LOUISIANA COASTAL PROTECTION AND RESTORATION (LACPR)

FINAL TECHNICAL REPORT

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U. S. Army Corps of Engineers
New Orleans District
Mississippi Valley Division

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Section 1. Introduction

In response to the destruction caused by Hurricanes Katrina and Rita, the U.S. Congress directed the Secretary of the Army to develop plans for hurricane risk reduction and coastal restoration in both Louisiana and Mississippi. The Louisiana Coastal Protection and Restoration (LACPR) Technical Report was prepared by the United States Army Corps of Engineers (USACE) New Orleans District in response to the Congressional direction for Louisiana. The USACE Mobile District has prepared a separate report to meet the Congressional direction for Mississippi.

The New Orleans District provides comprehensive water resources management for South Louisiana to ensure public safety and benefit the Nation, while balancing the primary missions of navigation, flood and hurricane storm damage reduction, and environmental stewardship. This Technical Report informs decision makers, stakeholders, and the public of the tradeoffs that should be considered in future decisions in order to maintain existing risk levels and/or reduce risk along the Louisiana coast.

Residents in vulnerable areas throughout southern Louisiana make up a work force that produces vital goods and services for the nation that are unavailable in other regions. The location of the New Orleans metropolitan area takes advantage of critical national transportation corridors; the Mississippi River is the main water-based transportation route serving the central United States. Until the 18th century, the mouth of the Mississippi River was frequently impassible due to log jams and shoals. The site of the City of New Orleans was chosen because it provided shipping access to the Mississippi River via Breton Sound, Lake Borgne, Lake Pontchartrain and various bayous without having to navigate the treacherous river mouth. As the United States grew, New Orleans grew with its port attracting industry and associated maritime development. New Orleans is unique among major U.S. port cities because much of the metropolitan area is on land below sea level, confined within levee systems.

Following World War I, construction of the Gulf Intracoastal Waterway (GIWW) encouraged further industrial development along the Louisiana coast for defense manufacturing and energy production. Ports located in South Louisiana grew to become the largest collective port facility in the United States. The State claims three of the top ten commercial fisheries ports as well as the nation’s only offshore oil port and support industry which contribute to vital domestic energy security. Coastal Louisiana is home to over 2.4 million residents (55 percent of the State’s population). The businesses and industries that employ these residents play a vital role in key sectors of the nation’s economy.

The complex and changing nature of coastal Louisiana's environment and communities creates a challenge for planners in the short term; these and other challenges are expected to continue well into this century. To address these many challenges, the USACE assembled a diverse team to work with stakeholders to formulate plans in a way that simultaneously meets technical requirements; achieves a level of public understanding and acceptance; and promotes transparency in decision making. The LACPR effort is the result of collaboration by more than 60 organizations including the USACE and the Louisiana's Coastal Protection and Restoration Authority (CPRA), as well as other State agencies, Federal agencies, non-USACE scientists and academics, non-governmental organizations, the Dutch Rijkswaterstaat, Dutch Water Partnership, independent technical reviewers, external peer reviewers, private engineering firms (U.S. and Netherlands), and stakeholders.

Congressional Authority for the LACPR Final Technical Report

The USACE developed this Final Technical Report in response to Public Laws 109-103 and 109-148. Under these laws, Congress and the President directed the Secretary of the Army, acting through the Chief of Engineers, to:

- Conduct a comprehensive hurricane protection analysis and design in close coordination with the State of Louisiana and its appropriate agencies;
- Develop and present a full range of flood control, coastal restoration, and hurricane protection measures exclusive of normal policy considerations for South Louisiana;
- Consider providing protection for a storm surge equivalent to a Category 5 hurricane; and
- Submit preliminary and final technical reports.

