Recovery and Monitoring Challenges with Water Quality Issues in New Orleans during Hurricane Katrina Recovery Operations

by

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ABSTRACT

Following the passage of Hurricane Katrina, New Orleans was left with eighty percent of its land area flooded. In some locations the flood waters were over thirty feet deep. In the heat and stagnation that followed the waters quickly became heavily polluted with petroleum products, industrial chemicals, raw sewage, dead animals etc. In addition, a super fund cleanup site was flooded and contributed to the water pollution problem. Pump out operations began in early September 2005 as a high priority to get the city dried out and on the road to recovery. Lake Pontchartrain was the primary receiving water body with the Mississippi River as a secondary receiver. A variety of approaches and technologies were evaluated to achieve treatment with minimal impact on pumping operations. Some of these methods and technologies included; sorbet booms in the channels and the lake near outfalls, oil and debris removal skimmers in channels and near outfalls, floating and bottom anchored containment screens around outfalls, sediment control devises for hot spots within the city, application of flocculation chemicals in contained areas, aerators in the channels and near the outfalls, application of specialized bacteria, etc. Over 100 water quality sampling sites were setup throughout the city to characterize water conditions as the pump out proceeded. High risk areas were identified in a dynamic process and decisions make for best corrective action. Lake Pontchartrain continues to be monitored and long term rehabilitation efforts will be predicated on water quality monitoring results. Lessons learned from a water quality perspective during this massive disaster is presented with the goal of assisting future recovery efforts.

KEY WORDS: Hurricane Katrina recovery, New Orleans, water quality, sediment sampling, expedient pollution controls, dewatering operations

1. INTRODUCTION

Hurricane Katrina made landfall on the coast of Louisiana near Buras, Louisiana as a category 4 hurricane during the early hours of August 29, 2005. The storm crossed the Mississippi River Delta, and Mississippi Sound, and came back ashore near the Louisiana-Mississippi border. Winds were recorded as high as 140 mph in the near shore areas of Louisiana and Mississippi. Storm surges of over twenty five feet were developed in some coastal area causing extreme damage for miles inland. New Orleans was hit particularly hard. Hurricane Katrina left the Crescent City with no poser, so drinking water, no wastewater treatment, dwindling food supplies and, because of levee breaches, rapidly rising floodwaters. By September 1, almost eighty percent of New Orleans was under water, in some places by more than twenty feet (figure 1). Thousands of people sought shelter from the rising waters on rooftops; thousands more gathered in shelters or in groups on high ground.

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2. DEWATERING OPERATIONS

The U.S. Army Corps of Engineers had primary responsibility through FEMA for the dewatering of New Orleans as well as many other missions in response to Hurricanes Katrina and Rita. The Corps Mississippi Valley Division (MVD) had developed a Hurricane Contingency Plan in 1998 following Hurricane Georges that was updated annually and used as a starting point for this emergency. Under the MVD contingency plan for a hurricane hit on New Orleans, New Orleans District, as the "impacted" district, would have reconstitution as its primary initial mission. The plan also assumed there would be a "dewatering" mission for New Orleans. In this case Rock Island District was brought in to handle the dewatering mission. Memphis and Vicksburg districts would handle the primary FEMA mission for Louisiana and Mississippi, respectively. St. Louis District would execute civil works missions such as levee repairs. The Motor Vessel Mississippi was used as the forward headquarters for MVD and positioned in Port Allen, LA just across the Mississippi River from Baton Rouge. This allowed for close interaction with state and federal agencies in Baton Rouge. Quarter boats from the Corps' Mat Sinking Unit were also positioned at Port Allen to feed and house first responders.

Dewatering operations began soon after hurricane Katrina passed New Orleans. Some of the initial actions involved notching levees to allow flood water to drain out by gravity in some areas. Portable pumps were installed and put into operation throughout the city (figure 2) and work was started to repair the main pumping stations. GIS maps were used to track the daily progress of the dewatering effort. Figure 3 illustrates the dewatering condition on September 2 and figure 4 illustrates the progress made in dewatering by September 15. The plan was to have major pumping operations begin as soon as the levee breaches were closed. Pumping began at the 17th Street Canal site on September 5, at the London Avenue canal location on September 10, and at the other locations throughout the city using portable pumps. Working twenty four hour days throughout September New Orleans was close to being pumped out when Rita swept through on September 24, reflooding almost forty percent of the area again, causing more damage to Southeast Louisiana. But even with the Rita set back, the New Orleans dewater effort was completed on October 11. Dewatering was completed in just forty three days, less than half the time estimated by some.

For the water quality aspects of the dewatering operation EPA emergency response personnel worked in partnership with FEMA and state and local agencies and the Corps to help assess the test results and evaluate health and environmental conditions to water quality from Hurricanes Katrina and Rita. In emergency situations such as this, EPA serves as the lead Agency for water quality including the cleanup of hazardous materials such as oil and gasoline. EPA national and regional Emergency Operations Centers were activated 24 hours a day. The Corps had employees embedded with the EPA/LDEQ team in Baton Rouge and onsite teams locally in New Orleans for rapid and effective communication regarding water quality issues. There were also numerous conference calls involving Corps and EPA Headquarters representatives with field personnel to advise and assist on water quality issues during dewatering.

The large amounts of water resulting from the hurricanes may have actually helped some of the water pollution concerns particularly in Lake Pontchartrain due to dilution. The large volumes of water from outside the city also provided dilution to the flood waters, and the time consuming process of dewatering allowed many solids to settle, likely removing some sorbed constituents from the water column. Lake Pontchartrain seems to have survived its hurricane-induced direct hit, but longer term data will be needed for the final assessment. Concerns have also been raised about impacts on the Gulf of Mexico. From a volumetric standpoint, these impacts are minimal - more water enters the Gulf from the Mississippi River every day than was moved out of New Orleans over the 43-day dewatering operation.

