenry. However, the state disaster office supplied a number of expediters to the disaster area and these persons frequently lost their way around the town, especially in the areas close to the beach.

Economic Status

A study of the economics of the Gulf Coast as shaped by Camille would be a massive undertaking. However, our observations, made with our own particular bias, may be indicative of the type and scope of the problems.

The timber industry is the largest industry in the area and undergirds much of the economy. Damage to timber was extensive and required immediate attention as was mentioned earlier. As a result sawmills and other buyers of timber were deluged with logs of uncertain quality. In order to maintain an equitable (and, under the circumstances, high) price for these logs, the largest of the buyers made greater economic concessions than might have been expected.

The motel industry, another major source of income, was almost wiped out, as it was confined to the waterfront. This is expected to depress income from tourism for almost a year, which in turn will reflect on the rest of the economy.

The fishing industry, also located on the waterfront, was almost wiped out. This will probably rebuild quicker than the motels but nevertheless represents an important medium-term loss of revenue to the city of Biloxi.

The pecan orchards were very badly damaged and will be producing at lower than pre-storm level for 2 decades. Local pecan shellers will be forced to buy pecans from out of state. This will add to the cost in two ways: buying costs will be higher and transportation costs will be higher. Yet their markets will be the same as before the storm. Therefore they will find themselves in an unfavorable competitive position compared with their pre-storm status.

Post-storm debris clearance operations, which paid wages above local scale, absorbed almost the entire local floating labor pool and, additionally, drew in many laborers and semi-skilled workers from local industry, thereby hampering the restoration progress of many, particularly the smaller ones.

The overall impact of Hurricane Camille on the economy of the city of Biloxi was that it knocked out about 90% of the industrial base for at least 30 days. Consequently, the revenues to the city were greatly restricted, and it is estimated that for the next several years, its yearly earnings will be only a fraction of those for 1968. To compound the problem, the city incurred increased expenses due to the damage and rebuilding required to restore services. The city of Biloxi was faced with the problem of perhaps not even being able to meet payrolls and feared that it was insolvent.

The federal and state governments moved very rapidly to mitigate Camille's devastation. "Hurricane Camille - A Month of Federal Action" (Ref. 1) gives an overall view of the scope soon after the storm of just the federal programs aimed at helping the Gulf Coast to rebuild.

Emergency Electric Generators

Several low-lying hospitals lost their installed emergency power generating capability when the rising tide flooded their emergency generators. Apparently they had no provision for keeping these generators dry.

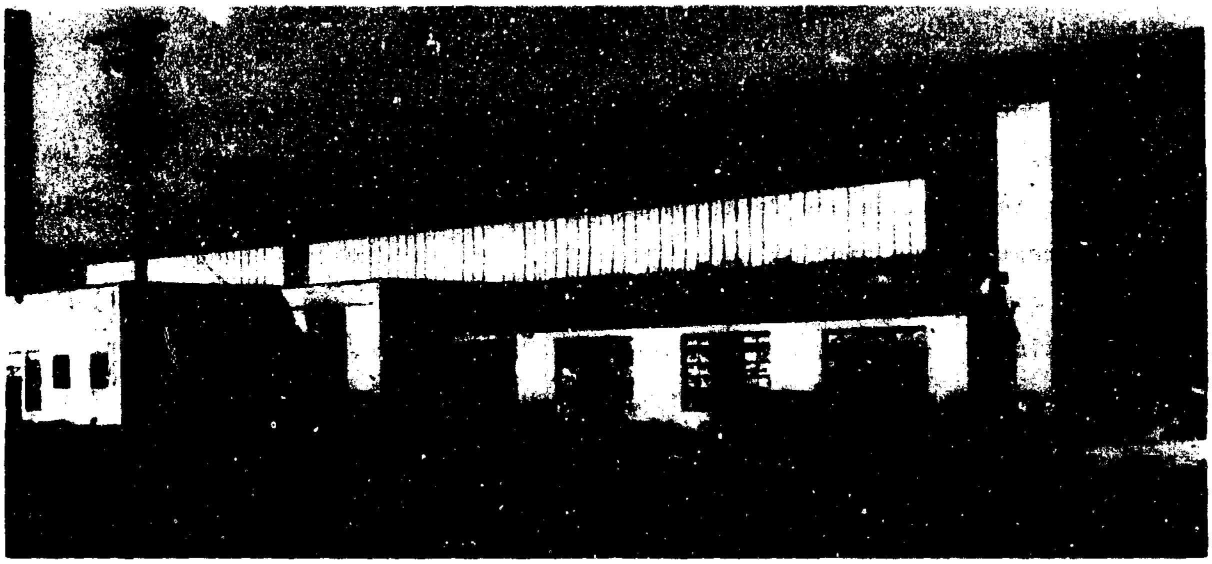


Fig. 19. Civil Defense Generators at Gulfport Airport (Sept 30, 1969)

Large numbers of portable emergency electric generators were shipped into the area as soon as the hurricane subsided. Many of these never saw service (Fig. 19). Others were delivered to sites where they could be used but were not connected. Some, as noted, were used effectively and were greatly appreciated by those who benefited. No adequate explanation for the poor utilization of some of the generators was apparent.