The original direction in the Energy and Water Development Appropriation Act of 2006 (Public Law 109-103) passed in November 2005 was replaced with the following wording from The Department of Defense Appropriations Act of 2006 (Public Law 109-148) signed on December 30, 2005:

> *''Provided further, That using $8,000,000 of the funds provided herein, the Secretary of the Army, acting through the Chief of Engineers, is directed to conduct a comprehensive hurricane protection analysis and design at full federal expense to develop and present a full range of flood control, coastal restoration, and hurricane protection measures exclusive of normal policy considerations for South Louisiana and the Secretary shall submit a preliminary technical report for comprehensive Category 5 protection within 6 months of enactment of this Act and a final technical report for Category 5 protection within 24 months of enactment of this Act: Provided further, That the Secretary shall consider providing protection for a storm surge equivalent to a Category 5 hurricane within the project area and may submit reports on component areas of the larger protection program for authorization as soon as practicable: Provided further, That the analysis shall be conducted in close coordination with the State of Louisiana and its appropriate agencies.''*

In addition, The Department of Defense Appropriation Act, 2006 (Public Law 109-148), included the following:

> *"…that none of the $12,000,000 provided herein for the Louisiana Hurricane Protection Study shall be available for expenditure until the State of Louisiana establishes a single state or quasistate entity to act as local sponsor for construction, operation and maintenance of all of the hurricane, storm damage reduction and flood control projects in the greater New Orleans and southeast Louisiana area…"*

The establishment of the Coastal Protection and Restoration Authority (CPRA) in December 2005 by the State of Louisiana complied with Public Law 109-148.

Policy Considerations

LACPR presents a complex water resource management challenge due to the range of interrelated human and environmental factors to be addressed, the size of the planning area, the requirement for new hydromodeling and risk-informed planning methodologies, and extensive stakeholder involvement. For these reasons, as well as the magnitude of the hurricane damage in 2005, Congress directed the LACPR analysis to be conducted "exclusive of normal policy considerations."

Under normal USACE policy, for projects which produce both National Economic Development (NED) benefits and National Ecosystem Restoration (NER) benefits, the plan selected for recommendation is the one that maximizes the sum of net NED and NER benefits. Exceptions to the normal policy for selecting the combined NED/NER plan may be granted when there are overriding reasons for recommending another plan based on other Federal, State, local, and international concerns. Since the authority directed USACE to develop plans exclusive of normal policy, this exception has been applied to LACPR.

Hurricanes Katrina and Rita clearly highlighted that maximizing excess NED benefits (i.e. only implementing projects with a cost-benefit ratio greater than one) did not result in a full understanding of the level of risk exposure in order to formulate complete plans. Therefore, the LACPR effort includes a comprehensive planning framework that assesses both economic and non-economic assets at risk. This framework follows the established planning principles but is not based on the traditional NED or NER analysis. The term "risk-informed decision framework" has been used to describe this framework which incorporates risk and decision science methods into the planning process. These methods incorporate the consequences of possible events, the associated uncertainty of the metric's performance in scoring plans, the uncertainties of planning assumptions, and the contribution of stakeholder input.

Congress directed reports on *"comprehensive Category 5 protection;"* however, achieving a "Category 5" level of risk reduction across all of South Louisiana would not likely be acceptable since it would entail large levees across the entire coast (termed "The Great Wall of Louisiana") or massive buyouts and abandonment of communities. Therefore, USACE policy guidance memorandums directed that a set of measures be presented that could reduce risk across a range of storm surge events including the following:

- 100-year risk reduction (one percent annual probability of being equaled or exceeded),
- Low Category 5 or Hurricane Katrina-like event (estimated as a 400-year surge event with a 0.25 percent chance of being equaled or exceeded in any given year), and

- High Category 5 event (estimated as a 1000-year surge event with a 0.1 percent chance of being equaled or exceed in any given year).

The LACPR Final Technical Report presents these options so that the public and decision makers can be confronted with the tradeoffs inherent in either pursuing or not pursuing new hurricane risk reduction projects.

Congress also directed a technical report rather than a reconnaissance or feasibility report as described by normal USACE policy; however, the LACPR Technical Report contains many of the same components as a reconnaissance or feasibility report. In response to the Congressional authority, this technical report presents the following:

- The planning steps used to develop the full range of coastal restoration, structural, and nonstructural measures as part of a multiple lines of defense approach.
- Details on the formulation and evaluation of a wide array of alternatives.
- A comparison of the alternatives and the tradeoffs involved in selecting risk reduction plans.
- An array of options for further investigation by the USACE and the supplemental measures to be implemented by other Federal, State, and local entities in order to realize a comprehensive risk reduction program for Louisiana.
- A communication and management framework for implementing coastal protection and restoration in Louisiana.
- An inventory of USACE authorities that could help implement the array of options.

