

## CHAPTER ONE: INTRODUCTION AND OVERVIEW

### 1.1 Introduction

This report presents the results of an investigation of the performance of the New Orleans regional flood protection system during and after Hurricane Katrina, which struck the New Orleans region on August 29, 2005. This event resulted in the single most costly catastrophic failure of an engineered system in history. Current damage estimates at the time of this writing are on the order of \$100 to \$150 billion in the greater New Orleans area, and the official death count in New Orleans and southern Louisiana at the time of this writing stands at 1,293 with an additional 306 deaths in nearby southern Mississippi. An additional approximately 400 people are currently still listed as “missing”; it is expected that some of these missing were temporarily lost in the shuffle of the regional evacuation, but some of these are expected to have been carried out into the swamps and the Gulf of Mexico by the storm’s floodwaters, and some are expected to be recovered in the still ongoing sifting through the debris of wrecked homes and businesses, so the current overall regional death count of 1,599 is expected to continue to rise a bit further. More than 450,000 people were initially displaced by this catastrophe, and at the time of this writing, more than 250,000 residents of the greater New Orleans metropolitan area continue to be displaced from their homes by the floodwater damages from this storm event.

This investigation targets three main questions as follow: (1) What happened? (2) Why? and (3) What types of changes are necessary to prevent recurrence of a disaster of this scale again in the future?

To address these questions, this investigation has involved: (1) an initial field reconnaissance, forensic study and data gathering effort performed quickly after the arrival of Hurricanes Katrina (August 29, 2005) and Rita (September 24, 2005), (2) a review of the history of the regional flood protection system and its development, (3) a review of the challenging regional geology, (4) detailed studies of the events during Hurricanes Katrina and Rita, as well as the causes and mechanisms of the principal failures, and studies of sections that performed successfully as well, (5) studies of the organizational and institutional issues affecting the performance of the flood protection system, (6) observations regarding the emergency repair and ongoing interim levee reconstruction efforts, and (7) development of findings and preliminary recommendations regarding changes that appear warranted in order to prevent recurrence of this type of catastrophe in the future.

### 1.2 Initial Post-Event Field Investigations

A critical early stage of this investigation was the initial field investigations performed by collaborating teams of engineers and scientists in the wake of the passage of Hurricane Katrina, to study performance of the regional flood protection system and the resulting flooding that occurred in the New Orleans area. The principal focus of these efforts was to capture perishable data and observations related to the performance of flood protection system before they were lost to ongoing emergency response and repair operations.

Several independent investigation teams jointly pooled their efforts in order to capture as much data as possible in the precious timeframe available. The two principal participating teams were from the University of California at Berkeley (UC Berkeley), and a team from the American Society of Civil Engineers (ASCE) organized by its Geo-Institute and by its Coasts, Oceans, Ports, and Rivers Institute. A team from Louisiana State University's Hurricane Research Center (LSU/HRC) also accompanied the field investigation teams during their first week of investigations. These teams were accompanied and assisted in the field by members of the U.S. Army Corps of Engineers (USACE) levee investigation team from the Engineer Research and Development Center (ERDC). All of these investigative teams shared data and findings freely and openly, and the mutual pooling of talents and expertise greatly benefited all as it enabled the field teams to gather more data in the critical days available.

These initial field investigations occurred over a span of approximately three weeks, from September 26 through October 15, 2005, and the preliminary observations and findings were presented in a report jointly authored by the UC Berkeley-led field investigation team and the ASCE field investigation team (Seed, et al.; November 15, 2005.)

### **1.3 Current Studies and Investigations**

Subsequent to these initial field investigations, three main investigations have been carried forward. The largest of these is the U.S. Army Corps of Engineers' own internal investigation, the Interagency Performance Evaluation Team (IPET) study. The IPET study is by far the largest of the three investigations, and has a budget of approximately \$20 million. The American Society of Civil Engineers (ASCE) has been hired, for an additional \$2 million, to form a review panel (called the External Review Panel, E.R.P.) to review the results of the IPET studies. This ASCE review panel works and consults closely with the IPET studies and is focused specifically on reviewing the IPET investigation efforts, data and findings. The National Research Council (NRC) has also been hired, by the Department of Defense, to provide an additional review of the IPET studies after the ASCE's E.R.P. completes its task. This NRC review panel has announced its intention of reviewing input from all investigation teams and efforts as part of this task.