Civil Defense Exercises

The Civil Defense offices in the major towns and cities of Harrison County, Mississippi, had an OCD exercise that simulated a nuclear attack. This exercise took place about 3 or 4 months before Hurricane Camille. Those involved in the exercise remarked that it sharpened their skill and made them more aware of their responsibilities and capabilities, so that they were able to be more effective during the Camille disaster.

DISCUSSION

The documentation of restoration and reconstruction effort following Camille was uneven in detail and quality. Although we were given access to available information and data, we found that it was not suitable for analyzing the restoration problem quantitatively. The information that was collected was more closely related to the data requirements of conventional cost accounting practices. That is, a description of the resources in the form of accountable items such as labor, machinery, and supplies, was well documented; however, these resources were not closely identified with the degree of damage, estimated restoration effort, or work performed, except in the broadest terms. Therefore, the information relating to restoration efforts following the disaster would be applicable to planning for future disasters only in general terms.

Debris Removal

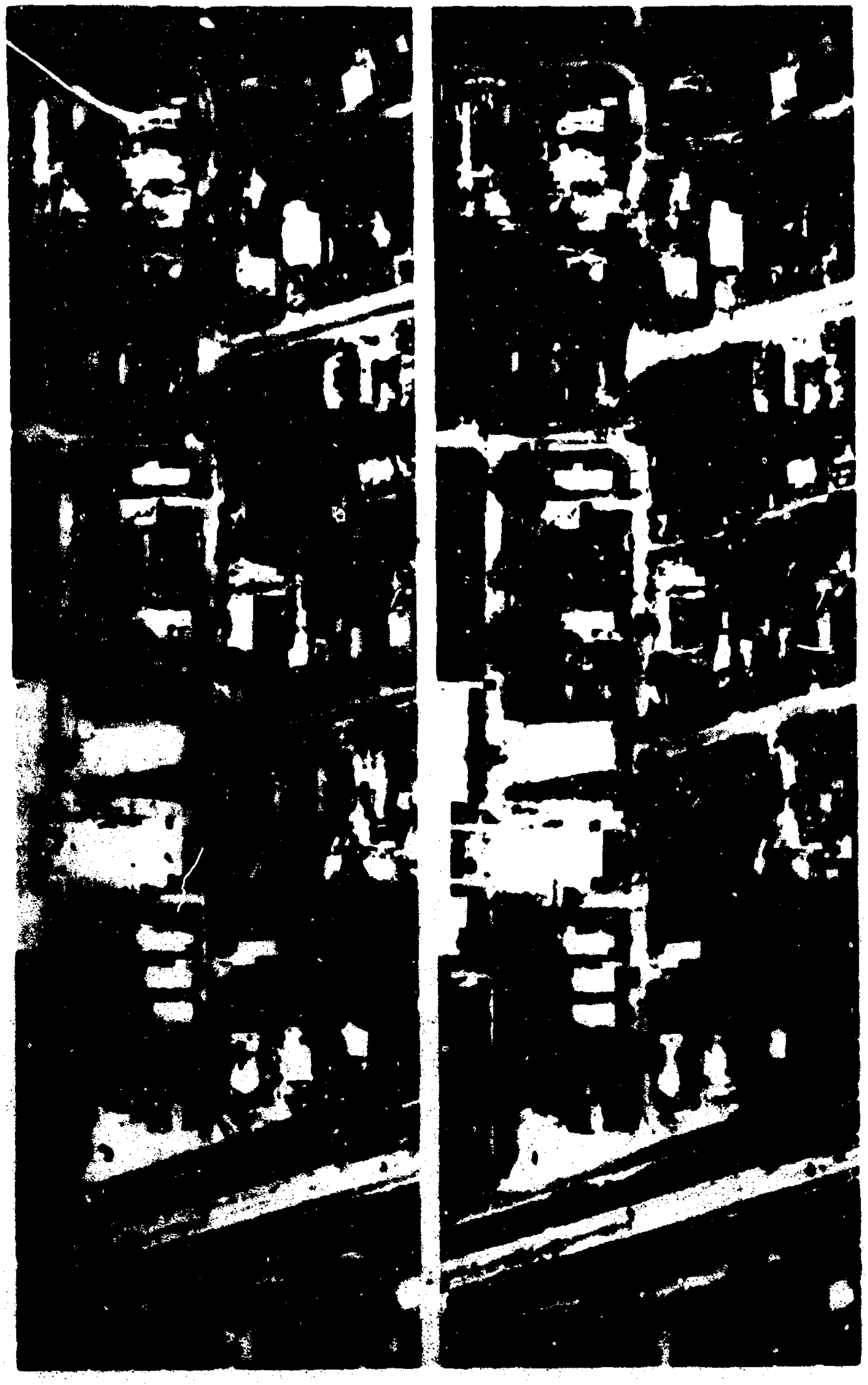
Debris removal, which was supervised by the Army Corps of Engineers, was an enormous task. The data required for cost accounting between contractors and the Corps of Engineers were most carefully collected and tabulated. However, as stated above, these data were not directly useful to developing predictive techniques. Useful information that we were not able to locate includes data on debris, truck loading, and hauling. Debris factors include type and composition (limbs, lumber, mortar, etc.), density (amount per square yard), and areal distribution. Truck loading factors include weight or volume of each load (or even of sample loads) and debris type. Hauling factors include haul distance, road conditions, e.g., traffic congestion, and time lost awaiting entry to the dump. URS and George Wickham of Jacobs Associates made some "back of the envelope" calculations and estimated that debris hauling rates may have been as high as one-half or as low as one-tenth the work rates calculated using formulas and factors developed by Jacobs for postattack road opening operations (Ref. 5). The work rates in Mississippi were not unreasonable when one considers qualitatively several factors that are not included in the work-rate formulas: contracts were let very quickly so that work could get underway; contracts did not contain any strong incentive features; many of the crews were untrained; experienced foremen were in short supply; hauling distances were much longer; traffic conditions between the loading point and the dump were bad; and traffic jams often occurred at the dump entrances. All things considered, the debris hauling operation progressed about as well as one would expect under the circumstances.