New Orleans pumps water into Lake Pontchartrain instead of the Mississippi River because the lake level is lower than the river's level. The estimated 5000 billion gallons (BG) of rain from Hurricane Katrina that fell on the continental US is based on the assumption of an average rainfall of 4" across the 90,000 square miles of federally declared disaster areas. Lake Pontchartrain, the chief receiving water for the waters removed from New Orleans, is a 640- square mile tidal basin with an average depth of about ten feet. The lake receives about ten billion gallons a day of freshwater inflows from its 4,500 square mile watershed. Its volume of 1,300 billion gallons would fit in a cube 5,600 feet on a side - slightly more than a cubic mile. By contrast the long-term average volume passing New Orleans in the Mississippi River every day is 400 billion gallons. The Corps of Engineers directed the removal of an estimated 200 billion gallons of floodwaters through dewatering breaches and pumping. About a quarter to a third of this volume was removed from inside New Orleans' levees. The average daily volume dewatered over the 43-day operation was about five billion gallons.

The floodwaters removed from New Orleans proper consisted of a mixture of rain, Gulf of Mexico and Lake Pontchartrain waters, and other constituents. The rainfall estimate assumes16 inches of Katrina and Rita rainfall across New Orleans' 75 square miles. Under normal conditions, New Orleans is able to pump 25 billion gallons per day - out of the city into Lake Pontchartrain. This is about the same volume that the Ohio River carries by Cairo, IL every day. However, Hurricane Katrina caused major damage to all of New Orleans pumping stations that significantly delayed getting them back into full operation.

3. EXPEDIENT WATER QUALITY MEASURES

EPA coordinated closely with the Corps in consideration of a number of alternative measures for the treatment of floodwaters and mitigation of potential environmental impacts on Lake Pontchartrain, from New Orleans floodwaters. The objective was to dewater New Orleans as quickly as possible but to do it in an environmentally sound manner. The major concern was minimizing the environmental impact of the pumped floor water. A number of treatment processes were evaluated for application in New Orleans.

An interagency technical sub-group (water quality/ecosystem restoration management experts) collaboratively identified an array of recommendations for preventative and remedial mitigation management actions during dewatering for both inside and outside the levees. Based on the interagency recommendations and the dewatering mission, the Corps deployed sorbent booms with sorbent skirts inside the levees at appropriate intake points. There was a special management strategy for appropriate containment and treatment of HOT-SPOT areas identified by personnel on the ground as the water lowers.

One was the deployment of temporary "floating passageways" for in-canal treatment. This configuration of floating passageway curtains in conjunction with injected flocculants and disinfectants was proposed for the 10,000 cfs discharge from Pumping Station #6 on the 17th Street Canal. The curtains lengthen the flow path and augment settling; trash and debris are captured by the net curtain at the end of the canal. An illustration of the approach is shown in figure 5. Dosing requirements for the suggested mix of a cationic coagulant in conjunction with an anionic polymer would be matched to the application. Similar configurations were developed for direct discharges to Lake Pontchartrain. Another was the use of Sequestration, Flocculation and Sedimentation materials for Removing Contaminants from Flooded Areas of New Orleans.

In addition to floating debris of various size many contaminants associated with flooding are essentially small colloidal particulates that are suspended in the water column. These include many organic contaminants, metals, and disease causing microorganisms. In addition, suspended clay particulates can hold adsorbed contaminants. Due to electrostatic charges found on the colloids, these particles can remain suspended indefinitely. However, coagulation, flocculation, and sedimentation (CFS) are accepted, established and commonly used set of methodologies to remove colloidal contaminants. CFS involves adding a chemical to overcome the electrostatic barriers between the particles, allowing the colloids to interact with each other to form larger particles, following by gravity settling of the larger particles. Large-scale applications of CFS have been conducted at lakes in Washington and Idaho to remove excess nutrients causing eutrophication, demonstrating its applicability in an environment with relatively low control. The large pools of floodwaters in New Orleans were an excellent opportunity to apply these methods to remove these colloidal contaminants.

The technology was deployed at the 95 acre Agriculture Street Landfill Superfund Site, which is a submerged CERCLA site in New Orleans. The treatment consisted of the addition of powdered activated carbon (PAC) and a synthetic polymeric coagulant, such as polystyrene sulfonate (a jar test would be conducted to select the exact coagulant and dosage). Based on experience with dredge waters in the same area, relatively modest dosages of these chemicals were needed to treat relatively large water volumes. Low tech barriers to reduce the sediment migration such as submerged sandbags, were used to create sedimentation areas are reduce off-site migration of contamination.

Though most of the City was dry by Sept 30, the Corps still is treating water in the three main canals, Orleans, London and 17th Street. The Corps has deployed artificial aeration devices in major channels to reduce biological oxygen demand (BOD) and support healthy dissolved oxygen concentrations in the water column. Two aerators in each of the three main channels draining to Lake Pontchartrain were strategically placed and operating successfully prior to Hurricane Rita and 20 more aerators are being placed in these and other strategic locations, even in the outfall areas of Lake Pontchartrain. More aerators also are being planned – about an additional 20, or total of 40. After a suspension of pumping operations during Hurricane Rita the Corps has resumed the aeration operations, and coordinated with the U.S. Coast Guard to deploy booms, skimmers, and suction at pumping stations where oil was observed. Based on input from EPA, the Corps is doing its best to address bacteria, suspended solids, and petroleum in storm water runoff. Options include more booms, silt screens, aerators, and possibly adding some mobile treatment plants. EPA and the Corps jointly formulated approaches to manage known and suspected areas of hazardous materials production and storage, and areas with contaminant sequestration materials such as flocculation, disinfection, and sorption.

