Expert Review Panel on Greater New Orleans Hurricane and Storm Damage Risk Reduction System Design Guidelines:

Final Report

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Produced for and Funded by:
Coastal Protection and Restoration Authority of Louisiana

THE WATER INSTITUTE
OF THE GULF

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ACKNOWLEDGEMENTS

This document was prepared by the review panel members: Robert B. “Bob” Gilbert, Ph.D., P.E. (University of Texas), Thomas “Tom” W. Wells, P.E. (WS Nelson Inc.), William “Bill” H. Espey, Jr. Ph.D., P.E. (RPS Espey Inc.), Sandra K. Knight, Ph.D., P.E (WaterWonks LLC), James “Jim” T. Kirby, Ph.D. (University of Delaware), and Clinton “Clint” S. Willson, Ph.D., P.E. , with support from F. Ryan Clark and Jena Milliner of The Water Institute of the Gulf (the Institute), as a product of the Coastal Protection and Restoration Authority (CPRA) Task Order 10: Hurricane and Storm Damage Risk Reduction System (HSDRRS) Review. Bios of the reviewers can be found in Appendix A. Staff of the United States Army Corps of Engineers provided assistance on the field visits to selected components of the Hurricane and Storm Damage Risk Reduction System.

This effort was funded by CPRA of Louisiana and overseen by members of the CPRA Liaison Team (John Monzon and Rickey Brouillette). Internal Water Institute review was provided by Denise J. Reed, Ph.D. and Ehab A. Meselhe, Ph.D., P.E.. External Peer Review was provided by William “Billy” L. Edge, Ph.D., P.E.

EXECUTIVE SUMMARY

This report presents the results from an independent technical peer review of the design guidelines used to develop the New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS). In 2007, USACE developed HSDRRS Design Guidelines (HSDRRS-DG) in order to ensure that consistent state-of-practice techniques were used in engineering, designing, and constructing the components of the system. The HSDRRS-DG have been revised several times since 2007. The HSDRRS system has been designed and constructed by the U.S. Army Corps of Engineers (USACE) using methods and techniques outlined in HSDRRS guidelines. As the HSDRRS design and construction process moved forward, USACE granted several waivers to address construction schedules, resources, and costs constraints. The State of Louisiana, through the Coastal Protection and Restoration Authority (CPRA), will be charged with operations and maintenance of the HSDRRS and requested this review of the guidelines and waivers. The peer review panel consisted of six technical experts familiar with the HSDRRS and the state-of-practice for the design of coastal and riverine flood-protection systems. This panel was tasked with the following objectives:

1. Assess the assumptions and analysis approaches in the 2007 HSDRRS -DG and whether they are consistent and appropriate within the current state-of-practice of engineering;
2. Assess the justification for exceptions and waivers, and whether they could result in an impact on component and system performance, operations and maintenance, risk, or reliability.

The process included panel review of documents and background material, touring the HSDRRS, meeting in Baton Rouge and preparing this report.

The panel concludes that the assumptions and analysis approaches in HSDRRS-DG are both consistent and appropriate within the current state-of-practice of engineering. The panel also concludes that the justifications for waivers to these HSDRRS-DG were generally appropriate with the exception of the waiver for adding sacrificial steel rather than coating steel piles for corrosion protection. This waiver concerning corrosion protection is inconsistent with the current state-of-practice of engineering in this region. Finally, the panel concludes that the waivers in total will not negatively impact the performance of the system performance in a hurricane, its risk, or its reliability, provided that uncertain design assumptions, particularly those concerning corrosion rates and ground settlements, are consistently monitored and mitigated if necessary over the design service life.

The panel has identified several design issues, however, that will affect the cost and effort required to operate and maintain this system. Specific areas of concern for operation and maintenance, and the responsibility for it, include the following:

1. The need to routinely inspect the piles that were not coated for corrosion protection in order to determine their condition and, when necessary, repair them;
2. The need to remove and then replace armoring to raise subsiding levees back to proper grade;
3. The potential for differential settlement to impede operations of pumps and gates and to distress structural components;
4. The potential for shallow slope failures on earthen levees to occur years after construction and require repair;

5. The need to update design assessments and possibly system components over the lifetime of the system as monitoring information becomes available and as new studies and data are obtained concerning surges and waves and structural and hydraulic performance.

If these additional O&M issues are not addressed fully, then it is possible that the performance of the system in a hurricane could be impaired.

The panel also concludes that implementation of the HSDRRS-DG in constructing, operating, and maintaining HSDRRS are as important to its performance as the HSDRRS-DG themselves. The major challenges in implementation are providing for effective communication and coordination between all parties responsible for the operation and maintenance of the system and clearly communicating the residual risk to the public so that the consequences of hurricane flooding are minimized.

The panel offers the following major recommendations:

1. The federal and state agencies be fully transparent and persistent about communicating risk to the public. This communication program should be highly visible and active in the public eye
2. The risk assessment be periodically updated based on improvements in hydrology and hydrodynamics analytical tools like advancements in modeling and high performance computing, as well as information on sea-level rise, land subsidence, land use, and the current condition of the HSDRRS;
3. A program be developed and implemented for long-term monitoring of settlement, corrosion, structural integrity, and slope stability. It also recommends that proactive plans be developed to address potential problems that may arise during operation and maintenance of the system;
4. A risk-based asset management plan be developed at CPRA level and implemented for the entire HSDRRS to accommodate changing conditions;
5. The state of Louisiana and the Corps work collaboratively to develop realistic cost estimates for operation and maintenance to reflect changes made during design and construction; Specific protocols be used to coordinate and communicate information between the federal, state, and local agencies before, during and after transfer of the project. For items that are not being resolved to the satisfaction of a party, the process for independent resolution laid out in the Project Partnership Agreement should be followed; and
6. The state of Louisiana work toward the formation of a public-public partnership (Federal-State) to share in future O & M Costs. Congressional authorization may be required. Less likely public-private partnerships to fund O & M costs should be investigated.

INTRODUCTION

The State of Louisiana, through the Coastal Protection and Restoration Authority (CPRA) has been tasked with planning, designing, implementing, and maintaining coastal protection and restoration projects. CPRA's Operations Division and Southeast Louisiana Flood Protection Authority – East and West (SLFPA-E and SLFPA-W) and the associated levee districts will be charged with operations and maintenance of constructed projects, which includes the responsibility of the New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS). HSDRRS has been designed and constructed by the U.S. Army Corps of Engineers (USACE) using methods and techniques outlined in HSDRRS -DG and waivers. The features of HSDRRS as of 2013 include:

- 350 miles of levees and floodwalls, including interior levees and floodwalls, hundreds of gates and structures for sealing the system;
- 78 pumping stations (federal and non-federal);
- Gulf Intracoastal Waterway – West Closure Complex;
- Inner Harbor Navigation Canal Surge Barrier;
- Seabrook Floodgate Complex; and
- Interim closure structures and pump stations for the three outfall canals.

Upon completion of the design and construction of each component of the protection system, USACE will turn the responsibilities over to the State of Louisiana. This will occur over the next few years.

Figure 1. HSDRRS map and components, from http://www.mvn.usace.army.mil/Missions/HSDRRS.aspx.

In 2007, USACE developed HSDRRS-DG in order to ensure that consistent state-of-practice techniques were used in engineering, designing, and constructing the components of the system. Since then, the HSDRRS-DG have been revised several times. As HSDRRS design and construction process moved forward, USACE granted several waivers to address construction schedules, resources, and costs constraints. For more information on HSDRRS -DG, waivers, or other related material, please refer to the USACE HSDRRS-DG website (online: http://www2.mvn.usace.army.mil/eng/hurrdesign.asp).

Many components of HSDRRS are near completion and will soon to be turned over to CPRA. Thus, it is in CPRA's, other nonfederal sponsor's, and other stakeholder's best interests to review HSDRRS guidelines and approved waivers to ensure that state-of-the-practice methods were employed as well as to assess potential impacts on future performance, operation, and maintenance of the system. In response, CPRA contracted with the Water Institute of the Gulf (the Institute) to convene an independent review panel to review HSDRRS -DG and waivers. The Institute coordinated regularly with CPRA, convened the review panel, and developed and delivered the final report and presentation.

While the HSDRRS panel took a holistic view of the system it is important to recognize that this review is only an initial step of HSDRRS review process. The goal of this panel is to identify possible technical issues and concerns with HSDRRS -DG and provide general recommendations on ways the system can be improved. With the issues and concerns identified, the groundwork is laid for more detailed future studies and reviews of the specific issues and concerns

WHY PEER REVIEW?

The importance of peer review is widely recognized as a means of validating technical products by engaging expert peers, which in turn helps to build credibility. By enlisting topical experts to take a critical look at HSDRRS -DG documentation, technical assumptions, design, and construction methodologies and waivers, the review process ensures CPRA receives an objective assessment of HSDRRS -DG and waivers, as well as advice on planning the system operation, maintenance, and/or improvement. Finally, peer review demonstrates that CPRA has proactively sought input and review guidance from national and international experts, prior to accepting the system as its Non-Federal Sponsor.

PEER REVIEW PROCESS

CPRA contracted with the Institute to coordinate this peer review process. The Institute recruited five HSDRRS review panel members, with one person serving as panel chair, to consider the following technical reports:

- Hurricane and Storm Damage Risk Reduction System Design Guidelines (USACE, 2007;
- Waiver: Resiliency Design Checks for Inner Harbor Navigation Canal, Lake Borgne Basin (USACE, 2009a);
- Waiver: Steel Piles Corrosion Protection (USACE, 2009b);
- Waiver: Use of Spiral Welded Pipe for Foundations in Southeast Louisiana Coastal Structures (USACE, 2010a);
- Waiver: Deflections of Proposed Inner Harbor Navigation Canal Floodwall, Lake Borgne Basin (USACE, 2010b).

All of the above documents are available for download from the following website: http://www2.mvn.usace.army.mil/eng/hurrdesign.asp

The peer review was intended to determine the extent the HSDRRS -DG and waivers were consistent with the state of practice and whether or not there were sufficient justifications in granting the waivers, as well as to offer advice on the system's operation, maintenance, and/or improvement. Reviewers were asked to focus on:

1. Assessment of the assumptions and analysis approaches in HSDRRS -DG and whether or not they are both consistent and appropriate within current state-of-practice of engineering;
2. Assessment of justification for the exceptions and waivers, and whether or not they could result in an impact on component and/or system performance, operations and maintenance, risk, or reliability.

The review material (HSDRRS -DG, waivers, etc.) was distributed to the panelists and each panelist sent his/her preliminary comments and observations to the Institute prior to the review panel meeting. The Institute compiled and organized all pre-panel meeting comments and material and organized a site visit to two HSDRRS project sites with CPRA and USACE staff to informally orient the panel members to the system. The Institute then hosted a two-day review panel in Baton Rouge and assisted the panel chair in running the meeting.

The panel members wrote the review panel report and the Institute assisted with the writing and editing of their sections in consultation with the panel chair, and after External Peer Review, the Institute prepared a final report and presentation for CPRA.

Figure 2. Review panelists visit the Inner Harbor Navigation Canal Surge Barrier.