Debris Estimating Using Aerial Photos

Debris estimating can be done by applying common photo-interpretation techniques to aerial survey photographs. Aerial survey photographs were taken of the Gulf Coast area on the third day following the storm. They were available for examination a few days later, but by this time the Phase I road clearing operation was well underway and several of the Phase II contracts had been let. Therefore they were not useful as a basis for writing contracts to be let soon after the disaster.

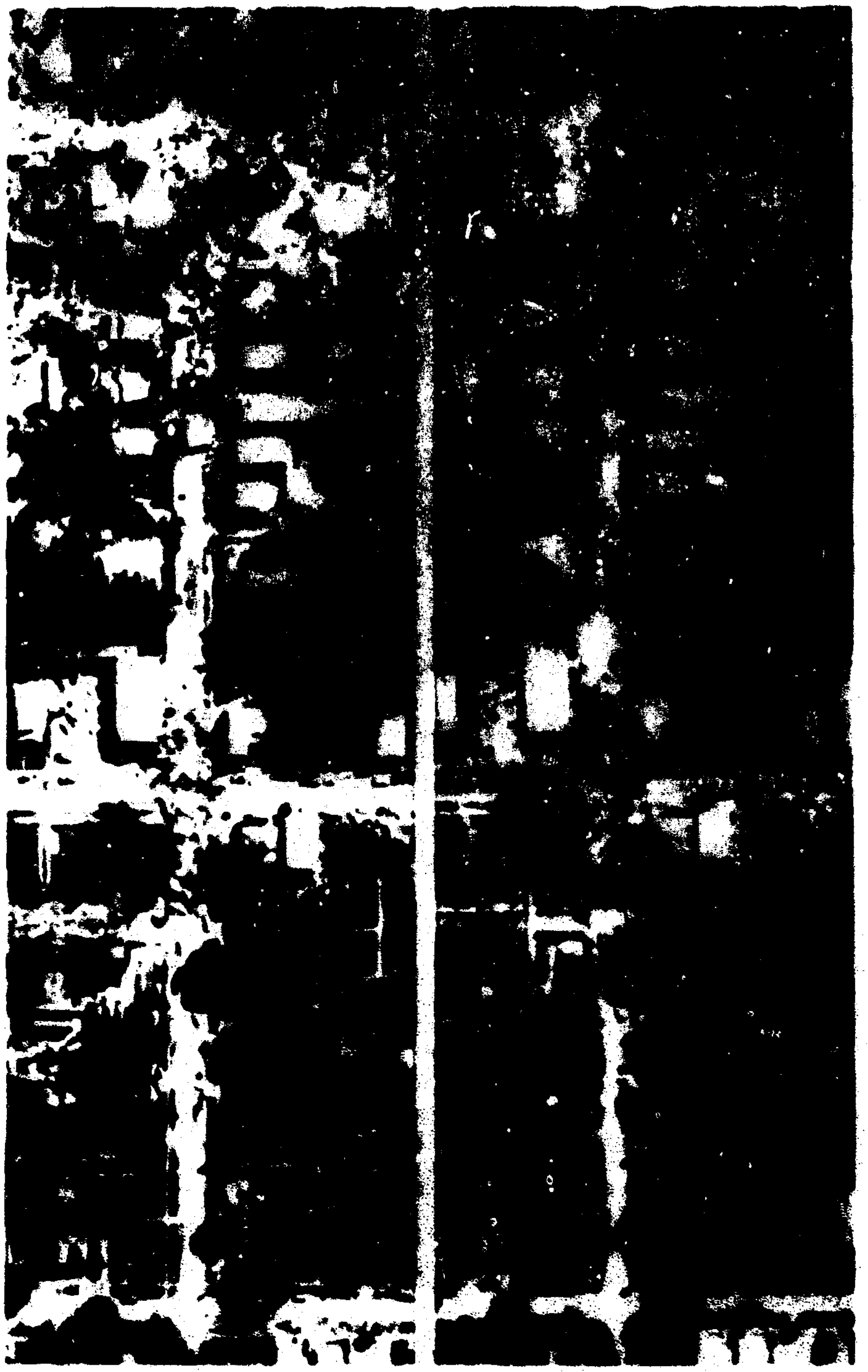
These aerial survey photographs revealed very clearly major debris blockages of roads, even to relatively untrained observers. Two examples showing wind-felled trees and water-driven building debris are given in Figs. 20 and 21. These are enlargements from aerial survey photographs taken at a nominal scale of 1 to 10,000, from an altitude of 5,000 ft. The enlargements were made from contact prints; therefore, these enlargements lost considerable quality over what could be obtained by enlarging or from viewing the original negatives.

Color transparency aerial survey photographs were also taken about the same time. The color transparencies showed very vividly the debris line left at high tide. When examined on a light table through a stereoscopic viewer, these photographs show debris heaps clearly enough so that an untrained observer could estimate their height by comparing them to objects of known height. Figure 22 shows debris from an oblique aerial photo taken at about 500 ft altitude.



