SPECIAL REPORT

DEFENDING NEW ORLEANS

Eight years after Hurricane Katrina struck, the New Orleans region is being ringed by a more than $14-billion system of stronger and higher levees, improved floodwalls, and new storm surge barriers that the U.S. Army Corps of Engineers says provides the best defenses against hurricanes that the region has ever known. This special report examines what was constructed, how it is expected to work, and why various experts and groups have such strong feelings pro and con about the new system.  

By Robert L. Reid

Eight years after Hurricane Katrina slammed into the levees and floodwalls that were supposed to protect the city of New Orleans, causing multiple breaches that flooded much of the region for days and even weeks, the U.S. Army Corps of Engineers is completing a new line of defense for New Orleans that features miles of raised, reconstructed, and reinforced levees and floodwalls, along with enormous sector gates and surge barriers, including what is believed to be the world’s largest drainage pump station and a nearly 2 mi long barrier structure that was the largest civil works project ever undertaken by the Corps. The new physical infrastructure, together with changes in procedures and other improvements, were designed to make the city safer than it’s ever been.

But even with a budget of more than $14 billion—of which $10.4 billion had been spent at press time—the Corps readily admits that this new system still does not actually protect New Orleans.

Instead, as its name implies, the new Hurricane and Storm Damage Risk Reduction System (which goes by the unwieldy acronym HSDRRS, pronounced “HIZ-ders” by some) is designed primarily to reduce the risk that the residents of New Orleans face from storm surge and flooding if and when another major hurricane strikes the region. Prior to Katrina, the levees and floodwalls that surrounded New Orleans were referred to as a hurricane protection system, but that designation created “a false sense of security,” notes Colonel Edward R. Fleming, the commander of the Corps’s New Orleans District during the construction of much of the HSDRRS. As he explains, “A
of major civil works. The engineering, financing, construction, and even purpose it represents a tremendous change in the Corps’s approach to “protection.” For the Corps’s New Orleans District, at least, adopted “a whole different mind-set,” he stresses. Fleming believes that the Corps has learned critical lessons from Katrina, and why, having adopted “protection” as the word, has adopted “risk” for the people of the Big Easy, Fleming says. And this is why, having learned critical lessons from Katrina, the Corps has adopted “risk,” he stresses.

The change is more than a semantic switch away from “protection.” For the Corps’s New Orleans District, at least, it represents a tremendous change in the Corps’s approach to the engineering, financing, construction, and even purpose of major civil works.

Fleming declared the HSDRRS “complete” in May after a series of practice drills at several of the new system’s major facilities in preparation for the 2013 hurricane season. He turned over command of the New Orleans District to Colonel Richard L. Hansen later that same month. Like “protection,” however, the designation “complete” also must be explained because certain critical construction projects for the system are still in the works. Of prime importance, the levees are not yet armored and construction has just begun on a series of permanent pump stations and closures to replace interim facilities at three outfall drainage canals along Lake Pontchartrain. But the system is complete in the sense that it is now capable of withstanding the surge from a storm that has a 1 percent chance of being equalled or exceeded in any given year, also known as a 100-year storm. The ability to withstand a 100-year storm is the standard used by the Federal Emergency Management Agency to certify the region for participation in the National Flood Insurance Program; the Corps has submitted a National Flood Insurance Program levee system evaluation report on the new levees to the Federal Emergency Management Agency, as required, but at press time certification from the program had not yet been granted.

The new system will actually defend the New Orleans region today at a level above a strict 100-year standard, Fleming notes, given that it was designed to accommodate the storm surge of a 100-year event over the next 50 years. The design took into account the expected rise in sea level as well as the subsidence of land over those five decades. Moreover, the planned armoring of the new levees will be designed to offer the resilience necessary to survive the storm surge of a 500-year event. The armoring of the new levees is key to the Corps’s efforts to provide the resilience to withstand a 500-year storm, notes Fleming. Although the levee and floodwall elevations are designed to the 100-year storm standard, “if we get a 500-year storm and get overtopped, there will be flooding,” Fleming concedes, “but you’re not going to get a levee and floodwall failure or the breaches like you would have before.”

That idea is critical to the Corps’s new approach to risk reduction. New Orleans has often been flooded during major storms, but the water was simply pumped out afterward. Considerable damage resulted, but there was not the city-wide devastation that occurred during Katrina when the levees and floodwalls were breached, which meant there was no way to stop the water or send it back out again.

The new system is also considered complete because for the first time since work began in the aftermath of Katrina, no temporary closures will be needed to secure construction openings during future storms because those openings have now all been closed, explained a May 30, 2013, issue of Task Force Hope’s Status Report Newsletter. (Task Force Hope is the name of the Corps office that is responsible for oversight of the HSDRRS program.)

As the clarification of such terms as “protection” and “complete” should indicate, however, little concerning the HSDRRS and post-Katrina New Orleans has been simple or easy. For example, the new system was tested in August 2012 by Hurricane Isaac and performed exactly as designed, according to Mike Stack, Jr., P.E., the New Orleans District’s chief of emergency management (see “New Orleans’ Defenses Weathered Isaac Very Well,” Civil Engineering online edition, September 25, 2012, http://www.asce.org/CEMagazine/Article.aspx?id=25769811641&terms=mike+stack+hurricane+isaca). But instead of being able to breathe the proverbial sigh of relief, the Corps faced criticism because while the new defenses had protected people and property within the perimeter system from Isaac’s surge-related flooding, it was contended that the HSDRRS might have worsened the flooding in certain regions outside of that system, including portions of Plaquemines and St. John the Baptist parishes that had not experienced flooding during Katrina.