Peer Reviewers

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REVIEW OF DESIGN GUIDELINES

The panel reviewed all the documentation provided to them. Given the length of the material and the need to focus on important technical issues, the panel identified several issues in HSDRRS-DG to review in detail based on the following criteria:

1. The issue required the granting of a waiver;
2. The issue could potentially impact system performance, operations and maintenance, risk, or reliability;
3. The issue involved a large step beyond the current state-of-practice of engineering.

These technical issues are organized into the following topics: Hydrology and Hydrodynamics (H&H), Geotechnical Engineering, Structural Engineering, and Resiliency. For each topic, the background is summarized, review comments are presented, and recommendations are offered.

HYDROLOGY AND HYDRODYNAMICS

Storm Surge and Wave Modeling: Background

The Hydrology and Hydrodynamics (H&H) analysis that was performed to establish the design basis for HSDRRS-DG incorporated a wide range of modeling improvements that represented a significant improvement in the practice of conducting a storm surge analysis. Due to the scope of the study and the need for a rapid resolution of design issues, the USACE-FEMA Joint Surge Study (JSS) necessarily carried out a number of activities, including model validation, statistical experimental design and final storm surge hazard analysis, on a compressed schedule.

Storm Surge and Wave Modeling: Comments

While the methodology utilized in the design of HSDRRS-DG represented a significant advancement in the state of practice for conducting hurricane surge hazards analysis, the scientific basis for performing such an analysis has seen rapid growth and evolution from the start of this analysis in 2006 to present. As a result, while the JSS method may have attained a state-of-practice status due to the magnitude and importance of HSDRRS study, there have been recent developments in the scientific understanding of, as well as the modeling techniques of, storm surge propagation. There are also gaps remaining in the existing knowledge, which could potentially be more effectively addressed in future studies.

Some of the recent improvements include the availability of new data, as well as modeling and computing advances. In particular, the database for hurricane properties in the region has increased as a result of events since Katrina. Improvements in knowledge of bathymetry, ground cover, and other factors as well as improvements in model gridding and handling of subgrid-scale features could possibly lead to a reduction in systematic biases noted in initial model verification studies based on Katrina, such as a consistent underprediction of surge heights along the shore of Lake Pontchartrain. While these biases may be adequately addressed at present in the HSDRRD-DG by the use of low exceedance levels in statistical estimates of surge, an improved understanding any systematic bias of available models would lead to greater confidence in establishing return periods and in assessing the need for system modifications such as levee lifts. In addition, state-of-the-art modeling has improved with the arrival of models with full coupling of wave and surge calculations, as well as full-plane wave models, ensuring that each phase of the modeling occurs in a more accurate representation and reducing the need for guesswork in factors such as the relative timing of maximum storm and wave surge. Additional factors have come into play in recent years; for example, it has been shown in related studies for Tampa Bay that the inclusion of three-dimensionality in surge modeling, resulting in significant changes in magnitude and distribution of bottom stress in complex spatial environments, can lead to significant changes in surge predictions even in relatively shallow environments (Weisberg & Zheng, 2006). Finally, the rapid advancements in massively parallel high performance computing systems makes it possible to handle increases in the number of candidate storms in the Joint Probability Method – Optimized Sampling (JPM-OS) analysis, potentially eliminating the coarse-gridding in parameter space.

In general, it appears that state-of-the-art methods and models were used to develop the best available data for design decisions. It seems appropriate that the state-of-practice prior to 2005 would not be acceptable for the complexities and sheer magnitude of the project area. Not only were the models top of the line and have become the industry standard largely because of their success on this project, but more importantly, the New Orleans District sought out and used leading experts in the field. While implementing more complex models could have slowed decision making, the analysis remarkably kept pace with the design decisions. Given the complexity of the problem and solution, the more sophisticated approach was warranted. In areas of uncertainty, studies were identified for clarification or the solutions were adopted from other projects such as those in the Netherlands (e.g., the use of one-dimensional Boussinesq models, fed by output of the two-dimensional surge and wave models, to estimate wave run-up and overtopping). The use of expert opinion, coupled with robust statistical analysis, attempted to fill gaps in necessary information and account for uncertainty in the design values.

Storm Surge and Wave Modeling: Conclusions and Recommendations

In summary, the panel concluded that the analysis to establish the H&H design basis for HSDRSS represented a massive injection of state-of-the-art modeling and analysis into the design procedure, leading to a scientific basis which greatly exceeded— in scope and likely accuracy—anything that had been undertaken before. This effort should be applauded for its scope, thoroughness, and willingness of participants to implement new technologies in order to conduct a study of undeniable importance. At the same time, it must be recognized that the floodgate of scientific enquiry opened by this effort and continuing due to the recognition of the problem's societal impact, has led to subsequent improvements in state-of-the-art practices that should not be overlooked in the process of the continual evaluation of HSDRSS design and performance. These advancements include the transition from a structured grid wave model (WAM-STWAVE) loosely-coupled with the ADCIRC model to an unstructured mesh wave model (UnSWAN) fully-coupled to the ADCIRC model (Dietrich et al, 2010).

Therefore, the panel recommends that a process of periodic updating of the design basis for 100- and 500-year surge and wave overtopping be established in order to take advantage of improvements in understanding of: (1) hurricane climatology, (2) physics of surge and wave flows, (3) improvements in numerical techniques and implementation of closely-coupled models for surge and waves, and (4) increased scope for simulation of larger numbers of model storms, made possible by large-scale, massively parallel computer systems. Such re-analysis, performed on a recurring ten-year interval, would benefit the O&M aspects of HSDRRS by refining and providing tighter confidence estimates for 100- and 500-year surge and wave estimates on a reach by reach basis, thus providing a better basis for decisions about the need and timing for future operations such as levee lifts.

The panel also recommends that the risk assessment be periodically revised based on updates in H&H modeling (storm surge and waves, and interior drainage), as well as information on sea-level rise, land subsidence, and land use. The updated risk should be communicated clearly to the public and considered in making decisions concerning modification or maintenance of the system.

In addition, the panel offers the following specific recommendations for improvement in future H&H analyses:

1. The section on H&H in the HSDRRS-DG refers to other reports, in particular, the report references Section O that captures future conditions in 2057. The panel recommends that all future conditions (e.g., land surface elevations, bathymetry, future restoration projects, and assets at risk) be carefully documented and reviewed, as these could have profound impacts on the life-cycle operations and maintenance of HSDRRS system.

2. The amount of freeboard appears to vary along certain sections of the levee and is different for walls versus levees. The panel recommends that either a table or drawing be provided that shows the existing (as-built) and future conditions of freeboard relative to the 1% and 0.2% events and explain variances. As subsidence and consolidation of materials will impact the freeboard, it is recommended that regularly scheduled surveys be conducted to update the record of the conditions. This will be critical to levee districts seeking to keep their FEMA National Flood Insurance Program (NFIP) accreditation.

3. There were numerous criteria used to represent conservative estimates for H&H parameters used in designing various components of the system. For instance, the HSDRRS-DG stated that the 1% flood does not consider climate change, but sea-level rise was incorporated in the design of future conditions. The panel would like to see clarification of this issue. Also, it appeared that different percentile values of wave heights were used for earthen levees or flood walls. In addition, different percentiles were used in designing for structural resilience. The panel recommends clarifying assumptions used for each component of the system (i.e., pumps, walls, levees, armoring, and structural components) relative to both design and resiliency (e.g., overtopping, sea-level rise, surge height, waves, etc.).

4. Advances in H&H modeling should be tracked and utilized in the periodic reanalyses. Advances in high performance computing, model code developments, the effects of natural landscapes including coastal vegetation on the propagation of surge and waves, and grid geometry/ geospatial data should be incorporated into the reanalysis, and consideration should be given to the balance between computational resources, grid resolution (computational demand), and model code refinements, to ensure adequate time and budget are allocated to the periodic reanalysis process.

5. Periodic reanalyses should also include the study of the joint probability of riverine and coastal flooding for flood control features that are subject to both types of stresses (Mississippi River and Tributaries Levees, e.g.). Consideration should be given to modifications to structures and operation of flood control system upstream of New Orleans, as part of a holistic approach.

Geotechnical Engineering

The panel identified two potential issues related to geotechnical engineering that could affect the long-term performance, operation, and maintenance of the system, specifically differential settlement and long-term stability of earthen embankments.

Differential Settlement: Background

The Mississippi Delta area is subject to considerable regional subsidence that is spatially variable. Regional subsidence rates ranging from 0.2- to more than 0.6 inches (5-15 mm) per year were estimated by Interagency Performance Evaluation Taskforce (IPET) (2007), producing total settlements ranging from 10- to 30 inches (250-750 mm) over the next 50 years. In addition, the added weight of new levees, flood walls, pump stations, and gate structures will lead to local consolidation of the ground surface. For example, total ground surface settlements were estimated in designing the T-Walls along Lake Pontchartrain and Vicinity (LPV) 145 and LPV 146 to be in the order of tens of inches and as much as 60 inches. The greater the total settlement, the greater the potential for differential settlement, both horizontally and vertically.

Total and differential settlements are a concern for the following reasons:

1. Differential settlement horizontally can distress the structural components of flood walls, gates and pump stations;
2. Differential settlement horizontally can disrupt the mechanical operation of pumps and gates;
3. Differential settlement horizontally and vertically can distress transitions between flood walls and earthen levees; and
4. Differential settlement horizontally and vertically can induce down-drag stresses in deep foundations, particularly for battered or raked piles, that exceed their structural capacity.

The intention behind designing the system was to address these concerns regarding settlement. Estimates were made of total settlements. Joints and transitions were designed to accommodate differential movements. Down-drag stresses in piles were checked.

Differential Settlement: Comments

While the potential settlement was considered in the design phase, there remains significant uncertainty in the magnitudes of total settlement, the patterns and magnitudes of differential settlements and angular distortions, and the responses of structures and foundations to settlement over the next 50 years.

Total settlements of tens of inches can readily produce horizontal angular distortions greater than what is allowable for typical structures (e.g., 2/1000 in USACE (1990)). Furthermore, mechanical systems such as pumps can be impacted by even smaller angular distortions, with allowable distortions as low as 0.2/1000. An example of data for measured settlements for the new Gulf Intracoastal Waterway (GIWW) pump station is shown in Figure 3; angular distortions between several pump bays exceeded 0.2/1000 within the first year of operation.

