Early Application of Agile in Project Management: How Agile Concepts were used to Accelerate Restoration of Post-Katrina New Orleans [1]

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Abstract

One of the most significant developments in project management has been the emergence of agile concepts. After Katrina flooded 80% of New Orleans and devastated most of the 350-mile protective perimeter, the restoration of New Orleans and vicinity was dependent on a massive reconstruction effort, complicated by the next hurricane season in 9 months. This paper chronicles an early application of agile project management concepts to accomplish this challenge. This included the forensic assessment of what happened and why, the rapid restoration of pre-Katrina protection and the design and construction of a long-term risk reduction system.

Key Words: Forensic Analysis, Risk and Reliability, Design and Construction, Infrastructure Systems

Introduction

Project management, PM, has become an essential element for success in major endeavors across many fields. It plays an especially large role in large infrastructure projects. These efforts often deal complicated stakeholder relationships, complex analysis and planning, time and resource constraints and considerable uncertainty. In many cases the outcomes have critical impacts on societal safety and well-being. For projects associated with natural disasters, the most challenging constraint can be time. Achieving a meaningful level of risk reduction before mother nature can strike again is the coin of the realm. This was aptly

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demonstrated in the wake of Hurricane Katrina in New Orleans. With only 9 months until the next hurricane season and a major metropolitan area under water, it was imperative to restore some level of mitigation before the next storm season. Equally important was the timely design and construct a long-term risk reduction system that would sustain New Orleans into the future. The information in this paper was presented as a Plenary Talk at the University of Maryland 2026 Project Management Symposium, 30 April and 1 May, College Park, MD.

The Katrina Event and New Orleans

Hurricane Katrina and its Impact

Katrina struck New Orleans and vicinity early on 30 August 2005. As the storm propagated across the Gulf of Mexico it intensified to CAT 5 (Saffir-Simpson Scale) with peak winds up to 175 mph. It eventually degraded to CAT 3 with peak winds around 127 mph when made landfall at Buras, LA. While in the Gulf, Katrina spawned surge and wave conditions which propagated to the coastline, representing the highest recorded surge and wave levels to strike North America. What Katrina encountered on shore was an incomplete and inadequate Hurricane Protection System.

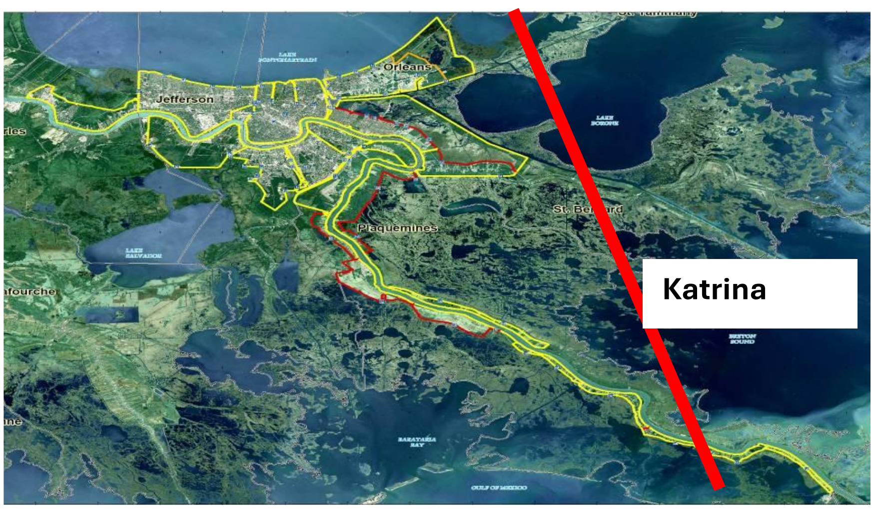

Figure 1. Graphical depiction of the hurricane protection system in New Orleans prior to Katrina and showing Katrina's path. The yellow lines show federal levees and structures and the red show non-federal levees. A good portion of the structures in the upper left portion of the graph were incomplete when Katrina struck. (Source: IPET)

The Lake Pontchartrain and Vicinity Hurricane Protection Project, HPS, was originally authorized by Congress in 1965, in response to Hurricane Betsey that caused the first billion-dollar disaster in the nation's history. Figure 1 shows the extent of the HPS with the path of Katrina superimposed. Unfortunately, the planning and design of the HPS was stymied by legal and financial challenges, largely attributed to the cost-sharing dictate from Congress that required the local governments to pay approximately 30% of the cost. A final plan was not approved and initiated until mid 1980's. With funding coming in relatively inconsistent increments and planning relying on legacy standards and methods, the status of the Hurricane Protection System (HPS) in August of 2005 was one of an incomplete and inadequate system, largely overwhelmed by Katrina's forces. For a comprehensive discussion of tortuous pathway from initial authorization to construction of the HPS see Reference 1.

Figure 2 shows the extent of damage to the HPS from Katrina. In the aftermath of the storm, it was obvious that the storm forces far exceeded the capacity of the structures in place. The result was flooding of approximately 80 percent of the city, 1800 fatalities and over $20B in direct property damages. Ultimately the total economic loss was estimated to be $200B. Approximately 78 percent of the losses were attributed to residential properties which were largely at the lowest elevations. In addition, 3 of every 4 fatalities were individuals over 60 years of age or infirmed and not self-mobile.

