HIGH STAKES: SOFT INFRASTRUCTURE FOR THE RISING SEAS

Guy Nordenson and Catherine Seavitt

At the end of a hundred leagues we found a very agreeable location situated within two prominent hills, in the midst of which flowed to the sea a very great river, which was deep at the mouth.
—Giovanni da Verrazano, 1524 CE

Ego sum, pleno quem flumine cernis
stringentem ripas et pinguia culta secantem,
caeruleus Thybris, caelo gratissimus amnis.
Hic mihi magna domus, celsis caput urbibus, exit.
—Virgil, 29–19 BCE[1]

INONDAZIONE

During a flood, a city is transformed. The displacement of a volume of water—the rise of a purely horizontal liquid datum along the vertical axis—creates radical planar reconfigurations. Perhaps the foremost example of such volatility is Rome, which is marked everywhere by the historically relentless floods of the Tiber River. Throughout the city, markers and hydrometers register the heights of extreme floods. Since the construction of the *muraglioni*, or embankment walls, a massive urban infrastructure project built between 1876 and 1910 in response to the severe flood of 1870, the urban course of the Tiber has been canalized into a uniform channel 328 feet (100 m) wide. The city has since been spared extensive flooding. Yet these vertical walls, rising to 39 feet (12 m) above sea level, have severed the city from the river. The *muraglioni* visually and physically depress the water below the level of inhabitation. Only during extreme flood events does the water rise high enough to be seen from the Lungotevere, the roads running parallel to the top of the floodwalls, as it did in December 2008. The flood deposited thousands of colored plastic bags (carried downstream by the current) in the branches of the trees growing along the river's edge at the base of the walls; the bags remained, flood markers of the new millennium, when the waters receded.

ABOVE: The Tiber River, shortly before the construction of the modern embankment walls. Here, the city touches the water. Alessandro Specchi's eighteenth-century baroque Porto di Ripetta is visible at the center of the image just before the river's bend. It was destroyed to make room for the walls

RIGHT: Stretch of the Tiber River above the Ponte Garibaldi showing the sectional displacement of the city from its river

Alternately, Venice is a city whose urban spaces are still radically transformed during periods of *acqua alta*, when the exceptionally high tidal waters of the Adriatic Sea enter the Venetian Lagoon. Elevated wooden platforms are strategically placed throughout the city, creating new and specific pathways of movement. During the *acqua alta* of December 2008, Venice's most significant flood of the last twenty-two years, the waters rose almost 5 feet (more than 1.5 m). And while the city continues to respectfully engrave the high-water marks onto the venerable marble walls of the *Ca' Farsetti,* Venice's city hall, it is also undertaking its own massive infrastructural scheme, the MOSE project, whose acronym derives from the Italian phrase for "experimental electromechanical module." This controversial defense system of seventy-nine mobile floodgates is intended to isolate the Adriatic Sea from the city during high-tide events by rising to block the three entrances to the lagoon. It is not clear that the project, initiated in the 1970s, has accounted for predicted sea level rise due to global climate change, nor if the environmental consequences for the Venetian Lagoon are sufficiently understood.

The movement of water along a vertical scale draws attention to the subtle configurations of topography and the consequential horizontal extent of flooding. During a flood, the vertical section gives rise to new formations and understandings of a city. Today, flooding has become synonymous with the impact of global sea level rise, and the threat of rising waters has taken on a new sense of urgency. Studying the planar transformation that takes place during high water is an opportunity to reinvent and redesign the twenty-first-century city and consider new notions of urban and ecological development.

Venice's Piazza San Marco with the Doge's Palace under the *acqua alta* of December 1, 2008. This was the city's most significant flood in twenty-two years, with the waters rising 5 feet (1.52 m)

ON THE WATER

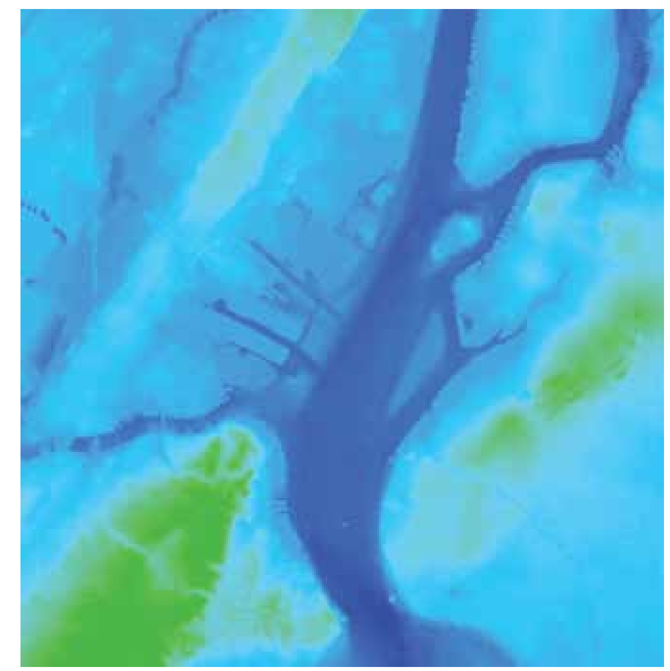
Our research and design study, *On the Water: Palisade Bay* (begun 2007), served as the basis and backstory for the development of The Museum of Modern Art's *Rising Currents* workshop and exhibition.[2] Our research led us to question both the notion and the effectiveness of "hard infrastructure," as exemplified by seawalls and storm surge barriers; this reduces the zone of floodwater absorption to a singular line in plan and a singular wall in section. Instead, the waterfront would best be conceived as a dynamic limit moving across a gradient. We propose the development of a new approach toward flooding that we call "soft infrastructure"—a collection of multiple and iterative strategies that buffer or absorb flooding. These strategies operate at the merged surface of the land's topography and the water's bathymetry—the shallow flats below the water—envisioning the water's edge as a fluid and temporal limit between the water and the land. And we respectfully accept some degree of flooding, as did the Romans for over 2,500 years.