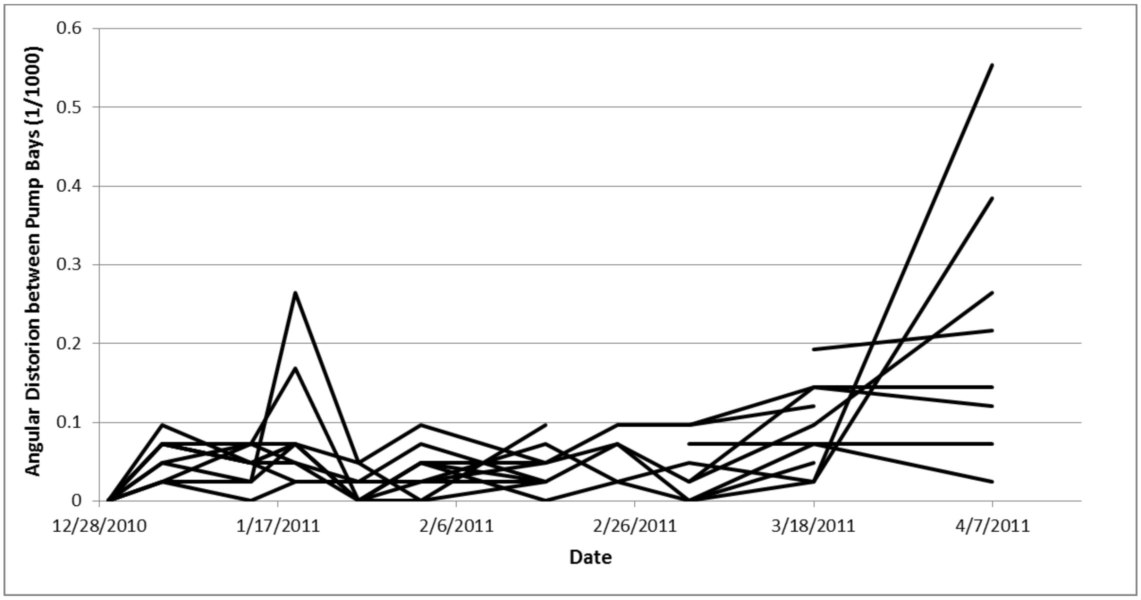


Figure 3. Calculated angular distortions, based on measured settlements at different benchmark locations (represented by lines of the graph), in the GIWW pump station at the West Closure Complex. Data provided by USACE, plotted by Panel Chair Bob Gilbert.

An example of the effect of differential settlement on a transition is shown in Figure 4. The differential settlement between the pile-supported T-Wall in the background and the earthen levee in the foreground has already created cracks in the caulk intended to keep water from eroding the levee material underlying this concrete apron, within 3-5 years of construction.

Indications of the uncertainty in down drag on piles are the substantial additions and revisions that were made to HSDRRS-DG between the interim version used to design the system (USACE 2007) and the newest version (USACE 2012). The interim 2007 version contained the following two sentences: "*Where levees will be raised or new embankments constructed, the adverse effects of foundation consolidation must be considered, which includes drag forces on both the sheet pile cut-off and support piles. In addition, these drag forces must be considered in settlement calculations.*" The updated 2012 version contains an entire section, Section 3.3.2, with six pages of guidance and a new Appendix, (Appendix F), with 144 pages.

Figure 4. Differential settlement at transition between T-Wall for Lake Borgne Closure (background) and earthen Levee for New Orleans east back segment (foreground) - Taken by R. Gilbert on July 16, 2013.

Long-Term Stability of Earthen Levees: Background

HSDRRS-DG provide detailed guidance on evaluating the short-term stability of levees and floodwalls under a variety of possible loading and seepage conditions during a hurricane. No guidance is provided, however, for evaluating the long-term stability of earthen embankments, including information about soil shear strengths, seepage conditions, and factors of safety.

Long-Term Stability of Earthen Levees: Comments

Steep and long slopes in embankments constructed with high-plasticity clays like those in HSDRRS, are prone to shallow slides occurring years or decades after construction, generally during wet periods. For example, Kayyal and Wright (1991), Wright et al. (2007) and Gregory and Bampus (2013) document nearly 100 slope failures in embankments constructed with high plasticity clays at slope angles typically around 3H:1V and as flat as 4H:1V. These types of failure are shallow (i.e., less than 10 ft. deep below the surface of the slope), correspond to a drained shear strength that is equal to or less than the fully softened strength, and correspond to seepage down the slope after rainfall events.

HSDRRS has many slopes constructed from high-plasticity clays with slope angles on the order of 3H:1V. An example of a shallow failure that has already occurred is shown in Figure 5. This slope is one of the steepest in the system, with a slope angle of about 2.8H:1V, which may be why it happened less than one year after construction.

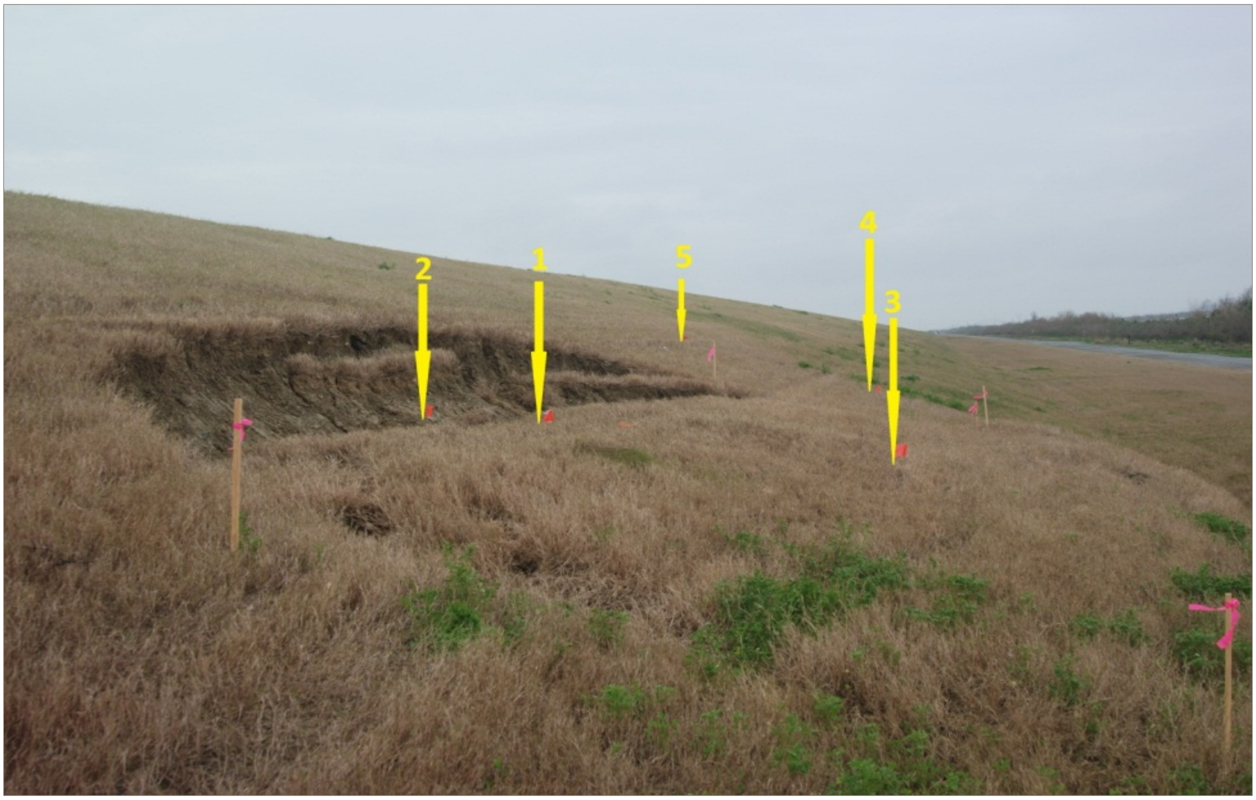


Figure 5. Shallow slope failure near toe of earthen levee for New Orleans east back segment. Numbered arrows indicate sampling locations for a previous study. (Provided by R. Brouillette, CPRA).

The panel anticipates that these types of shallow failures could occur regularly over the lifetime of the system, given that such a failure has already occurred and that there are many miles of slopes that are approximately 3H:1V or steeper. While these shallow failures do not necessarily threaten the functionality of the system, they will require timely repair so that they do not progress to a global instability of the levee. They also have the potential to cause substantial damage to any roads or structures near the toe of the slope.

Geotechnical Engineering Conclusions and Recommendations

The panel concludes that there is significant uncertainty in the long-term performance of the geotechnical aspects of the system, specifically settlement and shallow slope stability. Therefore, the panel recommends the following for operation and maintenance:

1. A program be developed and implemented for long-term monitoring of total settlement, differential settlement, and the response of structural and mechanical systems to settlement over the lifetime of the system. The panel also recommends that proactive plans be developed to address potential settlement-induced problems that may arise during operation and maintenance of the system. These efforts should place priority on critical points, such as transitions between components.

2. Long-term monitoring of slope stability be conducted over the lifetime of the system. The panel also recommends that slopes be identified and evaluated where a shallow failure could have significant consequences at the toe of the levee. Finally, the panel recommends that proactive plans be developed to address potential slope failures that may occur during the operation and maintenance of the system.

Structural Engineering

The panel identified three potential issues related to structural engineering that could affect the long-term performance, operation, and maintenance of the system, including waivers for corrosion protection, spiral welded pipe, and increased allowable wall deflections.

Corrosion Protection: Background

The conventional USACE requirement for piles, which was reflected in the original HSDRRS-DG and various standards, was to coat the piles with coal tar epoxy: HSDRRS-DG DTD 04-OCT-07: 5.6.8 Painting. "Only coal tar epoxy shall be used." This statement is repeated in Design Guidance dated June 12, 2008.

Due to cost and schedule (expediency), a waiver concerning corrosion protection was requested for the construction of HSDRRS projects. The waiver requested substituting "sacrificial thickness of steel" for the coating. The waiver request was supported by investigations into corrosion rates and standards and approaches used in various jurisdictions and countries. Based on observed and reported corrosion rates, the waiver was granted, and an additional thickness of steel was required.

The supporting investigations refer to piles embedded in various types of earth, disturbed and undisturbed, new and in-place, and various levels of corrodibility. Heavier-weight H-piles and sheetpiles were stipulated in "Section 8. Recommendations" of the supporting memorandum for record dated December 4, 2009. The memorandum refers to the greater corrosion rate that would occur with bare steel piles that are exposed to the atmosphere or to fresh or salty water. The memorandum indicates that exposed piles, being subject to renewable oxygen or an oxidizing environment (salt water), would corrode at a much higher rate and should be coated. The memorandum further indicates that piles supporting foundations constructed on fill or levees may eventually be exposed to the atmosphere or water/saltwater due to the settlement of the "form" soil on which the foundation is constructed. The memorandum describes a mitigation measure of using "shear keys" on each edge of the footing in order to close off the gap beneath the foundation and prevent continuous oxidation of the piles.

Corrosion Protection: Comments

The approach of adding sacrificial thickness to the steel piles rather than coating them for corrosion protection is inconsistent with the current state of design practice in this region. The panel is not aware of any modern designs that have used this approach for corrosion protection in the Greater New Orleans region.

For the significant majority of the floodwalls constructed in southeast Louisiana, settlement of the embankment under the wall base can be expected and will probably amount to several inches. This settlement could result in a significant gap under the foundation in which the corrosive environment (i.e., air or water/saltwater) can attack the steel. The use of shear keys with a grade beam at each edge to mitigate this effect would be expensive to build and of dubious effectiveness in blocking circulation of corrosive atmosphere. With the expectation of continual and significant settlement of embankments in southeast Louisiana, the panel believes that this gap will inevitably result in a corrosive environment for steel piles under the wall bases.

Some degree of corrosion may be considered acceptable, especially with piles with a “sacrificial thickness” of steel. The evaluation of the structural adequacy of the piles must include an analysis of the residual structural capacity of the corroded member. During flood/surge conditions, the piles under floodwalls are subject to axial tension and compression, significant bending and shear which occurs due to unbalanced load. The structural analysis of the damaged piles must consider the member loads (i.e., moment, shear, axial), which vary along the length of the piles, and member condition, which will also vary. It is possible that the worst corrosion will not occur where the loads are highest. If the elements of the piles, however, are so corroded that they are no longer strong enough to carry the design loads, then they must be repaired.

