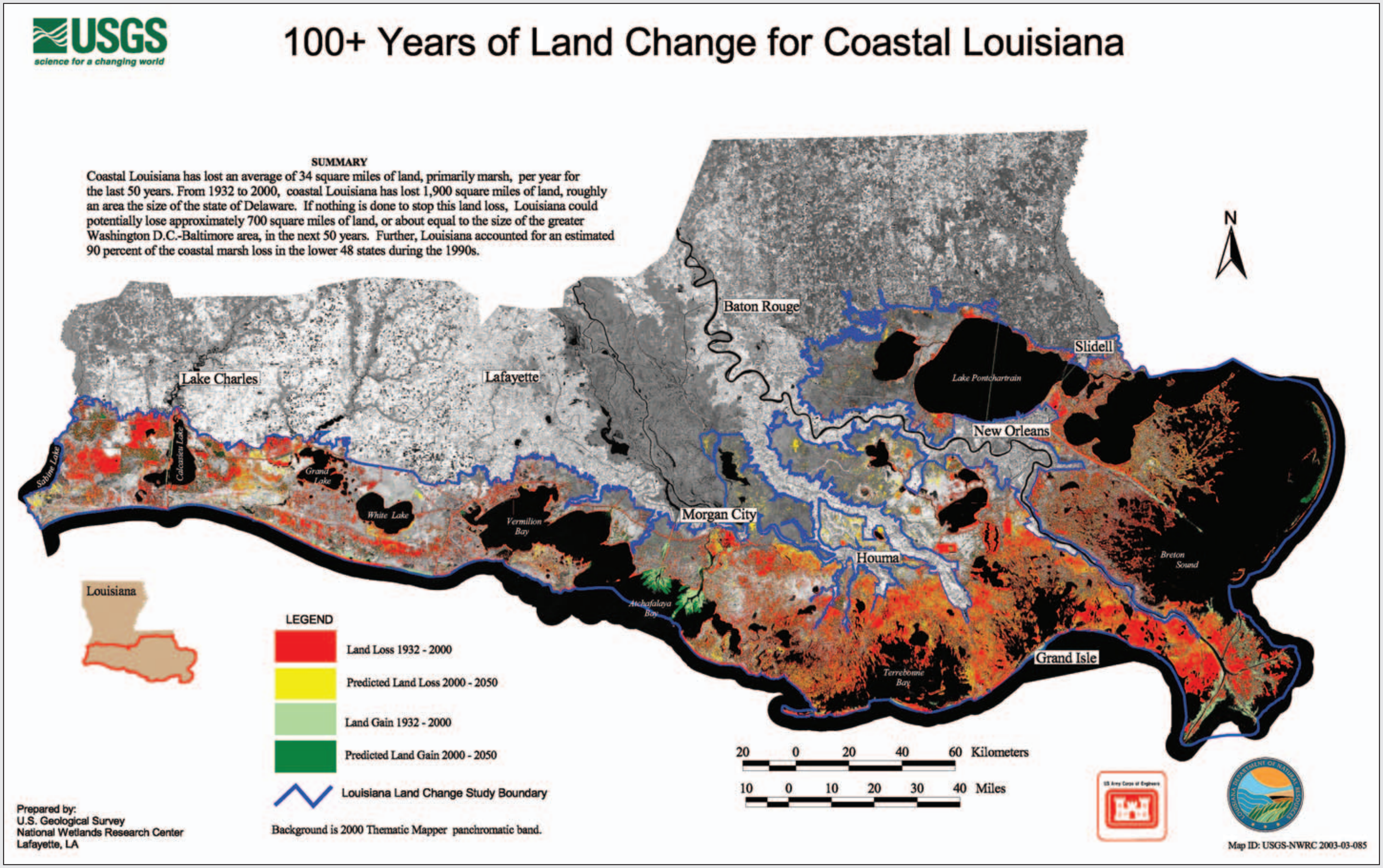

Coastal Louisiana's changing lands
U.S.Geological Survey

Effects of Environmental and Engineering Changes

A vital part of the Hurricane Katrina story lies in nearly two centuries of natural and man-made changes to the Louisiana coastline. When New Orleans was settled in 1718, the primary flood threat was from the Mississippi River, not the Gulf of Mexico. An expansive coastal landscape separated the city from the Gulf and served as a buffer from any storms moving ashore.[1]

That protective landscape no longer exists. The ever-changing and disappearing coastline has left New Orleans more susceptible to hurricanes and contributed to the damage inflicted by Katrina. Should this trend continue, New Orleans and the rest of coastal Louisiana will become even more vulnerable to damage from future storms, and efforts to protect the city with levees and floodwalls will be undermined.

