Protecting New Orl

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Hurricanes Katrina and Rita devastated the Gulf Coast. The storm season starts again this June—and every June. Can coastal communities ever be safeguarded?

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HIGH WATER pours through a burst flood wall along New Orleans's 17th Street Canal.

By Mark Fischetti

Immediately after Hurricane Katrina pummeled New Orleans last August, President George W. Bush and the U.S. Department of Homeland Security declared that no one could have predicted such devastation. Yet scientists, engineers and Louisiana state politicians had warned for years that a Category 4 or 5 storm crossing the Gulf of Mexico from a certain direction would drown the region. In 1998 computer models at Louisiana State University simulated such a terrible inundation. That same year the state proposed a $14-billion plan to restore the delta's natural wetlands—which, by absorbing water, can help protect inland areas from sea surges. But Congress turned it down.

What is more, engineering firms, as well as the U.S. Army Corps of Engineers, which is largely responsible for flood protection, had proposed constructing higher earthen levees as well as huge gates that could have prevented storm surges from pouring into inner-city canals and bursting their concrete flood walls. Indeed, documents show that various gates had been recommended as far back as 1968 and in each decade since.

None of these designs has ever been funded. The reason, for the most part, is turf battles among the Corps, local and state politicians, and Congress. In the meantime, countries such as the Netherlands and the U.K. have erected effective surge barriers that the U.S. has ignored. In Katrina's wake, the blueprints for all these structures are rapidly being dusted off, augmented and integrated into several grand plans by L.S.U., big engineering companies, and the Corps that could safeguard New Orleans and southeastern Louisiana. Similar measures could save populated coastal communities around the Gulf, the U.S. and the globe.

Poster Child

THE MISSISSIPPI RIVER DELTA is not alone in being endangered. Deltas worldwide are in trouble because human development is causing the land to sink. The soft delta earth compacts naturally, but annual river floods top-coat the slumping ground with new sediment. Yet man-made levees built to prevent floods in many of these regions also cut off the sediment supply. At the same time, underground extraction of oil, natural gas and freshwater deflates the land's support structure. As the surface subsides, saltwater from the ocean streams in, poisoning the usually thick expanses of wetland mangroves, trees and grasses. Without these lush buffers, even moderate storms can push sea surges far inland.

The earth's oceans are also rising, compounding the problem. At current rates, sea level will be one to three feet higher in 100 years. Low-lying cities from New York to Shanghai may have to armor themselves with walls and pumps and add revetments (waterproof masonry) to the bottom few feet of every building in town, measures already under way in Venice.

One third of the world's people live in coastal zones, particularly the deltas. Rich

in farmland, seafood and underground resources, these areas are also key exit and entry points for armadas of ships carrying piles of goods. Cairo, at the tip of the Nile River, is home to 16 million people. The Red River and Mekong deltas in Vietnam each support 15 million inhabitants, yet both are eroding. Shanghai has 13.5 million, the Ganges in Bangladesh, 10 million. Other threatened deltas include the Orinoco in Venezuela and the Rhine, Rhône and Po in Europe.

The Mississippi Delta, home to 2.2 million, represents the worst-case scenario. It is sinking and losing wetlands faster than almost any place on earth and faces the most hurricanes annually. The record sea surge that prompted the Netherlands and Britain to erect barriers was 15 feet; Katrina's peaked at 28 feet.

Fundamental to the trouble is that for the past century the Corps, with the blessing of Congress, leveed the Mississippi River to prevent its annual floods so that farms and industries could expand along its banks. Yet the levees have starved the region of enormous quantities of sediment, nutrients and freshwater. Natural flooding at the river's mouth had also sent volumes of sediment west and east to a string of barrier islands that cut down surges and waves, rebuilding each year what regular ocean erosion had stolen. But because the mouth is now dredged for shipping lanes, the sediment simply streams out into the deep ocean, leaving the delta—and New Orleans within it—naked against the sea.

The Corps and industry also tore up the marsh by dredging hundreds of miles of channels so pipelines could be laid. Even bigger navigation channels were dug, and wave erosion from ships turned those cuts into gashes that allow hurricane-induced surges to race into the city. Similar practices are in play at many of the world's deltas, which could well benefit from plans such as those now being considered in Louisiana.

