

CLARA Flood Risk Model Supports Louisiana's Coastal Planning

Coastal Louisiana is no stranger to catastrophic storms and the damage they cause. When hurricanes flood cities, towns, and farmlands, they force evacuations, damage and destroy buildings and infrastructure, erode wetlands, and threaten the health and safety of residents. Hurricanes Katrina and Rita in 2005, Gustav and Ike in 2008, and Isaac in 2012 are among the most recent examples of storms directly striking Louisiana and are familiar to many Americans because of their power and the extent of the devastation and suffering that followed.

The response by planners in the state of Louisiana has included a 2012 update of *Louisiana's Comprehensive Master Plan for a Sustainable Coast*. The Master Plan proposes a range of structural protection and coastal restoration projects to reduce storm surge flood risks to coastal communities and address other objectives to help create a more sustainable coast over the next 50 years. To support this process, the Coastal Protection and Restoration Authority of Louisiana (CPRA) convened a set of modeling teams to provide analytical support and help improve understanding of how coastal conditions might change in the future and how they could be improved through new investments in protection or restoration.

CPRA asked researchers from the RAND Corporation to create an analytical model, the Coastal Louisiana Risk Assessment (CLARA) model, to estimate flood depths and damage that occur as a result of major storms. CLARA made it possible to systematically evaluate potential projects for the Master Plan on the basis of how well they reduce storm surge flood damage in Louisiana's coastal region.

CLARA Supported the Comparison and Ranking of Projects

RAND's initial analysis with CLARA helped evaluate and compare risk reduction projects for inclusion in the Master Plan by estimating flood depths and damage in dollars in a future without action and with potential new projects in place. These estimates were calculated in two time periods and two scenarios: 2012 (current conditions) and 2061 (50 years from the beginning of the planning process) in the *moderate* and *less optimistic* future scenarios. The scenarios

Key findings:

The Coastal Louisiana Risk Assessment model

- is an analytical model that estimates flood depths and damage that occur as a result of hurricanes
- made it possible to evaluate potential flood risk reduction projects for inclusion in Louisiana's 2012 Coastal Master Plan
- shows that, without the Master Plan's protection and restoration projects, storm surge flood damage represents a major threat to coastal Louisiana
- supports the 2012 Coastal Master Plan in taking a major step toward protecting the state's economic livelihood for years to come.

reflect different assumptions regarding future sea-level rise (SLR), the rates at which coastal land subsides (naturally sinks compared with sea level), and other key uncertainties about the future. The moderate scenario assumes low to moderate SLR and subsidence rates, while the less optimistic scenario uses much higher assumptions.

The researchers then used CLARA to evaluate the combined damage reduction benefits from Master Plan investments in new or upgraded protection structures, nonstructural risk reduction projects, and coastal restoration in these same years and scenarios. They also included an additional interim period, 2036 (25 years from the beginning of the planning process), and an additional future scenario, the *moderate future with high SLR*, which makes the same assumptions as the moderate scenario but includes a higher rate of rising sea levels over time.

What Might We Expect in a Future Without Action?

In general, risk and damage results from the final Master Plan analysis show that storm surge flood damage poses a major threat to coastal Louisiana and that, if no action is

taken, this damage can be expected to grow substantially in the future. Figure 1 illustrates the potential increase in flood depths over 50 years in a future without action at the “1-in-100” or “100-year” flood exceedance—the flood depth that has a 1-percent chance of occurring or being exceeded in each year. Areas marked in blue on the map face deeper levels of flooding; areas marked in orange face less flooding.

CLARA calculated flood exceedances and the associated level of flood damage (damage exceedances) at two other levels as well: 50 years (2-percent chance) and 500 years (0.2-percent chance). The researchers also measured flood damage using *expected annual damage* (EAD), the average damage from Category 3 and higher storms projected to occur in a single year.