While a comprehensive analysis of coastal Louisiana's environmental challenges and potential remedies is beyond the scope of this report, this chapter briefly examines some of the potential impacts of Louisiana's altered landscape on hurricane protection.

Louisiana's Changing Coastal Landscape is Increasing Hurricane Vulnerability

The Louisiana coastline is changing more rapidly than any other part of the country and, as a result, is becoming more vulnerable to hurricanes. Over the last 70 years, Louisiana has lost more than 1,900 square miles of coastal land – an area roughly the size of Delaware.[2] At the peak of the trend in the 1960s and 1970s, Louisiana was losing 40 square miles of coastal land per year.[3] This loss has slowed in recent years, primarily because the most vulnerable lands have already disappeared, but Louisiana is still losing 10 square miles of coastal land per year.[4] As a civil-engineering magazine put it, "in southeastern Louisiana a football field worth of wetlands sinks into the sea every 30 minutes."[5]

These coastal lands primarily consist of wetlands, including extensive cypress swamps and grass marshes. But Louisiana's barrier islands (an elongated chain of islands running parallel to the coast and serving as a barrier against waves) and even many higher ridges, which were formed by large amounts of sediment piling up along past banks of the Mississippi River, are also disappearing. The U.S. Geological Survey (USGS) projects that an additional 700 square miles could be lost by 2050 if no further actions are taken to halt or reverse current processes.[6]

The Mississippi River is the single most important factor in sustaining coastal Louisiana.[7] The river brings water, sediments, and nutrients from 41 percent of the land area of the contiguous U.S. to the coast of Louisiana. Prior to the extensive building of levees and dams along the Mississippi, the river carried nearly 400 million tons of sediment to the Louisiana Coast every year – enough to cover 250 square miles of land a foot deep in sediment.[8] The growing wetlands fed by the accumulating sediments, nutrients, and fresh water of the Mississippi have added 9,600 square miles of land to the Louisiana coastline over the last 6,000 years – a rate of 1.25 square miles per year.[9] At its peak, this land, known as the Mississippi deltaic plane, accounted for nearly 20 percent of the land area of present-day Louisiana, including New Orleans.

Major causes of land loss in Louisiana have been identified.[10] Dams and diversions along the Mississippi River and its tributaries have greatly reduced the amount of sediment that reaches coastal Louisiana, and levees force the remaining sediment so far offshore that it falls directly onto the outer continental shelf and beyond, where it no longer contributes to sustaining or building coastal lands.[11] By blocking natural flooding cycles, levees prevent fresh water and nutrients from the Mississippi River from nourishing and sustaining wetlands.[12] Ten major navigation canals and more than 9,000 miles of pipelines servicing approximately 50,000 oil-and-gas production facilities in coastal Louisiana result in a large direct loss of land and also contribute to wetland loss from saltwater intrusion and dredging.[13]

In addition, the Louisiana deltaic plane is essentially sinking, in a process known as subsidence, which occurs naturally as sediments deposited by the Mississippi are compacted over time.[14] Oil and gas production further contribute to subsidence, potentially causing local subsidence three times greater than the highest natural subsidence rates.[15] Finally, sea level is rising, primarily as a result of global warming.[16]

The deterioration of Louisiana's coastal landscape of barrier islands, wetlands, and higher ridges, and the effects of subsidence have made coastal communities more vulnerable to hurricane flooding.[17] New Orleans, in particular, is widely considered to be more vulnerable to hurricanes both because land in the city has subsided and because much of the barrier islands and wetlands that once surrounded the city has disappeared.[18]

Many of the mechanisms by which barrier islands, shoals, marshes, forested wetlands, and other features of the coastal landscape protect against hurricanes are well known. Geologic features such as barrier islands or the land mass associated with wetlands can block or channel flow, slow water velocities, and reduce the speed at which storm surge propagates. These effects can significantly restrict the volume of water available to inundate the mainland.[19]

Forested wetlands can greatly diminish wind penetration, reducing surface waves and storm surge. Shallow water depths weaken waves via bottom friction and breaking, while vegetation provides additional frictional drag and further limits wave buildup. Where wetlands and shallow waters lie in front of levees, they absorb wave energy and reduce the destructiveness of storm waves on the levees.[20]

Depending on the rate of relative sea-level rise, healthy coastal wetlands can maintain a near-sea-level landscape by trapping sediments or accumulating organic material, thus helping to counter subsidence and global sea-level rise. In contrast, when Louisiana's coastal wetlands deteriorate and disappear, the land held in place by the wetlands undergoes wave erosion, eventually washing away and leaving behind open water 10 to 12 feet deep.[21]

On the other hand, the quantitative impact of wetlands and other coastal features on hurricane protection is poorly known. Anecdotal data accumulated after Hurricane Andrew suggests a storm-surge reduction along the Louisiana coast of about three inches per mile of marsh.[22] During Hurricane Katrina, bottom friction and breaking reduced the average height of the highest one-third of waves from 55 feet in deep water (with peak waves above 80 feet), to 18 feet in shallower water outside of the barrier island east of New Orleans,[23] to a fraction of that height in protected areas.