Under current regulations/law, the Non-Federal Sponsor (NFS) must routinely inspect these piles to determine their condition and, when necessary, repair them. Inspection requires excavation beneath the foundations to expose the unpainted piles, examination of their condition, evaluation of requirement to repair, and restoration of the earth beneath the foundation if repair is considered unnecessary. This inspection was performed in 2013 (CPRA, 2013), and will be required periodically. The excavation, inspection, and restoration of earth will be expensive. If the inspection and evaluation of the piles leads to a decision to coat or repair the piles, actions may consist of excavating and exposing the piles, blasting and cleaning, repairing any corrosion damage, painting with coal tar epoxy, and backfilling under the foundation. These actions will be expensive and, if found to be necessary in some areas or levee reaches, will probably be necessary in many more locations.

Spiral Welded Pipe: Background

The conventional USACE requirement for pipe piles, which was reflected in the original HSDRRS-DG and various standards, prohibited use of spiral welded piles:

- HSDRRS-DG update -4-OCT-07 does not allow spiral welded pipe
- HSDRRS-DG update 12-JUN—08: “Spiral Welded pipe shall not be used.” (5.2.2 – Precast-Prestress Concrete, Steel H and Pipe).

Due to cost and schedule (expediency), a waiver was requested to approve the use of spiral welded pipe for use as piles in construction of HSDRRS. The waiver request was supported by documentation of research conducted at North Carolina State University. Based on the evidence provided in the supporting study, the use of spiral welded pipes for piles was approved.

Spiral Welded Pipe: Comments

The prohibition of using spiral welded pipes for piles is common in southeast Louisiana. Many consulting engineers follow that practice in private (industrial and commercial) structures as well as public facilities. The basis for this state of practice are the following:

1. Evidence, supported by load tests, that spiral welded pipe piles have a lower supporting capacity due to the effect of the weld beads;

2. Concern that the spiral welded pipe is weaker in bending; and
3. Concern that the spiral welded pipe could be damaged during driving to install the piles.

The recommendations in the waiver addressed issue (1), presenting evidence that the capacity of the spiral welded pipe piles is equal to that of longitudinally welded pipes. If the piles are load-tested anyway, this concern becomes moot, because the load-tested piles would be identical to the specified production piles. The background regarding the concerns in issues (2) and (3) is that the common spiral welded pipe specification has been ASTM A252 Rejected Pipeline Pipe. The recommendation in the waiver included using a better grade of spiral-welded pipe with stricter inspection of the quality of the welds, and a limitation on the size of the weld profile to less than 3/16”. Further, the latest HSDRRS-DG limits the use of spiral-welded pipe piles to foundations with multiple piles, not with just one pile. The logic of the latter requirement is clear; a flaw in one element probably would not lead to a foundation collapse. It is difficult to conceive of a foundation with just one pile, however, and perhaps the recommendation should be qualified by defining multiple-pile foundations to have at least four piles.

Allowable Wall Deflection: Background

A waiver was requested concerning the allowable horizontal deflections of the piles supporting the Lake Borgne Surge Barrier due to the unusual geometry and scale of this wall compared to typical flood walls. HSDRRS-DG recommend an allowable horizontal deflection of one inch at the pile heads for flood walls. The Lake Borgne Surge Barrier is an atypical flood wall because it has an A-frame geometry with large battered piles providing lateral support and because it has a very large scale. This wall rises above the ground (mudline) two- to four times higher and it utilizes steel pipe piles that are four- to five times as large in diameter as used in a typical T-Wall or L-Wall.

The waiver was based on the following clause in HSDRRS-DG concerning the recommended allowable horizontal deflection of one inch for pile heads: “Larger deflections may be allowed for design checks if stresses in the structure and piles are not excessive. Larger deflections are limited to values that remain in the elastic state of the soil.” Based on lateral load tests on full-scale piles and numerical soil-structure interaction analyses, the waiver increased the allowable horizontal deflection to 2.5 inches for the pile heads in the Lake Borgne Surge Barrier. The technical memorandum supporting the waiver request stated on page 2:

> *Current deflection estimations have been substantiated by using detailed soil-structure interaction (SSI) and finite element (FE) analysis methods based on parameters measured during the geotechnical subsurface investigation and the axial and lateral load tests. This final waiver is requested to maintain the schedule to provide 100-year level hurricane surge protection by June 2011.*

Allowable Wall Deflection: Comments

A reasonable approach was taken to support increasing the allowable horizontal deflections at the pile heads in the Lake Borgne Surge Barrier. Notable attributes of this approach are: (1) conducting full-scale load tests on piles at the project site, (2) performing numerical finite element analyses of the pile-soil interaction modeling the soil as a continuum to assess the sensitivity of the foundation behavior to the strength and stiffness of the soil, and (3) conducting finite element analyses of the structure modeling the soil with nonlinear springs to assess the structural performance of the wall.

The technical memorandum supporting this waiver is brief and does not provide all of the relevant details in the analyses. Specific concerns are the following:

1. The paragraph Design Checks states that ". . . the resulting factors of safety all exceed one," but does not state the actual factors of safety and how they compare to those recommended by USACE for extreme load cases.

2. The study also refers to remaining in an elastic state of soil behavior, but does not define the elastic zone. In addition to checking the linearity of the load-deflection relationship, it is also of interest to know whether a permanent set is predicted after extreme loading and how that set may affect the capacity of the structure in future loading events.

3. It is assumed—but not stated—that the base case soil strength reflects the potential degradation of strength and stiffness under cyclic loading during an extreme event.

4. Another consideration that is not discussed in the waiver, in addition to strength of pile/wall structure, is the capacity of the various joints and connections to adjoining structures to withstand the extreme deflection. The relative stiffness of the A-frame pile/wall floodwall and the adjoining gate structures differ greatly, the latter being "infinitely stiff," relatively speaking. Significant relative movement at the joints between similar sections of the floodwall could be expected, and could result in damage to the joints if they weren't designed to accommodate those relative movements. A cursory review by the panel of some actual joint details that were available indicates that very large relative deflections could probably be accommodated. It is not clear, however, that all joint details have explicitly been designed to appropriately accommodate large relative deflections.

Structural Engineering Conclusions and Recommendations

In summary, the three waivers adopted concerning structural engineering design are not expected to have a detrimental impact on the structural performance of HSDRRS in an extreme loading event.

The Corrosion Protection waiver, however, is inconsistent with the current state of design practice and may result in a higher "operation and maintenance" expense for Louisiana to monitor corrosion of the unpainted steel piles. The panel concludes that the waivers in total will not negatively impact the performance of the system performance in a hurricane, its risk, or its reliability, provided that uncertain design assumptions, particularly those concerning corrosion rates and ground settlements, are consistently monitored and mitigated if necessary over the design service life. However, due to the uncertainty of the corrosion rate design assumptions, the panel recommends that a detailed plan and budget be developed concerning the frequency and method of monitoring for corrosion, the criteria to be used to evaluate whether mitigation is necessary, and the means and methods to be used in the event that mitigation is necessary.

Concerning the Allowable Deflection waiver, the unique geometry and scale of the Lake Borgne Surge Barrier warrant that it be carefully inspected and assessed after each extreme loading event. Therefore, the panel recommends that surveys be conducted to identify permanent deformations and that structural analyses be updated to assess the surge barrier's capacity after extreme loading events.

Concerning the Spiral Welded Pipe waiver, the panel recommends that the new best practices and specifications be included in an updated version of HSDRRS-DG, based on the experiences gained from the design and construction of these features, including as-built drawings and specifications, construction details, and post-construction inspections.

Resiliency

The panel identified two potential issues that could affect the long-term performance, operation and maintenance of the system: plans for armoring and design checks for resiliency.

Overtopping and Armoring: Background

When Congress authorized and funded HSDRRS, they stated the following in the 4th and 6th supplement: (USACE, 2011) ". . . armor critical elements of the New Orleans hurricane and storm damage risk reduction system. . . " Armoring is defined as a natural or artificial material placed on or around a levee, floodwall, or other structure to reduce the risk to the system or component to prevent breaching or major damage when confronted with wave attack, overflow, and overtopping associated with a greater than normal storm event. Congress authorized funding, under the Fourth Supplemental Appropriations Act (2006), for the armoring of critical elements of HSDRRS. The "critical elements of HSDRRS" were defined by IPET and the ASCE External Review Panel as those elements that suffered severe erosion and/or breaching during Hurricane Katrina and include levee transitions, pipeline crossings, utility crossings, and the landside of levees and floodwalls. The landside of levees were defined as "critical elements" versus the floodside of levees, as evident in the following IPET quote: "No levee breaches occurred without overtopping." (IPET Volume 5, page V-80)

Armoring of critical elements in the system perimeter contributes to the resiliency of HSDRRS when subjected to extreme storm surges greater than a 1% annual chance of exceedance. Levee Armoring of HSDRRSS-DG (Section 1.6.2) states: "The more critical design condition is to provide armoring for overtopping of protections that occur in the 0.2% event". The erosion resistance performance must be determined for overtopping waves of the 0.2% extreme storm surge for several potential commercially available armoring materials, such as: riprap, gabions, articulated concrete mattresses, geosynthetic mattresses, soil stabilizing devices, geocells, high performance turf reinforcement mats (HPTRM), and grass enhanced Bermuda. The most recent HSDRRS-DG, revised June 2012, have limited details on armoring and describe ongoing testing.

Overtopping and Armoring: Comments

A document describing the plan developed by USACE for armoring was released the week of the panel review meeting and there has undoubtedly been discussion between the state and USACE since. At the time of the review, however, there were concerns on the state's part of being able to maintain the enhanced grass and reinforcement mats with grass on the northeast end of system in New Orleans East. The ability to get mowing equipment, fertilizer, water and the like to the mats is limited due to access to the area. The panel also felt that adding the armoring was premature in areas where it felt the levees were still settling. The cost of removing the reinforced grass mat to raise the levees back to proper grade and then replacing it would be an added burden to the state (Monzon, Personal Communication).

In its cursory review of this plan, the panel is concerned about the use of grass only in the area subject to high flooding consequences along the Lake Pontchartrain waterfront. An eroded gap in this levee after the storm surge subsides could lead to Katrina-like flooding in the Orleans East Bank and Jefferson East Bank.

In addition, the panel is concerned about tying the need for—and level of—armoring so closely to the predicted overtopping rate with an annual exceedance frequency of 0.2%. As discussed in the Hydraulics and Hydrodynamics section, the surge and wave modeling was based on a limited set of data (the historical record of tropical events in the Gulf of Mexico, in the modern era of meteorological observations and recordkeeping, about 50 years). While appropriate attempts were made to account for uncertainty in developing design parameters, there is generally much greater uncertainty in predicting a design value with a 0.2% percent annual exceedance frequency versus one with a 1% annual exceedance frequency. As advancements in surge and wave modeling are made and as new data become available, it is likely that the design overtopping rates used to make decisions on armoring will change.