The Corps also developed a comprehensive non-point source control program to manage the first flush of rainfall from contaminated residuals as well as developing and executing programs to clean streets, canals, storm drains of contaminated residuals to minimize their flushing when receiving waters during rainfall events. This approach was formulated collaboratively between the Corps and EPA and coordinated with State and Local governments and water boards.

In addition to the floodwaters, the EPA and State of Louisiana are sampling and monitoring the sediments left behind from the New Orleans floodwaters for possible contaminants and infectious agents. Sampling site locations within New Orleans are shown in figure 6. Effective sampling and analysis are critical to effective evaluation and characterization to assure proper handling and disposal. The Corps and its contractors are working closely with the EPA and state of Louisiana to assure that this is achieved in a safe manner.

4. WATER QUALITY SAMPLING

EPA in coordination with the Louisiana Department of Environmental Quality performed chemical sampling of New Orleans flood waters for over one hundred priority pollutants such as volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), total metals, pesticides, herbicides, and polychlorinated biphenyls (PCBs). More than 190 water quality data parameters are constantly being updated, reviewed and validated through an EPA quality assurance process to ensure scientific accuracy. Example results are shown in tables 1 – 4 for testing of Primary pollutants. Table 1 lists the one pollutant, lead, that was found in this testing data that exceeded the EPA standard. Table two lists pollutants that were present but did not exceed EPA standards. Lead was the one pollutant most often found at measurement sites. However, when measured it was at locations that have historically been high in lead content. Table three lists material present but there are no standards at this time. Table four lists pollutant that was not present. Concerns about potential water-quality issues prompted discussions among the U.S. Environmental Protection Agency (EPA), Louisiana Department of Environmental Quality (LDEQ), and the LWSC to coordinate sampling locations and constituents sampled. The LWSC sampled fecal-indicator bacteria in Lake Pontchartrain in support of the LDEQ monitoring effort and water and bed-sediment samples from those areas in the lake not sampled by LDEQ. Dewatered sediments deposited by floodwaters were sampled in New Orleans and St. Bernard Parish as floodwaters retreated to determine what chemicals were in these sediments. At the same time high water marks along the north shore of Lake Pontchartrain, and in St. Bernard and Plaquemines Parishes were collected.

EPA, USGS and the State of Louisiana assessed Lake Pontchartrain as part of the broad, multi-agency assessment of damages to the region. Many of Katrina's impacts will emerge over different time spans and this mid- to long-term monitoring plan has been designed to detect effects as they appear. Most Pontchartrain sampling was done by the USGS and the State in collaboration with EPA. The Louisiana Department of Environmental Quality sampled Lake Pontchartrain and found no exceedances of water quality standards for organic and toxic compounds. Dissolved oxygen and bacterial impacts were most pronounced along the North Shore, while toxicity testing of New Orleans floodwaters showed little effect on fish and invertebrates.

Understanding why the floodwaters were not the toxic "witches brew" reported in the media depends on consideration of where the floodwaters came from. Perhaps 20 billion gallons (BG) of the New Orleans floodwater was rainfall, carrying little or no contamination. Human waste in the form of raw sewage was certainly present, but the total volume of effluent is not likely to be much beyond the 0.22 BG daily capacity of New Orleans' Dunbar WWTP. An additional small volume (with disproportionately large potential water quality impact) can be attributed to petroleum products and household wastes leaking out of cars and containers. The remainder - nearly 40 BG - must have been a combination of Lake Pontchartrain waters and the storm surge from the Gulf of Mexico. The waters entering from outside the levees are likely to have been heavily laden with resuspended bottom sediments. However, extensive pre-1990 shell dredging covering two-thirds of Lake Pontchartrain may have helped bury deposited metals and other toxics, making these waters comparatively clean from a human health risk standpoint (Mannheim). If so, the 1+ BG of sewage, petroleum products, and household wastes inside New Orleans were mixed with 60 BG of comparatively clean water. The 1300 BG volume of Lake Pontchartrain also acted as a buffer to water quality impacts, providing an additional opportunity for dilution.

4.1 Contaminant metals

Except for samples in the vicinity of New Orleans canal mouths, means of contaminant metals in analyzed sediment samples from Lake Pontchartrain were found to be lower than those from Mississippi River suspended matter, and in the range of pristine sediments. This surprising result can be explained by the fact that an estimated 2/3 of the total area of Lake bottoms had been dredged for clam shells prior to 1990. Core profiles were analyzed for trace metals. The profiles revealed that dredging had mixed pristine sediments with very low metal concentrations with shallow surficial sediments that had increased contaminant levels (but below toxicity guidelines) down to depths of nearly 3 m.

Water sampling by the Louisiana Department of Environmental Quality and partner organizations has found detectable contaminant metals rare in city flood waters. Unless increased concentrations of hazardous metals emerge in the rain water flushes from the city, the likelihood of significant enhanced contamination by metals in the sediments outside areas immediately adjacent to pumping station outfall appears small.

4.2 Toxic organic compounds

EPA in coordination with the Louisiana Department of Environmental Quality performed chemical sampling of New Orleans flood waters for over one hundred priority pollutants such as volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), total metals, pesticides, herbicides, and polychlorinated biphenyls (PCBs). Flood water sampling data for chemicals are being posted from September 3, 2005 on as they become available. The data has been reviewed and validated through a quality assurance process to ensure scientific accuracy.