Researchers at the Louisiana State University (LSU) Hurricane Center found that, during Hurricane Katrina, levees protected by wetlands had a much higher survival rate than those bordering open water. For example, large sections of the Mississippi River Gulf Outlet (MRGO) levees that had little or no wetland separating them from Lake Borgne disintegrated, while the nearby 20-Arpent Canal levee, protected by a buffer of marsh and wooded wetlands, remained standing. According to LSU researchers, an area about the size of a football field with the tree density equal to that found in most Louisiana swamps would reduce wave energy in a storm by 90 percent. These researchers further found that friction from marsh grasses and shrubs reduced water speed from Hurricane Katrina in some places from seven feet per second to three feet per second.[24]

Subsidence is also contributing substantially to hurricane vulnerability. Subsidence occurs across the entire region, and therefore impacts not only natural features such as wetlands and barrier islands, but also man-made structures such as buildings and levees. According to a recent report by the U.S. Army Corps of Engineers (Corps) Interagency Performance Evaluation Task Force (IPET), which examines the hurricane-protection levee system, the average rate of subsidence across the area is 0.6 feet over a decade.[25]

The rate of subsidence is frequently greater under cities and towns than under natural features: when areas are drained in order to prepare them for buildings, organic material in the soil decomposes and leads to further subsidence. In addition, the levees themselves further subside due to their own weight pressing down on the unstable soils of the New Orleans area. As a result, the effectiveness of the levee system deteriorates over time as both the levees and the region subside. The IPET report concluded that some portions of the hurricane protection system around New Orleans are almost two feet below their original elevations,[26] further increasing their own vulnerability, and that of the areas they are designed to protect, to the power of hurricanes.

The changes to Louisiana's coastline have serious implications for the long-term sustainability of the region. Land subsidence and predicted global sea-level rise during the next 100 years mean that areas of New Orleans and vicinity now 5 to 10 feet below mean sea level will likely be 8 to 13 feet or more below mean sea level by 2100.[27] At the same time, the loss of wetlands, barrier islands, and other natural features could eliminate protection from waves and allow for higher and faster moving storm surges.[28] According to the National Academy of Sciences, these trends will make much of Louisiana's southern delta uninhabitable without substantial new engineering projects.[29]

In the long term, New Orleans and other regions of the Louisiana deltaic plane cannot be protected without taking proper account of the tremendous change that is continuing to occur to Louisiana's coastal landscape.

The Mississippi River Gulf Outlet's Contribution to Damage from Hurricane Katrina

Congress authorized construction of the Mississippi River Gulf Outlet (MRGO) in 1956 to facilitate commercial shipping access to the Port of New Orleans from the Gulf of Mexico. Upon its completion in 1965, the MRGO provided a route 40 miles shorter than the alternative up the Mississippi River. The MRGO also provides a connection from the Gulf of Mexico to the Gulf Intracoastal Waterway (GIWW), which is a recreational and commercial waterway running east-west from Texas to Florida. Though the MRGO produced commercial benefits, those benefits came at a cost to the environment. The Corps estimates that the construction of the channel led to substantial loss of wetlands, which, as noted above, help slow and decrease the power of storms before they hit populated areas.

The MRGO also contributed to a potential "funnel" for storm surges emerging from Lake Borgne and the Gulf into the New Orleans area.[30] The "funnel" was created by the intersection of the MRGO from the southeast and the GIWW from the northeast into the confined channel, referred to as the GIWW/MRGO that separates New Orleans East and the Ninth Ward/St. Bernard Parish. The levees on the south side of the MRGO and the levees on the north side of the GIWW converge from being about 10 miles apart where they straddle Lake Borgne to a few hundred yards apart where the MRGO merges into the GIWW.[31] The western part of the "funnel" is a six-mile-long section of the combined GIWW/MRGO, which was enlarged by a factor of three when the MRGO was built in order to expand it from a barge channel to accommodate ocean-going vessels.[32]