Design Check for Resiliency: Background

HSDRRS-DG, revised June 2012, include design checks for extreme events above the authorized design level of protection (100-year return period or 1% annual exceedance frequency). These design checks were introduced to add resiliency to the overall HSDRRS following lessons learned from Hurricane Katrina. Resiliency is defined as the ability of HSDRRS to maintain functionality without catastrophic failure. The T-Wall and Slope Stability Design Criteria, as outlined in HSDRRS-DG (revised June 2012), require structural and geotechnical design checks with the still water level at the top of the wall in addition to the basic design loading conditions for the 1% hurricane event with waves.

Flood walls along the new hurricane system in the Lake Borgne Basin are designed with higher walls to control the overtopping produced by wave action such that armoring on the protected side is not required. This need produces wall heights 10-12 feet higher than the static water elevation (design water elevation) corresponding to the 1% (100-year) level of protection. This extra height leads to a design check for a still water level at the top of the wall with a recurrence interval that is extremely high and far beyond authorized the scope of design (Figure 6). The unintended consequence for the Lake Borgne Basin is that these resiliency design checks governed the structural and geotechnical design of the flood protection features and resulted in a significant increase in construction costs.

A waiver was requested in the resiliency design checks for the Lake Borgne Barrier to make these checks more realistic and consistent with the risk-based approach for HSDRRS. This waiver applies to the Inner Harbor Navigation Canal IHNC-Lake Borgne Barrier consisting of three gate structures and approximately 7,000 linear feet of barrier wall and a T-wall crossing the Golden Triangle marsh east of the Michoud Canal. The top of the barrier wall is crenellated with top of merlon (the solid upright section in a crenellated wall) at EL +26.0 and top of crenel at EL +24.0 feet. The top of T-walls are 32.0 ft. The basis for the waiver was to associate a return interval to the design checks on this portion of the system that is consistent with the resiliency design checks across the rest of the system, a loading with an annual exceedance frequency of 0.2% (or a 500-year return period). The details of this proposed change are shown in Figure 7 and summarized in Table 1.

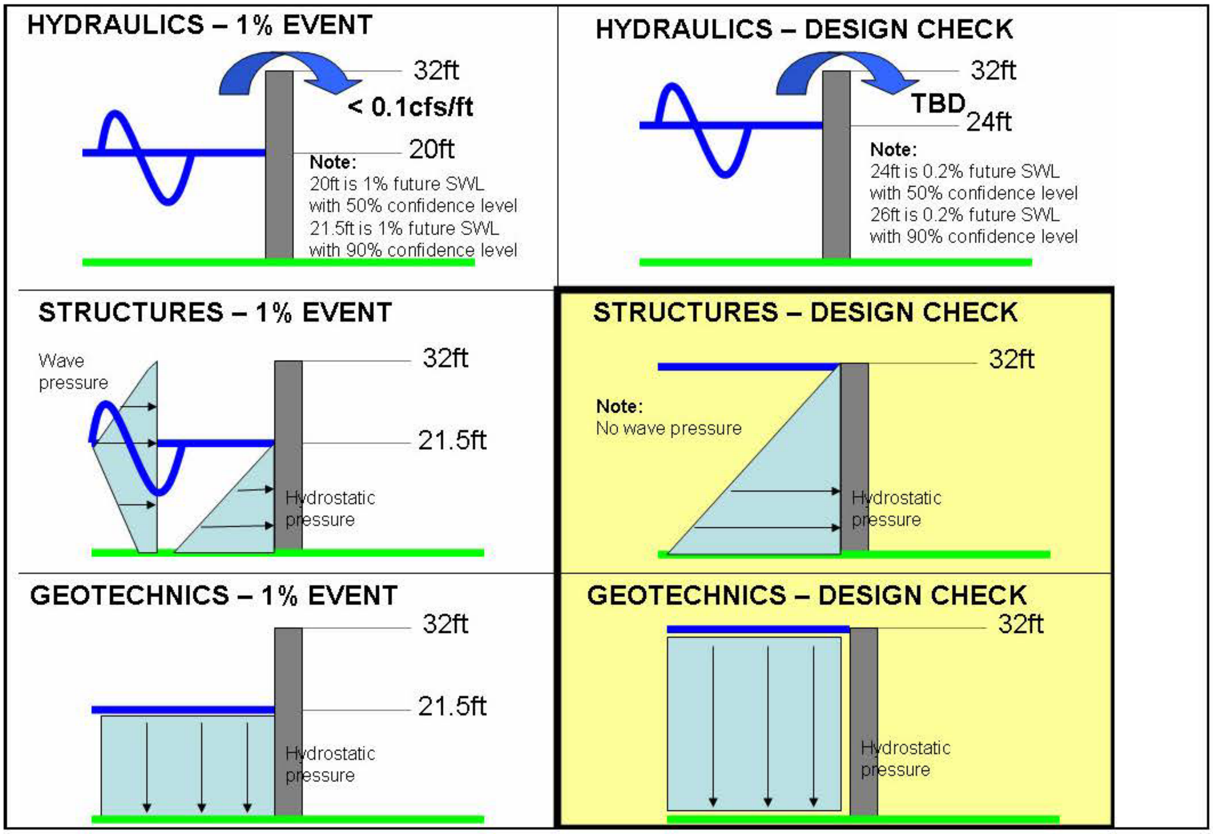
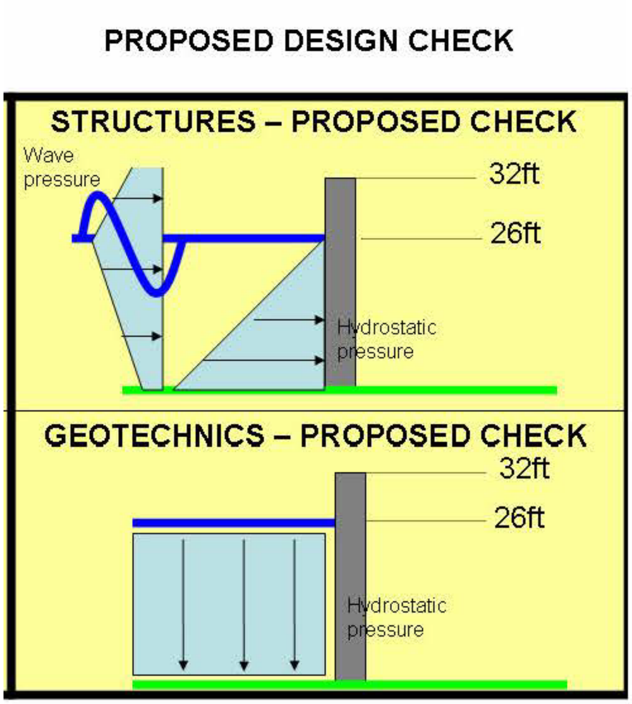


Figure 6. Inner Harbor Navigation Canal, Lake Borgne Basin – Standard HSDRRS design criteria for the resiliency design checks.



32ft = Top of T-Wall
26ft = Top of Surge Barrier Merlon
26ft = 0.2% @90%

Figure 7. Lake Borgne Area -- Approved design check waiver for the resiliency design checks.

Table 1. IHNC Surge Barrier Resiliency design checks – Proposed changes (approved waiver May 6 2009).

Lead discipline	Failure mechanism	Usual design case: 1% event in any given year	Extreme design check: 0.2% event in any given year (resiliency)
Hydraulics	Design height too low	Design height >1% SWL via erosion of inner slope mechanism	Design height >0.2% SWL (50% confidence interval)
	Erosion inner slope	1% overtopping rate less than 0.1 cfs/ft at 90% confidence level	0.2% overtopping rate (armoring to be considered)
	Erosion at outer slope	TBD	TBD
Geotechnical	Slope stability inner or outer slope	1% still water level with 90% confidence level using Spencer with FOS = 1.5	Still water to top of levee/wall using Spencer with FOS = 1.4 Proposed direction: 0.2% STILL WATER LEVEL WITH 90% CONFIDENCE USING Spencer with same FOS
	Seepage/piping	1% still water level with 90% confidence level with specific FOS for levee toe/berm	Still water to top of levee/wall (or design grade) with lowered FOS for levee toe/berm Proposed direction: 0.2% event still water level with 90% confidence with same FOS as above
Structures	Structural integrity pile foundation and structure	1% wave/hydrostatic forces at 90% confidence levels with allowable overstress factors and FOS	Still water to top of levee/wall with higher allowable overstress factors. Proposed direction: 0.2% event forces with 90% confidence levels with higher overstress factors/lower FOS

Design Check for Resiliency: Comments

The resiliency design guidance goes beyond the present standards of practice. This design guideline requirement may set a new standard of practice. Presently, the standard of practice has been to build to 1% (100-year) protection without a resiliency check.

The design check waiver for the Lake Borgne Surge Barrier produces designs consistent with the authorized level of protection, i.e., a 100-year level of risk reduction, and with a level of resiliency that is apparently comparable to that achieved elsewhere in the system. Therefore, these revised resiliency design checks for the Lake Borgne Surge Barrier are reasonable, should provide for a consistent level of performance across the system, and have no apparent impact to nonfederal sponsor O&M effort or cost.

Resiliency Conclusions and Recommendations

The approach to provide for resiliency in HSDRRS design is advancing the state-of-practice for flood protection systems in the U.S. This approach has merit and it should improve the performance and the reliability of the system. Since it is a new advancement, however, it will inevitably take time, patience, and experience to establish the best means for achieving resiliency.

With regard to armoring design, there are two important factors. First, it is essential to know the anticipated extreme loading for which armoring is required, and, second, it is essential to know the limits of applicability of various armoring protection systems and the upper limits of the extreme loading for which protection is desired. As new information becomes available on overtopping rates and armoring performance, this information should be used to update HSDRSS if necessary and should be included in updated versions of HSDRRS-DG. Therefore, the panel recommends that a plan be developed to periodically review the armoring decisions and provide for possible modifications to HSDRSS based on that information. In addition, scheduled surveys should be conducted to monitor the status of freeboard conditions and adjust estimates of overtopping rates based on those conditions. Levee/lifts and associated armoring as result of sea-level rise and/or settlement will require restoration of the original facility to meet original project design objectives. Therefore, the panel recommends that the state and USACE work together to establish realistic expectations for the costs and timing of placement and possible replacement for different types and locations of armoring. The panel also recommends that the state and USACE study the feasibility of adding lifts to levees without removing mat-reinforced turf. Last, the panel recommends that the consequences of an erosional failure be considered as well as the predicted 500-year overtopping rates in making decisions about where to place armoring.

The revised resiliency design checks for Lake Borgne are reasonable and should provide for a consistent level of performance across the system. The panel recommends that these design checks be periodically updated as new information becomes available in the future about the surge and wave loading.

IMPLEMENTATION OF DESIGN GUIDELINES

While the focus of the panel was on the HSDRRS-DG, the implementation of these HSDRRS-DG in constructing, operating, and maintaining HSDRRS will be equally important to the system performance, operations and maintenance, risk, and reliability. The panel identified four major issues concerning the implementation of the HSDRRS-DG: design and construction, operations and maintenance, communication and coordination, and policy.