Principal toxic compounds can be divided into three categories: polyaromatic hydrocarbons (PAHs) found in petroleum and coal tar products, polychlorinated biphenyls (PCBs), and pesticides and miscellaneous chemicals (see tables 1-4). PAH concentrations studied in the previous database were far lower than might have been expected, but for reasons different than in the case of metals. Unchlorinated hydrocarbons are broken down rapidly by microbial attack in warm salty waters like those of Lake Pontchartrain (about 1/10 to 1/8th the saltiness of seawater). Even stations near earlier creosote spills on the north coast of Lake Pontchartrain showed only faint traces of what must have been earlier heavy contamination from former Superfund sites, and former sites of offshore oil wells in Lake Pontchartrain. Recent reports by the Louisiana Department of Environmental Quality (DEQ) and partner agencies have reported no oil sheen in offshore water sampling sites investigated. This suggests that evaporation and biochemical breakdown of petroleum has already removed much of the oil reported to be dispersed in the flood waters. Early, alarming newspaper reports of spill of 78,000 barrels of oil in New Orleans posed much more serious concern. This spill turns out to have occurred not in New Orleans, but well downstream in the Mississippi River, at storage tanks Cox Bay.

Chlorinated hydrocarbons are 100 times or more resistant to bacterial breakdown than PAHs in the natural environment. However, the earlier inventory showed that these compounds too were well below toxic levels in sediments, except for isolated occurrences in the immediate vicinity of New Orleans' canals. In the decades since the early 1970s, PCBs and long-lived pesticides like DDT, dieldrin, and aldrin have been systematically removed from use in the U.S., and none were detected in the initial DEQ samplings.

4.3 Biological (sewage-related) and nutrient loads.

Two contaminants prominently identified in New Orleans flood waters were fecal coliform bacteria of sewage origin, and oil. Pathogens dispersed and diluted in Lake waters are expected to be broken down quickly. The load of sewage-derived organic matter is reflected in reduced oxygen levels in DEQ-sampled waters at. However, stations ½ mile from shore showed oxygen levels within the normal range. Table five shows E. coli testing results for September 8 at locations throughout New Orleans.

Once the sewage-derived organic matter is broken down into its component nutrients – especially nitrogen, a secondary bloom of phytoplankton is expected – which may extend farther into the Lake through normal dispersion and mixing. Information on this secondary productivity is not yet available. It could be tracked synoptically by multispectral satellite data as reported in by Stumpf in the abovementioned report and shown in the oral presentation.

The efforts of relevant New Orleans and Louisiana agencies, stimulated by the urgings and studies of public organizations like *Save Our Lake*, coastal New Orleans beaches became swim able and fishable in recent years. Hurricane Katrina also caused large-scale sediment and bottom topographic changes that remain to be assessed However, assuming appropriate restoration and upgrading of water treatment facilities and other appropriate measures in New Orleans, and barring factors not currently known, there should be few long-lasting contaminant influences that would inhibit restoration and future recreational use of New Orleans' shoreline.

Flood water samples for September 16, 2005 indicated that slightly elevated levels of hexavalent chromium were detected in two samples and manganese was detected at elevated levels in seven samples. Lead and arsenic were also found in two samples at levels which exceed the drinking water action levels. The Center for Disease Control (CDC) concluded that exposures at these levels during response activities would not be expected to cause adverse health effects.

4.4 Sediment Sampling

When Hurricane Katrina flooded the city of New Orleans, one of many concerns in its wake was contamination. Several chemical plants, petroleum refining facilities, and contaminated sites, including Superfund sites, were covered by floodwaters. In addition, hundreds of commercial establishments, such as service stations, pest control businesses, and dry cleaners, may have released potentially hazardous chemicals into the floodwaters. Figure 7 shows potential petroleum-related release points, including refineries, oil and gas wells, and service stations in the city relative to water inundation damage. There were also major hazardous-materials storage locations, Superfund sites, and Toxic Release Inventory reporting facilities located in the larger New Orleans area. Some of these sites located within the city are shown in figure 8.

Adding to the potential sources of toxics and environmental contaminants are metal-contaminated soils typical of old urban areas and construction lumber preserved with creosote, pentachlorophenol, and arsenic. Compounding these concerns is the presence of hazardous chemicals commonly stored in households and the fuel and motor oil in approximately 400,000 flooded automobiles. Uncontrolled biological wastes from both human and animal sources also contributed to the pollutant burden in the city.

Sediment, for the purposes of the hurricane response sampling effort, are defined as residuals deposited by receding flood waters which may include historical sediment from nearby water bodies, soil from yards, road and construction debris, and other material. Preliminary results indicate that some sediment may be contaminated with bacteria and fuel oils and human health risks may therefore exist from contact with sediment deposited from receding flood waters. As sediments begin to dry, EPA performed air sampling to monitor potential inhalation risks and will also assess long-term exposure scenarios.

E. coli was detected in sediment samples but no standards exist for determining human health risks from E. coli in soil or sediment. The presence of E. coli, however, does imply the presence of fecal bacteria and exposure to sediment should therefore be limited if possible. In the event contact occurs, EPA and the Centers for Disease Control (CDC) strongly advised the use of soap and water, if available, to clean the exposed areas, and the removal of contaminated clothing.

