Hurricane Katrina: Performance of the Flood Control System

Testimony of
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On behalf of the
NSF-Sponsored Levee Investigation Team
Before the Committee on Homeland Security and Government Affairs
U.S. Senate
November 2, 2005

Madam Chairman and Members of the Committee:

Good morning. My name is Raymond Seed, and I am pleased to be asked to appear before you today to testify on behalf of the Levee Investigation Team sponsored by the U.S. National Science Foundation.

A large number of leading national and international experts with a tremendous amount of forensic experience in sorting through major disasters have worked very hard this past month, and I am pleased to be able to present you with the first copy of the preliminary report of the findings of the combined ASCE and NSF-sponsored field investigation teams.

I am very grateful for their tremendous efforts in getting this material ready for you today.

I. Katrina and the Flood Control System

Our hearts go out to the many who have lost everything, even in some cases their lives, in this catastrophic event. Our teams have had considerable previous experience in many other disasters, including numerous major earthquakes around the world, the recent Indian Ocean tsunami, floods and levee failures, the space shuttle Challenger disaster, and more. But we were not prepared for the level and scope of the devastation that we witnessed when we were in New Orleans.

It must be the intent of our work that something like this not be allowed to happen again.

With that in mind, and in our hearts, I must make it clear that we know a great deal about what happened, and in many cases why, and that it is my intent today to speak as openly as possible. Our team, to a man and to a woman, feel that the people of the New Orleans region, and the Nation, and our governments at all levels, need and deserve nothing less. Important decisions are being made that will affect people's lives for years to come. We recognize the importance of providing the best possible informed information, responsibly studied and professionally and thoughtfully synthesized, that we can at this early juncture. Better and more

complete information will continue to evolve over the coming year, but that will be too late for many ongoing decisions being made right now, today.

Our preliminary report represents a consensus document, and it presents the initial observations and findings that we were able to agree to release with all the team members and organizations involved. If you will ask, I will do my best to answer questions well beyond the scope of our initial Preliminary Report.

II. Why Did the Levees and Floodwalls Fail?

This is a map of the central New Orleans region, prepared initially by the U.S. Army Corps of Engineers and then modified to reflect additional findings of our investigation teams. It shows the locations of many of the levee breaches that occurred, and serves as a good base map for our discussions today. Not shown on this map are the additional flood protection levee systems that extend down the lower reaches on the Mississippi River, providing a narrow additional protected corridor down to the Gulf.

The storm surges produced by Hurricane Katrina resulted in numerous breaches, and consequent flooding of approximately 75 percent of the metropolitan areas of New Orleans. Most of the levee and floodwall failures were caused by overtopping, as the storm surge rose over the tops of the levees and their floodwalls and produced erosion that subsequently led to failures and breaches.

Overtopping was most severe at the east end of the flood protection system, as the waters of Lake Borgne were driven west producing a storm surge on the order of 18 to 25 feet that massively overtopped levees immediately to the west of this lake. This photo shows one piece of a six mile section of levees at the northeast corner of the MRGO channel that were massively overtopped and eroded by this storm surge, which then sent floodwaters racing towards St. Bernard Parish. There is virtually nothing left of these levees along some parts of this stretch.

A very severe storm surge also occurred farther to the south, along the lower reaches of the Mississippi River, and significant overtopping produced additional breaches in this region as well. This photo shows homes that were carried across the narrow protected corridor in southern Plaquemines Parish by a breach on the west levee, and then thrown astride the crest of the Mississippi Riverfront levee.

Overtopping was lesser in magnitude along the Inner Harbor Navigation Channel and along the western portion of the MRGO channel, but the consequences of this overtopping were again severe. This overtopping again produced erosion and caused numerous additional levee failures. This photo shows the well known breach at the west end of the Ninth Ward. We spent some time figuring out the answer to the chicken and the egg question, and it is our preliminary opinion that the infamous large barge was drawn in through a breach that was already open.