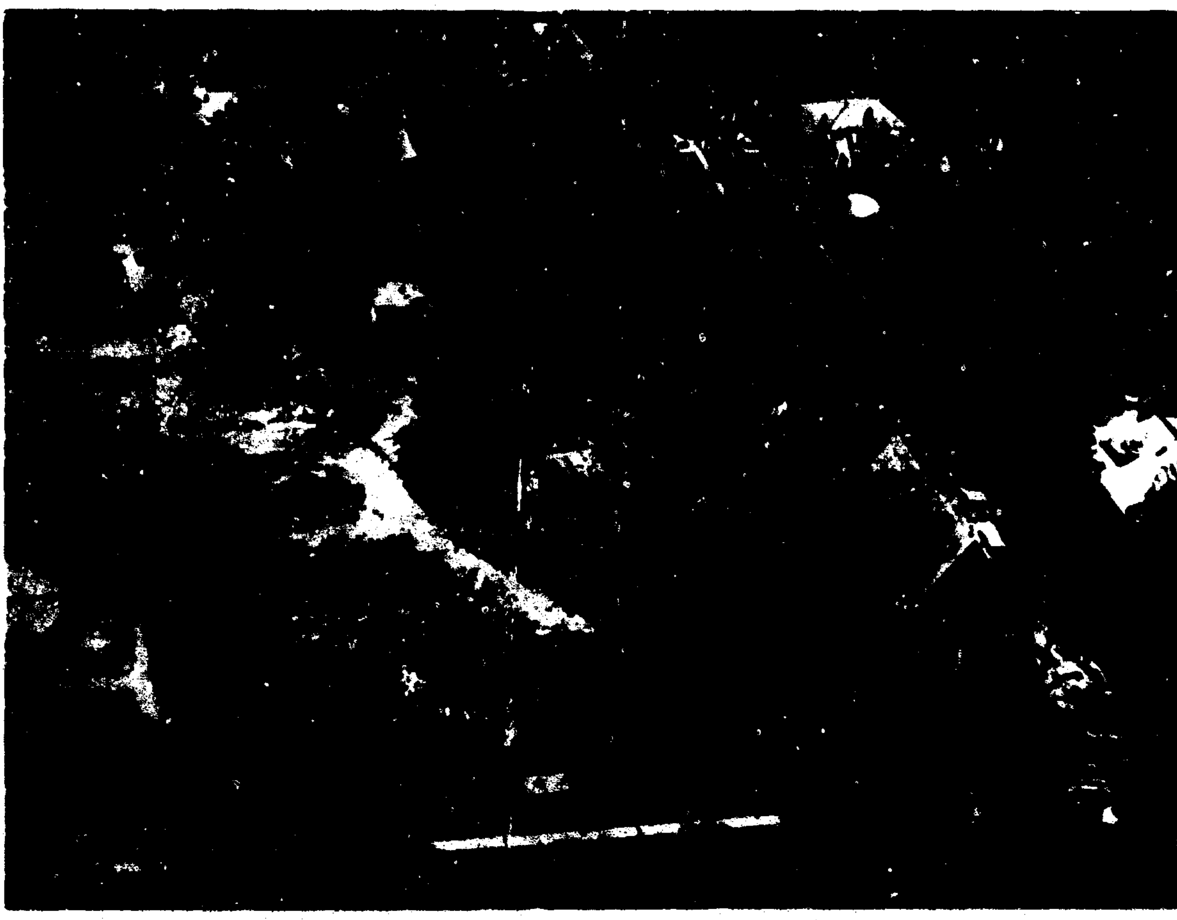
From Wallace-Zingery Photo

Fig. 20. Fallen Trees in Gulfport (Aug 20, 1969). North is up (Stereo pair; scale, about 1:1500)



From Wallace-Zingery Photo

Fig. 21. Water-Driven Debris in Biloxi (Aug. 20, 1969). South (and the Gulf) is up. (Stereo pair; scale, about 1:1500)



From Audrey Murphy Photo

Fig. 22. Water-Driven Debris in Biloxi (Aug 20, 1969)

Rescue Efforts

We gathered that a great deal of effort was directed toward the search for persons who might have been injured or trapped. We queried several of those who were in charge of rescue operations. Invariably they felt very strongly about the importance of rescue work and felt that rescue should have been given more support. Further inquiry on our part revealed that no lives were saved as a result of rescue efforts conducted more than a day after the storm subsided. This leads us to question the value of rescue work performed at so late a period. The question is not whether or not rescue should be performed, but rather what proportion of available resources should be applied to rescue and how to persuade emotionally involved persons to direct their efforts toward other, equally important operations.

Approximately 100 bodies of hurricane victims were recovered by search teams. These were brought to a local morgue for identification and preservation. The morgue was without refrigeration because of the lack of electric power. Much of the ice that was trucked into the area was required by the morgue. This experience showed that operating a morgue at an acceptable degree of risk to health would be an enormous problem in the postattack world.

Mutual Aid

We found no evidence that planning in the smaller companies included mutual aid, either by combining preparatory actions before the hurricane or by combining restoration efforts afterward. Only in one instance (Glenbrook Labs and Gulfport Glass) did we clearly see the possibility of a fruitful mutual aid arrangement. The Gulf Coast was never isolated to the extent that it had to rely entirely on its own resources, therefore mutual aid agreements, if they existed, would not have been very apparent.

The public utilities and Standard Oil did have arrangements to obtain aid from affiliated companies in other areas. This type of planning was of great value in restoring these establishments following the hurricane, and should be equally valuable for restoration following a small nuclear attack. It would be of less value following a large-scale attack.

Reliance on Civil Defense

We found very little evidence that, before the hurricane, industry had a significant interest in civil defense. Following Camille, civil defense was recognized as an important local function. Many of the facilities we visited gave high praise to the local Civil Defense Director and to the valuable assistance given by the local Civil Defense headquarters.

Warning

The hurricane warning was taken seriously by almost all of the establishments we contacted. Relatively costly preparations were initiated in Gulfport, Biloxi, and Pascagoula, even when it appeared that Camille would cross the coast of Florida and miss the coast of Mississippi by several hundred miles.