Of the 430 sediment samples collected by EPA between September 10 and October 14, a number exceeded screening criteria of the local regulatory authority, the Louisiana Department of Environmental Quality (LDEQ Risk Evaluation/Corrective Action Program or RECAP) (LDEQ, 2005). These criteria were developed to meet objectives similar to those of the EPA Health Specific Screening Levels and are similarly derived. The constituents most often found to exceed the RECAP screening criteria were arsenic, lead, several PAHs (including benzo[a]pyrene), and diesel range organics. Figure 9 illustrates the sediment sampling sites that were in operation in the New Orleans area.

On November 19 and 20, EPA resampled areas where previous sampling had indicated contaminant concentrations in excess of screening criteria and where sediment depth equaled or exceeded 0.5 inches (EPA, 2005b). Because of the complex nature of the storm surge and levee breaches and overtopping, the amount of sediment deposited in flooded areas varied widely, and only 14 of the 145 locations had sufficient sediment depth. Three samples showed arsenic concentrations higher than 12 mg/kg (14.4–17.6 mg/kg); one sample showed benzo[a]pyrene concentration of 0.77 mg/kg; and one sample showed a concentration of diesel range organics of 2,100 mg/kg. Other samples were below applicable screening values.

Samples were also collected at specific sites where there were known or potential leaks of hazardous materials. Elevated concentrations of total petroleum hydrocarbons and a variety of crude oil-associated contaminants were observed in the vicinity of the Murphy Oil crude oil tank failure and spill, which had a clearly identifiable source and could be easily differentiated from the general flooding-related contamination. This area is being managed separately from the rest of the flooded area and is not considered further here.

4.5 Tissue Sampling

In response to public concern for the water quality and related sea food contamination of Lake Pontchartrain and in the Gulf following Hurricane Katrina, the U.S. Geological Survey (USGS), in collaboration with the Louisiana Department of Environmental Quality (DEQ), U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and the Food and Drug Administration (FDA), is conducting intensive studies of water, sediment, and seafood quality of Lake Pontchartrain and the Gulf coastal region. Seafood harvesting in most of this area was stopped following the hurricane events and was reopened after tissue testing showed no presents of contamination. Figure 10 shows the location of sampling sites in the Gulf coastal region that were used in to evaluate the condition of sea organisms.

Findings suggest that, despite expectations that hurricane-related flooding in New Orleans could cause uniformly high concentrations of fecal bacteria in Lake Pontchartrain, water samples from sites in and around the lake commonly were within limits acceptable for recreational waters.

These results represent a first round of testing following Hurricanes Katrina and Rita. The Louisiana DEQ is continuing to monitor bayous along the north side of Lake Pontchartrain, areas found to be ‘hot spots’ in samples collected immediately following Hurricane Rita. USGS scientists measured fecal-indicator bacteria *Escherichia coli* (*E. coli*), enterococci, and fecal coliforms over a 3 week period. These indicator bacteria are not themselves pathogens, but scientists monitor for them because they are useful indicators of fecal contamination and the possible presence of pathogens. Concentrations in samples they collected in the third and fourth week after passage of Hurricane Katrina commonly were less than U.S. EPA criteria for *E. coli* and enterococci in fresh or marine waters and also met the Louisiana DEQ standard for fecal coli form bacteria. A week later, following the passage of Hurricane Rita, concentrations at several tributary sites were well above the criteria and standard, while concentrations in the lake remained generally below or near those limits.

Scientists collected water samples at 22 sites—including most inflows to the lake, sites within the lake, and the major outflows to the Gulf of Mexico by way of Lake Borgne and the Mississippi Sound. Nineteen of the sites are routinely sampled as part of the Louisiana DEQ ambient monitoring network. Corresponding data on water temperature, specific conductance (a measure of salinity), pH, and dissolved oxygen also were collected at each site at the time of sampling.

The scientists were especially interested to find the highest concentrations of fecal contamination in north shore tributaries rather than in the south shore canals that carried flood water from New Orleans into Lake Pontchartrain. Dennis Demcheck, the USGS hydrologist at Baton Rouge, La., who led the sampling effort, attributed this to a “settling pond” effect in New Orleans, which held flood waters during the weeks prior to pumping them back into Lake Pontchartrain.

The study included an extensive quality-control data set, and that data set largely indicates satisfactory analytical performance, even though scientists were working out of a mobile lab in less than ideal field conditions. These results are intended to help in completing the regional Interagency Environmental Assessment underway by USGS, U.S. EPA, NOAA and FDA.

5. CONCLUSIONS

The flooding in New Orleans resulted in the potential for unparalleled exposure to toxics and contaminants. Initial concerns about a "toxic gumbo," however, have not been supported by sampling and analyses to date. Although floodwaters did contain significant short-term biological hazards that posed risks to stranded residents and relief workers, they did not contain chemical toxicants at levels that are expected to lead to long-term impacts on the surroundings beyond the impacts expected of a similar volume of stormwater from the city. The floodwaters undoubtedly redistributed some contaminants, but the contaminant burden in soils and sediments appears to have generated few concerns for acute exposure and risk. However, although acute generalized hazards have not been identified, the population of New Orleans faces localized areas of more serious contamination, such as the neighborhoods impacted by failure of a crude-oil storage tank in St. Bernard Parish. The most serious continuing issue facing most residents is the presence of high concentrations of mold and airborne mold spores. However, respiratory protection during the removal of all mold-contaminated materials and reconstruction can mitigate the risk.

Ultimately, the lessons learned from Katrina should be crystallized in a generic form so that the country as a whole will be better prepared for the next natural disaster, major industrial accident, or act of terrorism. Thus, every effort should be made to focus on the way information is processed in emergency situations and to make sensible, safe, and equitable cleanup/habitability decisions in an environment of great uncertainty. Because existing institutions were largely unprepared for a disaster of the scale of Katrina, it may not be possible to implement these principles in New Orleans. However, we can learn from Katrina and provide more effective responses to future catastrophes.

