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Chapter One: The Need for Science in Restoring Resilience to the Northern Gulf of Mexico

Hurricane Katrina and its destructive aftermath in 2005 were unprecedented. Hurricanes Dennis, Rita, and Wilma were also powerful hurricanes affecting the Gulf of Mexico that year. These storms highlighted the need to integrate science that supports restoration of natural landscapes with intelligent coastal planning. The following essay describes both the value and vulnerability of the Gulf of Mexico's northern coast before the storms and the current need to connect science to the human dimension of restoring the coastal landscape. Readers are invited to ponder these concepts as they read the rest of the articles in this report that describe the scientific activities that the U.S. Geological Survey performed in late 2005 and early 2006.



Restoring Resilience to the Gulf of Mexico Coast

By Gregory J. Smith

... thousands of people had to chop their way through rooftops or cling to trees waiting for rescue ... thousands are camped upon broken levees ... this is a pitiable plight of a lost battle ...

Description of the human tragedy following the 1927 Mississippi River flood in *Rising Tide* by John M. Barry.

... thousands of people being rescued from their rooftops and attics ... there's a lot more people who need assistance ...

Description of the human tragedy following the 2005 Hurricane Katrina landfall broadcast by WWL-AM New Orleans radio following the posthurricane levee breaches.



Unprecedented Events

No recent events in the history of the United States have so highlighted the discord between the human landscapes (development patterns) and natural landscapes of coastal America as did the hurricanes of 2005. Hearing the news of stranded citizens after Hurricane Katrina made many recall the plight of those stranded by the 1927 Mississippi River flood. In the nearly 80 years following the great Mississippi River flood of 1927, the U.S. population, indeed the world's population, has migrated to coastal areas. During Hurricane Katrina, the Mississippi River and delta, the coastal habitats, the urban environments, and the massive storm came together on August 29, 2005, in coastal Louisiana. This storm produced a massive loss of life and property as well as an economic impact along the Gulf Coast that was unprecedented in U.S. history. Hurricanes Dennis,

Rita, and Wilma were also powerful hurricanes that affected the Gulf Coast in 2005 and were among the record 27 named storms of that year. The most intense storms took people's lives, homes, property, livelihoods, and futures as the world witnessed in disbelief, via sophisticated satellite technology, the raw, massive forces of nature. Of the record number of cyclonic storms in 2005, *Katrina and its aftermath stand as perhaps the best example of the critically urgent need to harmonize and integrate scientific, social, and economic coastal planning on a scale that has never before been attempted.*

USGS Response to the Storms

The geological and geographic setting, the hydrologic regime, and the biological landscapes of the northern Gulf of Mexico coast have intersected with human coastal development, creating a vulnerable coast. In many ways science, engineering, and technology played a role in the development of this situation; it is these same enterprises that offer the greatest opportunity for transforming our coasts from ones that are vulnerable, like those impacted in 2005, to ones that are resilient. The U.S. Geological Survey (USGS) investigations included in this volume represent some of the science needed to understand coastal landscapes and processes, their interrelationship with cyclonic storms, and ultimately the opportunity for harmonizing the human landscape and natural landscapes along the Gulf Coast and along coasts around the globe.

A Valuable Coast

The benefits of the Gulf Coast to the Nation's economy are numerous. For example, in Louisiana alone, the Port of South Louisiana handles more tonnage than any other port in the Nation; nearly 34 percent of the U.S. natural gas supply and over 29 percent of the Nation's crude oil supply moves through the State (U.S. Army Corps of Engineers, 2004). Additionally, the Mississippi River Delta is the gateway to the Nation's lifeline for moving goods and materials to and from the heart of the United States and the rest of the world. The Gulf Coast region accounted for the largest U.S. commercial fish and shellfish landings, by weight, in the lower 48 States, in 2003–04 (National Oceanic and Atmospheric Administration, 2004).

Beyond the stark economic figures, the Gulf Coast provides important natural benefits, such as the critical coastal habitat for wintering waterfowl and birds migrating from North America to South and Central America. Additionally, these valuable habitats of marshlands and barrier islands are critical to buffering human populations and property from the winds and flood waters of storms.

The economic and ecological benefits of the coast are considerable and are critical to America. Harmonizing economic and ecological processes and recovering the human landscape while restoring the natural landscapes are formidable tasks. Scientists, engineers, and resource managers, working together and using an adaptive management approach, offer the greatest promise of transforming a vulnerable coast to a resilient coast for the future. Adaptive



management is a type of natural resource management in which decisions are made as part of an ongoing science-based process. It involves testing, monitoring, and evaluating applied strategies and incorporating new knowledge based on scientific findings and the needs of society. Results are used to modify management policy, strategies, and practices (Unified Federal Policy for Watershed Approach to Federal Land and Resource Management, 2000).

A Vulnerable Coast

In 1994, the USGS National Wetlands Research Center published the land-loss figures (Barras and others, 1994) that have been the foundation for assessing, understanding, and restoring coastal Louisiana at different scales and by different programs. Additional studies have documented that Louisiana has lost more than 1,900 mi² (4,900 km²) of coastal lands from 1932 to 2000, a loss that clearly increased the vulnerability of coastal communities, including New Orleans, to cyclonic storms. Hurricanes Katrina and Rita have increased that loss by an additional 217 mi² (562 km²) (Barras, 2006; see also Barras, this volume).