Apparently the quantitative (magnitude and direction) information communicated in the Weather Bureau advisories and bulletins was used as a basis of planning insofar as time permitted. But Camille rapidly developed extreme intensity shortly before striking the coast so that, in several instances, the preparatory action, although extensive, was inadequate. The situation accompanying a warning of possible nuclear attack would be considerably intensified over that of a hurricane warning. Very likely less warning time would be given and predictions of possible impact site would either be unknown or only vaguely known. Later, should there be a threat of fallout, predictions of areas likely to be threatened by the fallout would probably be no more certain than those regarding the path of the hurricane and again, less time would be available for taking useful action following the warning. Nevertheless it does appear that such warning would be useful to and appreciated by most industrial segments.

The Problem of the Smaller Plant

The smaller plant seems to have fared somewhat more poorly than the larger ones. This may be attributable to several factors which include:

- Larger plants seem to be better constructed, and perhaps newer, and better maintained.

- Larger plants have a larger reservoir of personnel from which to draw, but of course they have more complex and greater operating problems

- The financial base of the larger companies is probably better, which allows them to order replacement parts freely and is probably a factor in attracting people back to the plant more rapidly, since they feel assured of a wage. (Some smaller companies report that absenteeism was much higher than usual, their workers apparently being attracted by higher wages offered by outside contractors.)

Injured

Upon reflection we do not recollect nor did we find in the after-action reports (Ref. 11) any mention of a large number of persons seriously injured during the storm or of a call for large quantities of blood. (We conjecture that most of the deaths were due to drowning.) We conclude that few persons were seriously injured compared to the number killed. In this respect, injuries due to the hurricane were substantially lower proportionally than Japanese nuclear bombing experience and what is expected from a megaton-sized attack. With this low proportion of injured, self-help (with only a modest amount of outside help) was sufficient to cope with the medical problem.

Attitude Towards Supporting Emergency Operations

Immediately preceding the hurricane and for a day or so following, the attitude of almost everyone appeared to be cooperative, outgoing and selfless. When financial arrangements were made, they were accomplished quickly and were not allowed to interfere with the progress of the job.

Within a few days the attitude changed markedly. Financial arrangements took on much greater importance. Willingness to help appeared to diminish in importance. Institutionalized aid grew in strength as national organizations, and state and federal governments sent officials and workers from distant points into the disaster area. By the time we arrived (a month after the hurricane), we found more than a little bitterness expressed in describing the work of many institutions, even though the express purpose of these institutions was to help relieve the suffering of the population and to help improve business and economic conditions.

We have no constructive suggestions to make relative to this problem. Perhaps we have not even identified the problem but only described some symptoms. Nevertheless the situation may merit further sociological study.

Investigating and Interviewing Comment

Arriving at the Gulf Coast at the time we did — although accidental — proved to be appropriate for a disaster of this scale. Events were still fresh in people's memories, yet they had time to talk with us. Most telephones were operating, power was restored, and roads were passable. Interviews could have been conducted without these conveniences, but the cost of the field work would have been much greater.

Camille Data Bank

Several other teams of investigators have studied other aspects of the Camille disaster, and much data has been collected. Appendix A lists those sources that came to our attention during the course of this project.

A Final Word

Many of the observations made in the course of this discussion are based on hearsay and off-the-record comments made during the course of the interviews. Others reflect the author's impressions of the situation a month after the hurricane.

The conclusions expressed in the next section are in part based upon limited observations of the relatively small geographical area that was ravaged by a hurricane of unprecedented power. This limited basis for drawing rather general conclusions is at least partly offset by our experience in studying disasters and the effects of hypothetical nuclear attack on industry, experience which has been incorporated in the conclusions set forth.

Section 3
CONCLUSIONS

DEBRIS REMOVAL AND CLEANUP

The opening of major arterials should be assigned the highest priority following a major disaster. Such action is required to provide lanes for emergency vehicles engaged in lifesaving activities and to provide routes that will allow recovery efforts to progress. The effort and resources involved in opening major arterials is relatively minor. On the other hand, removal of debris for health and reconstruction purposes, which requires massive commitment of manpower and resources, should proceed at a lower level of priority.

Present data-collecting practices for debris cleanup operations are inadequate for measuring work rate. These practices should be modified so that suitable data can be collected in the course of future operations.

INDUSTRY

Continued operation of manufacturing and production establishments in the face of a severe hurricane is impractical at best. It is safer and more practical to shut down almost all facilities except those providing vital services. All processes that can be shut down should be stopped; all non-essential personnel should be sent home or to shelters and the facility either left unattended or in the keeping of a small security force. On the other hand, if the facility is built very substantially, its use as a shelter for employees, their families, and possibly the public should be considered.

Facilities located on the waterfront are inherently vulnerable to damage by the rising tide from a hurricane. These include seafood canneries, sewage treatment plants, port facilities, etc. Not much can be done to reduce the vulnerability of these low-elevation facilities.