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Table 1: Sampled, Found Exceeds EPA Limits

CASNumber	Name	Measured Level (µg/L)	EPA Limit (µg/L)
7439-92-1	Lead	20	15

Table 2: Sampled, Found meets EPA Limits

CASNumber	Name	Measured Level (µg/L)	EPA Limit (µg/L)
7440-39-3	Barium	210	2000
7440-50-8	Copper	62	1300
57-12-5	Cyanide	29.7	200

Table 3: Sampled & Found No EPA Limits

CASNumber	Name	Measured Level (µg/L)
7429-90-5	**Aluminum**	1290
7440-70-2	**Calcium**	111000
7439-89-6	**Iron**	1930
7439-95-4	**Magnesium**	99200
7439-96-5	**Manganese**	669
7440-02-0	**Nickel**	22
7440-09-7	**Potassium**	52700
7440-22-4	**Silver**	12
7440-23-5	**Sodium**	724000
7440-66-6	**Zinc**	292

Table 4: Toxic Organic Compounds and Metals Sampled & Not Found

Name		
.alpha.-Endosulfan	Acenaphthene	Carbazole
.alpha.-Hexachlorocyclohexane	Acenaphthylene	Carbon tetrachloride
.beta.-Endosulfan	Acrolein	Chlordane, technical
.beta.-Hexachlorocyclohexane	Acrylonitrile	Chlorobenzene
.delta.-Hexachlorocyclohexane	Aldrin	Chlorodibromomethane
1,1,1-Trichloroethane	Anthracene	Chloroethane
1,1,2,2-Tetrachloroethane	Antimony	Chloroform
1,1,2-Trichloroethane	Aroclor 1016	Chloromethane
1,1-Dichloroethane	Aroclor 1221	Chromium
1,1-Dichloroethylene	Aroclor 1232	Chromium(VI)
1,2,4-Trichlorobenzene	Aroclor 1242	Chrysene
1,2-Dichloroethane	Aroclor 1248	Cobalt
1,2-Dichloropropane	Aroclor 1254	Di(2-ethylhexyl) phthalate
1,2-Diphenylhydrazine	Aroclor 1260	Di-n-octyl phthalate
1-Propene, 1,3-dichloro-, (Z)-	Arsenic	Dibenz[a,h]anthracene
2,4,5-T	Benz[a]anthracene	Dibutyl phthalate
2,4,6-Trichlorophenol	Benzene	Dichlorobromomethane
2,4-D, Dichlorophenoxyacetic acid	Benzidine	Dieldrin
2,4-Dichlorophenol	Benzo(b)fluoranthene	Diethyl phthalate
2,4-Dimethylphenol	Benzo[a]pyrene	Dimethyl phthalate
2,4-Dinitrophenol	Benzo[ghi]perylene	Dinitro-o-cresol
2,4-Dinitrotoluene	Benzo[k]fluoranthene	Endosulfan sulfate
2,5-Dichlorophenol	Benzoic acid	Endrin
2,6-Dichlorophenol	Beryllium	Endrin aldehyde
2,6-Dinitrotoluene	Bis(2-chloroethoxy)methane	Endrin ketone
2-Chloroethyl vinyl ether	Bis(2-chloroethyl) ether	Ethylbenzene
2-Chloronaphthalene	Bis(2-chloroisopropyl) ether	Fluoranthene
3,3'-Dichlorobenzidine	Bis(2-chloroisopropyl) ether	Fluorene
3,4-Dichlorophenol	Butyl benzyl phthalate	Heptachlor
Hexachlorobutadiene	Hexachlorocyclopentadiene	Hexachloroethane
Indeno[1,2,3-cd]pyrene	Isophorone	Lindane
Mercury	Methoxychlor	Methyl bromide
Methylene chloride	N-Nitrosodi-n-propylamine	N-Nitrosodimethylamine
Naphthalene	Nitrobenzene	Pentachlorophenol
Phenanthrene	Phenols	Pyrene
Selenium	Silvex	Tetrachloroethylene
Thallium	Toluene	Toxaphene
Tribromomethane	Trichloroethylene	Vanadium
Vinyl chloride	m-Chlorophenol	m-Dichlorobenzene

Table 5: Example of EPA Biological Water sample data for New Orleans on September 8, 2005