Too Late to Be Saved?

THE 1998 PLAN for protecting the Mississippi Delta region, titled Coast 2050, and a modified scheme in 2003 known as the Louisiana Coastal Area plan (LCA), called for gates to be inserted into the river levees. The gates would open at certain times of the year to allow freshwater and sediment to wash down into the wetlands, gradually restoring them. But "a growing number of people are recognizing that Katrina and Rita changed the landscape enough that they may have made Coast 2050 and LCA obsolete," laments Len Bahr, a leader in the Louisiana Governor's Office of Coastal Activities for 15 years and an architect of Coast 2050.

Furthermore, because the storm surge entered New Orleans from Lake Pontchartrain to the north and navigation channels to the east, "those plans would not have stopped Katrina," observes Hassan S. Mashriqui, an assistant research professor at L.S.U.'s Hurricane Center who has enhanced the university's 1998 surge models. He says the models show that gates across certain channels into the city would also have been needed to divert the surge.

Those gates would have done nothing for the rest of southeastern Louisiana, however. SCIENTIFIC AMERICAN therefore asked a wide range of experts

Overview/*Flood Control*

- Levees were too small and weak to hold back Hurricane Katrina's storm surge. Much more robust systems have been proposed for all of southeastern Louisiana.
- Flood control structures already in place in the Netherlands, England and elsewhere could help protect troubled deltas worldwide and also revive vast, dying marshlands.
- Engineers must embrace greater scientific input when considering the siting and construction of barriers—input that might have mitigated the Katrina disaster.

Grand Plan

Three main protection schemes (*top map*) are being proposed by government, industry and university groups to hold back floodwaters from Category 5 hurricanes. The "inner ring" (*red*) would extend and add height and width to current levees and canal walls throughout New Orleans, meant only to withstand Category 3 storms, and connect to existing Mississippi River levees.

A "comprehensive plan" (*yellow*) would continue the line to the Mississippi state border and west beyond Morgan City to protect more communities and industry. The 440-mile levee, 35 to 40 feet high, would loosely track the Intracoastal Waterway to the west, the primary intramarsh navigation route. The path shown represents a consolidation of contours plotted independently by the Shaw Coastal engineering firm, the U.S. Army Corps of Engineers, and Hassan Mashriqui of the Louisiana State University Hurricane Center.

In each case, diversions—sluices within Mississippi River levees—would open at certain times of the year to allow freshwater, nutrients and sediment to wash down into the marshes, reviving vegetation and building up land to counteract subsidence and sea-level rise. The Bonnet Carré floodway, completed, can siphon away flood-stage river water.

Other experts prefer dikes and long chains of gates that would link the barrier islands, forming an "outer shield" similar to that in place in the Netherlands. (No one has plotted a complete course, but examples appear in pink.) Diversions would still be installed to restore wetlands, important to the environment and industry. Along with any plan, a new shipping entry point is recommended partway up the Mississippi, which would require dredged channels but shorten travel times and end dredging of the river tips; they would fill, sending sediment to the barrier islands and marshes to replace sand eroded by wave action.

In each scheme, numerous gates of different styles would be erected (*bottom*). They would stay open for shipping and for maintaining the natural mixing of freshwater and saltwater but close when needed to prevent storm surges from entering Lake Pontchartrain or navigation and drainage canals.

Inner ring
Comprehensive plan
Outer shield (sample sites)
Diversion (samples)
Gate
Existing levee
Katrina levee breach