And while many local stakeholders interviewed by Civil Engineering for this special report did agree with a statement by Fleming that “the system that’s in place right now is the best system that New Orleans has ever seen, clearly better than it was before Katrina,” they also expressed strong reservations about individual aspects of that system. In particular, they questioned the adequacy of the 100-year standard itself, a standard that many have noted might not even prevent
Performance Evaluation Task Force (IPET), which was established to assess the performance of the hurricane protection system. The ERP conducted an independent technical review of the findings of the Corps-sponsored Interagency Vulnerability and Improving Mitigation and Preparedness. New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability, according to a 2009 report by the National Academy of Engineering and the National Research Council entitled The New Orleans Hurricane Protection System: Assessing Pre-Katrina Vulnerability and Improving Mitigation and Preparedness. Likewise, ASCE’s Hurricane Katrina External Review Panel (ERP) declared the 100-year standard “unacceptable” in an April 15, 2008, letter to Lieutenant General Robert L. Van Antwerp, Jr., PE., then the Corps’s commander and chief of engineers. The ERP conducted an independent technical review of the findings of the Corps-sponsored Interagency Performance Evaluation Task Force (IPET), which was established to assess the performance of the hurricane protection facilities in New Orleans and southeastern Louisiana during Katrina. Noting that the 100-year storm standard, even with a 500-year flood standard, means that there is a 10 percent chance every 50 years of Katrina-like catastrophic flooding and “loss of property, life, and lifestyle,” the ERP’s letter concluded that “this level of risk in the New Orleans area [is] far above that employed for other engineered structures.”

HOW THE CORPS MANAGED to construct the HSDRRS despite numerous challenges and impediments, the technical details of the system’s major features and facilities, and how these efforts have been perceived and received, as well as what the Corps might have to do next in terms of risk reduction in southeastern Louisiana, will be explored in this special report, for which I visited several of the major pieces of the new system, spoke with the Corps’s leaders and project managers and with its critics, and pored over stacks of reports, letters, news articles, the minutes of government agency meetings, and other documents.

The consensus among those interviewed is that the HSDRRS should enable the residents of the Big Easy to rest a little easier during future hurricane seasons. However, they note that such an ambitious infrastructure project will never really be finished. Even the new levees will need additional lifts over time, and in fact work has already been done on one section. Moreover, some feel strongly that critical aspects of the system were not considered and potentially even reworked.

To understand the facilities that were constructed for the HSDRRS and why and how the Corps’s work on this project differed greatly from the many other efforts undertaken by its engineers, it’s best to start with a reexamination of what went wrong during Katrina, especially since many of the actions and decisions made before and during that storm helped to guide the decisions about the design, construction, and funding of the new system.

First, it’s important to remember that much of the New Orleans region is located below sea level and that flooding during hurricanes is hardly a new problem there. But during Katrina the water could not simply be pumped out because of a series of failures that included breaches in the region’s flood protection defenses at about 50 distinct locations and problems with the region’s pumping stations, according to the ERP’s 2007 report, The New Orleans Hurricane Protection System: What Went Wrong and Why (see “The ERP Report: What Went Wrong and Why,” Civil Engineering, June 2007, pages 54–61, 73–76). Thus, the devastation during Katrina was a “unique” natural disaster in which “much of the destruction was the result of engineering and engineering-related policy failures,” the ERP report concluded.

In particular, although many of the failed levees had been overtopped by floodwaters that eroded the levee material, at least seven of the major breaches were caused by the failure of the concrete floodwalls known as I walls that had been constructed atop levees that were not armored or otherwise protected against erosion. These included I walls at two of the outfall canals on Lake Pontchartrain—the 17th Street Canal and the London Avenue Canal—which failed while the floodwaters were still about 5 ft below the top of the walls, “well below the design water level,” the ERP report noted. Moreover, at the 17th Street site, the engineers “responsible for the design of the levee and I wall overestimated the soil strength,” the ERP stated.

Potential problems with I walls in general had been disconcerted by the Corps as far back as 1985, when a field test under high-water conditions “revealed the potential for large I-wall deflections,” the ERP said. But as “research and new information evolved in the 1980s and 1990s, the design of the existing I walls was not checked for safety and stability in the light of new information,” the ERP explained.

Elsewhere in New Orleans, Katrina showed the city’s pumping stations to be inadequately designed. The pumps lacked the capacity to handle the water levels that resulted, and the pump station buildings lacked the structural strength to withstand the wind and water forces of the hurricane, the ERP concluded. In Jefferson and St. Bernard parishes, for example, nearly all of the pump station operators had to be evacuated during the storm, which meant their pumps lay idle. The pumping stations at the south end of the 17th Street, London Avenue, and Orleans Avenue outfall canals were designed nearly a century ago to pump out rainfall but were “never strengthened or retrofitted” to resist the hydraulic loads of storm surges even though these facilities had come to be considered part of the region’s hurricane protection system, the ERP noted.

During the design of the pre-Katrina hurricane defenses, Congress had authorized the Corps to protect the region against “the most severe combination of meteorological conditions that are considered ‘reasonably characteristic’ of the region,” which for the Corps has historically meant a hypothetical storm called the standard project hurricane, the ERP noted. But “reasonably characteristic” implied a storm that the ERP considered to be less extreme than, say, the probable maximum hurricane as defined by the National Weather Service. As a result, the pre-Katrina New Orleans hurricane defenses were “undesigned,” the ERP concluded.