Figure 2. Katrina flooded approximately 80% of New Orleans and damaged 34 of the 73 pumping stations that drain water from the city. New Orleans suffered 1800 fatalities and up to $200 B in total economic losses. (Source: Corps of Engineers)

The HPS structures along the east side of New Orleans were not only low but also lacked the robustness necessary to prevent catastrophic failure. In general, levee performance was directly relatable to the strength of the core materials of the structures. Those with hydraulic fill cores performed significantly worse than those with less erodible clay. Along Lake Borgne, the 12-14 ft high main levees experienced up to 20 ft of surge with 5 to10 ft waves on top of the surge. Most of the breaches resulted from overtopping and scour on the reverse (inland) side of the structures. Approximately 200 miles of the 350 miles (including the entire region) of perimeter structures were damaged with 55 major breaches (some miles in width).

Inside this perimeter, the navigation and drainage canals were rimmed by flood walls and floodwall-levee combinations. Most of the flooding of the interior of New Orleans resulted from 5 major structural failures of these walls. Three breaches occurred prior to overtopping and two in conjunction with overtopping. These failures were attributed to inadequate design, essentially the failure mode that caused their collapse was not considered in the design process. Katrina also produced approximately 14 inches of rainfall that accounted for approximately 20 percent of the flood water volume inside the city.

While New Orleans has a city-wide drainage and pumping system, its main purpose was to cope with rainfall. Few of the 73 pumping facilities were online during the Katrina flood, contributing little to the flood fight. The drainage and pumping systems were not considered part of the flood response capability. Subsequent investigations demonstrated that the pumps had no provision for keeping operators safe and their backup power supplies were not available during the storm.

The Aftermath and Recovery

The aftermath of the storm was bleak, many residents that were trapped in the city, with no services, few shelters and minimal emergency response. Hospitals, Nursing homes and retirement facilities were in dire straits. The Super Dome became the one beacon of hope, but it too became overwhelmed by the number of people needing assistance. Local first responders and emergency personnel from FEMA, the National Guard and NGOs such as Red Cross were quick to respond providing emergency supplies, water, ice and medical assistance. Many of the hospitals were without power and their emergency power supplies were compromised by the flooding.

Because New Orleans is a city largely below sea level, it was essential to remove the flood waters and create temporary barriers against future flooding events. Filling the major levee breaches and pumping out the flood waters took 53 days and was accomplished by Task Force Un-Water, set up by the Army Corps of Engineers.

The second step was to determine what happened and why. To rebuild New Orleans, it was essential to understand why the HPS structures were so vulnerable and what caused their failure. It was also necessary to understand the level of risk that existed prior to Katrina and the potential risk going forward. This knowledge was needed to avoid building the same vulnerabilities into future flood mitigation structures. This included defining the hurricane hazard that New Orleans may face in the future.

A key constraint was the need to temporarily repair the damaged sections of the HPS prior to the next hurricane season, officially starting on 1 June 2006. A longer-term fix could follow. Congress charged the Corps of Engineers to repair the structures to the level of capability that existed prior to Katrina by 1 June 2006 and then begin the planning, design and construction of a longer-term system. The long-term effort was designated the Hurricane and Storm Damage Risk Reduction System (HSDRRS), specified to provide the capability to deal with a 100-year storm surge event by 2011. Subsequent authorizations added additional resilience measures to reduce the chance of catastrophic failures if overtopping occurred.

The Federal Response

The federal response to this charge was fourfold: First, the Regional Recovery Office – Louisiana and the Regional Recovery Office - Mississippi were established to coordinate FEMA and emergency response efforts. Second, the Interagency Performance Evaluation Task Force (IPET) was established to conduct a comprehensive forensic analysis and risk assessment of the HPS and the region. Third, Task Force Guardian was established to oversee the immediate repair and rehabilitation of the damaged structures prior to the next hurricane season; and last, Task Force Hope was established to oversee the design and construction of the new HSDRRS.

The remainder of this document focuses on the U S Army Corps of Engineers IPET, Task Force Guardian and Task Force Hope efforts, in particular the Project Management methods that facilitated the accomplish of their missions in accelerated time frames. This represents an early application of what is now deemed "agile project management" for a large regional infrastructure system.

The Forensic Analysis: What went wrong and why?

IPET:

The IPET was established as an independent entity by LTG Carl Strock, Chief of Engineers. The IPET mission was to "provide credible and objective scientific and engineering answers to fundamental questions about the performance of the Hurricane Protection and flood damage reduction in the New Orleans metropolitan area." Independence from the federal government was essential to the credibility of the IPET findings and to facilitate the trust needed to apply those findings for rebuilding New Orleans.

The basic tasking to the IPET was to 1) understand the characteristics and associated performance of the HPS structures and system in place when Katrina struck, 2) Characterize the storm and quantify the static and dynamic forces the HPS structures experienced during and after the storm, 3) assess the performance of the HPS in light of the forces they experienced, 4) quantify to severity and distribution of flooding, 5) quantify the consequences of the flooding in terms of economic and life safety, and 6) quantify the distributed risk (expected levels of losses) represented by conditions prior to Katrina and going forward for alternative approaches to mitigating flood risk in the area.

Organization:

To achieve this mission, IPET established ten teams, each co-led by a senior expert from the Corps of Engineers and an external expert. A Senior Research Engineer in the University of Maryland Department of Civil and Environmental Engineering served as the IPET Director; the Chief of Engineering and Construction at the Corps Huntington District served as the Technical Director. Each team was comprised of diverse experts from academia, government and industry. Administrative support was provided through the Corps Engineering R&D Center to include financial management, legal, contracting, and public affairs. A project manager was provided through the Corps' Huntington District. The team members represented 25 universities, 23 private companies and 12 government agencies.