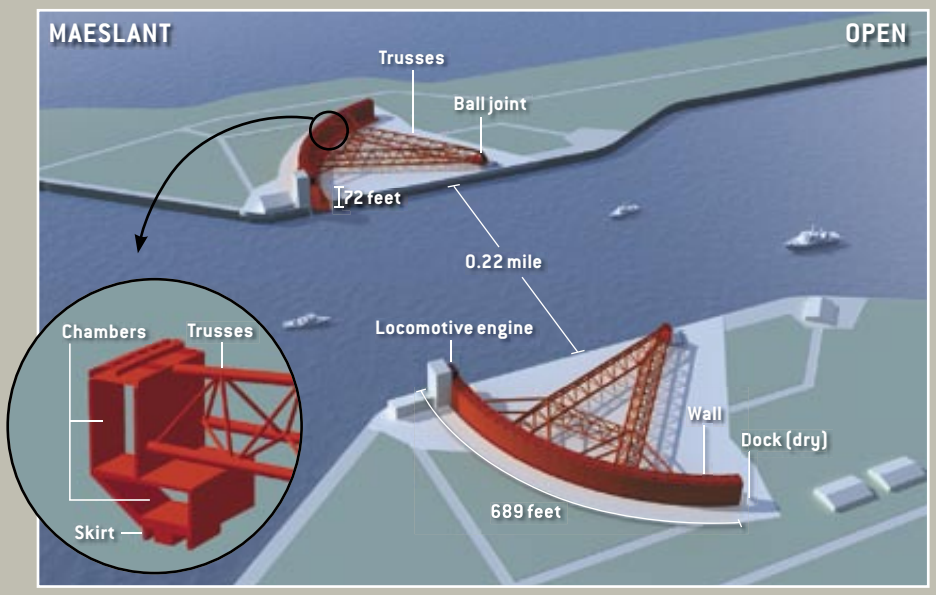
NOTE: Plots are approximate.
SOURCES: Louisiana State University, Shaw Coastal, U.S. Army Corps of Engineers, Coast 2050; satellite data available from U.S. Geological Survey at the National Center for EROS, Sioux Falls, S.D.

According to an L.S.U. plan, the so-called funnel of water that caused the largest flood-wall breach during Hurricane Katrina would be regulated, and the MRGO channel, a source of extensive wetland erosion, would be closed. Some experts propose a "safe haven"—walls underneath elevated highways that would create an unflooded refuge if problems arise.

JEN CHRISTIANSEN

Floating Gates

Floodgates around the world stop surges from pouring inland, and building ones like them could help New Orleans and other coastal cities. The Netherlands has the greatest variety. The Maeslant barrier (*right*) allows shipping on the New Waterway from the North Sea into Rotterdam's huge port but closes during storms. Each hollow barrier is stored in a dry dock, to limit corrosion and ease maintenance. For deployment, the dock is filled with water, the gate floats, and an engine turns it out. Valves then let water fill and sink the gate. After a storm, pumps empty the chambers, the barrier is floated back in, and the dock is pumped dry.



BRYAN CHRISTIE DESIGN (*diagrams*); JEN CHRISTIANSEN (*map*)

to present solutions for the region. Three strategies [*see maps on preceding page*] emerged: a tight ring around the New Orleans metropolitan area alone; a comprehensive, 440-mile levee system that would snake from the Mississippi border halfway to Texas but lie only partway to the shoreline, leaving the coast for lost; and an outer shield around the region's perimeter, such as the one in the Netherlands, which would spare every locale. The ring and comprehensive plans would inevitably leave some people "outside the wall." All three plans include gates of some kind that are not now in place.

Although each approach has its proponents, the parties agree on one thing: critics who say it is foolish to rebuild in such a vulnerable place are missing the big picture. In addition to being a cultural center, "the Gulf Coast is the economic engine that drives the country," Bahr declares. "We can't possibly abandon it." The delta produces one fifth of the country's oil, one quarter of its natural gas, and one third of its seafood. Trillions of dollars of goods and crops flow through the ports there. These activities require extensive infrastructure and tens of thousands of employees who cannot live in temporary trailers or in homes two hours away.