Flood depths and damage outcomes worsen over time in a future without action, with the amount of increased flood damage varying substantially by Master Plan scenario and with the assumed structural reliability of the New Orleans hurricane protection systems in future years. Considering *system fragility*, or the possibility that levees might fail, is critical to understanding the potential benefits and trade-offs associated with future protection system investments. For example, the analysis showed that parts of New Orleans could experience some flooding from storm surge or waves overtopping the levees in future decades. When potential failures of the protection system were also factored in, however,

both flood depths and damage estimates increased substantially for New Orleans in some Master Plan scenarios.

What Might We Expect in a Future with Master Plan Projects in Place?

The Master Plan projects help to reduce flood damage in many areas of the coast through a combination of structural and nonstructural risk reduction investments and coastal restoration projects. For instance, Figure 2 illustrates the possible coastwide reduction in flood depths in the less optimistic scenario with the Master Plan in place. The projects associated with the Master Plan are indicated on the map and include structural protection (in pink), river diversions to rebuild wetlands, and other coastal restoration projects.

This map indicates the difference in flooding between the Master Plan and the future without action and shows substantial depth reduction (orange shading) in many areas of the coast.

Damage reduction is also notable in all three scenarios (see Figure 3). For instance, in 2061, EAD is projected to increase to between \$7 billion and \$21 billion in the future without action, depending on the scenario (blue bars). With the Master Plan in place, this damage level is reduced to between \$3 billion and \$5 billion (orange bars). This corresponds to a reduction of approximately 60 to 80 percent compared with flood damage levels in the future without action.

Figure 1. Estimated Change in Flood Depth from 2012 to 2061, by Census Block, at the 100-Year Flood Exceedance (Less Optimistic Future Scenario)