In fact, when Katrina struck, the New Orleans region’s hurricane protection system was actually “a system in name only,” the ERP said, restating a conclusion reached by the members of the IPET, as well as by Lieutenant General Carl A. Strock, PE., Dist. D.NE, M.ASCE, now retired, who served as the Corps commander and chief of engineers during Katrina and is now employed by the international engineering firm Bechtel. Originally designed to provide flood protection and remove rainfall from the city, the presystem was in reality “a disjointed agglomeration of many individual projects that were conceived and constructed in piecemeal fashion. Parts were then joined together in ‘make-do’ arrangements,” the ERP explained.

Moreover, because of the congressional budgeting process, “the stream of funding for the New Orleans hurricane protection system was irregular, at best,” the ERP stated. “If a project was not sufficiently funded, the Corps was often required to delay implementation or to scale the project back.” As Fleming explains, the Corps does not receive an annual budget from Congress; thus, he says, “we cannot just go out and build things.” Instead, the Corps must acquire authorizations and appropriations—permission and funding—for each project on a case-by-case basis. In the New Orleans region that approach was followed over the past six decades, the first hurricane protection project for the region being authorized in the mid-1950s, Fleming notes. Unfortunately, it produced an
Unfinished line of defense that by August 2005 was roughly 60 percent complete for parts of the city on the east bank of the Mississippi, which cuts a winding course through the New Orleans region, and only about 40 percent complete for the neighborhoods on the west bank, Fleming says. Furthermore, even what had been constructed was not always adequate. The levees susceptible to overtopping had not been armored, and the levees and floodwalls had not been designed with sufficient additional height to accommodate the “well understood” subsidence in the region, the ERP noted. A lack of coordination among the various federal, state, and local agencies responsible for the construction, operation, and maintenance of segments of the hurricane protection system—including the pre-Katrina levee boards, some of which also ran non-flood-protection operations as airports, parks, and casinos—also meant that certain floodgates were out of service and left open during Hurricane Katrina because of repairs, allowing water to flood through them unimpeded, the ERP said. In other locations, the openings into key waterways or drainage canals had no protection at all against Katrina’s storm surge. To the north of New Orleans, the Lake Pontchartrain side, these openings included the mouths of the outfall canals and the Inner Harbor Navigation Canal, a 5.5 mi long channel that links the lake to the Mississippi. Likewise, there was nothing stopping storm surge from Lake Borgne on the eastern side of the city at the confluence of the Mississippi River–Gulf Outlet (MRGO)—designed as a shortcut for navigation between the Gulf of Mexico and the port of New Orleans—and part of the New Orleans portion of the Gulf Intracoastal Waterway, a navigable inland waterway that stretches from Florida to Texas. These unstructur- and existing levees, which impinged the region’s defenses during Hurricane Gustav, in August 2008, and applause the extensive efforts that were undertaken by officials throughout southeastern Louisiana and in New Orleans itself to evacuate vulnerable populations prior to Gustav. To correct one of the hardest assessments from the IPET and ERP reports, the Corps sought to create an actual system that would defend the New Orleans area against hurricanes. This risk reduction system features a 133 mi perimeter of new, strengthened, or raised levees, along with floodwalls, gated structures, and pumps. The Corps’ efforts have been so comprehensive, Fleming adds, that some sort of work—raising, strengthening, repairing, or replacing—has been done to “every inch of this perimeter system.” The scope of the HSDRRS increases to 350 mi when all of the levees and floodwalls within the perimeter and in other planned projects in the region are included, and the new system also features a different type of floodwall, known as a T-wall, to correct the problems caused by the earlier I walls. Existing structures, including gated barriers and pump stations, were strengthened and new facilities were constructed, especially where there had been no defenses at all against storm surge. And everything is tied into the existing levees on both banks of the Mississippi so that, in combination with new operating procedures that have been adopted, “we’ve worked very hard to make sure that it is in fact a system,” explains Fleming. Rather than relying on just that single “standard project hurri- cane” to determine the details of the new system, the Corps also took a new approach in analyzing the potential hazards, one based on IPET research that modeled 152 different possible hurricanes of different intensities. The modeling also looked at different tracks and explored how these storms might affect the new perimeter system, explains Mike Park, the chief of Task Force Hope. Using the best hydraulic modeling tools available at the time, the IPET team studied storms that ranged from 50- to 5,000-year events and considered such variables as water levels, maximum winds, storm surge speed, and direction. “It was a much more comprehensive definition of the hazard than anyone has ever had before to design a system like that,” notes Ed Link, Ph.D., M.ASCE, a senior research engineer in the civil and environmental engineering department at the University of Mary- land and the leader of the IPET team. As with most civil works projects, the cost of the HSDRRS, more than $14 billion, was split between the Corps and the local sponsor—the State of Louisiana through its Coastal Protection and Restoration Authority. Approximately $9.6 billion was funded completely through federal monies, while approximately $4.9 billion was covered through a cost-sharing arrangement, the federal government paying 65 percent and the local sponsor 35 percent. The Coastal Protec- tion and Restoration Authority will also be the official owner of the projects once they are all completed and turned over to local control, although the operation and maintenance of the facilities, as well as portions of the state’s share of the construc- tion costs, will eventually be the responsibility of the SLFPA–East and the SLFPA–West. In the New Orleans region, the HSDRRS consists primarily of two sets of projects that form distinct hydraulic units separated by the Mississippi—hydraulic units being developed portions of the region that require protection from storm surge. On the west bank of the Mississippi, in the hydraulic unit that the Corps formally refers to as the West Bank and Vicini- ty, the projects focused on risk reduction facilities and defenses in portions of St. Charles, Jefferson, Orleans, and Plaquemines parishes. The major civil works projects constructed here include the Gulf Intracoastal Waterway–West Closure

The Bayou Bienvenue 11 ft panel structure at the Lake Borgne surge barrier measures 56 ft wide by roughly 80 ft tall. It is designed primarily for recreational boats, flooding that caused more than 1,100 deaths and sank the