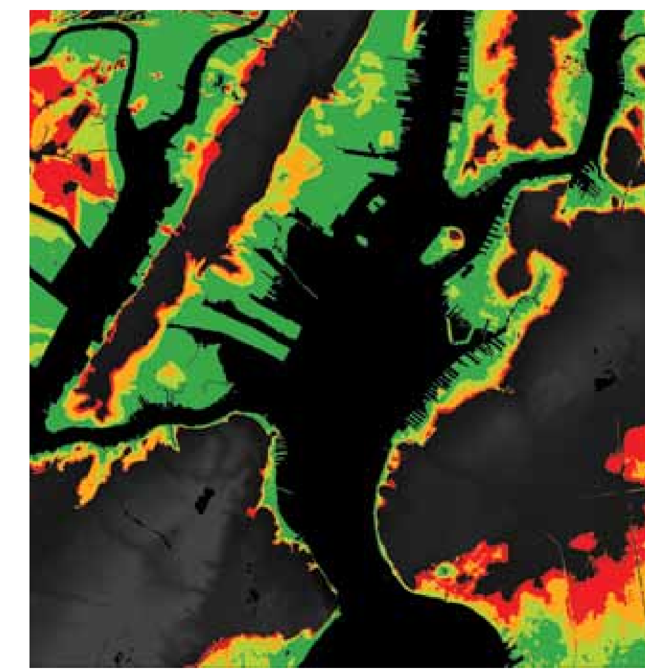
On the Water: Palisade Bay was funded by the 2007 Latrobe Prize, a biennial grant awarded by the College of Fellows of the American Institute of Architects for collaborative research leading to the advancement of the profession.[3] The work reflects the initiative of a group of engineers, architects, landscape architects, and planners, who collaborated to imagine the transformation of the New York/New Jersey Upper Bay in the face of certain climate change and sea level rise. Our area of study is framed by the Bayonne Bridge at the western edge of the Kill Van Kull (the tidal strait separating Staten Island and Bayonne), the Holland Tunnel and the Manhattan Bridge at the north, and the Verrazano-Narrows Bridge at the south. The surface area of the Upper Bay is approximately 20 square miles (52 km^2), and it measures almost 4 miles (6.5 km) across at its widest point. We chose the Upper Bay as the site for this proposal not only because of the massive impact that sea level rise and potential storm surge from hurricanes would have on this densely populated region, but also because of its capacity to be transformed into an urban center for the region. This center would be based on shared ecological and physical boundaries rather than the arbitrary lines of political districting. We imagine the Upper Bay as a kind of Central Park for the whole region, a recentering of the city away from Manhattan to the boroughs and adjoining New Jersey counties. We envision the bay's potential to be a common ground, a site that could represent to the region what the Bacino di San Marco is to Venice—a meeting place and crossroads on the water.

Sea level rise will affect infrastructures, environments, and coastal communities around the world. By 2050, it is likely that the mean sea level in the New York/New Jersey area will rise between 6 inches and 2 feet (5–61 cm) as a result of warming oceans. Recent scientific research on the melting of the Greenland and Antarctic ice caps indicates that the relative sea level in the area could rise up to 3 feet (91 cm) by 2080.[4] Twenty million people live within 50 miles (80 km) of the Upper Bay, and an increase of almost one million more residents is expected by 2030. In addition, the waters of the harbor itself are home to a rich but fragile estuarine ecosystem. Both the built and the natural elements of this tenuous relationship will be radically affected by global climate change, sea level rise, and its consequences.

Yet sea level rise is just the static aspect of climate change. The dynamic aspect derives from the depth and extent of flooding produced by storm surges. Because of higher global and local water levels, it is likely that the frequency and extent of flood damage due to severe storms—hurricanes and nor'easters—will increase dramatically. What is currently considered a 100-year storm flood will recur every 19 to 68 years, and the 500-year storm flood may recur closer to every 100 years.[5] Furthermore, higher ocean temperatures could increase the frequency and severity of hurricanes and thus the chance of extreme storm surges.[6] With a Category 3 hurricane, storm surge levels could reach up to 24 feet (7.3 m) in the New York/New Jersey area.[7]

The hazards posed by climate change, sea level rise, and severe storm surges make it imperative that we study the adaptive design of coastal cities. The conventional response to flooding in recent history has been hard engineering—fortifying the coastal infrastructure with seawalls and bulkheads to protect real estate, at the expense of natural tidal wetlands and ecosystems. This approach has proven environmentally damaging, unsustainable, and often ineffective. The failure of levees and other coastal protection structures confronted by Hurricane Katrina in 2005 is a dramatic example of infrastructural inadequacy. A core premise of our research and proposal is the transformation of hard engineering practice into soft infrastructural development.





ABOVE: Bathymetric model of the Upper Bay, indicating the deepest areas in dark blue. Note the deep Verrazano Narrows, the shallow Jersey Flats to the west, the Bay Ridge Flats to the east, and the straight dredged shipping channels cutting through the Jersey Flats.