Design and Construction

Evolving Nature of HSDRRS-DG

Due to the significant advancements that were made to the HSDRRS-DG for this new system and the pressure to meet construction deadlines, the HSDRRS-DG were (and are still) evolving as the project was designed and constructed. The versions of the HSDRRS-DG that the panel reviewed were not complete and did not include numerous recent studies that would clarify or improve the document. In some cases it was also unclear what recent studies and clarifications actually were included in the designs and were built. This seemed especially true for the H&H section, but was reflected throughout. The HSDRRS-DG and accompanying reports will be part of the enduring legacy documentation for HSDRRS. It is critical that all the documents, including the design specs, O&M manuals, letters of transfer, etc. that are associated with the project, be accurately updated, cataloged, and safely stored for future generations to allow them to manage and maintain this system. Therefore, the panel recommends that the documentation be brought up to date and put in a consistent format across the technical areas. It should include follow-up studies and decisions that were made during construction. There were several rather big decisions made during construction, such as going from 13 pump bays to 11 at the West Closure Complex, inserting a barge gate on the Lake Borgne Surge Barrier, and waiving the use of coatings on the steel piles. All of these could have implications for O&M and should be well-documented.

Level of Protection

The final HSDRRS clearly goes beyond just repairing and completing the pre-Katrina system. It seems USACE took as much leeway as possible under the direction of Congress—but still within its authorities—to build a first class system to minimize flood risk from tropical storms in the New Orleans vicinity. Conservative estimates for hydraulic parameters such as wave height and surge, redundancy, multiple lines of defense, and other decisions along the way, have led to what might be considered by some to be "over design." In fact, it is unclear to the panel what level of protection is provided by the system, given the conservative design considerations and the variability of components across the system. As an example, the flood walls were built to future conditions based on conservative estimates of surge, and the earthen levels are constructed to the current 1% event, not taking future settling and subsidence into account. Flood risk experts both in the U.S. and in countries like the Netherlands might argue that in an urban area where flooding consequences are high, using the 1% annual chance of flooding is too low a standard. The panel would not disagree on the need to rethink the U.S. flood risk reduction standard; however, even with that thought, the panel discussed whether there were adverse impacts to the conservative approach taken. The following questions were raised: (1) Does this give the public a false sense of security and encourage risky development decisions? (2) Will the assumptions and decisions used for the design and construction of HSDRRS now become the norm for other USACE projects and how might that impact project approval? (3) If all of the components are not built to the same standard, does it make the system vulnerable? As an example, the system ties into the Mississippi River and Tributaries projects, and was designed for a different level of protection and using different HSDRRS-DG. Will the system put adverse pressure on those levees during extreme events? It is recommended that consideration be given to defining and communicating to the public the actual level of protection and residual risk provided by this project and updating the assessed level of protection as new information becomes available in the future.

Contracting Strategies

During the site visits and based on discussions among panel members, it was clear that different contracting strategies may have led to decisions in the as-built system that could have impacts on O&M. First, USACE should be commended on using not only state-of-practice and beyond in their guidelines to design HSDRRS, but also in being innovative in setting up contracting to deliver the Corps' largest civil works project in history in a timely manner. East and West bank projects, however, were delivered using different contract approaches for design and construction.

Here are some of the questions that arose from this strategy:

1. Did contracting practices impact the decision on some waivers? For instance, to what extent were contractors driven by scheduling or unexpected cost, requiring choices that may have kept them on time and budget, but adversely impacting O&M. Was this the case in the waiver on epoxy coatings?
2. To what level were NFS (CPRA and/or the Levee Districts) engaged in decisions that were made that would impact future operations, such as the decision to install the barge gate on the Lake Borgne Surge Barrier?
3. How coordinated was the expertise of multiple contractors and in-house expertise when making construction decisions, such as the decision to go from 13 pump bays to 11, at West Closure Complex?

The panel recommends— if not already undertaken—that an evaluation be conducted of the contracting strategies used on HSDRRS to help identify any potential operational and/or maintenance requirements not identified specifically in waivers and to develop a "lessons-learned" guide for future projects.

System Considerations

The multiple lines of defense (consideration and incorporation of natural coastal features, as well as multiple built systems including levees, floodwalls, pumping systems, etc.) in HSDRRS design helps minimize any weak points in the system. There are numerous water drainage or flood risk reduction projects, however, which currently exist or are proposed by the various water drainage organizations/agencies and/or levee districts in the Greater New Orleans area. For example, the capacity and operational structure of the internal drainage and pump stations should support and/or match the pumping capacity of the larger pumping stations on the perimeter. And as mentioned above, variable levels of protection within the system and on the perimeter, could impact system performance and/or make certain areas more vulnerable. Given that the IPET report specifically indicated the previous hurricane protection system did not operate or function as a system, it would be important for HSDRRS to fully integrate with both the current and proposed local projects. What assurances are there that the federal project and the local systems will work together effectively to provide the intended level of protection? The panel recommends that identification of vulnerable components of both local and federal projects be evaluated in the context of the system's ability to provide the designed level of protection.

Operations and Maintenance

Actual versus Estimated Cost

Because of the complexity of the project and changes made during construction, it was unclear to the panel whether USACE's original O&M estimates accurately reflect the expected life cycle O&M. The panel recommends that USACE, in collaboration with the state, provide updated costs for O&M based on today's realities and changes made during the design and construction. These updates should be validated with the state and their estimates for O&M.

Regarding the earthen levees, it appears that the project will be turned over to the state prior to subsidence and settling, which could put the system at a near-term risk of not meeting the current design conditions. Further, the responsibility of raising the earthen levees to meet future risk conditions will also be the responsibility of the state. It is unclear to the panel if appropriate consideration has been given to both the timing and necessary funding to meet those requirements. Do the funds fall under existing federal authorities as a continuation of the construction of the project, or is it considered the responsibility of the state and therefore either budgeted within their O&M or appropriated by the state for capital funds? In addition, can dollars already federally appropriated be transferred to the state or be obligated by the federal government in some way to upgrade the levee heights after the project has been transferred? Whether paid by the federal or state governments or cost-shared, identifying when this will be done and budgeting for appropriations will be critical to maintain the level of flood risk reduction expected by the communities for the life of the project. If not already determined, it is recommended that projected upgrades and costs be identified as should the responsible party and funding sources. If levees lose freeboard as a result of subsidence, settling and/or sea-level rise, the system could become deficient and unable to provide adequate protection from the 1% annual event and jeopardize a community's eligibility for flood insurance or worse, result in catastrophic impacts should a large event occur.

Fundamentally Federal Operations

HSDRRS is an engineering feat unlike any flood risk reduction system in the world. With the world's longest surge barrier and the nation's largest pumping station to validate this statement, it protects a large urban area, and a major transportation gateway for the U.S. economy. While transferring cost-shared projects from USACE to the local sponsor is not new to the Corps, this project poses many complications due to its engineering complexity, the numerous political entities that will ultimately be responsible for managing and paying for the system, the already extensive maze of flood drainage and flood protection structures in the area, and the enormous costs required to operate this system. In consideration of the nation's economy and security, the panel discussed the possibility of USACE operating and maintaining some of the key components. The panel was told that the proposed O&M plan calls for the NFS to operate components of the Seabrook complex, the Lake Borgne Surge Barrier and the Western Closure Structure (Monzon, pers. comm.). Congressional language and appropriations notwithstanding, the panel recommends a subsequent review be given to the impacts of the state operating important national assets and whether any of those assets represent fundamentally federal operations.

System Operations

Within the project area there are numerous local entities that are responsible for flood related operations, specifically the sewerage and water boards and levee districts. It is the understanding of the panel that the levee districts through SLFPA-E and SLFPA-W reports to CPRA, while the water drainage districts report to the Louisiana Department of Environmental Quality (LDEQ). USACE operates and maintains the Mississippi River and Tributaries project and IHNC lock. Given there are hundreds of features along the perimeter where there are closure and/or control structures, coordinating operations among the many entities could be quite complicated. There are two types of operational plans that are being developed: Water Control Manuals and O&M manuals. USACE is submitting the manuals for the components as they are transferring them to the state. While many of the local operational entities may have O&M manuals specific to an asset or component, there did not appear to be an overarching Systems O&M manual nor much operational coordination or asset planning among the various owners/operators. The panel recommends that consideration be given to developing an O&M framework that views all assets, as related to the Greater New Orleans flood and hurricane protection operations, and workshops be regularly convened for training of all responsible parties.

System Monitoring and Remote Operations

Due to the number of assets, their geographically dispersed nature, and the accessibility of some of the critical components, the federal, state and local owners/operators should have a plan for monitoring the components in order to obtain an assessment of the systems conditions and operational readiness. O&M manuals identify the need for inspections and maintenance of these assets. Installation of innovative instrumentation technologies to remotely monitor access points, structures, and key components, regular inspections, and a data management system that aggregates information at the system level would be examples of ways to help manage the system. The panel commends CPRA for developing a Levee Information Management System and encourages them to continue in this direction with all of the assets.

Given the many structures at remote locations and the various entities responsible for their operation, the panel recommends that options for remotely controlled operations of critical facilities be considered. Whether used as the first mode of operations or as an emergency backup, this could help build redundancy to critical operations and potentially reduce human error, particularly during an emergency.

Emergency Operations and Contingency Planning

A critical and special component of operations and maintenance is emergency operations and contingency planning. Senior staff from CPRA indicated that during emergencies, they coordinate closely with the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), co-locating with GOHSEP under Emergency Support Function 3 (Public Works and Engineering). Critical to successful response is good contingency planning, exercising those plans, and training the staff to be prepared. Preparation in advance for worst-case scenarios helps the local operators, state, and if needed, the federal government, mitigate disaster during the real event. Due to the complexity of the system and the many operators that must respond during an emergency, the panel recommends that the state, with support from the federal government, lead regular table-top emergency exercises and follow up with on-the-ground exercises to ensure staff is fully prepared for all potential scenarios.

An example of special operations on HSDRRS occurs at the IHNC-Lake Borgne Surge Barrier. Three separate gate structures must be closed (the GIWW sector gate, the GIWW Barge Gate and the Bayou Bienvenue lift gate) in advance of a storm. All of these structures are remotely located and all gates require someone at the structure to activate the closures. In the initial phases of design and construction, the Barge Gate itself was intended to stay in the closed position and navigation was to pass through the GIWW Sector Gates. Due to adverse flow conditions for mariners with the gate closed, the Barge Gate must now remain open under normal conditions. This unexpected condition has created the need for closure during emergency conditions and has added a complicating factor to the operational paradigm on the Barrier. Further complicating the operations, the Barge Gate must be manually closed using a helper boat and winches that perform differently under various conditions. Due to the time it takes to close the Barge Gate, under what could be adverse conditions during a storm event, the operators need 72 - 96 hours advance notice and mariners must be notified that they can no longer use the navigation channel and pass through the barrier.

To reduce risk associated with gate closures, it is recommended that special attention be given to contingency planning, training and exercises. Further, if not already in place, there should be a back-up operation and/or closure method in the event a gate will not close.

Risk-based O&M

HSDRRS will be around for decades. As conditions change it will be critical to continually evaluate the condition of the assets, scheduled maintenance, and the need for capital outlays. Understanding the most vulnerable components, the condition of the assets and the consequences of failure should help to establish a risk-based approach to prioritizing maintenance and capital improvements to the system. The panel recommends that an asset management plan be developed at CPRA level and be implemented for the entire HSDRRS.