The teams included 1) Data Collection and Management, 2) Geodetic Vertical and Water Level Datums, 3) Hurricane Surge and Wave Analysis, 4) Hydrodynamic Forces Analysis, 5)

Geotechnical Structure Performance, 6) Floodwall and Levee Performance, 7) Pumping Station Performance, 8) Interior Drainage / Flooding Analysis, 9) Consequence Analysis and 10) Risk and Reliability Analysis.

Funding was provided by a congressional supplemental appropriation and totaled approximately $30M. Experimental capabilities were provided through the Engineer R&D Center and included priority access to their DoD High Performance Computing Center, geotechnical analysis and testing capabilities to include the world's largest centrifuge, and extensive hydraulic modeling facilities. Partnering organizations also provided their special capabilities, such as the centrifuge facility at Rensselaer Polytechnical Institute.

The Project Management Plan:

Step one in the Project Management process was the formulation of a comprehensive project management plan. While the principal knowledge gaps were reasonably well known, the most effective pathway to filling those gaps were not always clear. Ironically, it was important to guard against "perfection". IPET needed credible answers, but could not afford the luxury of exhaustive analysis. The teams had to monitor each other's progress to determine when specific results were "good enough" and then move on to the next challenge. This demanded an agile process where the status of the work drove the plan rather than the plan driving the work. It was necessary to move forward in steps, allowing a continuous iteration of the plan based on the most efficient way forward. IPET held virtual weekly all-hands meetings to facilitate this collaboration and make decisions on the status of efforts, essentially iterating in weekly sprints. The Project Manager became one of the most critical (and busy) individuals on the task force, in essence the keeper of the IPET dynamic road map, one with fixed end points but flexible pathways.

Some of the analyses were very complex and embodied significant uncertainty. Relying on a single approach was simply too risky. In these instances, multiple approaches were explored in parallel giving more complimentary information to generate a better result. Structural failure modes were one example. IPET teams employed three approaches. First, physical investigation at the site of the failure (excavation or coring of failure site). A second approach used analytical computer models that are typically utilized for design. A third approach is physical modeling, in the case of dynamic failures, this employed centrifuge technology. Figure 3 shows the world's largest centrifuge at the Corps Engineer R&D Center, Vicksburg, MS.

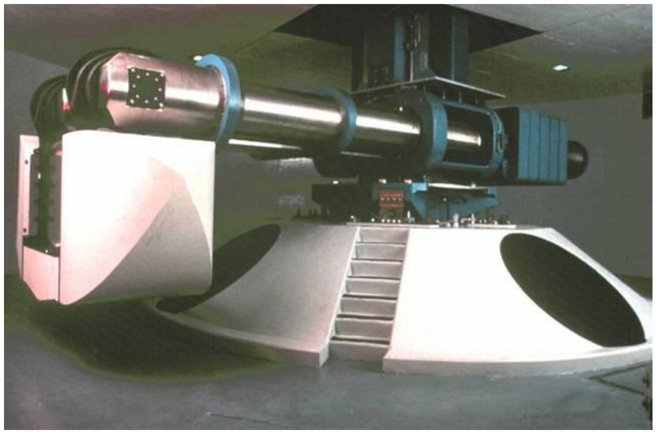

Figure 3. The Centrifuge at the Engineer R&D Center is the largest in the world. It allowed IPET to conduct scale model tests and observe the failure modes that caused the levees and floodwalls to fail. This was a primary means of validating the failure modes determined from more traditional analytical analysis. (Source: IPET)

As an example, the failure of the flood wall and levee complexes along the outfall canals, a backhoe was used to physically unearth the actual failure plane. Analytical models were used to simulate the structural behavior by teams at Virginia Tech and Texas A&M. The projected structural behavior that evolved from these efforts were physically modelled in the Centrifuge facilities at ERDC and RPI. The centrifuge allowed investigators to watch the failure take place and confirm the actual process. Conducting these investigations in parallel reduced the time and increased confidence in the results.

Peer Reviews:

While speed was essential, so too was credibility. Because findings and recommendations had to be transferred as soon as possible for Task Force Guardian implementation, continuous validation was necessary. The American Society of Civil Engineers, ASCE, established an external review panel to provide "just-in-time" review of the IPET results as they emerged. The ASCE panel, comprised of national and international experts, had members associated with each team. This process allowed rapid evaluation and transition of results as soon as they were validated. The traditional concept of peer review after all results are complete was simply not acceptable. The ASCE panel provided feedback in days, not weeks or months.

The National Research Council (NRC) Committee on New Orleans Regional Hurricane Protection Projects was also established to accomplish a formal peer review of the results. The IPET senior staff met with the NRC Committee periodically to provide details on the status of the analyses and the results. The Committee provided written feedback to IPET, the Corps of Engineers and the public after each meeting. All IPET meetings with the NRC Committee and ASCE Panel were public meetings to maximize transparency and public awareness.

Communications:

Beyond the weekly all-hands meetings, communications protocols and avenues to facilitate collaboration and economy of effort were an absolute necessity. The Groove Virtual Office technology was quite valuable and created a digital trail of communications and resulting decisions as the study progressed. Because of the necessity of conducting the bulk of the work virtually, there was no time to establish a physical central site, these communications initiatives were the backbone of IPET. Part of the communications process was maintaining the IPET public web site to keep everyone aware of what was going on. Responding to media requests, refereed by the public affairs officer provide through ERDC, was passed directly to the most appropriate IPET leader.

The IPET web site promoted public awareness of plans, status of efforts, emerging results and draft and final reports. The web site became the home for 4300 technical documents concerning the design and construction of the HPS, hurricane assessment methodologies and IPET documents. This web site also provided a means to solicit feedback from all sources. IPET conducted frequent media interviews, including live radio and national TV programs. The goal was to stay ahead of the news cycle 's tendency to "create" story lines from limited information.