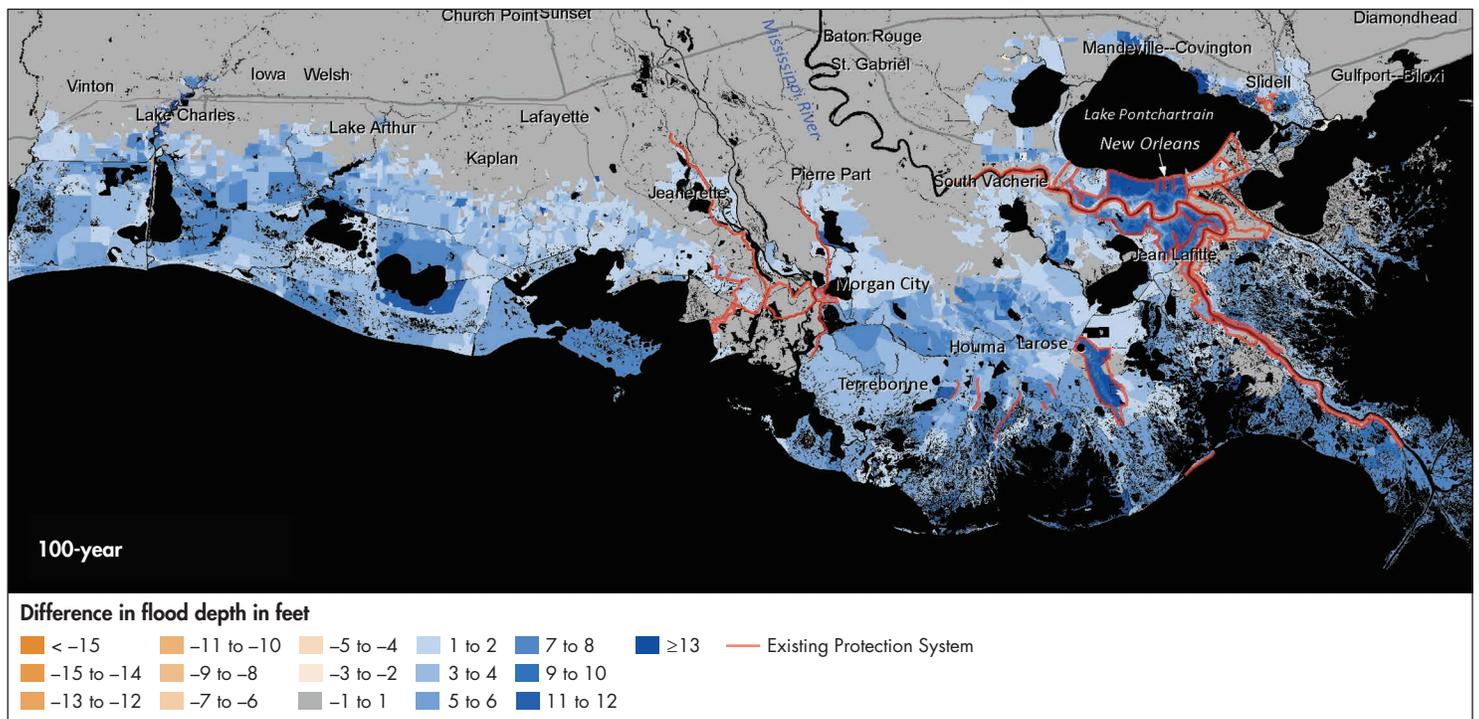


Figure 2. Estimated Change in 100-Year Flood Exceedance in 2061 for Coastal Louisiana, by Census Block, with the Master Plan in Place (Less Optimistic Future Scenario)

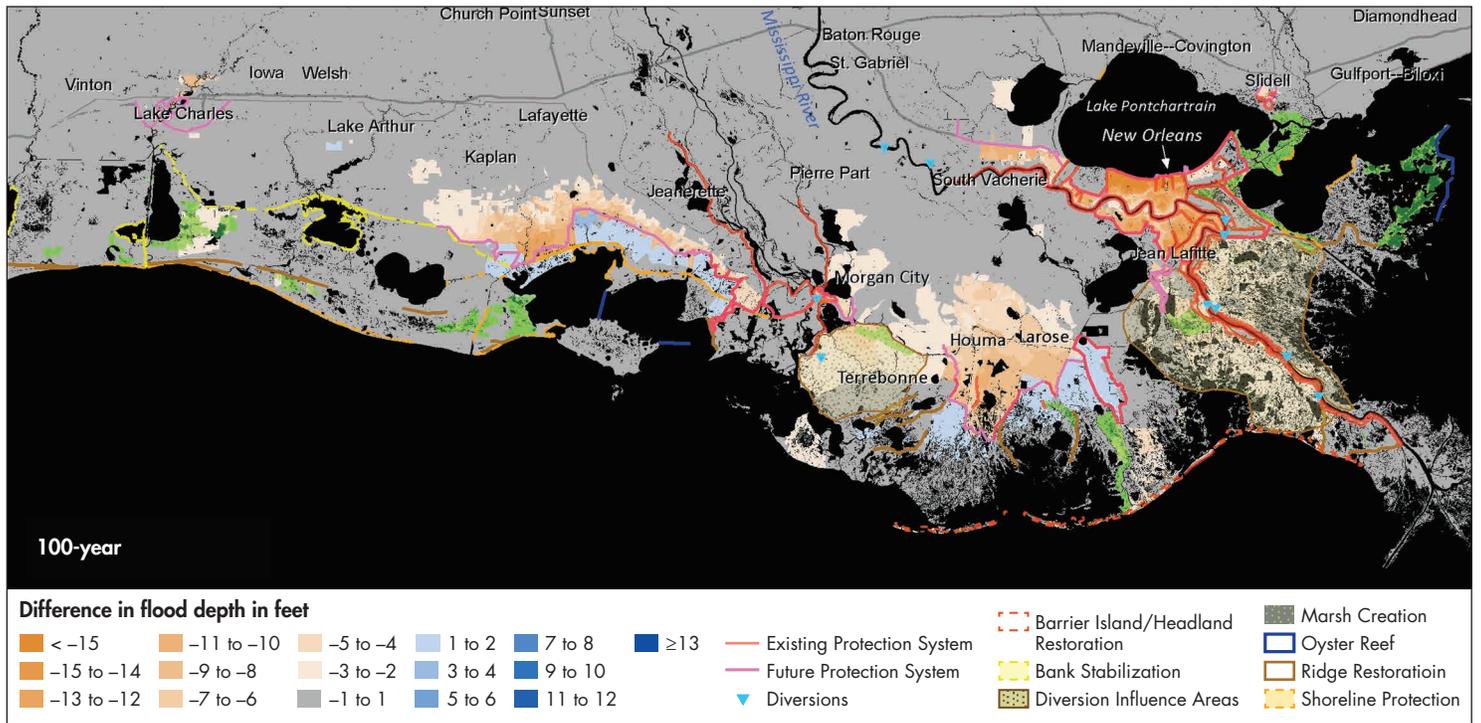
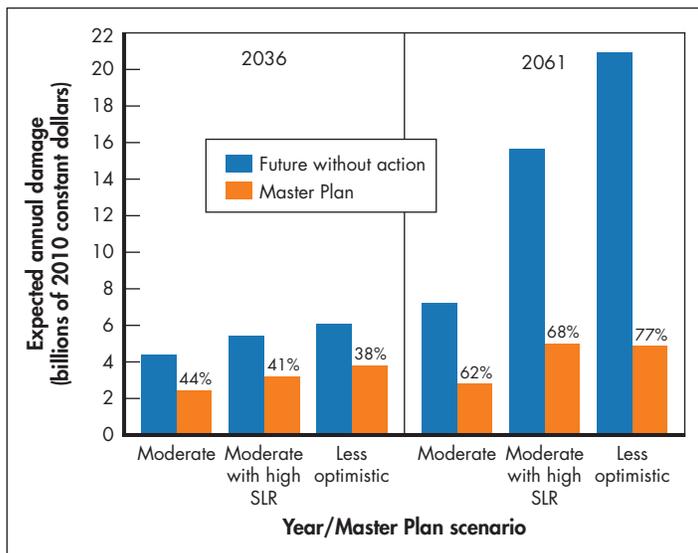