The IPET study is narrowly focused and constrained in its first year to consideration and study of only "what happened" in a strictly physical sense; it is specifically not to address underlying faults or to assign "responsibility" in its initial studies (Final Draft Report due to the ASCE review panel on May 15, 2006, and Final Report due on June 1, 2006), but rather to wait and study "organizational issues", "human factors", etc. during the following year.

The second investigation team moving forward is Team Louisiana, representing the interests of the State of Louisiana in performing an investigation independent of the USACE. Team Louisiana is led by Dr. Ivor Van Heerden, and its core is formed by a number of his colleagues from the Louisiana State University (LSU) Hurricane Research Center (LSU/HRC), with additional members from a number of local engineering consulting firms and state organizations. Team Louisiana does not have the massive funding or manpower of the IPET team, but they are strongly motivated and have worked very hard and well given their logistical limitations and the difficult situation of the region (which has directly affected some of the team's members, as well as many of their friends and colleagues.)

The third investigation team moving forward is our own UC Berkeley-led Independent Levee Investigation Team (ILIT). Our budget is also not as large as that of the IPET study, and currently stands at approximately \$350,000. We have, however, managed to assemble a team of 37 outstanding engineers and researchers. Pages “xxv” through “xxvi” describe the team. As a group, the conjugate forensic experience in prior investigations of numerous major engineering and natural disasters is very impressive. This is an amazingly strong team, and we could never possibly have afforded to hire them within our small budget. These leading experts have, instead, volunteered to work for free (pro bono), and our budget is thus devoted instead towards covering travel expenses, field borings and sampling, and laboratory testing, etc. We have elected to decline proffered offers of additional funding, as it appears important that our investigation team maintain its demonstrable independence and neutrality in these studies.

#### **1.4 Organization of this Report**

This report presents the results of studies directed towards answering three main sets of questions as follow:

1. **What happened?** What events transpired during Hurricane Katrina and during its aftermath? How did the regional flood protection system perform? What were the successes, and what were the shortcomings and failures? What mechanisms and forces, etc., led to these performances?
2. **Why did this happen?** What were the underlying issues that led to the observed performance of the system elements? What were the influences of regional and local geology? How did the history of the evolution of the flood protection system contribute to its performance? What were the design assumptions, engineering studies and analyses, etc., and what effect did these have on the performance of the system elements? What over-arching organizational, institutional, political and funding issues may have played a role?
3. **What can be done to ensure that a similar catastrophe does not recur in the future?** This report presents preliminary findings and recommendations regarding changes in organization of the overall governmental/institutional “system” responsible for the conception, design, construction, operation and maintenance of the complex regional flood defense system, as well as the making of political decisions regarding levels of protection to be provided, and the provision of funding to support the creation and operation/maintenance of such a system. This report also presents preliminary findings and recommendations regarding a number of focused areas for improvement of the conceptual design, analysis and engineering design, and construction and maintenance of such a system.

In the end, it is concluded that many things went wrong with the New Orleans flood protection system during Hurricane Katrina, and that the resulting catastrophe had its roots in three main causes: (1) a major natural disaster (the Hurricane itself), (2) the poor performance of the flood protection system, due to localized engineering failures, questionable judgements, errors, etc. involved in the detailed design, construction, operation and maintenance of the

system, and (3) more global “organizational” and institutional problems associated with the governmental and local organizations responsible for the design, construction, operation, maintenance and funding of the overall flood protection system.

Chapter 2 presents an overview of the principal events that occurred during and after the arrival of Hurricane Katrina in the New Orleans area, with emphasis on the storm surge and wave loadings, and the resulting performance of the regional flood protection system.

Chapter 3 presents a summary overview of the challenging regional and local geology that so strongly affects the difficulties associated with the creation of regional flood protection systems, and their performance as well.