RIGHT: Inundation analysis showing sea, lake, and overland surges from hurricanes (SLOSH). Inundation from a Category 1 hurricane is indicated in dark green, Category 2 in light green, Category 3 in orange, and Category 4 in red. Dataset by the National Oceanic and Atmospheric Administration (NOAA), National Hurricane Center

Significant research into the risks of climate change in the New York/New Jersey area has led to several proposed solutions to the problem—most notably a system of four storm surge barriers.[8] But the shortcomings of such conventional systems should provoke a comprehensive reconsideration of coastal planning. It is time for a new approach that is sustainable from an environmental, technical, and economic standpoint, and that also has the potential to improve the quality of urban life.

PALISADE BAY

The word "palisade" frames the argument of our proposal for the Upper Bay of New York and New Jersey. The term refers to plant ecology at a cellular level (the palisade cell), geological formations (the palisade sill), and man-made fortifications (the palisade fence). Palisade derives from the Latin *palus*, meaning "stake" and, by extension, "boundary." The possibility of creating porous boundaries across politically staked borders and along the edge of water and land deeply influences this research and our design proposal.

Our Palisade Bay proposal involves more than the invention of an adaptive strategy to address sea level rise and a protective approach to flooding and storm surge. It is equally focused on developing urban place, enriching estuarine health, diversifying habitat, and transforming our understanding of the dynamic force of water in the urban condition. The water of the Upper Bay might again be seen as fluid, entering the city and retreating, giving residents a sense of tidal variation and the transformations that might occur with controlled flooding. We developed ideas for both the fresh (rainwater and rivers) and the marine (saline and tidal) components of the estuarine mix, harnessing each for appropriate uses.

We propose three adaptive strategies to transform the physical characteristics of the Upper Bay, reduce flood risk from both sea level rise and storm surges, and challenge current development strategies for water, land, and shelter:

- Create an archipelago of islands, shoals, and reefs in the Upper Bay to reduce the impact of storm-induced wave energy and improve the ecology of the estuarine environment. The bathymetrics of the bay will be modified, but current shipping channels will be maintained. We are exploring the possibility of harnessing wind and waves to produce energy.

- Create a soft but resilient thickened coastline edge, combining tidal marshes, public parks, and finger piers and inland slips for recreation and possible development, and determine where to selectively place protective seawalls.

- Create flexible and democratic zoning formulas for coastal development that evolve in response to climate change and storms to increase community welfare and resilience to natural disasters.

Together, these three strategies—on the water, on the coast, and in the community—form a radical proposal to transform the Upper Bay into the central focus of the region. The Upper Bay has the potential to become an ecologically sound archipelago park, a place that will be to the New York/New Jersey region in the twenty-first century what Central Park was to Manhattan in the late nineteenth century.

EDGES, FLATS, AND AQUACULTURE

A principal hypothesis of this research is that a softer shoreline—a more gradual transition from land to water—is a more resilient edge, better able to contend with both sea level rise and increased storm surge flooding. Transforming this edge—thickening it from the solid line of the seawall to the mucky width of tidal wetlands, restoring a fringe of piers and slips, and building a protective archipelago of islands and reefs—is central to our proposal. This broadened gradient edge would offer a buffer zone of breakwaters and relieving structures during storm surges and floods. A thickened edge, graded as a tidal wetland terrace, would also provide new habitat, improving the health of the estuarine ecosystem.

In addition to a transformation of the edge, we propose an intervention into the flats of Palisade Bay. While maintaining active shipping channels, we would restore the shoals, anchorages, and oyster beds of the bay's original bathymetrics, particularly at the Jersey City and Red Hook shores. Our scheme for a matrixlike field of caisson islands—an archipelago of shoals, oyster beds, artificial barrier reefs, and low islands—would transform the bathymetrics of the Upper Bay, acting as a breakwater and diminishing wave action and thus the extent of storm surge flooding. In addition, this field would create a nature preserve on the water, diversifying habitat and enhancing the bay ecology.

Lastly, we envision the water of the Upper Bay as productive. Soft infrastructure would allow us to mitigate the effects of combined sewage overflow, and potentially collect and filter storm-water runoff to be used as freshwater irrigation for crops along the coastline. It would introduce mollusks, such as mussels and oysters, to clean and filter the polluted waters, with the hope that the bay will become so clean that it can once again support a thriving aquaculture. And ultimately it would also harness the energy of the region's water and air with tidal and wind turbines, perhaps creating green biofuel from algae farms. Our ambition is that, when its rich ecosystem is brought back to health through soft infrastructure, the Upper Bay will teem with life—not just a human population, but also mollusks, crustaceans, fish, birds, phytoplankton, and marsh grasses and other plants.

The Palisade Bay proposal seeks not merely to protect the New York/New Jersey region from sea level rise and storm surge flooding, but also to reconceptualize the relationship between adaptive infrastructure and ecology in the twenty-first-century waterfront city. It is an attempt to reconcile environmental stewardship and infrastructural development. With climate change as our catalyst, we aspire to develop a new and versatile system of coastal planning; to enrich the ecosystem, habitat, and health of the urban estuary; and to create new methods of making the water a vital urban place.

Details of the Palisade Bay proposal: an archipelago of caisson islands, seen from the Staten Island ferry terminal (top), retired subway cars transformed into underwater reefs near Liberty State Park, Jersey City (middle), and proposed archipelago of island formations and the reshaped gradient coastline at the tip of Lower Manhattan, incorporating parks, wetlands, and a shifted sea wall (bottom). Latrobe Research Team

RIGHT: Preliminary Palisade Bay master plan design strategies including wetlands, windmills, reefs, oyster beds, island fields, extended piers, detached piers, and extracted slips. Latrobe Research Team

REFLECTIONS ON *RISING CURRENTS*

The combination workshop and exhibition that was *Rising Currents* brought together five teams of architects, landscape architects, and many other collaborators to envision projects on five delineated sites within Palisade Bay. The workshop and exhibition also served as forums for discussions with government officials, both local and federal, community groups, and individual members of the public. These interactions helped shape and refine the projects and influence policy.