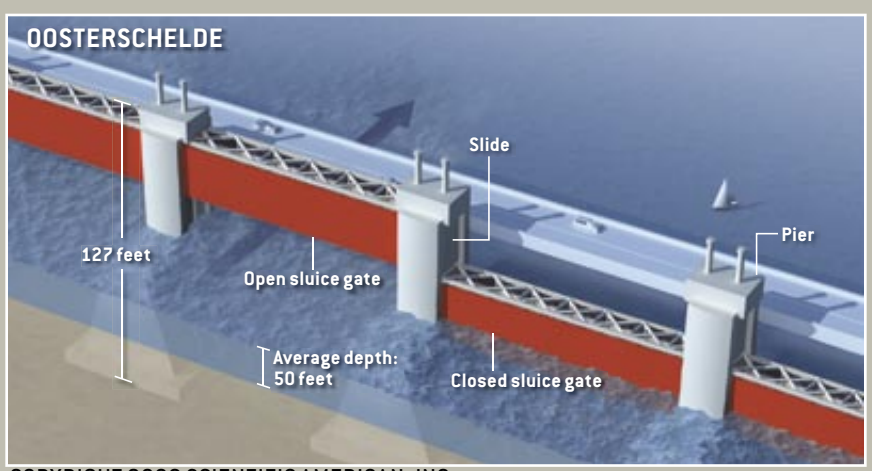
A New Path

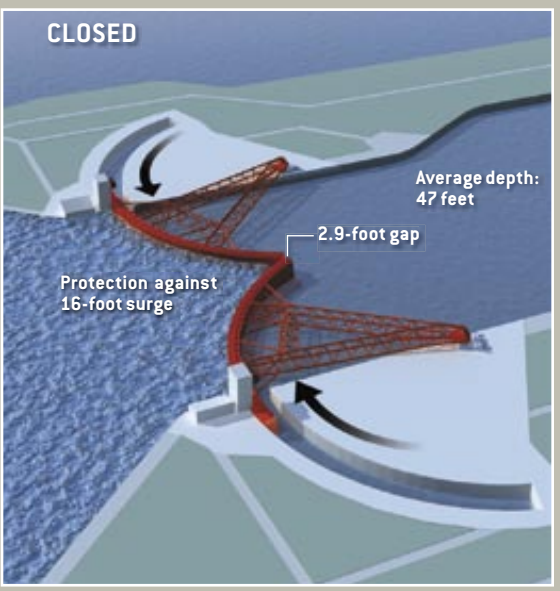
BEFORE ANY PLAN is implemented, designers should understand fully why the existing levees failed, so weaknesses can be avoided in the future. Four teams are investigating the levee and canal wall collapses in New Orleans—from the American Society of Civil Engineers, the Corps, the state of Louisiana and the National Science Foundation.

In October, Secretary of Defense Donald Rumsfeld announced that the National Academy of Sciences would review all the reports to ultimately determine why flood walls crumbled [see Working Knowledge, on page 92]. Rumsfeld said the academy would finish by June 2006. Yet hurricane season officially begins June 1, and Richard Wagonaar, a U.S. Army colonel and commander of the Corps' New Orleans district, says his goal is to restore all federal levees to their pre-Katrina level of protection (able to withstand Category 3 hurricanes) by that date. President Bush had asked Congress to appropriate $1.6 billion to repair levee damage from Katrina and in December requested another $1.5 billion to

Sluices That Slide

Long stretches of sluices link firm shorelines, barrier islands and dikes to form one part of Holland's outer shield—the Oosterschelde barrier (*right*). These floodgates could aid any of the New Orleans protection schemes. The Oosterschelde complex, 1.8 miles long, crosses three channels. When raised, the 62 steel gates between concrete piers allow for three quarters of the original tidal movement, which maintains the estuaries behind it.





improve city levees at Category 3 levels.

Wagonaar and others see restoration as only the first step, however. They agree that the city's protection must be raised to Category 5 levels. Congress would have to appropriate much more money for this work, whether it went to the Corps or a different contractor.

When it comes to the comprehensive plans, people become more contentious. Despite local differences, the plans outlined by Shaw Coastal (part of the Shaw Group), Mashriqui and Wagonaar follow a somewhat similar route. To the south and west, the course would link and raise existing, piecemeal levees now maintained by independent levee districts and would protect most major towns. The planners disagree, though, on who should do the work as well as on how long construction would take and what it would cost. Wagonaar estimates the Corps' plan "would take us five to 10 years to build" and that the cost "would be $25 billion to $35 billion—but remember, this is still in the concept stage."

That time frame seems unrealistic to O'Neil P. Malbrough, president of Shaw Coastal, an engineering firm that has built smaller levees and floodgates elsewhere in the country. "The Corps began building levees around New Orleans and Lake Pontchartrain in 1965, and there are still segments that are incomplete," Malbrough says. "That's inexcusable. If private enterprise were doing this, it would cost half the money and take half the time. The Corps is still building the same wall it was building then."

Wagonaar says he is not familiar with Malbrough or with Shaw's plan and notes that companies are unlikely to be involved unless Congress opens bids for the work. The Corps has had a de facto monopoly on federally funded flood protection for a century.