Most of the failures in this central New Orleans area were the result of overtopping, and one of the common failure modes was simply water cascading over concrete floodwalls and then carving sharply etched trenches at the back sides of these walls. This reduced the lateral support at the back sides of the walls, and left them vulnerable to the high water forces on their outboard faces.

Another repeated mode of failure and distress throughout this central region were problems at "transition" sections where two different levee and/or wall systems joined together. There is a need to better coordinate these connections, and their details.

Farther to the west, in the East Bank Canal District, three levee failures occurred along the banks of the 17th Street and London Avenue Canals, and these failures occurred at water levels below the tops of the floodwalls lining these canals. These three levee failures were likely caused by failures in the foundation soils underlying the levees, and a fourth "distressed" levee/floodwall segment on the London Avenue Canal shows signs of having neared the occurrence of a similar failure prior to the water levels having receded. This photo shows the north breach at the London Canal. The section directly across the canal, on the east bank, was very seriously distressed and also requires remediation before it can safely hold high waters again.

III. The Road Forward

Major repair and rehabilitation efforts are underway to prepare the New Orleans flood protection system for future high water events. The next hurricane season will begin in June of 2006. Preparing the levees for the next hurricane season, however, should also include a review of how the system performed during Hurricane Katrina, so that key lessons can be learned and then used to improve the performance of the system.

Based on our observations, a number of initial comments are warranted concerning the rebuilding and rehabilitation of the levee system.

Although it is somewhat customary to expect levee failures when overtopping occurs, the performance of many of the levees and floodwalls could have been significantly improved, and some of the failures likely prevented, with relatively inexpensive modifications of the levee and floodwall system details. The addition of overtopping erosion protection at the landside toes of the floodwalls through the provision of rip-rap, concrete splash slabs, or even paving of the ground surface at the inboard faces of the levee crest floodwalls might have been effective in reducing this erosion, and might have prevented some of the failures observed.

As the New Orleans regional flood protection system is now being repaired and rebuilt, it would appear advantageous to plan crest heights in a systematic and deliberate way, so that if and when overtopping does occur, it occurs preferentially at the desired locations along any given section of levee/floodwall frontage. Similarly, the transitions between disparate levee/floodwall sections (e.g.: transitions between earthen levees, sheetpiles, and/or concrete wall sections) should be more robustly designed and constructed so that these transitions do not represent locations of potential weakness in otherwise contiguous perimeter flood protection system.

Areas in which piping erosion occurred, including reported instances of piping along the MRGO frontage, suggest that there are areas of foundation that were weakened to a state worse than "pre-Katrina" conditions. Similarly, there may be additional sections like the west bank across from the North breach on the east side of the London Avenue Canal that were distressed (but did not fully breach) and are in need of remedial work. It is important to remember to

check, and to repair as necessary, levee sections that may have been damaged but that did not fail as part of the current repair operations.

Levees are "series" systems, where the failure of one component (one levee segment) means failure of the whole system. They have less redundancy than many other engineered systems. And the consequences of failure are high. The failure of at least several levees at less than their design water height in this hurricane warrants an overall review of the design of the system.

In the short-term, as interim levee repairs continue, consideration should be given to retaining the use of sheetpiles placed against the bridges at the north ends of the 17th Street and London Avenue canals to control storm and tidal surges. Until the levees in these canals are more fully repaired or more permanent canal surge check structures are emplaced, having the ability to rapidly prevent storm surges down these canals is still needed.

The USACE, like other public agencies, commonly uses Independent Boards of Consultants to review the adequacy of the design and construction (and remediation) of major dams. The levee system in New Orleans actually protects more life and property than almost any major dam in the United States. We recommend that the Corps should retain an Independent Board of Consultants to review the adequacy of the interim and permanent levee repairs being carried out in the aftermath of Hurricane Katrina.