Sample Date	County	Location Description	Sample Number	Bacteria	Colonies/100mL
9/8/2005	JEFFERSON	Bonneville Canal	15178	E. coli	5818
9/8/2005	JEFFERSON	Outfall	15561	E. coli	6260
9/8/2005	JEFFERSON	Outfall	15562	E. coli	7568
9/8/2005	ORLEANS	Louisa & Almonaster	15172	E. coli	462
9/8/2005	ORLEANS	Independence & Marais	15175	E. coli	7308
9/8/2005	ORLEANS	Independence & Marais	15176	E. coli	8212
9/8/2005	ORLEANS	Kenilworth Canal	15177	E. coli	5702
9/8/2005	ORLEANS	610 & I-10 split	15180	E. coli	11588
9/8/2005	ORLEANS	W610 Exit 4	15181	E. coli	9768
9/8/2005	ORLEANS	Chantilly & Chef HWY	15184	E. coli	610
9/8/2005	ORLEANS	Wilson & Chef HWY	15185	E. coli	1820
9/8/2005	ORLEANS	Schinduie Dr & Chef HWY	15188	E. coli	264
9/8/2005	ORLEANS	I-510 & Chef HWY	15189	E. coli	462
9/8/2005	ORLEANS	Mayo Rd & Dwyer Rd	15192	E. coli	2356
9/8/2005	ORLEANS	Louisa & Chef Menteur	15196	E. coli	976
9/8/2005	ORLEANS	Paris Ave & Prentiss Ave.	15198	E. coli	3348
9/8/2005	ORLEANS	Paris Ave & Prentiss Ave.	15202	E. coli	4210
9/8/2005	ORLEANS	Marais & Poland Ave	16190	E. coli	8704
9/8/2005	ORLEANS	W610 Exit 2C	16198	E. coli	6896
9/8/2005	ORLEANS	610 & Elysian Fields	16199	E. coli	5226
9/8/2005	ORLEANS	Croader Blvd & Chef HWY	16200	E. coli	576
9/8/2005	ORLEANS	Hickerson Dr. & Chef HWY	16201	E. coli	346
9/8/2005	ORLEANS	E. AdamsCt & Chef HWY	16202	E. coli	4196
9/8/2005	ORLEANS	LakeForestBlvd & SamOvar Dr.	16203	E. coli	862
9/8/2005	ORLEANS	Dwyer Rd & I-10	16204	E. coli	1970
9/8/2005	ORLEANS	StephenGirard & St Ferindad	16205	E. coli	1508
9/8/2005	ORLEANS	Chef Menteur & Iroquois St	16206	E. coli	3870
9/8/2005	ORLEANS	Paris Ave & Lafreniere St.	16207	E. coli	4718
9/8/2005	ORLEANS	Paris Ave & Mirabeau Ave	16208	E. coli	2402
9/8/2005	ORLEANS	Franklin Ave & Gentilly Rd	16209	E. coli	992
9/8/2005	ORLEANS	Franklin Ave & Mirabeau Ave	16210	E. coli	5702