During hurricane season (and as a part of increased readiness preparation) industry should control the amount of loose material stored in the open so that all such material can be properly stowed during the warning period through the use of labor and equipment whose availability can be relied on.

Commercial electric power to a plant to be left unattended should be disconnected at the service entrance to avoid the possibility of short circuits within the plant and the consequent hazard of fire. Similarly, gas should be shut off at the service entrance and also at each piece of equipment. Plant utilities (boilers, generators, etc.) of plants to be manned with a skeleton crew should be put on standby.

Damage Estimation and Repair

Interior damage, that is damage to manufacturing equipment, cannot be reliably estimated on the basis of external building appearance. Minor breaks in siding and roofing can admit storm water, which, in turn, can seriously damage electrical and electronic items and initiate rusting of production equipment; such damage generally wouldn't be visible outside the plant.

At low damage levels, most repair and restoration work can and should be performed by plant employees. Outside assistance will be required mainly for glazing and roofing and for repair and replacement of electronic and electrical equipment and controls.

Plants should maintain duplicate sets of prints in separate locations. Blueprints and plans of plant layout and equipment are essential for rapidly estimating damage significance and for planning and performing repair. Those establishments that suffer moderate damage, including loss of their blueprints, will be at a distinct disadvantage.

WARNING

Industry does make use of hurricane warnings issued by the Weather Bureau. Industry can be expected to make use of other warnings, such as a Civil Defense attack warning, if properly informed regarding their import and meaning.

EMERGENCY POWER SOURCES

Installed emergency power sources are highly useful in an emergency. They are very valuable for maintaining operations that either cannot be shut down or have a long start-up time. Emergency power sources are useful for maintaining plant illumination and they can be used to expedite repair and reclamation.

Emergency power generators should be provided permanent, extra-reliable weather protection so that they will not be put out of service during a storm as a result of flooding or entry of rainwater. The reliability of generators not given this extra protection can be improved somewhat by providing tarps, etc., for temporary weather protection of the generator and its controls in case building siding or roofing fails, as can occur in severe storms.

The operational problems for distributing, installing, and running Civil Defense emergency power generators have not been solved and merit further study.

UTILITIES

The hurricane plans of the investor-owned public utilities (i.e., power, telephone, and gas) are adequate for coping with localized disasters, but these plans would be much less effective in case of a nationwide disaster, in which cooperation among affiliated companies would likely be restricted.

Public utilities should begin working closely with civil authorities, civil defense, and with other local utility companies to prepare a coordinated general plan for self-sufficient post-disaster operations and for the (perhaps limited) reconstruction of the service area.

EMERGENCY HEALTH

Loss of potability of the water in municipal water systems represents a considerable inconvenience to the population and results in inefficient use of resources (e.g., chemicals, packaging materials, and labor) caused by the requirement to treat and distribute water in small lots.

The current conservative practices of the Food and Drug Administration and the Public Health Service, that is, destruction of food and supplies which may be tainted or contaminated, can lead to possible needless waste of such resources at a time when food may be in very short supply. These agencies should be prepared to supply guidance on the salvage of suspect or contaminated materials.

CD EXERCISES

Civil Defense exercises that simulate nuclear attacks or large-scale disasters should be performed regularly. They are an especially useful device for sharpening the skills needed for operating effectively during disasters.

Section 4

RECOMMENDATIONS

DISASTER INVESTIGATIONS

Large-scale disasters and the responses to them represent an important source of information on the effectiveness of civil defense and related preparations, on the weaknesses of current programs, and on improvements that can be incorporated into programs in the future.

The Office of Civil Defense should continue to support directed site investigations of disasters. All areas of civil defense appropriate to a specific disaster should be included: emergency operations, industrial recovery, debris removal, economic recovery, social system changes, the response of institutions, etc.

DATA BANKS

Each disaster, and Camille would be included here, should be documented by a "data bank" in the form of a library (or at least a bibliography) of all pertinent information, maps, photos, reports, etc., so that disaster and civil defense researchers can select from a comprehensive collection of materials. Appendix A gives some sources of other information on Camille.

DEBRIS CLEARING

The Corps of Engineers' file of data on debris hauling after Camille should be screened once more, now that the file is complete. It may be possible to obtain reasonable estimates for some of the parameters for which we had inadequate information, such as haul distance and debris density, so that production rates can be computed. This would be valuable feedback for proof-testing estimating methods (such as Ref. 3).

