THE NEW ORLEANS HURRICANE PROTECTION SYSTEM: What Went Wrong and Why









A Report by the American Society of Civil Engineers Hurricane Katrina External Review Panel





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Executive Summary

On the morning of August 29, 2005, Hurricane Katrina—one of the strongest storms ever to hit the coast of the United States—brought intense winds, high rainfall, waves, and storm surge to the Gulf of Mexico shores of Louisiana, Mississippi, and Alabama. Communities in all three states suffered damage, but this report focuses on the devastation to New Orleans and southeast Louisiana.

New Orleans was built on low-lying marshland along the Mississippi River. Levees and floodwalls were built around the city and adjacent parishes to protect against flooding. During and after Hurricane Katrina, many of those levees and floodwalls were overtopped and several were breached, allowing billions of gallons of water from the Gulf of Mexico, Lake Borgne, and Lake Pontchartrain to flow into New Orleans and flood major portions of the city.

As of August 2, 2006, 1,118 people were confirmed dead in Louisiana as a result of Hurricane Katrina. Another 135 people are still missing and presumed dead. Thousands of homes were destroyed. Direct damage to residential and non-residential property is estimated at \$21 billion, damage to public infrastructure another \$6.7 billion. Nearly half the region's population has not yet returned after evacuating. Nearly 124 thousand jobs were lost, and the region's economy was crippled.

The catastrophic failure of New Orleans's hurricane protection system represents one of the nation's worst disasters ever. The members of the American Society of Civil Engineers (ASCE) Hurricane Katrina External Review Panel have conducted an in-depth review of the comprehensive work of the United States Army Corps of Engineers (USACE) Interagency Performance Evaluation Taskforce (IPET)—at the USACE's request. The ASCE Hurricane Katrina External Review Panel's findings and conclusions are presented in this report.

A storm of Hurricane Katrina's strength and intensity is expected to cause major flooding and damage. A large portion of the destruction from Hurricane Katrina was caused not only by the storm itself, however, but also by the storm's exposure of engineering and engineering-related policy failures. The levees and floodwalls breached because of a combination of unfortunate choices and decisions, made over many years, at almost all levels of responsibility.

There were two direct causes of the levee breaches: collapse of several levees with concrete floodwalls (called I-walls) because of the way they were designed, and overtopping, where water poured over the tops of the levees and floodwalls and eroded the structures away. Furthermore, the many existing pump stations that could have helped remove floodwaters were inoperable during and after the storm.

The I-walls failed because the margin of safety used in the design process was too low—especially considering that the hurricane protection system was a critical life-safety structure. The engineering design did not account for the variability in the strength of soft soils beneath and adjacent to the levees. The designers failed to take into account a water-filled gap that developed behind the I-walls as they bowed outward from the forces exerted by the floodwaters.

Some overtopping of levees is to be expected in a major storm. However, the levees were not armored or protected against erosion—an engineering choice of catastrophic consequences because this allowed the levees, some constructed of highly erodible soil, to be scoured away, allowing water to pour into New Orleans.

In addition to these direct causes of the levee breaches, a number of other factors also contributed to the catastrophe:

- The risk to New Orleanians (i.e., the probability of failure combined with the consequences to human health and safety if that failure were to occur) was much higher than many people are generally willing to accept. Because these risks were not well understood or communicated effectively to the public, the importance of evacuating people and protecting property was under-estimated.
- The hurricane protection system was constructed as individual pieces—not as an interconnected system—with strong portions built adjacent to weak portions, some pump stations that could not withstand the hurricane forces, and many penetrations through the levees for roads, railroads, and utilities. Furthermore, the levees were not designed to withstand overtopping.
- The hurricane protection system was designed for meteorological conditions (barometric pressure and wind speed, for example) that were not as severe as the Weather Bureau and National Weather Service listed as being characteristic of a major Gulf Coast hurricane.
- Levee builders used an incorrect datum to measure levee elevations—resulting in many levees not being built high enough. Some levees were built 1 to 2 feet lower than the intended design elevation. Furthermore, despite the acknowledged fact that New Orleans is subsiding (sinking), no measures were taken into account in the design to compensate for the subsidence by monitoring the levees and raising them up to the pre-subsidence design elevation.