Chapter 4 presents a review of the history of the development of the New Orleans regional flood protection system. It is a truism of levees and flood protection that the fabric and history of a given region is usually closely interwoven within the fabric of the levees and flood protection systems that are created in that region.

Chapters 5 through 8 present the results of studies and analyses of the performance of the four main levee-protected areas principally affected by Hurricane Katrina. These chapters present overviews of the performance of the flood protection system in each of the four areas, of the flooding that occurred within each of these areas, and detailed analyses of the performance of critical sub-elements of the system within each area. These analyses include an investigation of the causes of critical failures, and the apparent reasons for these including both engineering/construction types of issues as well as organizational/institutional issues. These chapters also present observations, recommendations and findings related to some of the emergency post-hurricane repair and reconstruction efforts.

Chapter 9 presents the results of studies of issues associated with overtopping erosion and scour; a key phenomenon involved in both the successful and unsuccessful performances of numerous critical levee and floodwall sections throughout the region.

Chapter 10 presents a summary review of the engineering issues addressed in Chapters 2 through 9, a brief overview of design standards, discussion of recurrent issues that appear to be problematic throughout the regional flood protection system, and recommendations for changes in engineering and design practices to address these.

Chapter 11 briefly addresses a series of “other issues”, including observations regarding apparent damage and distress at locations away from the four main New Orleans flood-protected areas that are the principal focus of these studies, a brief overview of the performance of the pumping systems that “unwater” the protected areas of these studies, and observations and comments regarding the initial emergency levee and floodwall breach repair efforts, and the ongoing interim repair and reconstruction efforts, at a number of locations.

Chapters 12 through 14 examine a number of organizational and institutional issues that affected the performance of the regional flood protection systems during Hurricane Katrina. They also address recommendations for moving forward; recommendations for a

number of changes to ensure that we never again have to study a catastrophe of this type and scale in southern Louisiana.

Chapter 12 begins with a review of background and history pertaining to these types of issues. Chapter 13 then presents a review and examination of critical organizational, institutional, political and funding issues that directly affected the performance of the New Orleans regional flood protection system, and also some of the post-hurricane repair and reconstruction efforts. These organizational/institutional issues had a dominant impact on the overall performance of the regional flood protection systems, and many of the problems that led to the catastrophic flooding of much of the greater New Orleans region can be traced directly (at least in large part) to these types of underlying issues.

Chapter 14 presents preliminary recommendations for changes that can and should be made in moving forward, in order to ensure that a catastrophe of this scale is never repeated in the future. The New Orleans regional flood protection system did not perform well in Hurricane Katrina. We can do better. This chapter presents recommendations for changes in specific engineering analysis and design procedures, conceptual design features and approaches, specific system elements, etc. This chapter also presents recommendations regarding changes in the overall system of governmental bodies, governmental agencies, outsourced (private sector) engineering and construction, local oversight agencies, and the regulations and procedures involved in the overall conception, design, construction, operation and maintenance of complex and regionally massive systems protecting vital public safety for populous regions such as this.

Finally, Chapter 15 presents a summary overview of these studies, and of the principal findings and recommendations.

## **1.5 Elevation Datum**

There are a number of datums that have been and continue to be used for elevation references throughout the New Orleans Region. A good discussion of these is presented in the IPET Interim Report No. 2 (IPET; April 1, 2006). The situation is further confused as some regional benchmarks, which were considered stable, have recently been found to have instead subsided, so that elevations based on these require correction. In this present report, all elevations are stated in terms of local Mean Sea Level (MSL), which corresponds approximately to the NAVD88 (2004.65) datum. [This NAVD88 (2004.65) datum is currently thought to be within approximately 3-inches of Mean Sea Level in the New Orleans area.] All elevations in this report have been resolved, as best we were able with the information available, to this MSL (or approximately NAVD88; 2004.65) datum.

## **1.6 References**

Seed, R. B., et al., "Preliminary Report on the Performance of the New Orleans Levee Systems in Hurricane Katrina on August 29, 2005", Report No. UCB/CITRIS – 05/01, November 17, 2005