Reports were issued often, starting with interim reports. Report 1 was a summary of the IPET overall plan and initial progress in January 2006. Report 2 followed in March 2006 and provided a detailed progress report on major investigations and preliminary results. On 1 June 2006, the official beginning of the next hurricane season, the first official draft of eight of the nine volumes planned for the final IPET report was published. Remarkedly, the key findings and recommendations concerning structural performance and recommendations for more robust structures were already "in the ground", having been applied by Task Force Guardian to restore temporary flood protection by June 2006. The final version of all 9

Volumes, including Volume 8, that chronicled the landmark risk and reliability analysis, was published on 1 June 2009 (Reference 2). In addition, in response to NRC recommendations, IPET published the Supplemental Report, A General Description of Vulnerability to Flooding and Risk for New Orleans and Vicinity: Past, Present and Future, presenting the comparative risk assessments of the HPS, the short-term repaired structures and the HSDDRRS design (Reference 3). Dr. David Daniel, President, University of Texas at Dallas and Chair, ASCE External Review Panel stated, "I think we have a shockingly accurate picture of what went wrong. IPET made that possible."

The weekly "sprints" allowed rapid adjustments in the plan and efforts based on progress made in the eyes of the investigators, peer reviewers and the end users of the knowledge being gained. This was a magnificent "time machine".

Secret Sauce:

The bottom line - there are a few **must haves** and another few **should haves** to a large, complex project with significant time constraints.

Must Haves

Purpose: Purpose drove the entire process. A compelling need with a genuine sense of urgency will dramatically facilitate the "must haves" and "should haves" listed below. Katrina certainly provided the need and the urgency.

Financial Resources: Without adequate funding and flexibility with respect to its application, it is impossible to craft and execute a plan. IPET was fortunate to receive full funding (congressional supplement) and top-down flexibility to apply the resources optimally.

Human Resources/Talent: Without the necessary individuals, with appropriate experience and expertise, dedicated to the project, it is impossible to build the team(s) needed to execute the plan. In many instances those individuals represented a variety of organizations. IPET was fortunate to have key individuals available from academia, industry and government who dedicated their time to this endeavor.

Plan: Without a comprehensive plan the human and financial resources would never be enough. The plan in fact defined and justified the resources needed and provided the basis for immediate action. The plan, especially for a non-routine and complex endeavor, must be framed to be agile, providing flexibility with respect to the pathway and resource allocation to meet the end goals.

Should Haves

Total Alignment: Nothing gets done efficiently if the top echelon is not enabling the operators and executers. Similarly, horizontal alignment of all teams and agencies was essential to productivity and success.

Policy and Guidance Flexibility: Agility/flexibility was not baked into engineering policy and guidance. Focus on standardization and compliance were barriers to innovation and execution. Fortunately, during IPET, considerable flexibility was granted concerning contracting, information flow and private sector-government interactions. IPET independence from direct government oversight was an essential element to make decisions that were driven by knowledge gaps and need. It was also a key factor in the credibility of the results and recommendations and the public perception of the validity of the results.

Analysis Assets: For analysis of complex processes and/or structures there is little substitute for the right experimental and computational tools. IPET was fortunate to have the world-class computational and experimental facilities of the Army Corps of Engineer R&D Center as well as those in the federal and academic partners.

Continual Review and Validation: Validation of the emerging experimental and computational results was essential to both the formulation of findings and specific recommendations relevant to the ongoing repair and restoration efforts. The ASCE External Review Panel provided near-term feedback (at times within 24 hours) and the NRC Panel provided formal peer review. Both were essential to the public trust in the short- and long-term recovery efforts.

Transparency: Complete transparency with respect to the ongoing analyses and the emerging results was another cornerstone of credibility and trust. Not having to spend time responding to conspiracy theories and unfounded speculation was a tremendous time saver. The feedback received from external sources was of great value in understanding how the information published on the IPET web site was being perceived and providing insights for the IPET teams to consider.

Implementing the Restoration

The restoration of flood mitigation for New Orleans and vicinity was accomplished in two phases. First the temporary restoration of the damaged sections of the Hurricane Protection

System in place prior to Katrina. This was necessary because of the extensive breaching which left the city highly vulnerable to flooding by even small storms. The second phase was designing and constructing a new system that would sustain New Orleans and vicinity for the longer-term into the future. This new system became known as the Hurricane Storm Damage Risk Reduction System, HSDRRS.

The overall description of the Task Force Guardian and Task Force Hope efforts and contributors is provided in Rebuilding Hope: Task Force Hope and the U. S. Army Corps of Engineers, Mississippi Valley Division: A History of the response to Hurricanes Katrina and Rita (Reference 4).

The reports, Hurricane Storm Damage Risk Reduction System Elevation Report (Reference 5) and Hurricane Storm Damage Risk Reduction System Design Guidelines, Interim (Reference 6), provide detailed documentation of the coastal and hydraulic engineering analysis performed to determine the project design elevations for the three legacy projects within the spatial domains of the HSDRRS. This work was the primary purpose behind the IPET forensic and risk analyses discussed earlier. The analysis conducted to design the resilience component for the HSDRRS is documented in New Orleans Hurricane Protection System, Risk Analysis of Armoring Alternatives. Draft Report, US Army Corps of Engineers. 2011 (Reference 7).

The drivers of Task Force Guardian and Task Force Hope was congressional authorization and a supplemental Appropriation. In summary, Congress authorized the Secretary of the Army to:

- repair and restore these projects. challenges speaks to the flexibility and resilience of the Corps and its contractor teams.