Residents in the hurricane danger zones hope that whoever gets the job incorporates new understanding of how Katrina and Rita ravaged New Orleans, and some worry that the Corps may not be fully responsive to external scientific information. For example, Mashriqui at L.S.U. has determined that a wide breach in the Industrial Canal, which flooded the eastern section of the city after Katrina, was caused by what is called a funnel effect. Computer simulations, and physical evidence Mashriqui obtained in October as a member of the state inspection team, show that Katrina pushed water from the east up a wide navigation channel called MRGO and simultaneously up an adjacent channel, the Intracoastal Waterway. The two wave fronts met where the inlets join and narrow into the Industrial Canal. This geometry amplified the height of the water by 20 to 40 percent, Mashriqui says. That increase raised the water pressure so high that the canal wall burst.

Scientists had predicted the funnel effect, and Mashriqui says a preparedness exercise run in 2004 by the Federal Emergency Management Agency based on a simulated hurricane called Pam also involved a funnel effect in that place. "The wind pushes a huge volume of water into this narrow strait, and the water just piles up," he says.

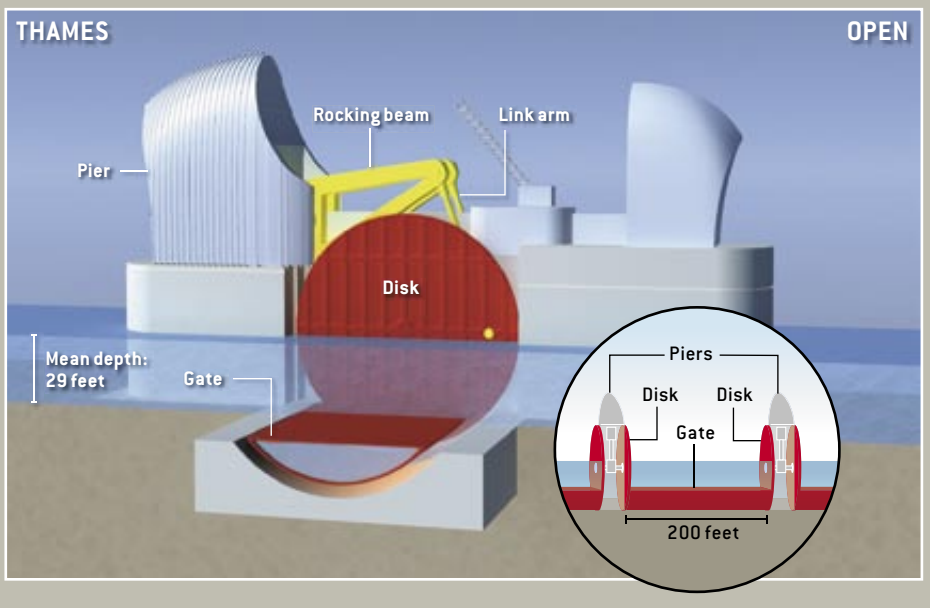
MRGO must be closed and gates must be put across the Intracoastal Waterway to protect the city, Mashriqui says. Numerous other experts speaking to the national press have concurred, noting that it supports very little ship traffic and costs a lot to maintain. But the Corps built MRGO, Mashriqui notes, "and for them to agree, they would be admitting a mistake was made in the first place."

Mashriqui is not the only one worrying about the need to avoid funnel effects. This very phenomenon was a chief reason for building the Thames Barrier in 1982, to prevent storm surges from piling up along the Thames Estuary close to London. "As the channel narrows by 50 percent, the water piles up by 100 percent," says Martin Earlam, chief engineer for the barrier at the country's Envi-

OOSTERSCHELDE: SKY PICTURES; MAESLANT: RIJKSWATERSTAAT, MINISTRY OF TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT

Hydraulic Disks

A 1953 storm that drowned the Netherlands also sent a 15-foot surge up the Thames Estuary, killing 300 in England. Today 10 steel gates span the river, held by piers covered by shining hoods (*photograph*). The four central gates are each 200 feet across and lie flush in the riverbed, full of water, to not obstruct shipping. A disk on each end of the gate is mounted on a shaft. To raise a gate, hydraulic rams and arms rotate it while air enters the gate and water drains. Water refills the gate when it is brought back down.