Figure 1: Aerial view of New Orleans Flood

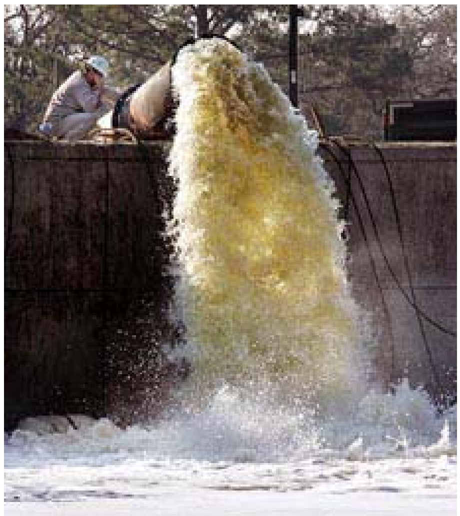

Figure 2: Portable Pump Operation

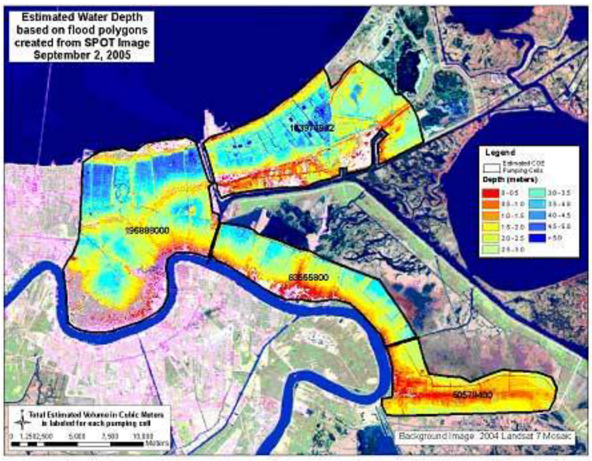

Figure 3: Flooded Area on Sept 2

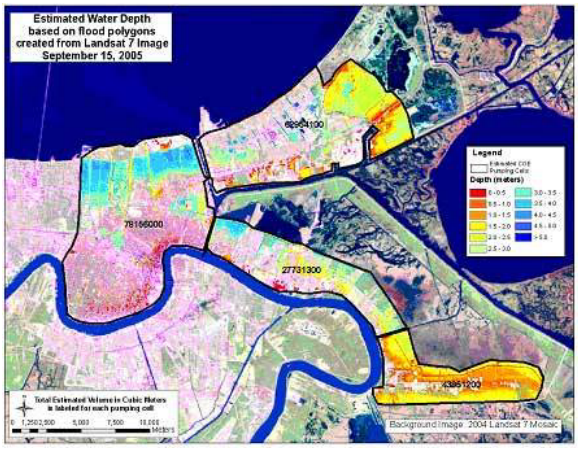

Figure 4: Flooded Area on Sept 15

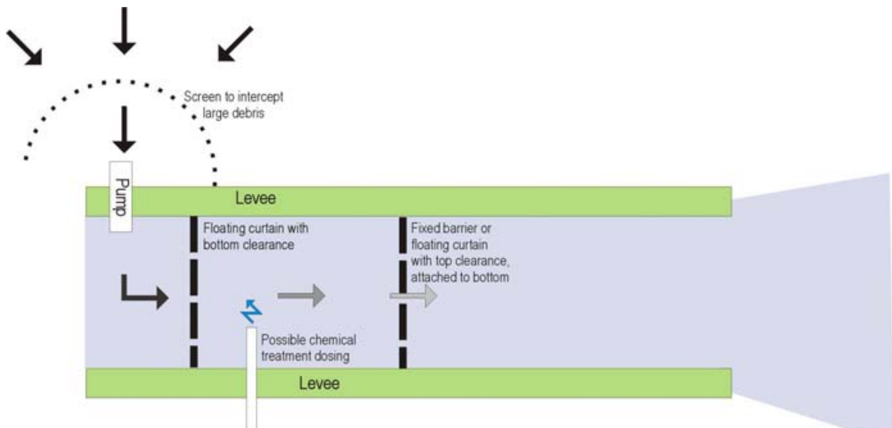

Figure 5. Illustration on in-canal expedient water treatment system

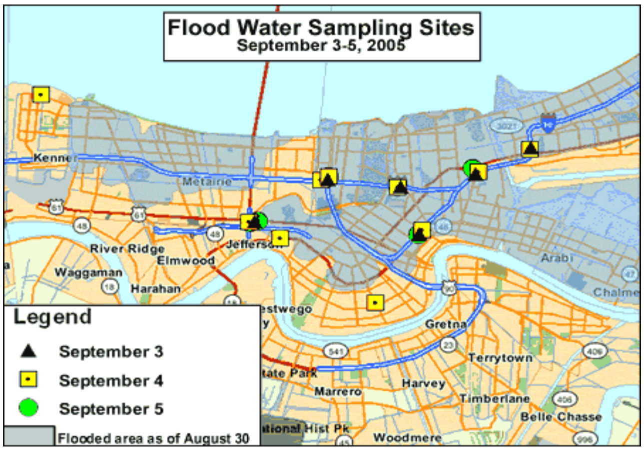

Figure 6: Flood Water Sampling Sites

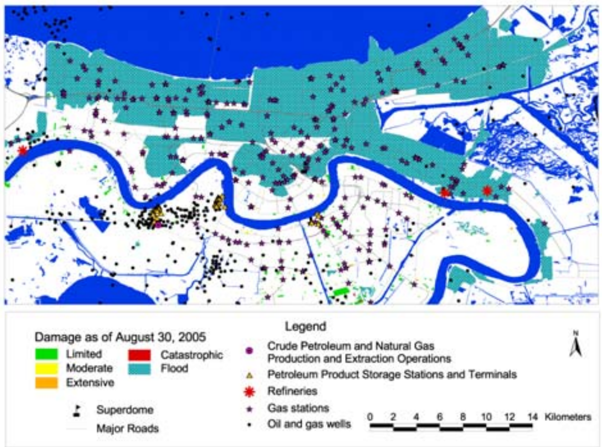

Figure 7: Petroleum Risk Sites

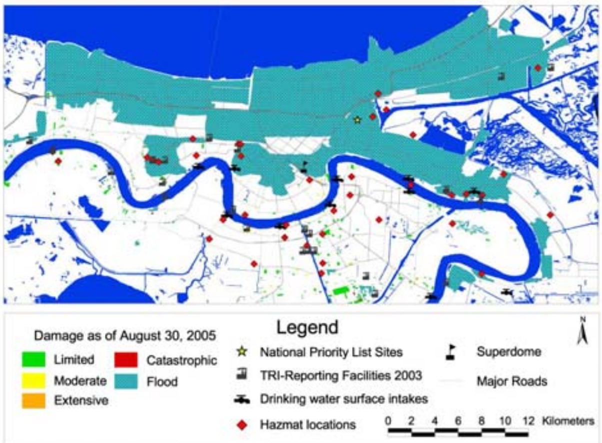

Figure 8: Critical Infrastructure Risk Sites

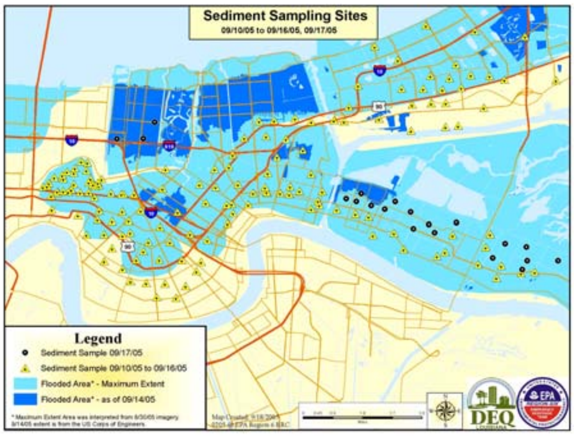

Figure 9: Sediment Sampling Sites

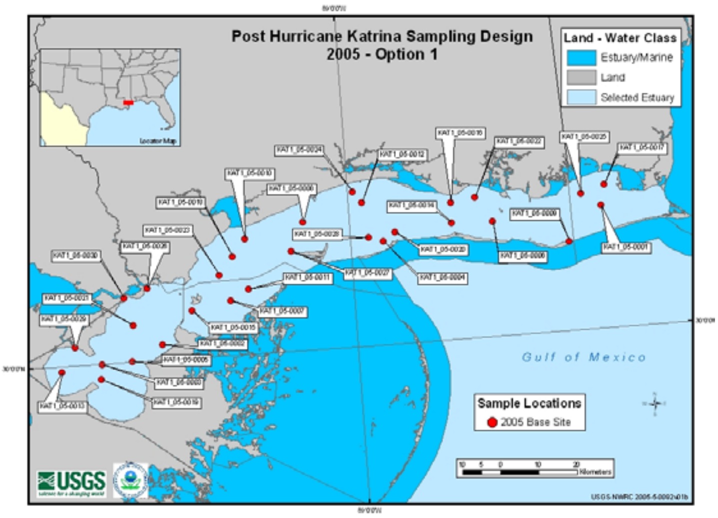

Figure 10: Tissue Sampling Sites in the Gulf Coastal Area