Task Force Guardian

The first task of the New Orleans restoration was reconstitution of the pre-Katrina HPS level of protection until a longer-term system could be put in place. This was the primary focus of Task Force Guardian. Of the 350-mile perimeter, 220 miles of structures were damaged. Most of the damage involved earth levees but the failed floodwalls presented a more complicated challenge. For example, restoring some protection in the three outfall canals was particularly challenging because of the design flaws that were pervasive in the parallel I-wall/levee systems. Repairing all thirteen miles of the canal structures would have taken much too long. Rather, it was decided to close off the entrances to the canals at the Lake and employ temporary pumps to move water from the canals into the lake. The massive levee breaches could only be repaired by restoring the levees using higher quality materials. In the end, more than 5.2 million cubic yards of borrow material, largely clay, was transported to the breach sites to reconstitute the levees.

TF Guardian efforts were managed with emergency operations procedures, mostly by the Corps' St Louis and New Orleans District personnel. Guardian was funded approximately $1B via emergency supplemental appropriations. Because of the strict 1 June 2006 deadline, Guardian deviated considerably from typical government competitive-bid contract protocols. They used no-bid and limited competition contracts to save time. Pre-vetted defense and engineering firms were deployed using existing indefinite delivery/indefinite quantity (IDIQ) federal contracts. Over 60 inspectors from the Department of Homeland Security's Inspector General's Office were deployed to audit these contracts. Guardian effectively completed its primary goal of restoring the pre-Katrina protection levels by 1 June 2006 and was disbanded in the fall of 2006 with their remaining work transferred to Task Force Hope.

In the end, TFG accomplished (In 9 Months) the following:

1) Removed from the levees, 155 boats and barges
2) Repaired 195 miles of levees (using new criteria provided by IPET)
3) Constructed 25 miles of new levees and floodwalls Built 3 interim gates on the Outfall Canals
4) Managed the acquisition of over 4.6 million cubic yards of clay for $47 M
5) Purchased 34 major pumps for $35 M
6) Completed 59 projects with 26 contractors for $557 M

The drivers of Task Force Guardian and Task Force Hope was congressional authorization and a supplemental Appropriation. In summary, Congress authorized the Secretary of the Army to:

• repair and restore these projects.

• accelerate the completion of unconstructed portions.

• armor critical elements; and

• raise levee and floodwall heights where necessary and enhance existing projects.

The end objective was to achieve the certification required for participation in the National Flood Insurance Program, hence the ability to mitigate a 1 in 100-year storm and wave environment. These objectives were to be achieved by 2011 for the principal structures and components. Additional time beyond 2011 was allocated for completing the armoring. Figure 4 provides a graphical perspective of the scope of the HSDRRS overall plan.

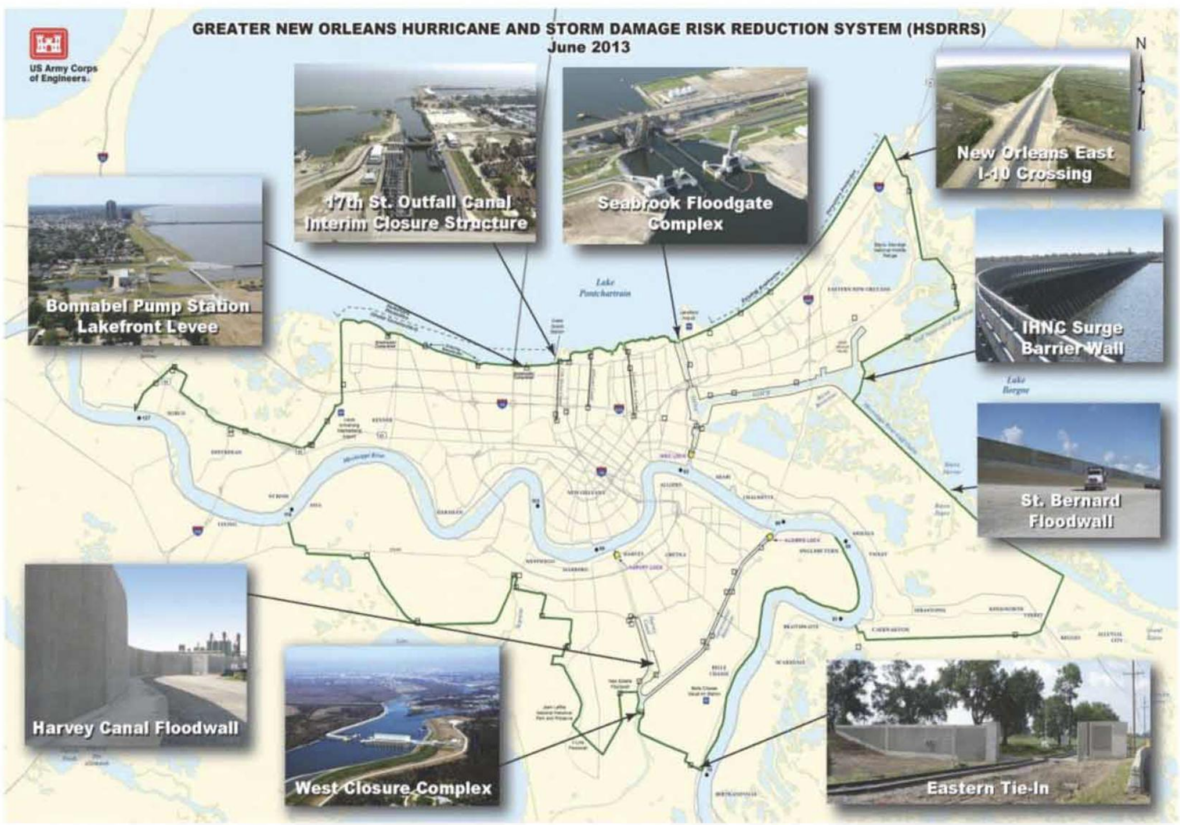

Figure 4. Map showing the major components for the Hurricane Storm Damage Risk Reduction System. This included considerable improvements and elevation of existing levee and floodwall sections that did not fail during Katrina. (Source: U S Army Corps of Engineers)