Figure 3. Estimated Expected Annual Damage in a Future Without Action and with the Master Plan in Place in 2061, by Master Plan Scenario



CLARA Analysis Shows Different Results for Different Parts of the Louisiana Coast

The final Master Plan analysis with CLARA shows that a large proportion of the coastwide damage reduction occurs in Greater New Orleans after 2032 as a result of new investments that reduce the likelihood of the protection system being breached by waves or storm surges.

The new Morganza to the Gulf surge barrier, built to an elevation of 20 to 37 feet, provides substantial flood depth reduction and consequent damage reduction in the vicinity of Houma and Terrebonne. Our analysis shows that the new alignment could provide substantial risk reduction benefits to Houma and the surrounding Terrebonne Ridge communities (see Figure 2). Specifically, Morganza to the Gulf could reduce depths across all three flood exceedances considered, with depth reduction of 2 to 5 feet (50 years), 2 to 7 feet (100 years), and 2 to 11 feet (500 years), respectively. Depth reduction extends for a large area of the coast behind the new alignment, including other portions of Terrebonne Parish and some upland areas. These changes in flood depth reduce EAD by 63–78 percent in Houma and vicinity, depending on the scenario.

However, the Morganza to the Gulf levee also displaces surge that previously flooded areas to the north, leading to an increase in surge heights and flood depths for areas outside the levee system. In addition, a notable result is that the new levee displaces surge onto the existing Larose to Golden Meadow protection system (see Figure 2), leading to induced flooding on the interior.

Finally, some areas receiving nonstructural investments in the Master Plan, such as the community of Mandeville on the north shore of Lake Pontchartrain, see very limited flood damage reduction from the Master Plan because of the limited range of nonstructural projects considered in this

analysis. For these areas, a wider range of risk reduction alternatives may need to be considered to reduce vulnerability to damage from future storm surge events.

How Does CLARA Work?

CLARA’s structure is based on the principles of quantitative risk analysis, which describe risk as the product of the *probability* or *likelihood* of a given event occurring—in this case, the annual probability of storm surge flooding at different depths—and the *consequences* of that event—the damage that results from the flooding. In CLARA, references to flood risk are best understood as flood risk to structures, physical infrastructure, and other local economic assets.