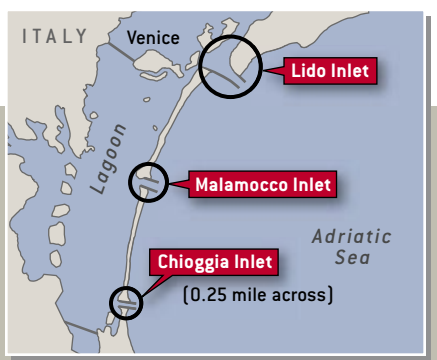
ronment Agency, which operates it. And S. Jeffress Williams, a coastal scientist with the U.S. Geological Survey who worked for 20 years in Louisiana and has studied deltas worldwide, says funnel effects "have been underappreciated."

Outer Shield

THE COMPREHENSIVE PLAN may seem more feasible than the total shield, but there are reasons to consider enclosing the significant tracts of marsh that the other plans would leave exposed to the sea. The marshes provide wintering grounds for 70 percent of the nation's migratory waterfowl, cushion ocean waves that could otherwise disturb shallow underground pipelines, and could partially absorb rising sea levels. The region could be walled in by connecting the barrier islands with dams and long stretches of gates—the option the Netherlands embraced after a horrific 1953 storm generated a 15-foot surge that killed 1,800 people and flooded 800 square miles. Virtually the entire country is delta; 26 percent of it is below sea level, bottoming out at –22 feet, lower than New Orleans. The surface is subsiding, too, accelerated by extraction of freshwater and peat, and is home to several major lakes and river outlets. Today the nation is outlined by more than 1,000 miles of dikes (levees), dunes, dams and gates—far longer than the line needed around Louisiana.

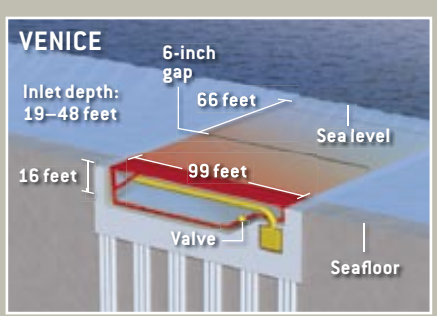
Joop Weijers, a longtime senior engineer at the Dutch Ministry of Transport, Public Works and Water Management, which oversees the Delta Works network, says a similar approach could protect Louisiana and deltas in other nations. Although the Netherlands's shield may seem grandiose, Weijers says "building the whole system right now would cost $15 billion to $16 billion." Maintenance runs about $500 million a year. But after the coast was secured, he adds, "the region got an economic boost in tourism, farming and industry."

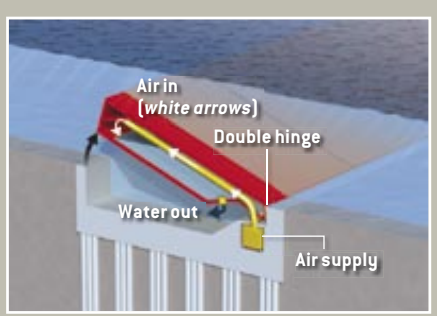
Coastal administrator Len Bahr says an outer shield is a wild idea, but given the delta's alarming deterioration, "we may need some wild new ideas." Williams of the USGS concurs: "Considering