The Corps addressed these objectives by establishing them as the highest priority of the agency and establishing a management structure to facilitate what was to become the largest project ever constructed by the Corps. The management structure consisted of two task forces under the direction of the Corps' Mississippi River Division, Task Force Guardian and Task Force Hope. It should be noted that during this time frame, the Corps and the Mississippi River Division were also challenged by the occurrence of Hurricane Ike in 2008, hurricane Ida in 2009 and the great flood on the Mississippi River in 2011. Each of these events significantly impacted the New Orleans region. Coping with these Repaired 4 closure structures

Task Force Hope and the HSDRRS

Katrina spurred a major shift in philosophy, from 'Protection' to 'Risk Reduction'. It was recognized that the term protection was often mis-perceived by the public, as absolute and fail-safe. However, absolute protection is not feasible. Going forward the public needed to understand that regardless of the mitigation in place, there is always a chance of the system failing. Risk, expressed as expected annual losses, provides a metric that includes both the chance of something happening and the magnitude of the consequences. Hence, there is always a chance of failure, and you can never achieve zero risk.

In the case of the New Orleans Hurricane and Storm Damage Risk Reduction System, the risk reduction objective was a major shift in philosophy. Risk reduction focused on reducing the likelihood of losses, with the realization that there will always be some chance of flooding and losses from potentially larger and statistically likely storm events regardless of what mitigation measures are deployed. That remaining potential loss is defined as the residual risk.

The lessons learned through the IPET forensic and risk analyses and the Corps of Engineers applications of that knowledge in Task Force Guardian were leveraged into the design and construction of the HSDRRS. The HSDRRS was a first in many aspects for US flood mitigation efforts, one was using probabilistic quantification of the flood hazard. This approach used joint probability analysis methods, incorporated new failure modes and fragility analyses to examine the probability of structural failure, and explicitly included uncertainty in consideration of structure design. 'Structural resilience' was added to compensate for the uncertainty associated with overtopping. Differences from the past included defining the hazard in terms of surge and wave elevation likelihoods, estimating structural fragility and uncertainty individually for each major section of the perimeter and considering resilience measures to reduce the potential for catastrophic failure from overtopping. This was a new ball game for the Corps and the Nation.

Organization: Task Force Hope was the focal point for managing the HSDRRS effort. The Corps assembled an ensemble of Districts and special organizations in association with TF Hope to parse out the multitude of efforts needed to accomplish the work within the time frame allotted by Congress. Six District Offices were assigned roles for managing components of the work, along with the Protection Restoration Office (PRO) and Hurricane Protection Office (HPO). The HPO and PRO were responsible for oversight of different sections of New Orleans. Given the broad spectrum of the districts and contractors involved, the Corps had a large and diverse talent pool to address the huge workload. At its peak up to 3500 Corps employees were working under this umbrella. Congress provided $14.7B of emergency supplemental funding for the HSDRRS and specified that the HSDRRS should be capable of dealing with a 100-year surge, have a design life of 50 years and be completed by 2011. It also specified that additional resilience should be incorporated to guard against catastrophic failure if structures were subjected to conditions beyond their design criteria.

The dimensions of the challenge include rehabilitating and upgrading 350 miles of structures, 481 transitions (from one type of structure to another), 590 flood gates and the upgrading of the entire interior drainage system in New Orleans and the bulk of the pumping stations. On the West Bank, the bulk of the intended original HPS structures had not been built. On the East Bank, many miles of I-walls (which failed in numerous location) were being replaced by the much more capable T-wall systems.

Two projects represented major $1B plus efforts. The Lake Borgne Surge Barrier on the east (Figure 5) where the Inner Harbor Navigation Canal intersected with Lake Borgne, was approximately two miles long and required 60 ft deep foundations and a 26 ft barrier above water. The West Closure Complex (Figure 6) on the southwest corner of New Orleans has the largest drainage pumping station in the world, coupled with a 255 ft sector gate, each half weighing 750 tons, with an ability to open in 15 minutes. The West Closure barrier was designed to handle up to 16 ft of surge.

Figure 5. The Inner Harbor Navigation Canal Surge Barrier at Lake Borgne was one of the largest in the world and was executed using the largest Design-Build contract in the Corps' history. Total cost exceeded $1B. This structure has a foundation 60 feet deep and rises over 26 feet above normal water levels. (Source: U. S. Army Corps of Engineers)

Figure 6. This image shows the West Closure Complex. These structures prevent high water entering the Harvey and Algiers Canals from the Gulf on the west side of New Orleans. It includes the world's largest drainage pump station and the nation's largest gated structure spanning 225 feet with two 700-ton sector gates. (Source: U S Army Corps of Engineers)

The HSDRRS became the first major coastal water infrastructure system with risk-informed design. It was also a true system approach, preventing catastrophic flooding through a synchronized network of massive barriers, pumps, gates and reinforced earthen levees, providing a cohesive system of systems.

