"Este documento contiene imágenes en mal estado"

Mother Nature is full of surprises to vent upon the Earth's inhabitants: droughts, earthquakes, tornadoes, blizzards, monsoons, volcanoes, and the like. Geographical areas can be characterized by their indigenous natural disasters; in the Caribbean and along the Atlantic and Gulf coasts, the focus is on hurricanes.

Hurricane season runs from June through November, and with each tropical disturbance comes the threat of the eventual landfall of an ornery, unpredictable hurricane. This year, the whirling dervish named Hugo spun terror through the Caribbean and the Carolinas, unleashing winds of up to 135 mph and a storm surge of between 15 and 20 ft on coastal communities.

photo by Andy Fairey

**Tons of construction materials lie scattered in the aftermath of Hugo.**

A comprehensive emergency preparedness plan at the Plum Island Wastewater Treatment Plant in Charleston, S.C., minimized damages and allowed operations to resume soon after Hurricane Hugo devastated the area.

## A Detailed Plan

The Plum Island Wastewater Treatment Plant sits on the edge of Charleston Harbor, its highest point just 16 ft above sea level. The facility, which treats 18 mgd, is in the midst of expanding to 27 mgd.

Although Charleston had not suffered extensive damage from a hurricane since 1959, plant Superintendent Andrew Fairey has made the plant's emergency preparedness plan a priority. "It is difficult to implement a preparedness plan when there is no impending threat, but resources must be devoted," said Fairey. Money spent in planning and preparations seems wasted until a hurricane hits; with Hugo, Fairey says, planning efforts paid for themselves 10 to 20 times over.

Plum Island's Hurricane Preparedness Plan is divided into six phases. Phase 0, from December through May, merely denotes normal facility operations, but steps were taken in May to ensure that the plan was current.

Under Phase 0 emergency response procedures were reviewed with all plant personnel and the roster of employees volunteering to work during hurricanes was set. Hurricane staff inspected and replenished emergency supplies and diesel fuel reserves, which must be sufficient to sustain power for 7 consecutive days. Emergency generator operating procedures were also reviewed.

The plan was fully updated, and copies were given to the Charleston Commissioners of Public Works (CPW), the Emergency Preparedness Agency of Charleston County, the Coast Guard, and local fire departments.

Phase 1 began on opening day of hurricane season. This phase entails normal plant operations, but was designated as a distinct phase to denote that a hurricane could soon be headed toward the plant. According to Fairey, staff began tracking Tropical Storm Hugo on September 12.

The Hurricane Preparedness Plan enters Phase 2 when a tropical storm/hurricane watch is issued by the National Weather Service (NWS). Plant staff entered Phase 2 of the plan on Wednesday morning, September 20.

## Following The Plan

Staff secured the plant site according to the plan. A cool-down cycle was initiated for the plant incinerator, and a dewatering pump was set in the caisson (influent pumping station) sump. Items that could blow away or become projectiles such as barrels, dissolved-oxygen meters, and sample bottle sticks were moved into secure buildings and placed away from doors, walkways, and equipment.

photo by Andy Fairey

**Despite efforts to secure the plant's equipment and buildings, duct work was easily torn out of the holding tank domes.**

Three of the five air packs stored in the chlorine building were moved to the plant control room, one to the shop, and one to the generator room. Chlorine cylinders and tanks were secured with chains.

Vehicles were fueled and moved into the garage; to save space three vehicles were moved inland. All equipment was fueled, and extra gas cans were filled and stored in the garage. Plant windows were boarded or taped, and doors were sandbagged based on their elevation.

Communication equipment and generators were thoroughly tested, and emergency supplies were inventoried. Meanwhile, Hugo was closely monitored.

Phase 3 began when NWS issued a Hurricane Warning at 6:00 a.m. on September 21. Hurricane staff were called in, and all nonessential equipment such as the boiler and automatic samplers was se-

cured and shut down. The ash line was plugged with a "damage control" plug (tape and wood) because the unvalved line originates from a pump in the basement of the incinerator building, and could back-flow if flooded. An extra 30 sandbags were filled and stored in easily accessible areas around the plant. Plant records were moved to the old lime room, which is the plant's highest area. When these tasks were completed, all nonessential staff were sent home and hurricane staff reviewed hurricane procedures once again.