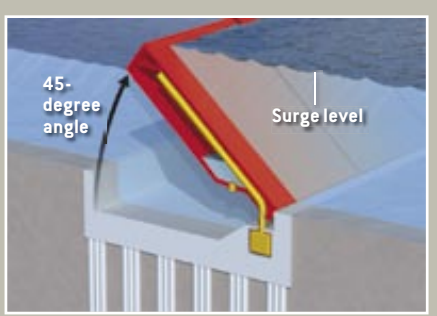


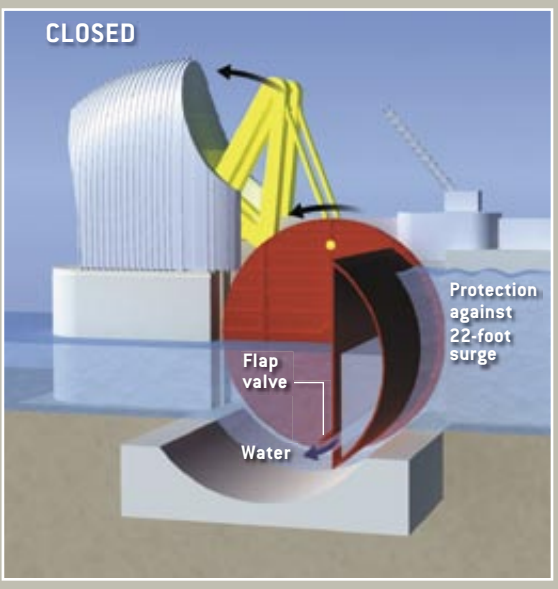
Rising Flaps

Many low-lying coastal cities worldwide will have to fend off tidal surges and rising sea levels. In Venice, engineers are preparing sites for barriers that will close inlets when menacingly high tides approach, which now occurs three or four times a year (record surge, 6.5 feet). In each inlet, 20 or 40 hollow, steel flaps will rest in heavy concrete cradles. To raise them, air will be pumped in to push water out, and they will float up into position in less than 30 minutes (*diagrams*). An adjacent lock will permit boats to pass.









the rates of sea-level rise, land subsidence, and the increasing frequency and severity of storms, it's a legitimate option."

Take a Scientist to Lunch

PANICKED BY the devastation in 1953, the Dutch quickly set out to build solid dams across several wide estuaries to the North Sea. Those berms, however, cut off the interchange of saltwater and freshwater and altered the environment. In recent decades, Delta Works has changed direction, emphasizing man-made barriers that close only when surges are imminent. "It took us a long time to learn that we could work with nature, not just defy it," Weijers says. He advises U.S. planners to "really think it through."

Wagonaar at the Corps, Malbrough at Shaw Coastal, and Mashriqui at L.S.U. agree that certain aspects of the original Coast 2050 and LCA plans that would revive the marshes must be incorporated into any plan adopted. Diversions—large doorways inserted into the levee along the Mississippi River's banks—would supply freshwater and sediment to the wetlands. The Corps' plan includes a significant number of gates to "let water flow in and out to support the LCA objectives," Wagonaar says.

Although the Netherlands and Britain probably have much advice to offer, Malbrough says, "we don't need the Dutch to tell us how to build a levee system." The Corps apparently felt that way at one time, too; its officials made similar statements to SCIENTIFIC AMERICAN during research for a 2001 article about restoring the delta [see "More to Explore" below]. But collaboration may improve. In 2004 the Corps and Delta Works leaders signed a memo of understanding to exchange information, and in October several Dutch engineers helped the Corps analyze New Orleans's flood-wall failures.

The need to coordinate physical protection across levee districts and to incorporate coastal restoration means a clear leader is needed. The experts interviewed for this article acknowledged that political infighting in Louisiana killed smaller proposals in the past. Malbrough hopes this message may be sinking in; he was hired by various levee boards together to present the state and federal government with one coordinated plan. Both he, Mashriqui and Bahr think a federally run consortium should oversee the work. They oppose putting the Corps in charge, seeing it as too slow, too politicized by Congress, and too unwilling to entertain novel technical approaches. "I'm inclined to change horses," Mashriqui says.

He and others also strongly recommend that scientist input be sought much more extensively. "I don't care who wants to control the work," Mashriqui asserts. "But whoever it is has to listen to the data. If our models show that the funnel effect will kill people, then there is no excuse not to close the funnel."

Bahr agrees that engineers "have not so far engaged research scientists nearly enough. And we need anthropologists and social scientists to help figure out the people issues. Some parishes [counties] were virtually wiped out by Katrina. Where does it make sense, socially, to rebuild?" Williams, the USGS veteran who also worked at the Corps for 13 years, says scientists continually "put data out there, but it has no effect on its own. Politicians and planners have to take it from there."

Wagonaar, a longtime Corps member who took over the New Orleans district last July, says that in the future the Corps will better integrate outside experts: "We are generally a lot more open than we were five or six years ago, especially with regard to environmental issues. But we can't study this situation forever either. Someone will have to make a decision." SA

MORE TO EXPLORE

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BRYAN CHRISTIE DESIGN (*diagrams*); JEN CHRISTIANSEN (*maps*); THAMES: SKYSCAN