Design of the HSDRRS was accomplished with Corps and contractor teams for various major components. An Expert External Panel reviewed the Greater New Orleans Hurricane and Storm Damage Risk Reduction System Design Guidelines. This peer review ensured that consistent state-of-practice techniques were used. A final Independent External Peer Review: Design Review Report, was produced through Battelle Memorial Institute. Figure 7 portrays the resulting performance of the "as built" HSDRRS derived from the IPET risk modeling for the final system. The figure shows the expected 500-year flood depths for New Orleans, most of the areas shown as flooded are wetlands that are designed to reduce flooding in the inhabited areas.

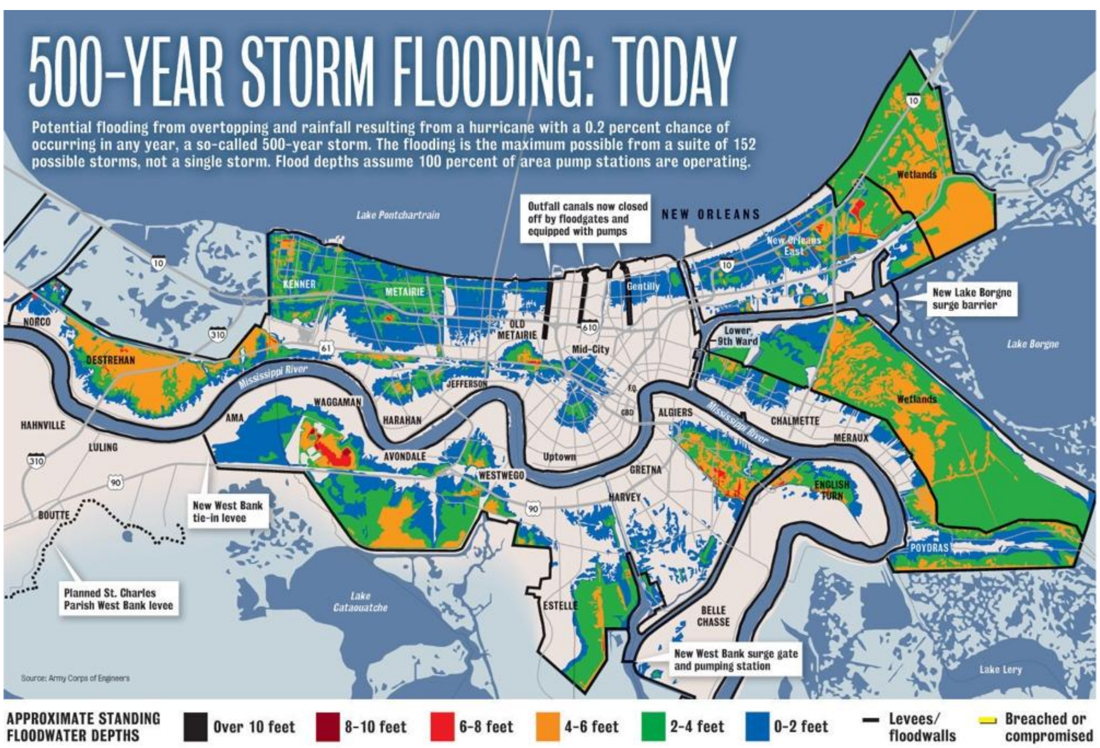

Figure 7. This map shows the expected flooding from a 500-year storm surge with the HSDRRS in place. Most of the flooded areas are wetlands designed to flood. The HSDRRS reduced risk of loss of life by 98% and economic losses by 86%. (Source: Times Picayune)

PM initiatives: The HSDRRS comprised 481 construction contracts facilitated by the network of Corps Districts and Task Force Hope sub-entities. While each contract had individual PM attention, many of the contracts were aligned as parts of larger components of the HSDRRS. There were several fundamental assumptions that significantly expedited the simultaneous conduct and completion of these efforts. First was the assumption to limit new construction to the established footprint of the HPS, dramatically reducing the time-consuming process for real estate actions. The Corps also adopted early partnering to forge common understanding and partnering agreements between all providers and relevant agencies for the larger contracts. The Corps also used "Executive Teaming", involving senior leaders from government and contractors to resolve project management and construction issues as they arose. Best Value and Design-Build contracts were implemented for the major projects to reduce the overall time required.

Compliance with NEPA is typically very time consuming. The U.S. Army Corps of Engineers used NEPA Emergency Alternative Arrangements, authorized by the Council on Environmental Quality (40 CFR 1506.11) to expedite the post-Katrina Hurricane and Storm Damage Risk Reduction System (HSDRRS). The Corps utilized the following:

- **Individual Environmental Reports (IERs)**: Used to evaluate impacts on smaller, project-by-project geographic units rather than the entire system at once.
- **Public Involvement & Transparency:** Draft IERs were posted online for 30-day public review periods, and frequent public meetings were held to maintain community engagement.
- **Comprehensive Environmental Document (CED)**: Once individual projects were evaluated, a CED was compiled to assess the cumulative environmental impacts of the entire HSDRRS.

The last time-oriented initiative was to delay implementation of resilience measures until after the 2011 completion of the main HSDRRS structures. Resilience in this case was gained by armoring the back sides of levees to prevent scour from overtopping, the principal cause of structural failure during Katrina. This was necessary because of the need to complete the primary construction before adding the armoring. The armoring type was tailored to individual sections based on modeling and primarily used augmented natural plantings.

Secret Sauce: The PM approaches used for the HSDRRS mirror many of those cited for the IPET. While the nature of the HSDRRS work was significantly different from that in the forensic analysis, the capabilities required to compress timelines and maintain credibility were similar. TF Hope had the additional constraint of integrating the new knowledge and criteria developed through IPET with the ensemble of legacy design and construction guidance and best practices. IPET had considerably more freedom to innovate.