Land loss in this region generically refers to the transformation of land, especially wetlands, to open water largely because of subsidence (sinking), sea-level rise, and erosion. These processes were caused by natural and human-induced factors including coastal storms, movement along geologic faults, gas and oil extraction, channelization and leveeing of rivers, canals dredged through wetlands and barrier islands, and impacts of invasive species such as the nutria (*Myocastor coypus*). The landscape change analyses have continued and further define the spatial and temporal dynamics of landscape change along the Gulf Coast. Land-loss estimates of the past and projections for the future show a high degree of variability over time and space. High rates of land loss occurred during the 1960s and 1970s and were correlated with a period of high gas and oil production on the Louisiana coast. Widespread subsidence and associated wetland loss were induced by extraction of hydrocarbons (oil and gas) across Louisiana's Deltaic Plain (Morton and others, 2005). The end result of these diverse processes has been a variety of landscape changes over time that are generally slowing but still high in certain geographic areas.

While there are clearly immediate concerns that increase the vulnerability in relation to coastal storms, the long-term impacts of sea-level rise that is due to climate change must be considered when planning for future sustainability of coastal communities and landscapes. Louisiana is especially vulnerable to relative sea-level rise because of the region's low elevation and subsidence of coastal lands (Burkett and others, 2001).



An increasing trend in sea-surface temperature during the 20th century that has been more pronounced in the past 35 years has been attributed to global warming and associated with human activity (Intergovernmental Panel on Climate Change, 2001; Trenberth 2005). Increasing sea-surface temperatures have implications for producing hurricanes with greater intensity (Knutson and others, 2001; Emanuel, 2005; Webster and others, 2005). The outcomes of climate change have obvious and serious implications for coastal vulnerability for the future. Not only do the impacts of the massive storms of 2005 need to be considered, but storm intensities that have never before been witnessed also need to be integrated into plans and models for the future. Increased relative sea level and storms with greater intensities require that consideration of climate change and the warming of Earth's atmosphere and oceans be integrated into all aspects of creating a resilient coast for the future.

The results presented in this volume and the questions left unanswered relate to the opportunity to connect science to the human dimension of landscape restoration and conservation. Cyclonic storms are a part of natural coastal ecosystems throughout the world. Natural landscapes and coastal habitats have been shaped over millennia by these storms. Human changes to these landscapes that include hydrologic alterations, digging canals and draining wetlands, altering vegetative communities, and introducing invasives species all leave these coastal habitats less resilient and more vulnerable to multiple impacts from hurricanes and other coastal storms. The human impact on the coast will not only continue in decades to come but also will likely increase in some areas. Identifying the impacts of these storms is just the first step in developing a new paradigm or model for coastal restoration and management that is larger, more comprehensive, and completely integrated across the diverse array of social, ecological, and economic interests in coastal areas. The challenge for the future is not just conducting the science but also fully integrating science in the process of harmonizing the human development and natural landscapes of the coast for increased resilience.



Science and a Resilient Coast

In the aftermath of the storms of 2005, there was an increase in the already active efforts for coastal restoration and planning that have involved biologists, hydrologists, geologists, engineers, planners, and the public. Previously, virtually all of the coastal restoration efforts and programs had cited hurricane protection as a key benefit to restoring coastal Louisiana (Coastal Wetlands Planning, Protection and Restoration Act, 1990; Louisiana Coastal Wetlands Conservation and Restoration Task Force, 1998; U.S. Army Corps of Engineers, 2004). Following the 2005 storm season, it has become obvious not only that coastal restoration efforts are urgently needed but also that these efforts must be completely harmonized with hurricane protection, flood control, navigation, river and hydrological management, and ultimately with human development and activities. Restoration of the coast affords the opportunity to integrate and harmonize the diverse activities and ecological benefits provided by a resilient coast ecosystem. Integrating these massive enterprises will require that goals transcend each of these independent endeavors beyond the interests of any single stakeholder group. Maintaining navigation of the Mississippi and Atchafalaya Rivers, flood control structures, hurricane levees, and storm protection—while simultaneously restoring land lost to the northern Gulf of Mexico to an ecologically functional system—will be a massive and complex challenge for the future. The hurricanes of 2005, with their dramatic impact on lives and property, have clearly brought a new sense of urgency to this challenge in which the entire Nation holds a stake.

Two major efforts that pointed to the need for integrated, harmonized planning across human and natural landscapes were focused on a new planning framework and a new vision for the future of the Gulf Coast (Working Group for Post-

hurricane Planning for the Louisiana Coast, 2006; Technical Group, 2006). These efforts have built consensus and recommendations for approaches to building a resilient coast.

One such recommendation focuses on retaining Mississippi River sediments in coastal wetlands instead of allowing them to bypass the Continental Shelf. This retention of sediments would emulate the historical geological and hydrological processes on the coast that once built land and sustained the wetlands that are now critically needed to protect coastal communities. Such recommendations focus on restoring the coast as opposed to simply armoring the coast (with levees, barriers, and other hard structures). The diversity of factors that drive recovery and restoration will certainly include hard structures and will deal with both flood control and hurricane protection. Scientific studies, however, have made it clear that the restoration of natural coastal wetlands and ecosystem function must be a part of this equation if we are to achieve a sustainable coastal landscape.

USGS Science and the Storms

This volume contains a synoptic overview of the immediate scientific assessments that were conducted by USGS throughout the Gulf Coast region. The science addressed issues as they arose, since establishing a research design and specific study area prior to the occurrence of a hurricane is unrealistic. While poststorm science tends to focus on impacts and rely less on experimental methods, there is a great deal to be learned through assessing the changes caused by these storms in relation to the human landscape. These studies provide important understandings and point to additional scientific work that is needed to produce further knowledge critical in transforming our coast from a state of vulnerability to one that is resilient and sustainable.

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