Communications and Coordination

Risk Communication

The panel strongly encourages the federal agencies and state agencies to be fully transparent when communicating risk to the public. HSDRRS provides a much improved level of protection to the Greater New Orleans Area, but not without residual risk. The public should fully understand their risk and their role in mitigating, preparing, and responding to emergencies. Working with the NFIP state coordinators, GOHSEP and FEMA, USACE, and CPRA should help communicate flood risk to the community.

Internal Communication and Coordination

Internal communication and coordination between and within USACE and the state will be critical to successful performance of this system throughout its lifetime. It was evident to the panel that while regular communications between USACE and state are occurring and, in many cases, are effective, a very tight coordination between the two entities is necessary for long term success. It was not clear to the panel what steps are being used during transfer and how differences are rectified. Because CPRA was a new agency in the early stages of organization and USACE was on a fast track to complete the project, there appear to be some decisions that were communicated to the state, but not necessarily approved by the state. To ensure that all parties understand their roles and responsibilities, the panel recommends that specific protocols, if not already in place, be used to communicate information before, during, and after transfer of the project. For items that are not being resolved to the satisfaction of either party, a process for appeals or independent resolution could be implemented.

SUMMARY

RECOMMENDATIONS

The panel offers the following major recommendations:

1. The federal and state agencies be fully transparent and persistent about communicating risk to the public. This communication program should be highly visible and active in the public eye;
2. The risk assessment be periodically updated based on improvements in hydrology and hydrodynamics analytical tools like advancements in modeling and high performance computing, as well as information on sea-level rise, land subsidence, land use, and the current condition of the HSDRRS;
3. A program be developed and implemented for long-term monitoring of settlement, corrosion, structural integrity, and slope stability. The panel also recommends that proactive plans be developed to address potential problems that may arise during operation and maintenance of the system;
4. A risk-based asset management plan be developed at the CPRA level and implemented for the entire HSDRRS to accommodate changing conditions;
5. The state of Louisiana and the Corps work collaboratively to develop realistic cost estimates for operation and maintenance to reflect changes made during design and construction;
6. Specific protocols be used to coordinate and communicate information between the federal, state, and local agencies before, during and after transfer of the project. For items that are not being resolved to the satisfaction of a party, a process for independent resolution should be established; and
7. The state of Louisiana work toward the formation of a public-public partnership (Federal-State) to share in future O&M Costs. Congressional authorization may be required. Less likely public-private partnerships to fund O&M costs should be investigated.

PREPARING FOR THE FUTURE

The panel was charged with only addressing a subset of the federal responsibilities to the state. That is, whether state-of-practice guidelines were used and whether waivers during design and construction have any adverse impacts to future O&M by the state. But there are other aspects of the transfer that concern the panel. This is a highly complex system and much different from the pre-Katrina patchwork systems. While state law tasked CPRA to oversee the SLFPA-E and SLFPA-W levee boards, they are still comprised of politically bounded levee districts within those boards that are responsible for operating many existing structures in addition to HSDRRS components that are being transferred. Those entities, under the oversight of CPRA, are responsible for paying for O&M, paying back their share of the NFS costs to the federal government, and for ensuring that additional elevation is added to the levees to maintain the required level of protection now and in the future. In discussing the readiness of transferring HSDRRS to the NFS, there are two perspectives to consider. The first regards the actions USACE has taken to fulfill its responsibilities as the federal partner and its role over the lifecycle of the project. The second regards the state's ability to financially and operationally fulfill its responsibilities as the new owner/operator.

The panel recommends that going forward, clear roles and responsibilities of the entities involved be identified and transparent, particularly on the following issues:

- What is the plan to train operators for coordinated and integrated operations?

- Who has overarching responsibility for system operations during major storms?
- What is the operational chain of command?
- Have emergency plans been developed and adequately exercised?
- Have funds been appropriated and planned for? Will they adequately match the requirements to operate, maintain, and upgrade as needed this system?
- What assurances are in place that the NFS can meet the requirements to operate and maintain the system to its design level over the life of the project?
- What in general is the readiness level of the state?
- Is USACE prepared to resume or assist operations in the event the state cannot fulfill its responsibilities?

CONCLUSIONS

The panel concludes that the assumptions and analysis approaches in HSDRRS-DG are both consistent and appropriate within the current state-of-practice of engineering. The panel also concludes that the justifications for waivers to these HSDRRS-DG were generally appropriate with the exception of the waiver for adding sacrificial steel rather than coating steel piles for corrosion protection. This waiver concerning corrosion protection is inconsistent with the current state-of-practice of engineering in this region. Finally, the panel concludes that the waivers in total will not negatively impact the performance of the system performance in a hurricane, its risk, or its reliability, provided that uncertain design assumptions, particularly those concerning corrosion rates and ground settlements, are consistently monitored and mitigated if necessary over the design service life.

The panel has identified several design issues, however, that will affect the cost and effort required to operate and maintain this system. Specific areas of concern for operation and maintenance include the following:

1. The need to routinely inspect the piles that were not coated for corrosion protection in order to determine their condition and, when necessary, repair them;
2. The need to remove and then replace armoring to raise subsiding levees back to proper grade;
3. The potential for differential settlement to impede operations of pumps and gates and to distress structural components;
4. The potential for shallow slope failures on earthen levees to occur years after construction and require repair;
5. The need to update design assessments and possibly system components over the lifetime of the system as monitoring information becomes available and as new studies and data are obtained concerning surges and waves and structural and hydraulic performance.

If these issues are not addressed fully, then it is possible that the performance of the system in a hurricane could be threatened.

The panel also concludes that implementation of the HSDRRS-DG in constructing, operating, and maintaining HSDRRS are as important to its performance as the HSDRRS-DG themselves. The major challenges in implementation are providing for effective communication and coordination between all parties responsible for the operation and maintenance of the system and clearly communicating the residual risk to the public so that the consequences of hurricane flooding are minimized.

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APPENDIX A: REVIEW PANELIST BIOS

WILLIAM H. ESPEY, JR., PH.D., P.E., D.WRE, M.ASCE

Senior Vice President – RPS Espey

Education

Dr. W.H. Espey originally went to the University of Texas at Austin in 1955, on a football scholarship and left with a PhD. Bill completed his Bachelors of Science in 1960, Masters of Science in 1963, and Doctor of Philosophy in 1965 in Civil Engineering.

Summary of Experience

As an outgrowth of Dr. Espey's Ph.D. dissertation, his Urban Unit Hydrograph methodology has found application in both state and city drainage design manuals and is published in several textbooks, including the "Civil Engineering Reference Manual" for PE exam. Dr. Espey, as a visiting professor, has taught several courses and participated in seminars at the University of Texas. Dr. Espey started his career with the U.S. Geological Survey Water Resources Division and later joined TRACOR in 1965. In 1972 he co-founded Espey Huston & Associates Inc. (EH&A) and served as President and Chairman of the Board until 1993. In 1993 he founded Espey Consultants, Inc. Dr. Espey has served as the chairman, every five years since 1980, of the Lake Michigan Diversion Committee that was mandated by the modified Supreme Court Decree of 1980. The following are selected Honors, Awards and Professional Registrations for Dr. Espey:

- Registered Professional Engineer in the States of Texas, Louisiana, Oklahoma and Mississippi
- Founding Diplomate of the American Academy of Water Resources Engineers (AAWRE), 2005 – Past President and Treasurer, 2010
- Water, Wastewater & Stormwater Council's Award of Excellence, EWRI/ASCE, 2013
- TSPE - Travis Chapter and State of Texas Engineer of the Year, 2009
- The Department of the Army Outstanding Civilian Service Medal, presented by Gen. Carl A. Strock and Assistant Secretary of the Army John Paul Woodley, Jr., for his work as a member of the ASCE Katrina External Review Panel, 2007
- Lifetime Achievement Award, EWRI/ASCE, 2006
- Appointed as Chair of the Basin and Bay Expert Science Team (BBEST), as mandated by Senate Bill 3 (State of Texas 88th Legislature), 2007
- Charter Member, Civil and Architectural Engineering Academy of Distinguished Alumni, University of Texas at Austin, 2003
- Dr. Espey was honored as a Distinguished Graduate of the College of Engineering, at the University of Texas, 1986.

ROBERT B. GILBERT, PH.D., P.E., D.GEO

Brunswick-Abernathy Professor of Civil, Architectural and Environmental Engineering
The University of Texas at Austin

Education

Ph.D. Civil Engineering, University of Illinois at Urbana-Champaign	October 1993
M.S. Civil Engineering, University of Illinois at Urbana-Champaign	May 1988
B.S. Civil Engineering, University of Illinois at Urbana-Champaign	May 1987

Professional Experience

Prof. of Civil Engineering, Univ. of Texas	2005 - present
Assoc. Prof. of Civil Engineering, Univ. of Texas	1999 - 2005
Asst. Prof. of Civil Engineering, Univ. of Texas	1993 - 1999
Project Engineer (part time), Golder Assoc. Inc.	1990 - 1993
Project Engineer (full time), Golder Assoc. Inc.	1989 - 1990
Staff Engineer (full time), Golder Assoc. Inc.	1988 - 1989

Selected Honors

Hall of Fame Paper Award, Offshore Technology Conference (2014)
Lockheed Martin Teaching Award, Cockrell School of Engineering (2012)
Teaching Award, Department of Civil, Architectural and Environmental Engineering (2012)
Norman Medal, American Society of Civil Engineers (2011)
Engineer of the Year, Travis Chapter, Texas Society of Civil Engineers (2011)
Sigma Xi Lecturer (2008-2011)
Civil Engineer of the Year, ASCE Austin Branch (2007)
Outstanding Civilian Service Award, U. S. Army Corps of Engineers (2007)

Recent Service

Member, International Organization for Standardization (ISO) Working Group 7 on Recommended Practice for Offshore Foundations (2010-present)
Member, Task Force on Flood Risk Management, ASCE (2012-present)
Member of ASCE External Review Panel, New Orleans Hurricane Protection System (2006)
Advisor, Student Chapter of American Society of Civil Engineers (2004-present)

JAMES T. KIRBY, PH.D.

E. C. Davis Professor of Civil Engineering
Professor of Physical Ocean Science and Engineering
Center for Applied Coastal Research, University of Delaware, Newark, DE 19713

Education

Jim Kirby received his B. S. and M. S. from Brown University in 1975 and 1976, and his Ph.D. in Civil Engineering from the University of Delaware in 1983.

Summary of Experience

Dr. Kirby has served on the Faculty of the State University of New York at Stony Brook (1983-1984), the University of Florida (1984-1988) and the University of Delaware (1989-present), and has also served as a visiting professor and guest lecturer at the Universidad de Granada (2010 and 2012). Kirby's main research interests are in the area of surface water waves and nearshore hydrodynamics, with recent focus on the mechanics of bubble populations under breaking waves, rip current dynamics, wave-current interaction in strongly sheared flows, tsunami generation, propagation and inundation, and morphology of tidal marshes. He has supervised 10 Ph.D. and 26 MS or MCE theses on related topics. He has directed the development of a number of public domain software packages including REF/DIF, FUNWAVE, NearCoM and NHWAVE. He has authored or coauthored over 95 refereed journal articles. He has received the Walter L. Huber Civil Engineering Research Prize (1992) and the Moffatt-Nichol Port and Coastal Engineering Award (2011), both from the American Society of Civil Engineers. Kirby has served as Associate Editor for the Journal of Engineering Mechanics (1994-1996), Editor of the Journal of Waterway, Port, Coastal and Ocean Engineering (1996-2000), Editor of the Journal of Geophysical Research – Oceans (2003-2006) and Editor in Chief of the Journal of Geophysical Research – Oceans (2006-2009). He served on the Board of Governors of the American Institute of Physics (2011-2013) and presently serves on the Coordinating Committee for the National Tsunami Hazard Mitigation Program.