- No single agency was in charge of hurricane protection in New Orleans. Rather, responsibility for the maintenance and operation of the levees and pump stations was spread over many federal, state, parish, and local agencies. This lack of inter-agency coordination led to many adverse consequences from Hurricane Katrina.
- The hurricane protection system was funded on a project-byproject basis over many years. As a result, the system was constructed in a piecemeal fashion. In addition, there were pressures for tradeoffs and low-cost solutions that compromised quality, safety, and reliability.
- The design of the New Orleans hurricane protection system was not subject to the rigorous external review by senior experts that is often conducted for similar life-safety structures and systems.

The first of ASCE's Fundamental Canons in its Code of Ethics states, "Engineers shall hold paramount the safety, health and welfare of the public...." Serious deficiencies in the southeast Louisiana hurricane protection system must be corrected if the New Orleans area is to avoid a similar catastrophe when the next major hurricane strikes.

The ASCE Hurricane Katrina External Review Panel strongly urges that organizations responsible for critical life-safety facilities be organized and operated to enable, not to inhibit, a focus on safety, and that engineers continually evaluate the appropriateness of design criteria, always considering how the performance of individual components affects the overall performance of a system. Specific recommendations include:

- Keep safety at the forefront of public priorities by having all responsible agencies re-evaluate their policies and practices to ensure that protection of public safety, health, and welfare is the top priority for infrequent but potentially devastating impacts from hurricanes and flooding. Also, encourage Congress to establish and fund a mechanism for a nationwide levee safety program, similar to that which is in place for dams.
- Quantify and periodically update the assessment of risk. This approach should be extended to all areas in the United States that are vulnerable to major losses from hurricanes and flooding.
- Determine the level of acceptable risk in the community through quality interactive public risk communication programs in New

Orleans and other areas threatened by hurricanes and flooding. Once determined, manage the risks accordingly.

- Correct the system's deficiencies by establishing mechanisms to incorporate changing information, making the levees survivable if overtopped, strengthening the l-walls and levees, and upgrading the pumping stations.
- Assign to a single entity or individual (a licensed engineer) the responsibility of managing critical hurricane and flood protection systems such as the one in New Orleans.
- Implement more effective mechanisms for coordination and cooperation. (For example, those responsible for maintenance of the system must collaborate with system designers and must upgrade their inspection, repair, and operations processes to ensure that the system is hurricane- and flood-ready.)
- Upgrade engineering design procedures and practice to place greater emphasis on safety.
- Engage independent experts in high-level reviews of all critical lifesafety structures, including hurricane and flood-protection systems.

In a very real sense, the findings and conclusions in this report extend far beyond the New Orleans hurricane protection system. The lessons learned from the engineering and engineering-related policy failures triggered by Hurricane Katrina have profound implications for other American communities and a sobering message to people nationwide: *we must place the protection of safety, health, and welfare at the forefront of our nation's priorities*. To do anything less could lead to a far greater tragedy than the one witnessed in New Orleans.

CHAPTER 1

Introduction

On the morning of August 29, 2005, Hurricane Katrina struck southeast Louisiana and triggered what would become one of the worst disasters ever to befall an American city. The storm overtopped levees and floodwalls throughout southeast Louisiana and also caused the levees and floodwalls in the New Orleans area to fail or breach in more than 50 locations. Water rushed into New Orleans and flooded over 80 percent of the city—more than 10 feet deep in some neighborhoods.

One thousand one hundred eighteen (1,118) people lost their lives in the New Orleans area, and 135 more are still missing and presumed dead. Tens of billions of dollars worth of property was damaged. More than 400,000 people fled the city. Many have not returned. The educational and health care systems of the New Orleans area have been crippled. The devastation was so extensive, and the residual risk looms so ominous, that, more than a year and a half later, the future of New Orleans remains clouded.

The members of the American Society of Civil Engineers (ASCE) extend their sincere condolences to the families and friends of those who lost their lives during and after Hurricane Katrina. Our heartfelt sympathy goes out to the people of the New Orleans area who are left without homes, communities, and jobs, and to those who face an uncertain future.

The members of the ASCE Hurricane Katrina External Review Panel have conducted an in-depth review of the comprehensive work of the United States Army Corps of Engineers (USACE) Interagency Performance Evaluation Taskforce (IPET). We are indebted to the dedicated efforts of more than 150 engineers and scientists who have, in the year and a half following Hurricane Katrina, evaluated the causes of the New Orleans area hurricane protection system failures.

As a result of this excellent work, we now better understand what went wrong and why. The ASCE Hurricane Katrina External Review Panel has an obligation to share its findings and insights, which go beyond the scope of the IPET review, so that others may learn from this tragedy and prevent similar disasters from happening again, not only in New Orleans, but in other communities throughout the United States that are also vulnerable to hurricanes and flooding.