The Lake Borgne surge barrier features a 150 ft wide sector gate with two steel-framed segments that swing open and closed to provide navigation for vessels of shallow draft.
The Corps is also in the process of raising and improving certain riverine levees along the Mississippi between river miles 70 and 85 as part of the 100-year risk reduction system, notes Fleming. The earthen levees and concrete floodwalls along this 15.5 mi section of the river could be improved because hurricane storm surge is the governing event in these locations. Levees improved in this way are referred to by the Corps as colocated. That means the height of a levee to reduce the risk from storm surge in a 100-year event is higher at that location than the levee height required to protect people and property from riverine flooding. Elsewhere, the Corps cannot perform HSDRRS work on levees if riverine flooding is the governing event, one of the many complicated restrictions governing the work of the Corps, notes Fleming, who adds that the exact location of that distinction between riverine and storm surge flooding will probably move farther north on the Mississippi as sea levels rise.

In addition to being raised, the HSDRRS levees and floodwalls along the Mississippi will be designed to offer greater resilience and longevity and easier maintenance, their slopes chosen so as to reduce wave run-up, adds Garnet Hartlin, M.ASCE, a Corps project manager.

In one area, a roughly 5 mi long levee section in New Orleans East following the Gulf Intracoastal Waterway east of the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier was reconstructed roughly 10 ft higher than it had been before Katrina and ultimately reached a height of approximately 28 ft. Known as the LPV-111 project (“LPV” denoting the Lake Pontchartrain and Vicinity hydraulic unit), the new levee was so large that the engineers were especially concerned about consolidation of the levee material and subsidence, Park says. Prior to the construction of the larger levee section, the foundations were buttressed via a method known as deep soil mixing, auger drills being used to mix cement and water slurry into the soil to form a stabilizing column. Believed to be the largest such project in the United States, the deep soil mixing at LPV-111 involved 1.7 million cu yd of mixed material in the construction of more than 18,000 columns, each approximately 5 ft in diameter and 67 ft long on average, along the length of the levee.

The Corps used the same technique at the NAS reassessment levee section along the 17th Street and Orleans Avenue outfall canal. Another subsurface stabilization project in New Orleans East, where the soils are weak and marshy but the new levees required extensive footprints, involved the construction of a sand blanket several feet thick atop the footprints of the future levee and the insertion through that sand layer of approximately 250,000 Wick drains, notes Park. The corrugated Wick drains serve to preconsolidate the soil, creating “a pathway for groundwater to rise to the surface as we compress this under the sand blanket load, essentially pressing the water out,” Park explains. The Wick drain system seems to be yielding benefits, Park adds, because little loss of elevation has been observed in the levees at which that technique was used.

To address the problem of unarmored levees that were overtopped and failed during Katrina, the Corps plans to armor “virtually every point around the perimeter... in some fashion,”
explained René Poché, a public affairs specialist for the Corps, who responded in writing to Civil Engineering questions. This armoring will be installed especially in such critical areas of the HSDRRS as the protected sides of levees, the transition points between levees and structures, and the points at which pipelines and utilities cross levee alignments, Poché explained. Although the final decisions on exactly which sections of levees will be armored and which methods will be used have not been made, the Corps has been testing different approaches and materials over the past several years with assistance from the U.S. Army Engineer Research and Development Center, Texas A&M University, and Colorado State University, which is equipped with a full-scale, computer-controlled wave overtopping simulator. The Corps and Louisiana State University have also conducted field tests on a section of levee in St. Charles Parish involving high-performance turf reinforcement mats through which grass was grown; various methods of mowing the grass also were tested during the experiment, which was carried out in the fall of 2011.

More recently, the Corps conducted additional pilot tests involving five manufacturers of high-performance turf reinforcement mats on two 5,000 ft long levee sections, one on an east-bank levee in St. Charles Parish and the other on a west-bank levee in the area encompassing Westwego and Harvey. At press time, additional armoring tests were under way. The armoring construction contracts are not expected to be awarded until June 2014, and construction is not expected to be completed until the fall of 2016. In contrast to the cost-sharing agreements governing most of the civil works projects carried out by the Corps, the cost of the armoring project, estimated at more than $300 million, will be the civil works projects carried out by the Corps, the cost of the

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In the West Closure Complex, the nation’s largest sector gates and drainage pump station was the site of a carefully planned and constructed floodwall along an environmentally protected area.
The barrier wall itself and the gates are supported by an A-frame system that consists of more than 1,200 vertical concrete piles, each 66 in. in diameter, and more than 600 barrier piles, each 234 ft long and 36 in. in diameter. The vertical piles were driven into the marshland to a depth of 130 ft below the water level, the inclined piles were driven in at an angle of 40 degrees to a depth of 190 ft, and the two types of piles were connected by concrete caps that were precast or cast in place, according to Ragolia and information in the paper “Design and Construction of the Lake Borgne Surge Barrier in Response to Hurricane Katrina,” by Scott R. Huntsman, Ph.D., P.E., G.E., D.G.E., F.ASCE, an engineer for Shaw Environmental & Infrastructure Group, of Concord, California. Huntsman presented his paper at the 2011 Conference on Coastal Engineering Practice, which was organized by ASCE’s Coasts, Oceans, Ports, and Rivers Institute.