SANDRA K. KNIGHT, PHD, PE, D.WRE, D.NE

Senior Research Engineer
A.J. Clark School of Engineering
University of Maryland, College Park

Education

Dr. Knight has a PhD from the University of Memphis, MS from Mississippi State University and a BS from Memphis State University, all in Civil Engineering.

Summary of Experience

Sandra Knight is a Senior Research Engineer in the Department of Civil and Environmental Engineering at the University of Maryland where she works with her other colleagues in the development of water policy and flood risk management initiatives. Additionally, she is founder and President of WaterWonks LLC in Washington, DC. Her company was formed to capitalize on her extensive experience in federal disaster reduction, flood risk management and marine transportation policies and programs, having spent more than 30 years administering these and other policies at three federal agencies.

Sandra finished her federal career in October 2012 as the Deputy Associate Administrator for Mitigation, FEMA, responsible for the nation's floodplain mapping, management and mitigation grants supporting the National Flood Insurance Program, environmental compliance for the agency, and oversight of the National Dam Safety Program. At NOAA, 2007-2009, she was responsible for the development of policies and strategies to ensure scientific excellence and improved performance of NOAA's research portfolio. Prior to that, she spent 26 years with the US Army Corps of Engineers. Her last position with USACE was as Technical Director for navigation research.

She is a registered professional engineer, a Diplomate, Water Resource Engineer and a Diplomate, Navigation Engineering. She is a member of the American Society of Civil Engineers, the American Meteorological Society, the Society of Women Engineers, Sigma Xi and a Fellow for PIANC.

THOMAS W. WELLS, PE

Senior Vice President - Manager of Civil and Environmental Engineering

Education

University of Florida, 1965, B.S. in Civil Engineering (with Honors)
University of Illinois, 1970, M.S. in Civil Engineering
Loyola University, 1978, Master of Business Administration

Summary of Experience

Experience since 1965 in structural and foundation engineering for drainage, navigation/flood control, residential, military, commercial, municipal, industrial and marine facilities, including design, supervision of design and project management.

Project Experience: 1976 to Present
South Florida Water Management District:

- ITR of design of 2 drainage pump stations in STA 3/4: 2700cfs and 3500cfs;
- Preliminary design of two drainage pump stations, at Site 1 (640cfs) and C-11 (1610cfs), including cost estimates;
- Review of environmental and hydraulics reports for Everglades Restoration; and
- Review of two existing small craft locks in order to improve operational safety and efficiency.

LDNR/CPRA Bayou Lamoque Freshwater Diversion Project, Plaquemine Parish. Lead Engineer for preliminary design. Reviewed design, drawings, and report.

New Orleans District General Design Services IDT contracts: Project Manager and Lead Structural Engineer for assignments including: design of Flood Protection at Cousin Pump Station Outfall Canal into Harvey Canal; and forensic investigation into foundation failure of potable water support piers in Harvey Canal.

New Orleans District General Design Services IDT contracts: Project Director for work including Morgan City flood protection improvements, improvements to IHNC lock (new miter gates, new floating guide wall), IHNC lock replacement projects (demolition, utilities relocations), improvements to earthen chamber lock; replace sluice gates at Bayou Courtableau hydraulic structure; and independent technical review of sector-gated floodgate on Harvey Canal.

New Orleans District Miscellaneous Planning and Design Services IDT contract: Project director or manager for development of Benefit Cost Methodology to establish economic linkages of Louisiana coastal wetlands; hydraulic/hydrologic UNET model of Terrebonne Basin; and analysis of loss of land mass at Weeks Bay.

Vicksburg District General Design Services IDT contract: Project Director for work including analysis of Poiree trestle dewatering bulkheads at several locks in central Louisiana; value engineering and preparation of plans, specs and cost estimate for replacement and extension of sediment barrier wall on Lindy Boggs Lock and Dam; high-drop weir structure and 5 culverts in Yalobusha River Watershed; and maintenance facility, wingwalls, fuel facility, and intake structure for 14,000cfs Yazoo River Pumping Plant.

Old River Low Sill Control Structure: Project Engineer for investigation of methods to inspect and repair stilling basin and for design of spare bulkheads and storage facility.

East Atchafalaya Basin Protection Levee: Project Engineer for P&S engineering to upgrade levee with I-wall, including access Ramps and gates (wildlife and vehicle).

Red River Lock & Dam No. 1 Sediment Barrier Wall. Participated in presentation of results of Value Engineering Study of design of structures to extend, vertically and horizontally, existing concrete, steel and timber barrier wall. Study de-vised alternatives to COE design that will save approximately $1 million on $3 million project.

New Orleans Sewerage and Water Board Pump Station No. 7 Improvements. Project Manager for study to raise flood protection level, replace pumps and make other improvements to 2760 cfs pumping station.

Professional Registrations

Registered Structural or Civil Engineer in more than 30 states including Louisiana.

Professional Memberships

American Society of Civil Engineers (Fellow, Life Member, Lifetime Achievement Award)
American Concrete Institute (Past President of New Orleans Chapter)
Louisiana Engineering Society
Society of American Military Engineers (former Vice President of Louisiana Post)

Clinton S. Willson, Ph.D., PE

Director of Engineering Design and Innovation
The Water Institute of the Gulf

Education

Dr. Willson earned a bachelor's degree in aerospace engineering from Pennsylvania State University. He earned a master's in environmental health engineering and a doctorate in civil engineering from the University of Texas. He spent seven years as an officer in the U.S. Marine Corps.

Summary of Experience

With more than 17 years' experience in applied research in environmental and coastal engineering, Clinton Willson, Ph.D., P.E., is an expert in physical modeling systems that test river management proposals. He joined The Water Institute of the Gulf to develop innovative concepts, technologies, and projects that protect communities from large storms while improving the effectiveness of coastal restoration efforts.

In addition, Dr. Willson is a professor at Louisiana State University's Department of Civil and Environmental Engineering and serves on the university's Coastal Sustainability Studio executive board. At LSU, he oversees construction of a new, large-scale physical model of the lower Mississippi River that will be used to test the effectiveness of various river management strategies.

Dr. Willson is also chairman of the technical team for the Changing Course Design Competition, has served as a review panel chair for the Rijkwaterstaat (Netherlands) and as a reviewer for the National Science Foundation, the U.S. Geological Survey and numerous peer-reviewed journals. In 1997, he was a visiting professor at the Laboratory for Soil and Environmental Physics at Ecole Polytechnique Federale de Lausanne in Lausanne, Switzerland.

He is a registered professional engineering (Louisiana) and a member of the American Society of Engineers (having served as the ASCE Baton Rouge Branch President in 2012-13), the American Geophysical Union and the Association of Environmental Engineering and Science Professors.

APPENDIX B: POLICY CONSIDERATIONS

Both current and proposed federal laws, regulations, and policies can and will generate requirements for the state and USACE as they operate and maintain HSDRRS.

THE NATIONAL FLOOD INSURANCE PROGRAM

Notably, the National Flood Insurance Act requires that flood risk mapping for the purposes of insurance ratings (Flood Insurance Rate Maps, FIRMS) be reviewed on a 5-year cycle. Preliminary maps for the area were released in November 2012 and include the effects of HSDRRS. Since final maps are forthcoming, another review is over 5 years away. At that time, NFS will be required to provide data certifying that the system still provides protection from the 1% annual chance of flood. Under the act in CFR 44, 65.10, FEMA requires levee owners to provide proof that their levees meet accreditation requirements for the 1% annual flood if they are to waive mandatory flood insurance behind levees. This has been a hardship for some levee owners as their maps undergo renewal. Additionally, the Biggert-Waters Flood Insurance Act of 2012 states that future maps will reflect sea-level rise and future development. It also requires maps to show both the 1% and 0.2% annual probabilities and to map the level of protection provided by the system. This may prompt questions from the public regarding vulnerable areas or highlight any inequities in the system protection. Biggert-Waters also establishes a levee task force to ensure better coordination between FEMA and USACE in serving nonfederal sponsors. It is also charged with reviewing the accreditation requirements for levee certification.

WATER RESOURCES DEVELOPMENT ACT

Another important change in legislation could come with a new Water Resources Development Act. The House and Senate currently have versions of this act and are in conference to develop a workable version. The Senate version calls for a National Levee Safety Program modeled similarly to the National Dam Safety Program. States participating in the program may be required to provide data to the national levee inventory and establish national levee safety officers to manage state programs. The act also calls for a Water Infrastructure Finance Innovation Act (WIFIA) that encourages innovative project financing of water projects. While this may not affect the current HSDRRS project, other federally proposed and authorized projects in the area may be financed under this new approach rather than the classic cost-share method.

OTHER FEDERAL POLICIES AND STUDIES IN THE WINGS

In addition to changes that may result from a congressionally mandated Levee Task Force, there are other agency policies that could shape how the state, as a levee owner, assesses the condition of the levees and maintains HSDRRS.

If for any reason during the life of HSDRRS the levees become unaccredited, FEMA has developed a new mapping policy for levees that will help the state more accurately represent the risk. The Analysis and Mapping Procedures for Non-Accredited Levee Systems, http://www.fema.gov/final-levee-analysis-and-mapping-approach, released July 2013, is an interim policy that analyzes levees on a reach-by-reach basis and takes into account the level of protection the levee does provide in determining the Special Flood Hazard Area. Further, a study by the National Academy of Sciences recommends a risk-based assessment of levee systems and flood risk management as opposed to a levee certification process based on the 1% annual flood (NAS, 2013). USACE has recently developed a levee screening tool, the Levee Safety, Action, and Classification (LSAC) tool:

http://www.nwo.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/2034/Article/10360/levee-safety-action-classification.aspx. This screening tool conducts a risk analysis that rates levees on a I to V scale, with "V" being Normal and "I" being unsafe. While not intended to affect levee accreditation, it could call attention to critical levee reaches that require repair. The panel recommends that the state, working with the Corps, continually update maintenance priorities as a key component of a risk-based O&M plan. Additionally, USACE continues to research the effects vegetation has on levees which at some point could impact the current policy.

As new owners/operators, the panel recommends the following for CPRA and the SLFPA-W and SLFPA-E:

- To continually analyze the risk and the level of protection offered by the system;
- To ensure the public is aware and understands its risk;
- To operate and maintain the system and upgrade as needed to keep accreditation in the NFIP and to remain eligible for emergency assistance under USACE Disaster Operations Public Law 84-99;
- To use available screening and risk assessment tools to help prioritize major maintenance and rehabilitation projects; and
- To work closely with federal officials to stay apprised and help shape new and evolving policies.