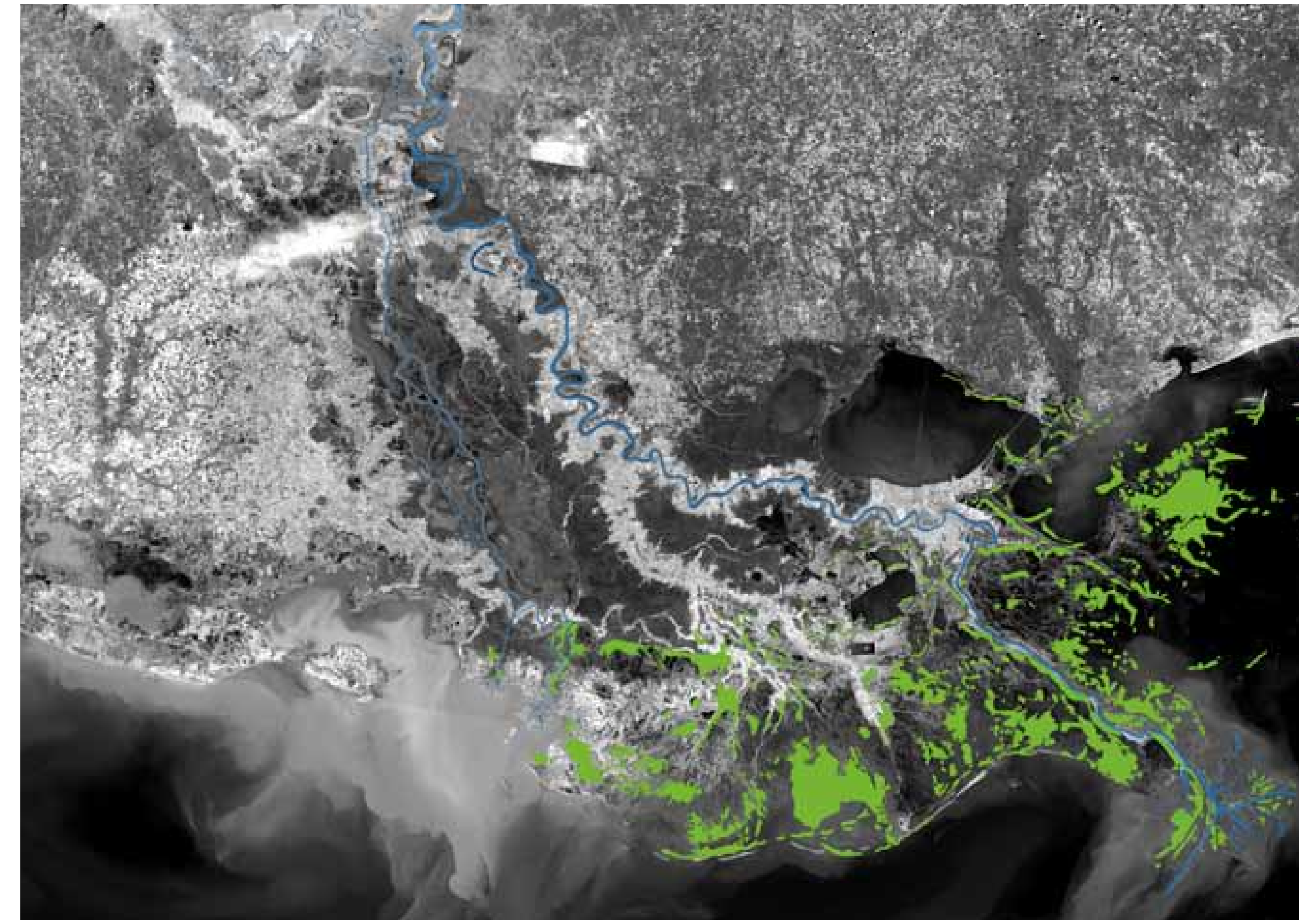
In residence at MoMA PS1, the five teams developed their visions for five discrete zones of the Upper Bay waterfront. Our etymological *palisade* triad (ecology, geology, and fortification) appears in each proposal to varying degrees: in SCAPE's use of the shallow bathymetry of the Gowanus Canal/Bay Ridge Flats and fuzzy rope as materials to reseed oyster reefs and attenuate wave energy; in Matthew Baird Architects' harnessing of cellular ecology in disused Bayonne oil tanks, creating biofuel from algae fed by wastewater; in LTL's subtle topographic shifts at Liberty State Park, resulting in programmatic "petri dishes" of protected and productive areas; in ARO and dlandstudio's protective strategy for Lower Manhattan, transforming the underbelly of the hard streets into an absorptive sponge leading to a thickened wetland edge; and in nARCHITECTS' infiltration basins on land and inflatable bathymetric airbags offshore, inverting the notion of a fortified edge.

With the exception of SCAPE's oyster beds and Baird's recycled-glass reef, the proposals focus on the waterfront edge, which is reworked, crenellated, and softened. Although no new inhabited islands or archipelagos in the bay have been proposed, all of the teams embrace the notion that it is necessary and appropriate to construct on and in the water. Perhaps this is the exhibition's most significant contribution to public discussion. It is evident in recent policy—including *Vision 2020: New York City Comprehensive Waterfront Plan,* recently issued by the New York City Department of City Planning—that building ecologies on and in the water is no longer anathema. In fact there may even be a convergence of interests, as the Port Authority of New York and New Jersey considers the possibility of developing island wetlands as a strategy for both disposing of clean dredge spoils and enriching the bay ecology, and as the United States Environmental Protection Agency sponsors an oyster reef and wetland study project.