Shaw Environmental was the design-build contractor for the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier. Designed to act in tandem with that barrier, the Seabrook complex was constructed at the Lake Pontchartrain end of the Inner Harbor Navigation Canal just south of a railroad bridge and a highway bridge. During Katrina the roughly 350 ft wide channel here was wholly open and experienced storm surge in two directions, notes Gilmore. First, Katrina pushed storm surge northward from Lake Borgne “through this channel into Lake Pontchartrain,” he explains. “Then Katrina got past us, a little north of us, then flipped around and the storm surge came back from north to south.” This doubling back contributed to flooding in the area the Corps refers to as New Orleans Metro, which encompasses the east bank of Orleans Parish west of the Inner Harbor Navigation Canal and a small portion of Jefferson Parish near the Mississippi River. Flooding was also experienced in New Orleans East, Gentilly, the Ninth Ward—which includes the Lower Ninth—and St. Bernard Parish.

In the HSDRRS, the Lake Borgne surge barrier is designed to prevent an east–west storm surge, whereas the Seabrook complex is designed to prevent the north–south surge, Gilmore says. The Seabrook complex features a 95 ft wide sector gate with two steel-framed segments shaped like pie slices in plan that are flanked by two 50 ft tall vertical lift gates. When I visited the site toward the end of the 2012 hurricane season, the air was filled with the sound of birds courtesy of a recording designed to keep birds away so they do not nest on top of the structure, where nests would “cause maintenance nightmares,” Gilmore explains.

New sections of T walls, each roughly 900 ft long, were also constructed to tie the floodgate complex into the existing levees that line the lake to the east and west. A new gate on land also was constructed to accommodate an existing railroad line that passes the Seabrook complex.

When the new gates are closed, they and the new floodwalls provide a 16 ft tall barrier against storm surge; some of the preexisting floodwalls also were raised to match that 16 ft elevation.

Although the sector gates are designed to accommodate boats on the Inner Harbor Navigation Canal, the nonnavigable lift gates are designed primarily to ensure that water flow in the channel remains the same as before the complex was constructed, Gilmore explains.

To construct the Seabrook complex, the Corps first filled the existing scour holes in the channel, which were roughly 90 ft deep, with sand and then introduced piles, sheet piles, and cofferdams to dewater the site, Gilmore explains. The concrete structures that support the steel gates were then constructed, and the gates were brought to the site via barge. The bottom of the channel was lined with new rock for erosion control, and riprap was installed along the banks. Although the earthen levees around the floodgate complex will definitely need additional lifts periodically to ensure that the proper elevation is maintained, the concrete and steel gate structures cannot be raised easily. Thus, they were designed to provide the full 50-year design life right from the start. “So in 50 years, Seabrook should still provide that 100-year level of risk reduction,” Gilmore notes.

The $165-million Seabrook complex was designed by the New Orleans office of Bioengineering Group and the international engineering firms ARCADIS, based in Amsterdam, the Netherlands, and HNTB, based in New York City. St. Louis–based Alberici Constructors, Inc., served as the general contractor under a so-called early contractor involvement arrangement. In contracts of this type the general contractor provides certain preconstruction services concurrent with the design effort.

To the west of the Seabrook complex are the three outfall canals (17th Street, Orleans Avenue, and London Avenue) on Lake Pontchartrain for which permanent canal closures and pump stations are now under construction. Ground was broken in June, and the three facilities are expected to be completed by early 2017, explains Dan Bradley, an engineer and senior project manager for the Corps. The three outfall canals run south–north from internal pump stations within New Orleans. The canals are between 11,000 and 15,000 ft long and serve as critical elements in the city’s flood control system, especially for rainfall. Because the lake-ends of the canals were unobstructed during Katrina, storm surge rushed into them, breaching the levees and floodwalls that lined the 17th Street and London Avenue canals and flooding much of the central portions of New Orleans.

In recognition of the threat presented by the wide-open outfall canals, which have widths reaching 300 ft at their mouths, the Corps moved quickly in 2006 and 2007 to construct interim closure structures with gates and pumps that would block the mouths without impairing the drainage functions of the canals. Those interim facilities, however, had a limited life span and were not powerful enough to handle major hurricanes over the long term, Bradley says. They were also subject to extensive corrosion and required considerable maintenance. Robust and powerful permanent canal closures and pumps were therefore always envisioned to achieve the 100-year level of risk reduction at the canals, Bradley says. The $615 million-design-build project is being designed and constructed by a joint venture known as RCCP Constructors, comprising Kiewit Louisiana Co., of Metairie, Louisiana; Traylor Bros., Inc., of Evansville, Indiana, and M.R. A roughly 50 ft tall space within the West Closure Complex structure houses 11 giant pumps that weigh 70 tons apiece. The pumps were designed primarily to handle the heavy rainfalls that accompany storms.
Katrina. Instead, it draws on the lessons learned from Katrina to deal with potential flooding from future storms, says Tim Connell, the Corps’s project manager for the West Closure Complex.

"Katrina basically brought an awareness that the whole system would have to be different," he says. "We had to go beyond what we had before."

Connell notes that the insulation of the fuel tanks protects them from the elements, ensuring that fuel is available should the pumps and generators be needed. The generators are being designed with deeper foundations and in-kind pumps if the canals were ever deepened by as much as 17 ft, as envisioned under Options 2/2a, Bradley says.

The new barriers will be closer to the lakefront than the interim facilities had been. Those facilities were kept back from the lake’s edge by as much as 1,000 ft as a safety measure so that they did not displace commuters as they entered the canals, says Bradley. But the permanent closures and pump stations can be located right at the lakefront because they will be designed to better withstand both storm surge and wave impact, he says.

The new facilities will also be designed to accommodate a disagreement that exists between the SLFPA–East and the Corps over how exactly water should be removed from the canals. The SLFPA–East is in favor of deepening the three canals and adapting them so that water would flow by gravity to the new drainage pump stations at Lake Pontchartrain, thus obviating the need for interior pump stations. This approach is referred to as Option 2b. The Corps favors Option 2a, which means Tim Doody, who serves as the SLFPA–East’s project manager.