The U.S. Army Corps of Engineers are stretched very thin right now, trying to respond and effect emergency and interim repairs in the wake of this catastrophe. It must be the job of the Federal government, and oversight committees such as this one, to ensure that they have the resources and technical capabilities to get their job done safely and well. The Corps have responsibility for many potentially high hazard dams and levee systems, and we must be able to have high confidence in their ability to perform these vital tasks.

The ASCE and NSF-sponsored levee assessment team(s) have already been instrumental in providing insights and recommendations for mitigating potentially serious deficiencies in the temporary/emergency repairs at a number of breached sections. It is anticipated that additional important lessons will be learned in the months ahead as these investigations continue, and that some of these lessons are also likely to be useful in moving forward with the ongoing repair and long-term rebuilding of the New Orleans regional flood protection systems. Such lessons will continue to be passed along as quickly as practicable.

As much of the population is currently being permitted to re-occupy portions of the New Orleans area, doing everything possible to ensure the safety of these people and their neighborhoods must continue to be the highest priority.

This concludes my testimony. Thank you.

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Dr. Raymond B. Seed was born in San Francisco on February 9, 1957. He received his Bachelor of Science Degree in Civil Engineering from the University of California at Berkeley in 1980, and his Master of Science and Doctor of Philosophy Degrees, both in Geotechnical Engineering and both from the University of California at Berkeley, in 1981 and 1983, respectively.

After working between 1980 and 1983 as an engineer for several geotechnical consulting firms, (Dames and Moore, Woodward-Clyde Consultants, and Converse Consultants), he joined the faculty of Stanford University where he served for four years as an Assistant Professor of Civil Engineering. He returned to U.C. Berkeley in 1987, where he is now a Professor of Civil and Environmental Engineering.

Since 1982, Professor Seed has served as a geotechnical consultant to numerous domestic and foreign engineering firms and government and civil agencies on problems spanning a number of areas including: geotechnical earthquake engineering, static and seismic stability evaluation of dams and embankments, numerical analysis of soil-structure interaction, design and performance of buried structures and conduits, stability and performance of waste fills and hazardous waste repositories, advanced geotechnical laboratory testing for a variety of applications, seismic risk analyses of lifeline systems, seismic response analyses, slope stability studies, liquefaction hazard assessment and mitigation, foundation design, and geotechnical finite element analyses of a variety of problems.

The author of more than 200 professional research publications, Professor Seed's research activities also span a wide range of subject areas. His research has had a significant impact on geotechnical practice in a number of areas including: analysis of compaction-induced stresses and deformations, seismic stability and performance evaluation for dams and embankments, analysis of soil liquefaction potential and post-liquefaction behavior, analysis of reinforced soil systems and deep braced excavations, mitigation of membrane compliance effects in undrained testing of coarse granular soils, effects of site conditions on seismic site response, finite element analysis of soil-structure interaction, stability and performance evaluation for hazardous waste fills, and others. He has also served as an advisor to local, state and national governmental agencies and professional organizations on the development of policies and design codes for practice in the fields of geotechnical and earthquake engineering.

Among the professional honors accorded him, he has received the Thomas A. Middlebrooks Award (1987), the Edmund Friedman Young Engineer Award for Professional Achievement (1989), the Arthur Casagrande Award (1989), and the Huber Research Prize (1996) from the American Society of Civil Engineers, the Prakash Award for international contributions to Seismic Geotechnics (1997), the Presidential Young Investigator Award (1985) from the U.S. National Science Foundation, a Special Resolution from the California Geology Board recognizing his contributions to State seismic safety (2001), and a formal citation of appreciation for consulting services from the Egyptian Government's High and Aswan Dam Authority. Professor Seed has also received a number of awards and honors recognizing his contributions as an educator, including the 1989 University of California Distinguished Teaching Award (the University's highest teaching award), the New Engineering Educator Excellence Award (1988) from the American Society for Engineering Education, and several other teaching awards from the Department of Civil Engineering at U.C. Berkeley.