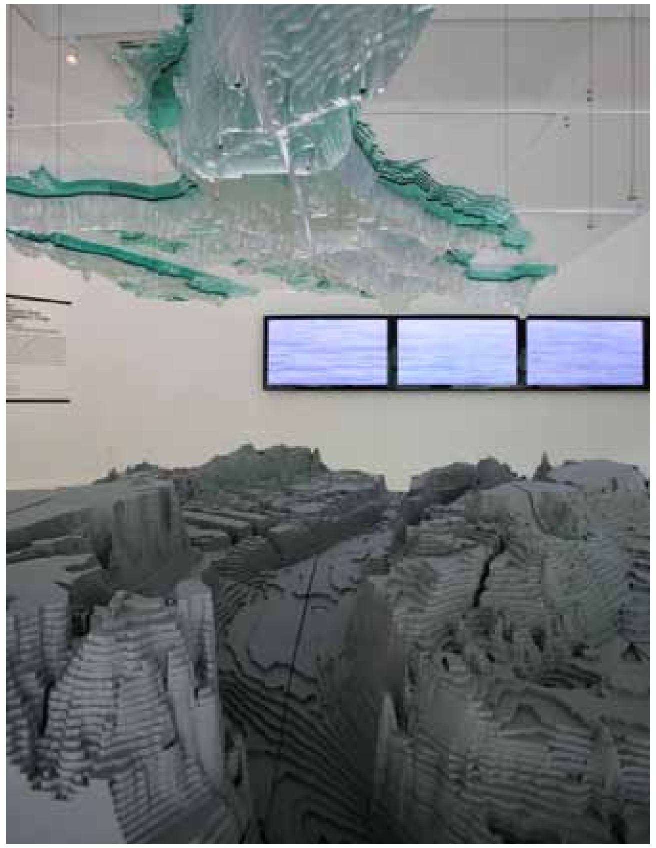
With impending sea level rise, the stakes have never been higher. The inspired collaborative solutions of these five teams—ranging, in terms of scale, from the cellular (oyster spats) to the sublime (an aggregate glass reef)—do much more than just protect our region from flooding. Their projects address energy production and use, ecological health, waste management, and global green shipping. Perhaps most importantly, they capture the imagination of a regional community, celebrating the body of water that Giovanni da Verrazano called "a very agreeable location situated within two prominent hills" upon his first sighting of the Upper Bay in 1524.[9]

CONTROLLED FLOODING AND THE MISSISSIPPI DELTA

Shortly after the *Rising Currents* exhibition opened in March 2010, we were invited by Jonathan Solomon to present our Palisade Bay project in the exhibition *Workshopping: An American Model of Architectural Practice,* which he was organizing with Michael Rooks of Atlanta's High Museum of Art for the United States Pavilion at the Venice Biennale's 12th International Architecture Exhibition. We decided to extend our research beyond the New York/New Jersey Upper Bay to the place that in many ways inspired us in the first place: New Orleans and the Mississippi River Delta. The loss of wetlands from subsidence in the delta is dramatic; many scientists agree that healthy wetlands help absorb the force of storm surges. Sea level rise will certainly have its most devastating effects in areas where the land is also subsiding; the extremely flat terrain and soft sediment of the Mississippi River Delta is certainly the foremost example of this condition. Here, one must address not only rising sea levels but also sinking ground, leading to a proposal for a parallel adaptive strategy of land building. Unlike the deep fjord geology of New York harbor and the Hudson River estuary, carved by slow glacial movement, the terrain of the Mississippi River Delta is broad and expansive in its flatness, a landscape of slow-moving but dynamic mud. Working with the Louisiana State University Coastal Sustainability Studio, led by Jori Erdman, Jeffrey Carney, Lynne Carter, and Elizabeth Mossop, and oceanographers and coastal scientists Robert Twilley and Clint Willson, we held a charette in May and June 2010 to visualize the effects of Twilley's proposal for five great diversions of the Mississippi River's water and sediment.[10] They would rebuild the region's wetlands and alleviate subsidence to allow for what he calls "controlled flooding." With a group of Princeton University graduate students, we built two large models of the continuous bathymetry and topography of both the New York/New Jersey Upper Bay and the Mississippi River Delta, directly manifesting our idea of the continuity of land and water and presenting water as volumetric form. These scale models, which render the land in medium-density fiberboard and the water as a suspended acrylic volume above, were the focus of an installation that succinctly presented the position of our Palisade Bay project and Twilley's proposal for Mississippi River diversions.

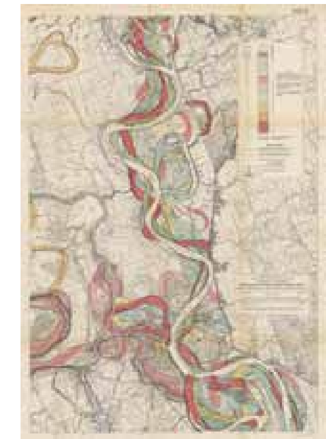


Mississippi River Delta wetland loss (in green) since 1900. The wetlands are disappearing at a rate of 25 square miles (about 64 km²) per year. Michael Blum and Harry Roberts, Coastal Sustainability Studio, Louisiana State University



TOP LEFT AND RIGHT: New York/ New Jersey Upper Bay topographic/ bathymetric model in *Workshopping: An American Model of Architectural Practice*, United States Pavilion, 12th International Architecture Exhibition, Venice Biennale, 2010. Catherine Seavitt Studio and Guy Nordenson and Associates