Through PCCP Constructors, the Corps is designing a system that will operate the new pump stations together with the existing interior pump stations, the Corps argues that the project is underfunded, and therefore it is petitioning Congress to study Options 2/2a, explained Pocheı́. The new facilities, however, are being designed with deeper foundations and intake basins than are currently required to accommodate Options 2/2a in case that approach is ever adopted and funded, notes Bradley. The superstructures are also being designed to be large enough to accommodate the larger motors and generators that would be necessary to operate the permanent facilities.

As part of the West Closure Complex project, the Algiers Canal section was also dredged, a nearby road was realigned, and large intake and discharge basins were dug out on respectively the northern and southern sides of the complex, says Connell. As a secondary line of defense against storm surge in the Gulf Intracoastal Waterway, a new floodwall also was constructed along the Harvey Canal section. Approximately 3.5 mi long, this new T-wall section is 14 ft high and is founded on 130 ft deep H-piles. During major storms, the Harvey Canal and Algiers Canal sections will now provide approximately 12.5 mi of detention basins for the interior pump stations, notes Connell.

One of the most challenging projects in the West Closure Complex vicinity, however, involved a 4,200 ft long T-wall structure that was constructed on a narrow strip of land just 100 ft wide along the western side of the channel just north of tiny pump stationGPIO. The site was selected because it bordered the Bayou aux Carpes wetlands area, which is protected by the U.S. Environmental Protection Agency under section 104(c) of the Clean Water Act. The Corps needed to construct the new floodwall to prevent seawater intrusion into the wetlands area. But the site was a reminder of the work site limitations, says Connell. "You understand that you didn't go past the border fence for any reason—that's the limit. You didn't clear over there, you didn't throw anything over there," he explains.

To the east of the West Closure Complex, the Corps constructed a permanent Canal Tie-In. The work included a new pump station, two 53 ft wide steel swing gates across a highway used for hurricane evacuations, and a swing gate for an adjoining railroad line. These projects included five streets and structures that cross an area known as Bayou Vertre, an elevated crossing at one highway, two railroad gates, and a sec- tion of the Gulf Intracoastal Waterway before it connects to the Mississippi River levees near river mile 118.

The Corps spent approximately $123 million repairing the existing The Tropical islets and stormwater drainage system in the New Orleans metropolitan area and an estimated $340 million in making those facilities stormproof. This work included the construction of new, elevated safe rooms, the hardening of the building structures, the installation of new generators and additional fuel capacity, the construction of perimeter floodwalls and berms, and other measures designed to prevent the conditions that forced many pump station operators to abandon their facilities during Hurricane Katrina.

Because evacuation is now seen as a major part of the new emphasis on risk reduction, the HSDRRS also features a new floodwall, as well as an elevated road and bridge over that floodwall, at the southern end of the New Orleans East Causeway Bridge. During storm surges the entrance to the bridge was used to be closed off with sandbags that were piled up against the surrounding, taller I-10, while roads were blocked to allow for evacuation. Today, with the new HSDRRS, the floodwall serves as a barrier directly across the area covered by section 404(c) and is the zone of impact. Outside the floodwall, the Environmental Protection Agency and local environmental groups, Connell notes. Working with the agency and other groups, however, the Corps developed a compromise solution: it would construct new floodwalls and levees, but not in the portion of the water level. Shielded by 16 in. thick reinforced-concrete walls and designed to withstand winds of up to 250 mph, the safe room can accommodate approximately 12 people, providing protection for people, buildings, and structures.
In the end, the answer involved not shutting the bridge at all. Instead, the causeway project involved the replacement of the original I walls with taller T walls in 40 ft sections and the construction of new, longer bridge ramps that pass over the new floodwall. The new ramps are supported on a series of concrete piers founded on piles driven to depths reaching 120 ft, explains Justin Smith, a project manager for the Corps.

The causeway project was especially challenging because of the confined area on which the work was conducted and because the numerous underground utilities, some of which had to be relocated, were not well documented, says Herr. Furthermore, complicated detours and lane openings and closings were necessary to keep the causeway in operation throughout the construction phase, and a canopy arch bearing the name of the causeway had to be preserved and then reinstated, along with new cameras to monitor the traffic flow, says Herr.

In the end, the answer involved not shutting the bridge at all. Still, every time you close it, it’s a different experience,” Turner explains. Moreover, the Corps ‘Comprehensive Environmental Document: Greater New Orleans Hurricane Levee Prompt $1.3 Million Repair.” More specifically, the Corps had always anticipated that the area would have to be monitored regularly and that additional lifts would be needed, he noted.

The malfunctioning barge gate in the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier was finally closed successfully during the practice drills in May and has been opened and closed several times since then, Poché said. A special training program was implemented for the barge gate operators, he added, noting that each time “our crew operated the gate, they became more experienced and more familiar with its operation.” Although certain sensors and gauges failed during the recent drills, those faulty systems have been replaced, and none of these problems prevented the successful operation of the barge gate, Poché stressed.

The interim closure and pump station at the Orleans Canal and facilities at the 9th Street and London Avenue connections tap into the edge of Lake Pontchartrain so that the storm surge waves would dissipate somewhat before striking them.