**Riding Out The Storm**

Plant flow was split at 4:30 p.m. on September 21 when it was assured that the hurricane would strike. Fairey bypassed the secondary treatment system because the influent flow, diluted by rainfall, had increased to 22 mgd. He wanted to prevent solids from washing out of the activated sludge system and into the harbor and ensure a rapid startup of secondary treatment after the storm passed. Thus, the system provided primary treatment and chlorination before discharging effluent to Charleston Harbor.

At approximately 8:00 p.m., Phase 4 began as 74-mph winds began buffeting the plant.

In Phase 4, the plan admonishes staff to remember, "Personal safety is your num-ber one concern." A list prioritizing equipment to be kept operating is provided in Phase 4, eliminating the need for decisionmaking. If utility power is out, the emergency generators are the first priority. After this, or if the utility is still providing electricity, the main lift station is most important. This station must remain operating to keep wastewater flowing through the plant rather than overflowing into residential areas. Following, in order, are the non-potable water system, the chlorination system, primary clarifiers and pumps, the secondary system, and the sludge thickeners.

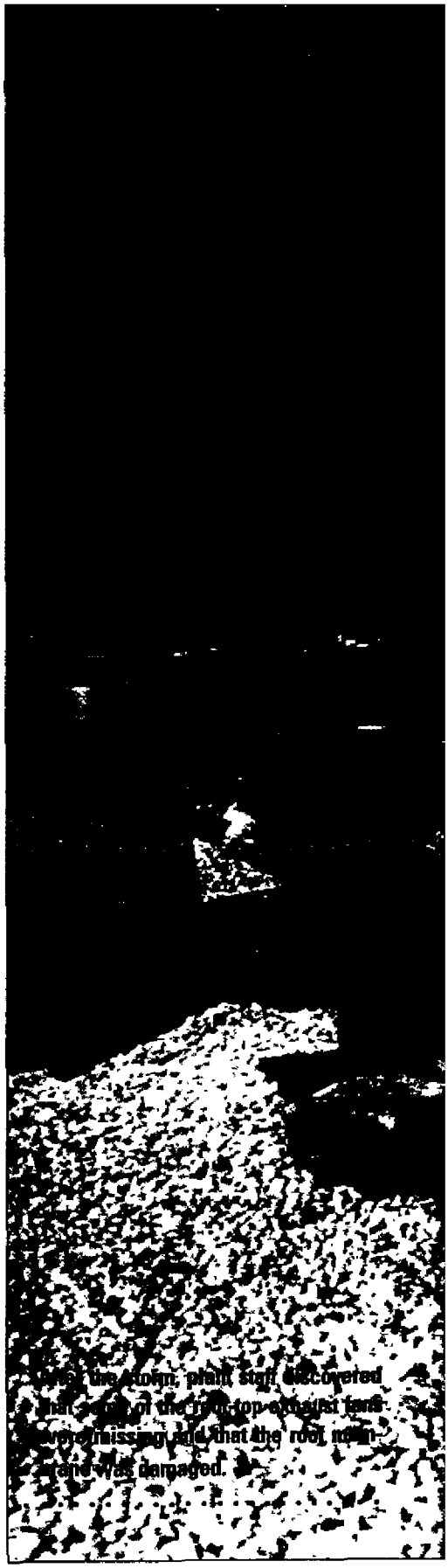
The emergency generators were turned on at 10:00 p.m. At 11:00, the secondary treatment system was shut down. By 11:30, the storm surge, coincident with a rising tide, became a concern.

After one of the four lift-station pumps broke down, Fairey had to decide whether to shut off the entire lift station. Someone would have had to travel from the belt press and incinerator building, where hurricane staff were riding out the storm, through the driving winds and rain and flying debris to the control room to restart the pump. In addition, the roll-up door to the lift station was flapping in the wind, although it had been heavily fortified with sandbags. If the surge were to flood the dry well while pumps were still operating, they could explode. Also, the influent waste was very dilute, and because power to pumping stations throughout the area was down, there were going to be overflows regardless of whether the lift station was operating. Realizing that it was vital to be on-line the next day, Fairey shut down the lift station.

At midnight, the eye of the hurricane passed over the plant. During the 30-minute respite from the battering, plant personnel assessed initial damages. Chlorine odors were noticed, but the source of the leak could not be identified. To prevent a larger leak, the chlorine system was shut down.

**Storm Aftermath**

After the hurricane had passed, Phase 5 began with staff assessing damage and operational capability. Heavy erosion had occurred around the primary effluent discharge pipe and effluent had pooled in construction areas. Building materials and equipment for the plant expansion were strewn about. Covers for the sludge holding tanks were torn up at the edges, and light fixtures had been uprooted and carried away.