The LACPR effort was originally constrained by a two-year Congressional deadline but additional time was needed to complete the technical report due to the engineering, environmental, and economic complexities. The extent of the geographic area prevented the collection of field data in this timeframe. This Technical Report does not contain construction recommendations or the National Environmental Policy Act documents, feasibility-level designs, real estate plan, and cost estimates that are required for the USACE to make such recommendations.

LACPR Risk-Informed Decision Framework

Since December 2005, the LACPR team has faced a unique challenge in conducting a comprehensive hurricane risk reduction analysis for a 26-parish area in South Louisiana covering 23,273 square miles, an area almost the size of West Virginia. The magnitude of data, and the tools required to analyze the data, far exceed any prior USACE hurricane risk reduction efforts. The team was directed to evaluate alternative solutions without reliance upon the traditional cost-benefit analysis methods and to identify a final array of comprehensive, coastwide plans that will reduce risks of flooding caused by storm surge and coastline degradation while considering a full range of risks to people, cultural heritage, environment, property and economy as well as infrastructure, construction, operations, and maintenance costs. This planning approach is referred to as the Risk-Informed Decision Framework (see **Figure 1-1**).

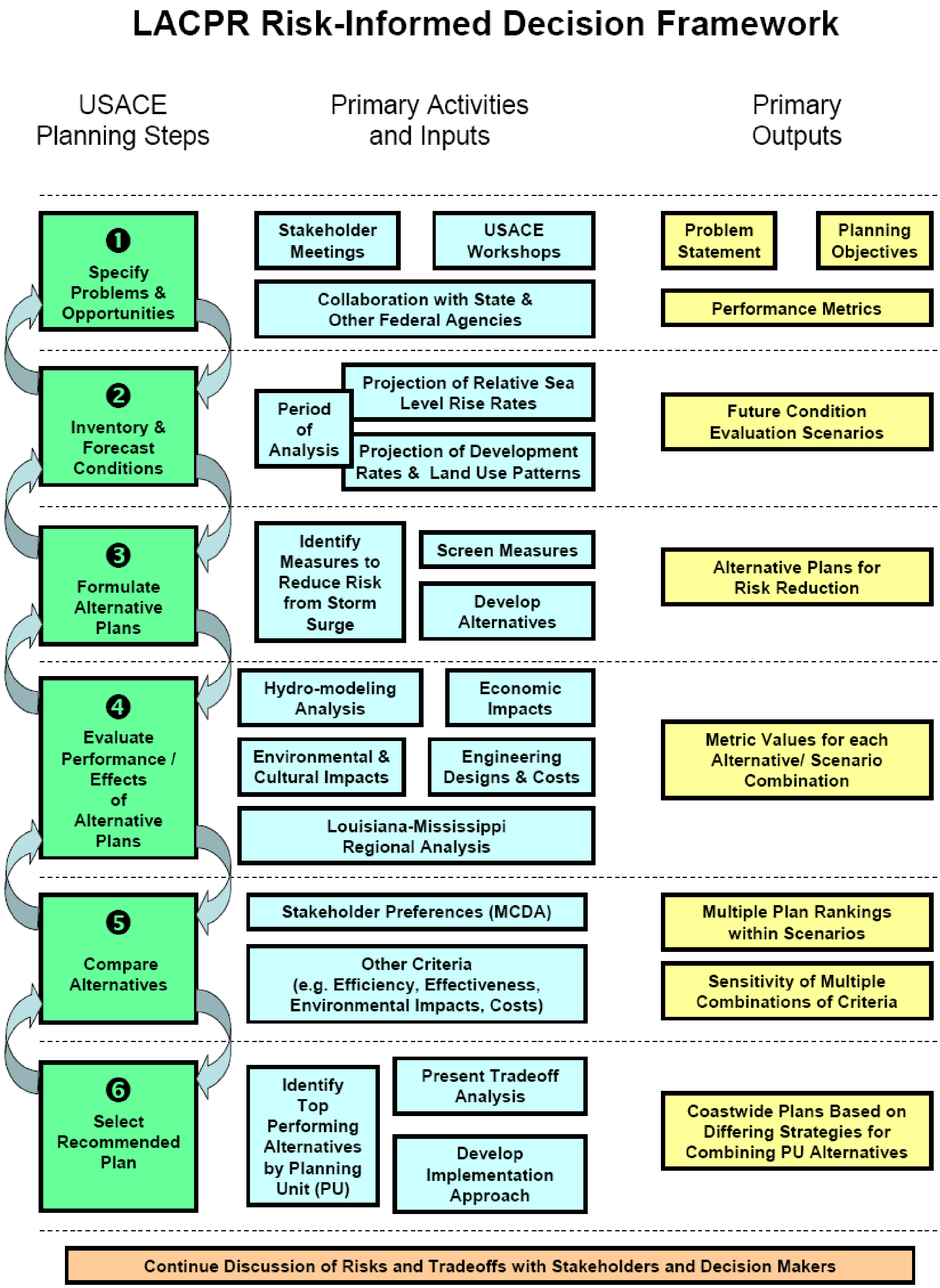


Figure 1-1. LACPR planning process or Risk-Informed Decision Framework.

The Risk-Informed Decision Framework (RIDF) closely follows the USACE's 6-step planning process but augments this planning process by incorporating specific techniques and methods from risk analysis, scenario planning, and multi-criteria decision analysis (MCDA). MCDA is an integral part of the RIDF because it allows comprehensive evaluation of project alternatives and comparable consideration of assets that are difficult to quantify in monetary terms. Over the course of the LACPR effort, considerable learning regarding the possible approach to, and application of, such a framework has occurred, and it is necessary to clearly state the revealed shortcomings. The issues encountered during application of the RIDF and MCDA are described in Section 13 of this report; however, it has not yet been feasible to incorporate lessons learned. Nevertheless, MCDA has been a successful means to inform tradeoffs and is an effective means of communicating the wide spectrum of risks to stakeholders.

The results of the RIDF analysis performed in the LACPR effort provide some insight and may be used as a foundation for further evaluation and development. However, additional investigation and refinement of both the MCDA approach for stakeholder value elicitation and the consideration of impacts from extreme storm events is recommended. The Findings, and Conclusions and Recommendations Sections of this report identify some of the needs and possible actions that might be utilized to continue to refine and development a risk informed decision approach.