Prior to Hurricane Katrina, many warned that the potential funnel would accelerate and intensify storm surges emerging from Lake Borgne and the Gulf into the downtown New Orleans area. The funnel had been described as a "superhighway" for storm surges or the "Crescent City's Trojan Horse" that had the potential to "amplify storm surges by 20 to 40 percent," according to some storm modeling.[33] Researchers at LSU believed that in creating this funnel, "the US Army Corps of Engineers had inadvertently designed an excellent storm surge delivery system – nothing less – to bring this mass of water with simply tremendous 'load' – potential energy – right into the middle of New Orleans." [34]

The extent to which MRGO, and the funnel it helped create actually contributed to the hurricane's damage is still being investigated, but there have been some preliminary findings. A recent report issued by the Corps' IPET concluded that the portion of MRGO running from the GIWW to the Gulf (called "Reach 2") did not significantly impact the height of Katrina's storm surge, not because the "funnel" effect was nonexistent, but because the storm was so great it nullified the impact of either the wetlands or the intersection of the MRGO and the GIWW – the funnel – at the height of the surge.[35]

While the IPET report concluded that the Reach 2 portion of MRGO had little impact on Katrina's storm surge, it did find that the six-mile combined section of the GIWW/MRGO (called "Reach 1") carried the storm surge from Lake Borgne into New Orleans. The combined GIWW/MRGO served as a link between Lake Borgne and Lake Pontchartrain, enabling the storm surge in one lake to affect the storm surge in the other. During Katrina, a 14 to 17-foot surge coming from Lake Borgne into the funnel between MRGO and the GIWW was as much as 10 feet above water levels in Lake Pontchartrain.[36] This large difference in the water levels between the two lakes increased the flow of water in the direction of the city and eventually into Lake Pontchartrain.

To address this problem, the IPET report recommended that flow through the combined channels "must be dramatically reduced or eliminated," either by a permanent closure or a structure that can be selectively used to block storm surges flowing between Lakes Pontchartrain and Borgne along the combined GIWW/MRGO.[37]

Researchers at the LSU Hurricane Center who have looked at models of Katrina have concluded that it is not just the volume of water that is important, but also the velocity. These researchers found that the funnel accelerated the speed of the water when the larger volume in the funnel, and especially the water in the MRGO, was forced into the single merged GIWW/MRGO channel.[38] The increased velocity of the water as it made its way through the channel pounded on the floodwalls lining the sides,[39] weakening them and making them more vulnerable to the overtopping and scouring that occurred during the storm. Maximum current velocities in the combined GIWW/MRGO channel were greater than eight feet per second, which is nearly three times the velocity necessary to cause serious potential for erosion in the soils of the adjacent levee.[40]

Investigations continue into MRGO's contribution to damage caused by Katrina, but there is general agreement that the presence of the MRGO destroyed wetlands that otherwise would have provided additional defenses. This happened because the MRGO served as a conduit for saltwater from the Gulf of Mexico to intrude into the freshwater wetlands. The saltwater damaged and destroyed wetlands, which resulted in the loss of land that had served as part of the city's defenses against hurricanes and other storms.[41] According to the National Academy of Sciences, MRGO has resulted in "tremendous environmental damage, including saltwater intrusion, land loss, and worsening the effects of wave damage during hurricanes and storms."[42]

Over the past 40 years, the erosion from the saltwater has contributed to the widening of the MRGO from 600 feet to 2,000 feet, an average of 35 feet per year, and the loss of more than 19,000 acres of land.[43] Had there been no wetlands at all east of the MRGO and the GIWW, preliminary storm modeling has shown, the Katrina storm surge may have been anywhere from three to six feet higher along St. Bernard Parish/Ninth Ward and New Orleans East.[44] Continued wetland loss will increase the vulnerability of the city, making overtopping by storm surges even more likely in the future.[45]

The building of MRGO and the combined GIWW/MRGO resulted in substantial environmental damage, including a significant loss of wetlands that had once formed a natural barrier against hurricanes threatening New Orleans from the east. MRGO and the GIWW/MRGO provided a connection between Lake Borgne and Lake Pontchartrain that allowed the much greater surge from Lake Borgne to flow into both New Orleans and Lake Pontchartrain. These channels further increased the speed and flow of the Katrina surge into New Orleans East and the Ninth Ward/St. Bernard Parishes, increasing the destructive force against adjacent levees and contributing to their failure. As a result, MRGO and the combined GIWW/MRGO resulted in increased flooding and greater damage from Hurricane Katrina.

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