**The Malfunctioning Barge Gate in the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier was Finally Closed Successfully during the Practice Drills in May and Has Been Opened and Closed Several Times Since Then.**

**While Overcoming These and Other Bumps, the Construction of the HSDRRS Benefited from at Least Three Critical Developments, says Fleming.** First and perhaps most important, the HSDRRS projects were not limited by the usual short-term, incremental funding that affects so many other major civil works efforts, he explains. Instead, from late 2005 through 2008 Congress passed seven supplemental appropriation bills that totaled more than $4 billion—roughly three times the Corps’ usual annual civil works budget, notes Fleming—to fund the new system for the New Orleans area. Other Corps projects, including the ongoing dredging of the Mississippi, still had to cope with the uncertainty of not knowing from year to year how much money would be available, but this was not the case with the HSDRRS program. Even as the budget battles in Washington raised the possibility of federal government shutdowns over the years, Fleming knew he had the money he needed to work with the HSDRRS’s efforts.

In addition to the certainty it afforded those working on the HSDRRS, the guaranteed funding enabled the Corps to benefit from economies of scale and award contracts more easily, Fleming says. “We even got into the steel business,” he notes, explaining that the incremental approach would have meant awarding different contracts to various contractors, and those firms would then have had to “wait in line at steel mills” to obtain the necessary pieces, essentially competing with one another and driving up the cost of the steel or causing delays. But because the Corps knew how much money it had to work with, as well as what sort of steel it would need, “we bought a lot of steel in advance, put it in storage yard, and told the contractors ‘every time you need it, just come get it from us’,” Fleming says. It was the first time the Corps had tried such an approach, he says, and it definitely saved both time and money.

A second major development that enabled the Corps to complete the HSDRRS faster than other civil works projects involved an expedited environmental review process to meet the requirements of the National Environmental Policy Act (NEPA). If the Corps had been required to follow the typical requirements set forth in that law, especially the completion of several detailed reports that analyzed the HSDRRS projects in their entirety, it would have taken “a significant amount of time,” perhaps as much as three years, before any construction could have begun, according to the final version of the Corps’ “Comprehensive Environmental Document: Greater New Orleans Area Hurricane and Storm Damage Risk Reduction System,” which was published in May.

Typically, the Corps would have had to prepare a document of this nature years in advance of actual construction and would have dissipated, perhaps by the late 1990s or early 2000s, as the Corps knew the money it had to work with, as well as what sort of steel it would need, “we bought a lot of steel in advance, put it in storage yard, and told the contractors ‘every time you need it, just come get it from us’,” Fleming says. It was the first time the Corps had tried such an approach, he says, and it definitely saved both time and money.

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I. The New System

The system underwent a baptism by storm surge last when Hurricane Isaac, a large, slow-moving storm of low intensity, stalled over the region for roughly 45 hours. In preparation, all of the major new features of the HSDRRS were either deployed or under deployment in an actual storm, including the first closure of the sector gates at the West Closure Complex—where the site’s massive pumps also were put into action—the Breakthrough Floodgate Complex, and the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier (the barrier’s large gate was already in its closed position, but it was still under construction at the time.)

Some 300 of the more than 300 openings in the perimeter were closed, providing protection for railroads and motor vehicles and serve other purposes as well were closed for Isaac, the remaining openings along the Mississippi did not have to close because the water levels there were not considered high enough to require closure. This was explained by Stack who recounted in the Civil Engineering online article “New Orleans’ Defenses Weathered Isaac: Very Well.” Temporary closures also had to be erected in several locations at which construction work was still under way, including two sites that were not expected to be flooded because, as Stack explained and as was reported in the above article, once closed they would have blocked major evacuation routes.

During Isaac, there were several locations, especially at the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier, at which “we had not had this system in place, the old system would have been overtopped,” says Fleming. Senator David Vitter (R-Louisiana) concurs, noting in written responses to Civil Engineering’s questions that even if Isaac “didn’t fully test the system,” the new HSDRRS defenses definitely prevented significant flooding within its perimeter.

The Corps’s analysis, Hurricane Isaac with and without 2012 ISSE, was published in February 2013 and year-peer-reviewed by Battelle Memorial Institute, of Columbus, Ohio, and the Water Institute of the Gulf, based in Baton Rouge, Louisiana. Although Isaac’s “nearly 35-hour duration of tropical force winds, track, size and slow motion during heavy rainfall and resulting storm surge” made the water delivered onshore, “the Corps concluded that “the HSDRRS could not have significantly influenced inundation at communities external to the system.” Instead, the flooding of communities outside of the HSDRRS “was caused by intense and long duration storm surge due to the long duration of tropical force winds, in which some cases were aggravated by extreme local rainfall.”

In response, Vitter emphasized that there is “more important work to do” with regard to flood protection in southeast Louisiana. Many of the areas flooded during Isaac “have little to no flood protection,” Vitter stated, adding that “many of the areas were protected by either Army Corps projects that have been since ‘dramatically slowed or cancelled.’ Stressed the need for critical flood protection in areas outside the 100-year system,” Vitter called on the Corps to “expedite ongoing projects to protect those areas that were heavily flooded because of Isaac.”

Vitter has also called for reforms to the Corps designed to eliminate “unnecessary bureaucracy” and cost overruns, reduce red tape, and streamline and complete other Corps projects in the region. The senator’s proposed reforms are included in the Water Resources Development Act of 2013, which passed the Senate in May and at press time was still being considered by the House.

II. Engineering

A number of local stakeholders, as well as other engineers who have studied the new system, have both praise and misgivings regarding the HSDRRS. For example, Neil Shubin, E.D. and president of the SLFPA–East, and a regular member of the Corps over the Options 2/2a gravity flow proposal, said that the Corps might eliminate “the use of a risk analysis in determining how much of the HSDRRS should be armored for resiliency.”

In another system, the SLFPA–East unanimously voted to request that an independent external peer review group be assembled to examine and comment on both the sufficiency of overtopping rate calculations and the necessity for making risks more than just meeting a part of determining the armoring footprint,” according to the May 16 resolution.