BOTTOM LEFT AND RIGHT: Mississippi River Delta suspended water model with rods indicating the depth of the Mississippi River, in *Workshopping: An American Model of Architectural Practice*. Catherine Seavitt Studio and Guy Nordenson and Associates



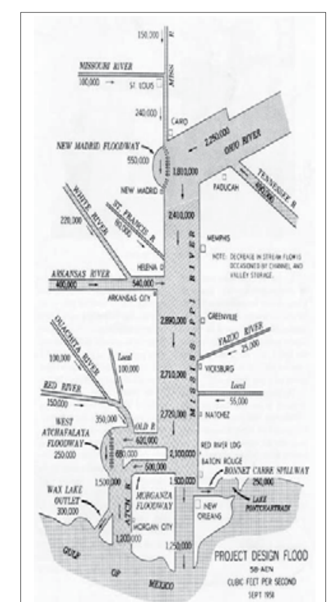
Harold N. Fisk, US Army Corps of Engineers. *Map of ancient courses of the Mississippi River Meander Belt (Cape Giradeau, MO–Donaldsonville, LA)*. Plate 22, Sheet 13. 1944

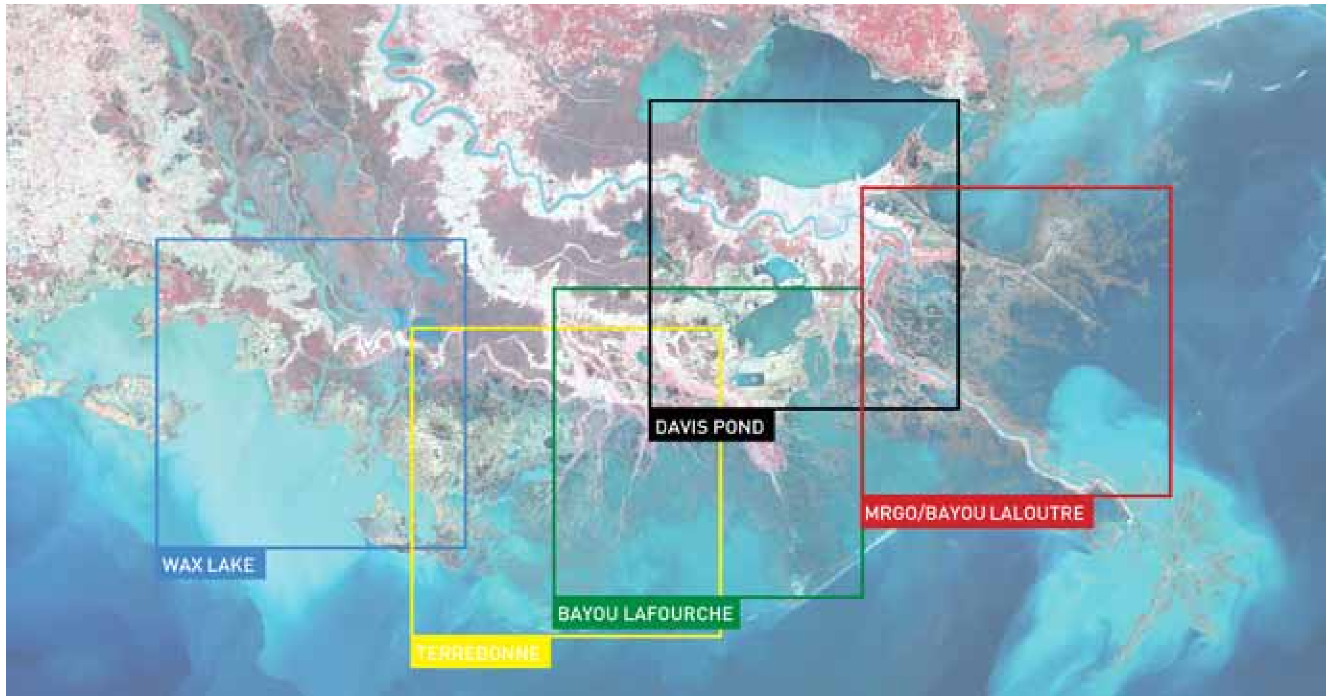
BOTTOM LEFT: Transformation of the meandering Mississippi River system into a highly engineered and constructed landscape, in support of navigable waterways and a precise flood-control strategy. 1958. US Army Corps of Engineers

BOTTOM RIGHT: Aerial view of the Old River Control Structure (completed in 1963), at the divergence of the Atchafalaya and Mississippi rivers, 1999

The Mississippi River once took a meandering course along an alluvial plain, changing its route slowly over thousands of years. Since the nineteenth century, it has become a constructed landscape supporting both flood protection and navigable waterways serving industry. In 1879 the engineer James Eads intervened at the mouth of the Mississippi with projecting jetties fabricated from reed mattresses. The result was a newly channelized river with a greater speed of flow at its mouth that carried sediment along at a greater velocity. This engineering produced the desired result: the reduction of sedimentation at the mouth of the river and the improvement of navigability. But scientists and engineers now recognize a negative consequence. Rather than being deposited to create wetlands, the rich sediment carried along the great watershed of the Mississippi was dumped off the edge of the continental shelf of the Gulf of Mexico.