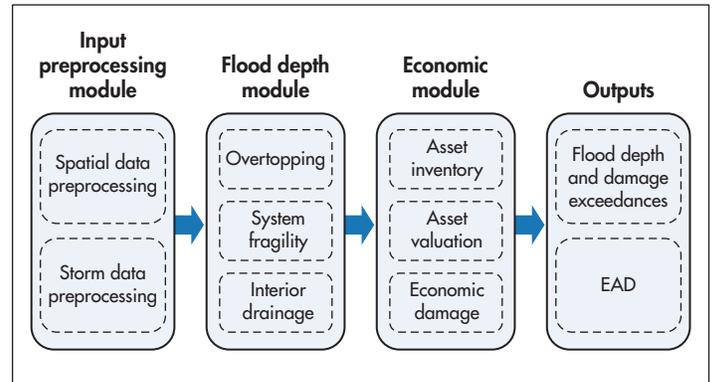
CLARA uses two types of information to estimate flood depths and resulting damage. First are estimated peak storm surge and wave heights. Second are data that characterize the hurricane protection system. One of the key decisions to be made as part of the Master Planning process was where to construct or improve levees, floodwalls, and other structures. These structures define which areas are protected from hurricanes and which areas are not.

The study area was adopted directly from the recent U.S. Army Corps of Engineers Louisiana Coastal Protection and Restoration (LACPR) analysis. The northern boundary of this area roughly follows Interstates 10 and 12; storm surges are not expected to affect areas to the north of these highways. CLARA labels each area as *unprotected*, with no levees, floodwalls, or other barriers; *semiprotected*, with levees or floodwalls that do not fully enclose the population at risk; or *protected*, with hurricane protection that fully encloses the area in a ring.

The structure of the CLARA model is illustrated in Figure 4. In the **input preprocessing module**, CLARA uses information about the study region and generates flood depth estimates in unprotected and semiprotected areas and storm hazard conditions for a sample of hypothetical storms. It also records surge and wave conditions along protection structures.

In the **flood depth module**, CLARA estimates flood depths with a particular focus on storm surge or wave overtopping and system fragility. CLARA also equalizes the flood

Figure 4. Structure of the CLARA Model



depth among adjacent protected areas. Flooding is a result of a complex set of factors, so, by necessity, CLARA simplifies what actually occurs. For example, when estimating levee fragility, we considered only peak storm surge that occurs during a storm, ignoring the period of buildup and withdrawal.

The depth of the flood directly determines the amount of damage that occurs, so flood depths are inputs to the **economic module**. In this step, CLARA values the assets at risk from flooding and estimates the damage in dollars.

During Master Plan development, CLARA’s outputs were used as inputs for the separate, RAND-developed Planning Tool, which assessed the overall benefits and costs of proposed protection and restoration projects, taking into account uncertainty regarding future conditions.

CLARA Allows a Flexible Exploration of Options

Louisiana faces a growing threat from increased future flood risk, but the 2012 Master Plan takes a major step toward protecting the state’s vibrant cultural history and economic livelihood for years to come. CLARA establishes the capability to perform comparative evaluations of many options in a rigorous manner while accounting for a wide range of future uncertainties, including those emerging from a changing climate. CLARA can also serve as a road map for future evaluations of coastal flood damage or damage reduction in Louisiana and other coastal regions.

This research brief describes work done for RAND Infrastructure, Safety, and Environment documented in *Coastal Louisiana Risk Assessment Model: Technical Description and 2012 Coastal Master Plan Analysis Results*, by Jordan R. Fischbach, David R. Johnson, David S. Ortiz, Benjamin P. Bryant, Matthew Hoover, and Jordan Ostwald, TR-1259-CPRA, 2012, 144 pp., \$37.95, ISBN: 978-0-8330-7708-0 (available at http://www.rand.org/pubs/technical_reports/TR1259.html). This research brief was written by Shelley Wiseman. The RAND Corporation is a nonprofit institution that helps improve policy and decisionmaking through research and analysis. RAND’s publications do not necessarily reflect the opinions of its research clients and sponsors. RAND® is a registered trademark.



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