Planning guidelines should then be developed for future large-scale debris-clearing operations. These guidelines should include a listing of all factors of importance in debris hauling estimation and evaluation, and descriptive information on the importance and application of each factor.

Future debris-clearing operations should make use of the planning guidelines and should be documented by engineers well schooled in production rate estimating. Aerial survey photos, if available, should be used in a pilot study of job-estimating. Experiments should be performed in the course of these debris-clearing operations on candidate methods for improving operational efficiency, including varying equipment ratios, operating trucks with and without tailgates (and tailgate modifications), employing various types of incentive contracts, and testing various methods of measuring production rates.

Debris disposal operations should make use of current waste disposal technology. Studies should be performed and contingency plans formulated that apply to large-scale operations following area-wide disasters.

FOOD HEALTH STANDARDS

Inspection procedures and standards that are adequate during peacetime disasters might lead to unacceptable wastage of food if they are applied during a wartime national emergency. Present procedures for deciding the disposition of foods that have lost refrigeration, or canned goods whose containers are damaged, should be re-examined and if found in need of revision, new guidance on safe salvaging methods should be developed.

EMERGENCY ELECTRIC GENERATORS

Methods for fully utilizing portable emergency electric generators should be developed. The factors that merit study include establishing priorities for the use of generators, requirements for managing their distribution, methods of announcing their availability, transportation requirements for siting the generators, and requirements for an estimated availability of electricians for connecting the generators or adapting instructions so they can be installed by non-electricians. Guidance that is developed for the installation of emergency power generators should include recommendations for protecting generators subject to flooding by high water and recommendations for temporary emergency weather protection of those in lightly constructed buildings.

Section 5

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9. Hurricane Camille, Aug. 14 - 22, 1969 (Preliminary Report), Environmental Sciences Services Administration, U.S. Dept of Commerce, Sept 1969

10. "Hurricane Camille," Power Lines, Vol. 43, No. 7 (Special Issue)

11. After Action Report, Operation Camille, Mississippi Civil Defense Council, Nov. 6, 1969

12. Quice, Wade, Hurricane Plan, Civil Defense Council, Harrison County, Mississippi

13. U.S. Army Corps of Engineers, Mobile District, After-Action Report, Hurricane Camille, Mobile, Alabama, Feb 1970

Appendix

SOURCES OF OTHER INFORMATION ON HURRICANE CAMILLE

Public Response to the Hurricane

Dr. E.L. Quarantelli, Disaster Research Center, Ohio State University

Warning Response by the Public

Dr. Kenneth P. Wilkinson, Director, Social Sciences Research Center, Mississippi State College, Hattiesburg, Mississippi

Business and Industry Damage Survey

Mr. Edmond Brunini, Governor's Emergency Council, Post Office Drawer 2470, Jackson, Mississippi 39205

Aerial Survey Photographs

1. Wallace-Zingery Aerial Surveys, Inc., P.O. Box 476, South Houston, Texas 77587
   - Black-and-white photographs scaled 1:10,000 (from 5,000 ft altitude). Photographed on Wednesday, Aug 20
2. Robert Piland, Acting Chief, Earth Resources Division, Manned Spacecraft Center, NASA, Houston, Texas
   - Black-and-white transparencies and color transparencies, scaled at 1:10,000 (from 5,000 ft altitude). Taken on Wednesday, Aug 20
   - Infrared transparencies and black-and-white transparencies taken at a scale of 1:60,000 (from 60,000 ft altitude). Photographed on Wednesday, Aug 20

Oblique Aerial Photographs and Surface Photographs

1. Audrey Murphy Photography, 309 Reynoir St., P.O. Box 575, Biloxi, Mississippi, 39533
2. Gulf Publishing, Co., Inc., Gulfport, Mississippi
3. Graphic Press, P.O. Box 202, Biloxi, Mississippi

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13. ABSTRACT

This report describes the results of an investigation and a site inspection of the industry along the Mississippi Gulf Coast following Hurricane Camille. The investigation covered public utilities; selected samples of the manufacturing, chemical processing, and food processing industries; and public works, including debris removal. The major topics covered during the interviews were hurricane plans and preparations, emergency actions during the hurricane, damage inflicted, and restoration activities.

The results are examined from the viewpoint of their relationship to civil defense and restoration efforts following a nuclear disaster. Conclusions are drawn that relate to both hurricane and nuclear disasters. Recommendations are made on measures to reduce the effects of such disasters and on subjects warranting further study.

Security Classification

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Hurricane Plans and Preparations						
Wind Damage						
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Restoration of Public Utilities						
Industrial Restoration						
Water Damage						

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