During the storm, plant staff discovered that parts of the roof-top exhaust fans were missing and that the roof membrane was damaged.

# Dealing With Unforseen Events

When a preparedness plan is developed, planners attempt to predict what will happen in a worst-case scenario. The primary aim is to protect endangered or vital areas, but not all problems can be foreseen.

After Hugo swept through the Charleston area, the South Carolina Department of Health and Environmental Control (DHEC) assumed that all water was contaminated and issued a "boil water" notice. The Hanahan Treatment Plant provides 55 to 60 mgd to Charleston and surrounding areas; thus, its laboratory had to rapidly determine whether the water was contaminated or prove otherwise to rescind the "bo" water" notice.

On the morning after the storm laboratory personnel traveled throughout the Charleston area, pulling samples to analyze for bacteria from wherever it was possible. Over the next 3 days, staff worked long shifts to collect and analyze over 100 samples. An emergency generator supplied by the National Guard provided "just enough outlets to keep everything that we absolutely needed running," said Fanning. Despite the great potential for contamination after the huge storm, bacteria were not detected in any sample, and on September 25, the "boil water" notice was rescinded.

Suddenly, on October 1, water quality took a turn for the worse. Elevated influent phenol levels were observed, and the addition of chlorine combined to exacerbate the already objectionable taste of the water. It was assumed that a spill occurred somewhere in the basin, and DHEC looked for treatment discharges, possible spills, or landfill leachates. DHEC found nothing unusual in on-site inspections of all facilities in the area, and thus had to consider other factors.

**Detective Work**

Charleston's water is supplied by the Edisto River. The river's heavily wooded drainage basin was devastated by Hugo, which felled countless pine trees in Indian Field Swamp and Four Hole Swamp.

It was hypothesized that as pine detritus began decomposing in the water, it released phenols. Further, the lag between Hugo's passage through the area and the appearance of elevated phenol levels at the plant allowed time for the leaching of phenol into the water and for the contaminated water to flow from the swamps to the plant.

To test the hypothesis, pine boughs and cones were brought to the lab, submerged in 3 L of uncontaminated Edisto River water, and placed in the sun at ambient temperature. Initially, the phenol concentration was less than 10 ppb. Within 18 hours, the concentration had increased to 19 ppb; after 40 hours, it was 94 ppb; and after 113 hours, it was 280 ppb.

Once the cause of the taste problem was identified, the media was contacted to reassure customers that the water was safe to drink and that the objectionable taste would disappear over time.

The taste problem lasted for about a week. Thereafter, when it rained in the basin, spikes of phenol occurred after the appropriate lag time, but each decreased in magnitude.

Relief personnel arrived, and the staff worked to get the treatment system operating. Electrical equipment was checked for unusual amperage draw before it was tested.

Wet electrical equipment was dried and vehicles that were driven off-site were returned. The plan called for laboratory personnel to run presumptive fecal coliform tests on plant drinking-water sources to check for contamination; instead, an on-site deionization system was used to produce drinking water. The chlorine leak was traced to a ruptured feed line, which was repaired before chlorination resumed. The wind and storm surge had deposited huge amounts of sediment in the primary and secondary clarifiers, which were drained and cleaned.

Despite the ferocity of the storm, damage was relatively minor — a tribute to the plant's construction, its staff, and the Hurricane Preparedness Plan. The plant, which was providing primary treatment and chlorination by noon Friday, was the first wastewater treatment plant in the Charleston area to go back on-line.

Initial assessments of power line damage indicated that electricity could be down for weeks, prompting Fairey to forgo the plan's schedule for restarting the secondary treatment system. The amount of diesel fuel at the plant could provide 15 days of primary treatment, but only 7 days of full secondary treatment. Further, plant influent was still very dilute because of the rainfall, and pumping stations throughout the area were still without power.