Must Haves

Purpose: The need for a long-term solution to risk reduction for New Orleans was blatantly clear. The next major hurricane could come at any time. The importance of New Orleans as an economic and cultural hub, both regional and national, was obvious.

Resources/Talent: The Corps had a rich tapestry of talent for planning, design and construction projects. The dedication of the entire Mississippi Valley Division and its Districts provided a large pool of talent to draw from, and their use of common guidelines and practice facilitated teamwork and efficiency. The relationships of the Corps Districts with major contractors in their mission areas also facilitated partnering. Congress provided $14.7 B upfront which was a huge factor in being able to execute and to attract contractors for the work.

Plan: Blending 481 contract efforts into a comprehensive system within the time frame of the overall effort was facilitated by the formation of Task Force Hope and the subordinate organizations to parse out responsibilities and facilitate continuous collaboration across the scope of the HSDRRS efforts. Using new contracting tools tailored to reducing time was a significant advantage, as was the emphasis on partnering for issue resolution during construction.

Should Haves

Total Alignment: The Corps had total vertical and horizontal alignment on the HSDRRRS. From Congress to the Corps, across federal agencies and with state and local governments. Signing the required partnering agreements with local sponsors was perhaps the biggest challenge given the new policy of cost-sharing.

Transparency: The design Guidance and overall HSDRRS plans were published for public awareness. The Corps held over 500 public engagements during the design and construction of the HSDRRS. The use of new criteria and methods became a driver for updates of key Corps planning and engineering guidance and policies.

Policy and Guidance Flexibility: The ability to tailor contract tools to individual contracts, use of design-build and best-value contract vehicles and the waiver for using the alternative NEPA compliance methods were significant "time machines" for executing the massive amount of construction.

Analysis Assets: IPET teams remained intact during the design and early construction stages of the HSDRRS and provided analysis for Task Force Hope as requested.

Continual Review and Validation: Validation of the HSDRRS design criteria and the designs themselves were provided by Peer Review Panels facilitated by The Water Institute of the Gulf and Battelle Memorial Institute.

What about the Future?

A paper recently published in the Water Policy Journal (Reference 8) highlighted the many changes in analysis and mitigation measures stimulated by Hurricane Katrina. Many of those changes have been highlighted here. The larger question is how well does the current methods and guidelines fit the future? In the opinion of the authors, not well. The "not well" judgement is largely based on the growing levels of uncertainty that pervades all aspects of weather driven events, the dynamics of populations and changing societal needs and priorities.

Weather events have trended towards being more frequent and more severe. Development continues to occur in vulnerable. The traditional practice of using historical records to define hazards and planning projects for extended lifetimes (e.g., 50-year project life) coupled with societal dynamics is no longer a credible approach. Given the persistence of these trends, large infrastructure projects will have to adopt a different paradigm. The question is, what should project formulation and management look like in the future?

Some of the obvious challenges will be 1) the dwindling capability to forecast future conditions using probabilistic processes, 2) new mechanisms to accommodate increased uncertainty in conditions and processes now simplified by assumptions of stationarity, and 3) integrating the ever-changing needs of society.

The Netherlands, in their recent "Delta Program" addressed the need for a long-term strategy to adjust to the uncertainty of climate and land management. In recognition of the above challenges, they shifted to a philosophy of incremental adaptation, allowing them to adjust to change as it happens rather than attempting to generate infrastructure and management paradigms that will stand the test of time in one step. They achieved a reasonable foundation for this approach by using scenarios to better understand what demands will be placed on their water infrastructure for a range of potential future environmental and societal conditions and requirements. The result was a quantitative assessment of their current infrastructure and plans for incrementally dealing with the future. They now have a plan for an initial upgrade to their current structures and management practice, and insight into the next logical amendments that will be required if conditions and/or needs continue to change. This provides a more reasonable path for coping with change and precludes the need to do long-term forecasting and construction to meet a future situation that may not represent what really occurs.

Adopting adaptation means replacing many of the established criteria and processes for design, construction and resourcing. Examining what Project Management might look like under this or other new approaches is prudent and deserves attention.

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About the Author

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Lewis E Link, PhD, is Senior Research Engineer for the Department of Civil and Environmental Engineering and a Senior Fellow, Project Management Center for Excellence, University of Maryland, USA. Dr. Link received a BS degree in Geological Engineering from N C State University, an MS Degree in Civil Engineering from Mississippi State University and a PhD in Civil Engineering from Pennsylvania State University.

He worked for the U. S. Army Corps of Engineers for 34 years, culminating as the Director of Research and Development and Chief Scientific Advisor. Upon retiring in 2002 he joined the Department of Civil and Environmental Engineering, University of Maryland, teaching natural hazards risk and resilience in the Honors College.

After the devastation of New Orleans by Hurricane Katrina, he served as the Director of the Interagency Performance Evaluation Task Force, conducting a comprehensive assessment of Katrina and what happened and why. This work laid the technical foundation for the immediate temporary fixes to the over 200 miles of structures damaged by Katrina and the design and construction of the $15B risk reduction system put in place to provide long-term sustainability of the New Orleans area.

He served as the U.S. representative to the International Advisory Commission for The Netherlands, addressing the threat of long-term climate change to that nation. Dr Link served on the Coastal Engineering Research Board for the U.S. Department of Defence, is currently a Contributing Editor for The Military Engineer, Society of American Military Engineers and on the Board of Directors of Taylor Engineering. He was elected to the National Academy of Construction and received the MacGraw Hill – Engineering News Record Award of Excellence and The Army Engineer Associations Gold Order of the DeFluery Medal. He has served on numerous National Research Council, National Science Foundation and American Society of Civil Engineers technical panels and committees in the United States.