The devastating flood of 1927 compelled Congress to enact the Flood Control Act of 1928, which eventually led to the construction of the Old River Control Structure, started in 1954 and completed in 1963. This structure maintains the Mississippi River's current path by diverting the Atchafalaya River just north of the state line separating Mississippi and Louisiana. Thirty percent of the upstream Mississippi River flow is sent down the Atchafalaya at the Old River Control Structure and the remaining seventy percent down the Mississippi through New Orleans and into the Gulf of Mexico. Without this structure, the waters of the Mississippi would again shift slowly westward toward the course of the Atchafalaya.[11] The implementation of this and many other flood-control structures and levees along the river has reduced the deposition of sediment to the delta's wetlands and coastal basins. However, in the Wax Lake Basin, a naturally occurring diversion, the Atchafalaya is now forming a new delta with depositional sediment—the only place in the region that is gaining ground.

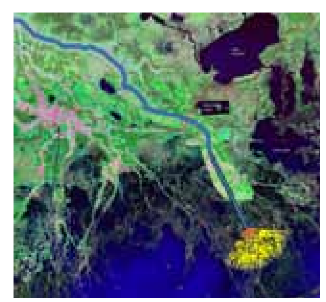




ABOVE: Proposed Mississippi Delta diversion sites. Guy Nordenson and Associates and the Louisiana State University Coastal Sustainability Studio

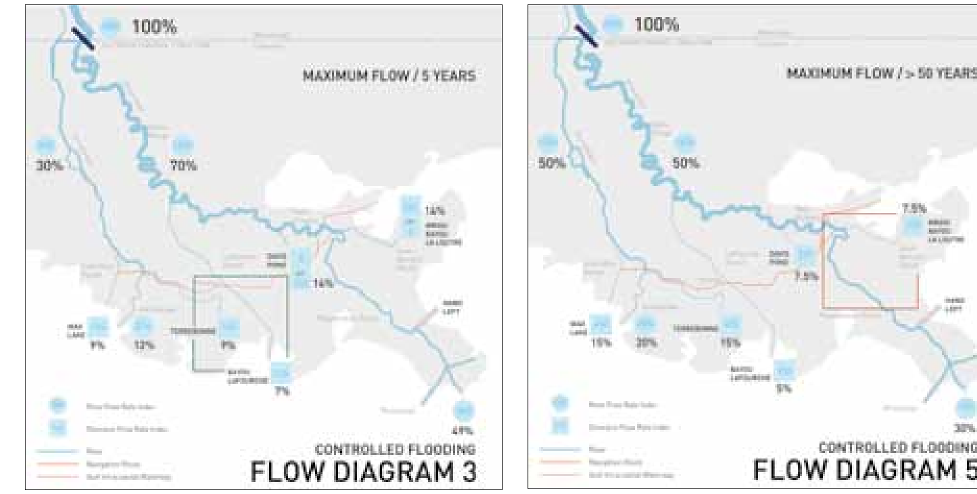
Hoping to emulate this land-building success, Twilley and Willson have proposed the construction of five new diversions of the Mississippi River, recreating a constructed landscape in which sediment will again be carried along with freshwater and deposited, thus forming new land. These locations, from west to east, include Wax Lake, Terrebonne, Bayou Lafourche, Davis Pond, and MRGO/Bayou La Loutre. The strategy is to restore the river's role as a conduit for sediment, balancing man-made structures with natural coastal processes. The additional diversions would also promote flood control and navigation. For example, Bayou Lafourche, near the geographic center of the delta, was once a main distributary channel of the Mississippi River. In 1903 a dam was constructed across its head at Donaldsonville, and now it is a small stream that runs alongside Louisiana State Highway 1, linking together a chain of towns. The proposed diversion would reopen the bayou, widening it to convey more water and sediment, and thus rebuild wetlands in Terrebonne and Barataria bays. This would represent a serious disruption of the existing social and rural conditions along the bayou and would likely be resisted by the communities. Yet perhaps an integrated design of soft infrastructure and ecologies that would both protect and improve the existing circumstances along Bayou Lafourche would ultimately find acceptance.

The project exhibited at the Venice Biennale also envisions a rearrangement of the flows of water and sediment on a scale not imagined since the 1963 completion of the Old River Control Structure. Our team worked with Willson to develop a series of controlled-flooding flow diagrams integrating the Atchafalaya/Mississippi River system with the five proposed diversions, creating various flow scenarios for the Mississippi. The flow diagrams illustrate the necessity of taking advantage of peak flows during spring flood events by opening the diversions to freshwater and sediment while controlling the volume of water channeled to each diversion as a flood-control measure. This could be the basis for a new strategy for soft infrastructure that is both protective and constructive. Over time, the process would reestablish vibrant wetlands in the delta region, create barriers against storm surges, and restore dynamic natural habitats.



Bayou Lafourche diversion site. This was once a main distributary channel of the Mississippi River. Guy Nordenson and Associates and the Louisiana State University Coastal Sustainability Studio

Controlled-flooding flow diagrams. Guy Nordenson and Associates and the Louisiana State University Coastal Sustainability Studio



CLIMATE-CHANGE ADAPTATION DESIGN AND ENGINEERING

> I don't want to be a product of my environment, I want the environment to be a product of me.
> —Francis "Frank" Costello (Jack Nicholson) in *The Departed,* 2006

The Promethean truth of climate change is that it is the direct consequence of the very technical prowess we would depend on to arrest its course. And it is difficult to be optimistic when one reads daily of the skepticism, sometimes genuine, but mostly instrumental and self-interested, that confronts efforts at mitigating climate change by reducing carbon and other greenhouse gas emissions. It is tragic, all too human, and frightening at times—a dark narrative that could very well end badly.