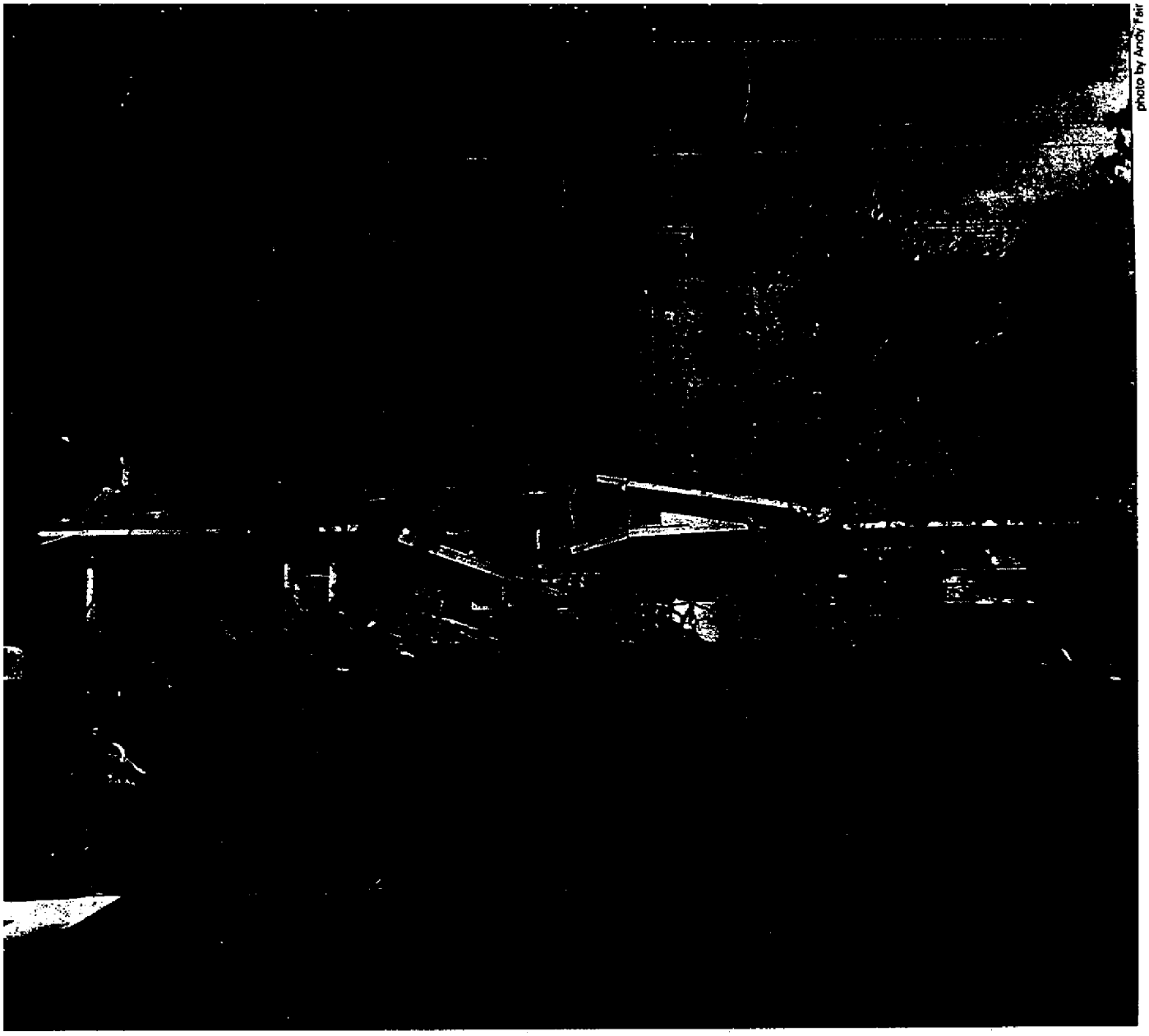


photo by Andy Fair

**While damage to the Plum Island Wastewater Treatment Plant was relatively minor, many homes and businesses were devastated.**

Power was restored sooner than estimated, so within a week, the secondary treatment system was back on-line. Initially, there was foaming in the effluent channels and the effluent was black because of organic matter, but within 24 hours, permit limits were met.

After the plant resumed operations, emergency supplies were inventoried and replenished, and Phase 6, which involves a critique of the Hurricane Preparedness Plan by all staff, began.

The plan's performance is being assessed, and it will be revised to correct any problems that were encountered during Hugo, or to include measures that will help the treatment plant and its staff better weather future storms.

Some recommendations include adjusting plant circuitry, placing sump pumps on a distinct circuit directly linked to the emergency generators, purchasing an industrial drying oven for motors, waterproofing flow meter pits, and securing chlorine cylinders more firmly. The menu for staff during the hurricane will definitely be changed, as, according to Fairey "There was too much Spam!"

Because of the plant's success in enduring Hugo, Fairey is now confident that staff could ride out a worse storm. The Hurricane Preparedness Plan, which was a key to the success, will be revised to reflect this.

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*Christopher R. Powicki is associate editor of WPCF's publication* Water Environment & Technology. *This article was reprinted from February's issue of* WE&T.