The SLFPA–East is particularly concerned about armoring because the Corps did not initially plan to armor most of the authority’s levees with anything other than regular grass, not even metal. However, he considers the makeup of those things that were done? Yes, I do!”

Jackson notes that the SLFPA–East “fought tooth and nail on a number of issues” with the Corps, including the decision to use the Surge Barrier in place of the Corps’ Surge Barrier in place, he notes, but he recommends the use of many more to measure ground or slope movement of the levees, settlement, seepage, gaps, or any of those things (Continued on Page 8)
Defending New Orleans

(Continued from Page 67) that may be occurring on a very slow and routine basis that have the potential to undermine the performance of the system when impacted by a major storm event,” he explains. The long-term maintenance of the HSDRRS “presents a tremendous engineering challenge,” Luettich notes, “but also a tremendous engineering opportunity to really develop a system that can monitor the performance and the robustness of the system as it goes forward and gets ready to meet the next major event.”

Although the Corps has started to hand over control of certain aspects of the HSDRRS to the local authorities that will be responsible for the operation and maintenance of the new system, this has mainly involved sections of levees and floodwalls so far, notes Turner. Most of the large infrastructure facilities, especially the West Closure Complex and the Inner Harbor Navigation Canal–Lake Borgne Surge Barrier, are still being operated by the Corps because they are only about 99 percent complete rather than 100 percent, explained Poché. These facilities will probably be turned over to the local authorities by the end of the year, says Turner, who commends the Corps for its commitment not to turn over any of these major facilities in the midst of the current hurricane season.

Of course, once such organizations as the SLFPA–East do assume responsibility for the HSDRRS features within their jurisdictions, they will have to find a way to pay for the new defenses year after year. Doody estimates that operating and maintaining the risk reduction facilities will cost the SLFPA–East roughly $16 million annually and that perhaps another $20 million annually will have to be expended over the next several decades to help pay the local share of the construction cost.

Both Doody and Barry contend that many of the hurricane defenses constructed in the New Orleans region, including aspects of the HSDRRS, involve projects that provide benefits to the rest of the United States, for example, protecting navigation channels for commerce throughout the region. Yet the local residents end up bearing the costs that arise both in operating and maintaining the systems and in recovering from the losses that are sustained when the levees and floodwalls along those navigation routes fail, they explain.

A prime example involves the gated structures that have been constructed along the Gulf Intracoastal Waterway. “The Corps says that is flood protection,” Doody muses, “but we say it’s a hole in our flood protection.” Such systems should, like the Corps-operated locks along the Mississippi, be owned and operated by the Corps, Doody says.

The costs of operating and maintaining a large system like the HSDRRS become “a kind of unfunded mandate” for the local authorities, notes Thomas D. O’Rourke, Ph.D., M.ASCE, who holds the Thomas R. Briggs Professorship in Engineering at Cornell University and also served on the National Academy of Engineering and National Research Council team that produced the 2009 report. Levees, in particular, are a “wasting asset” in the New Orleans region because of the ongoing local settlement, regional subsidence, and erosion and thus require expensive maintenance and improvements over time, O’Rourke says. New Orleans, which still has not returned to its pre-Katrina population levels, faces the additional challenge of finding the tax base to fund the costs of such maintenance, he adds. O’Rourke predicts that some sort of financial assistance from the state or federal government may be necessary.

O’Rourke praises the Corps’s efforts in the construction of the HSDRRS, but he also stresses that “we have residual risks here that we just don’t fully understand...so I always call this a work in progress.”

Indeed, many of the experts interviewed for this special report say that much work remains to be done to improve hurricane defenses in the entire southeastern Louisiana region. The efforts will include restoring wetlands and barrier islands, elevating houses and other structures, adopting new approaches to land use planning, and even considering whether people should be living in certain parts of New Orleans. As O’Rourke notes in voicing a sentiment expressed by many, “Nature’s going to control, ultimately, and bring up some event that exceeds the capacity of the system.” At that point, he concludes, “we’ll have to see how the human side responds.”

Robert L. Reid is the senior editor of Civil Engineering.

PROJECT CREDITS
Hurricane and Storm Damage Risk Reduction System owner and local sponsor: Coastal Protection and Restoration Authority of Louisiana
Oversight of Hurricane and Storm Damage Risk Reduction System design and construction: U.S. Army Corps of Engineers and numerous contractors
Inner Harbor Navigation Canal–Lake Borgne Surge Barrier designer: Joint venture of Tetra Tech INCA, Bellevue, Washington, and Ben C. Gerwick, Inc., Oakland, California
Seabrook Floodgate Complex designer: Bioengineering Group, New Orleans; ARCADIS, Amsterdam, the Netherlands; and HNTB, New York City
Seabrook Floodgate Complex contractor: Alberici Constructors, Inc., St. Louis
Gulf Intracoastal Waterway–West Closure Complex design: ARCADIS, Amsterdam, the Netherlands
Gulf Intracoastal Waterway–West Closure Complex contractor: Gulf Intracoastal Constructors—a joint venture of Kiewit Corporation, Omaha, Nebraska, and Traylor Bros., Inc., Evansville, Indiana
Outfall canal permanent closure and pump station design/build contractor: PCPP Constructors—a joint venture of Kiewit Louisiana Co., Metairie, Louisiana; Traylor Bros., Inc., Evansville, Indiana; and M.R. Pittman Group, LLC, St. Rose
Louisiana Causeway project designer: Gulf Engineers & Consultants, Baton Rouge
Louisiana Causeway project contractor: Boh Bros. Construction Co., LLC, New Orleans