Since preparing our research for *On the Water: Palisade Bay,* the consensus of scientists monitoring the melting ice caps in Greenland and the Antarctic is that sea level will rise by at least three feet by 2100.[12] At the beginning of the *Rising Currents* workshop, this figure seemed to be the upper limit, but now it may well be what we must expect. And of course sea level will continue to rise after 2100, as well. We are still unprepared either to arrest the accumulation of greenhouse gas or to confront the necessity of climate-change adaptation. In time there will be disasters, whether relentless changes in weather patterns, repeated flooding, or the sudden dissolution of major glaciers or ice caps, and the world will come to its senses as it once did to confront the destruction of the ozone layer by fluorocarbons.

If climate change is our own doing, how would we best adapt to it? First it is necessary to change our own minds and the minds of others on the subject. While policy and politics can help, we believe that images, design, and art will lead the way. As the great metallurgist and historian of science Cyril Stanley Smith showed, it is art that leads the way to technology and inspires science. Humans used steel—if mostly to destructive ends—long before they knew what made it so strong and hard. The craftsmen of the Damascus blades and Japanese samurai swords had a sophisticated understanding of how to form and forge complex and balanced steel blades that also displayed their properties in gorgeous grain patterns. It was long after these craftsmen had perfected their art that scientists unraveled the atomic nature of steel alloys.

As John McPhee wrote in a 1987 article (and later in the book *The Control of Nature*),

> The Mississippi River, with its sand and silt, has created most of Louisiana, and it could not have done so by remaining in one channel. If it had, southern Louisiana would be a long narrow peninsula reaching into the Gulf of Mexico. Southern Louisiana exists in its present form because the Mississippi River has jumped here and there within an arc about two hundred miles wide, like a pianist playing with one hand—frequently and radically changing course, surging over the left or the right bank to go off in utterly new directions.[13]

We must align our infrastructure with the flows and courses of these and other waters, and, where necessary, make protective structures that share nature's adaptability. If we continue to imagine and represent the complex natures of resilient, soft infrastructure, then the engineering science, the designs, and the will necessary to bring them about may too emerge.

NOTES

1. "The god am I, whose yellow water flows/Around these fields, and fattens as it goes:/Tiber my name—among the rolling floods/Renowned on earth, esteemed among gods./This is my certain seat. In times to come,/My waves shall wash the walls of mighty Rome!" Virgil, *The Aeneid*, book 8, trans. John Dryden (New York: Macmillan, 1965), 90.
2. Guy Nordenson, Catherine Seavitt, and Adam Yarinsky, *On the Water: Palisade Bay* (New York: The Museum of Modern Art, 2010).
3. The Latrobe Prize, named for architect Benjamin Henry Latrobe, is awarded biennially by the College of Fellows of The American Institute of Architecture for collaborative research leading to significant advances in the profession of architecture. The 2007 Latrobe Prize was awarded to Guy Nordenson and Associates (GNA), Catherine Seavitt Studio (CSS), and Architecture Research Office (ARO). Guy Nordenson PE SE, professor of architecture and structural engineering at Princeton University's School of Architecture and partner at GNA, was the overall project director. Nordenson worked with Professor James Smith of Princeton University's Department of Civil and Environmental Engineering and with Michael Tantala to direct the engineering analyses and infrastructural design. CSS principal Catherine Seavitt AIA and ARO principal Adam Yarinsky FAIA oversaw the urban planning, architecture, and landscape design. Seavitt also provided the ecological analyses. Additional key team members included ARO principal Stephen Cassell AIA and Lizzie Hodges and Marianne Koch of GNA.
4. Vivien Gornitz, Stephen Couch, and Ellen K. Hartig, "Impacts of Sea Level Rise in the New York City Metropolitan Area," *Global and Planetary Change* 32 (2002): 72.
5. Ibid., 85.
6. The Intergovernmental Panel on Climate Change concluded that it is "likely" that tropical cyclones will be more intense in the future. See R. K. Pachauri and A. Reisinger, eds., *Climate Change 2007: Synthesis Report: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva: IPCC, 2007), 47.
7. Gornitz et al., "Impacts of Sea Level Rise," 66.
8. Malcolm J. Bowman et al., *Hydrologic Feasibility of Storm Surge Barriers to Protect the Metropolitan New York–New Jersey Region: Final Report to HydroQual, Inc.* (Stony Brook, N.Y.: Marine Sciences Research Center, State University of New York, March 2005).
9. This description is from a letter to King Francis I of France. See Lawrence C. Wroth, *The Voyages of Giovanni da Verrazzano, 1524–1528* (New Haven, Conn.: Yale University Press, 1970).
10. The Louisiana State University Coastal Sustainability Studio is committed to developing pragmatic, transdisciplinary, systems-oriented techniques for reducing environmental vulnerability and enhancing community resiliency along the dynamic coast of Louisiana. The team includes Jori Erdman AIA, Jeff Carney, Lynne Carter PhD, Elizabeth Mossop, Robert Twilley PhD, and Clint Willson PhD PE, with assistance from Natalie Yates and Ursula Emery McClure and Michael A. McClure of emerymclure architecture.
11. "The Mississippi River and Tributaries Project," United States Army Corps of Engineers: New Orleans District, May 19, 2004, http://www.mvn.usace.army.mil/pao/bro/misstrib.htm.
12. Justin Gillis, "As Glaciers Melt, Science Seeks Data on Rising Seas," *New York Times*, November 13, 2010, http://www.nytimes.com/2010/11/14/science/earth/14ice.html.
13. John McPhee, "Atchafalaya," *The New Yorker*, February 23, 1987, http://www.newyorker.com/archive/1987/02/23/1987_02_23_039_TNY_CARDS_000347146. *The Control of Nature* (New York: Farrar, Straus & Giroux, 1989), 5.