Stakeholder Involvement

Stakeholder involvement has been a critical component of LACPR and the development of a coastwide vision for protection and restoration through the State of Louisiana's planning effort. Starting with a Plan Formulation Workshop in February 2006, the USACE and CPRA sought input from individuals, private entities, local governments, academia, and other State and Federal agencies, in addition to other stakeholders such as environmental, navigation, commercial fishing, recreation, agricultural, and oil and gas interests. Public and stakeholder communication included meetings, workshops, radio interviews, and presentations at local community events, as well as print and broadcast media, internet sites, newsletters, and fact sheets. Over the course of more than a year, the LACPR team held three sets of stakeholder workshops across coastal Louisiana in order to update stakeholders on the progress of the technical evaluation and to engage them in a new risk-informed decision making process. These workshops culminated in a fourth set of meetings where more than 100 stakeholders weighted performance metrics based on the values of their groups.

Alternatives Development

In order to catalogue and begin screening the extensive numbers of risk reduction measures proposed by various groups and individuals, the LACPR team prepared and made public the LACPR Plan Formulation Atlas dated April 16, 2007. The Atlas identified hundreds of measures which could be combined into over 200 million alternatives across the coast. Those alternatives were then screened down to a set of 111 alternatives for evaluation and comparison representing over 4 million coast-wide combinations. The final array of options consists of five or six alternatives in each of five planning units, or a set of 3,600 possible coastwide combinations. This final array has been organized into different strategies for a set of seven coastwide plans.

Risk-based Hurricane Frequency Simulation

One of the most significant accomplishments in the last few years is the development and application of numerical models to replicate hurricane surges and to statistically determine the potential frequency of events at individual locations across the coasts of Louisiana and Mississippi. The models address storm frequency events of the rarest magnitude including a range of “Category 5” hurricanes. The Federal government adopted these models for the rebuilding of the New Orleans levee system, for determining flood insurance maps, and for evaluation of hurricane risk to the Louisiana and Mississippi coasts. The LACPR technical evaluation also applied these state-of-the-art storm surge models in order to quantify the risk reduction benefits provided by the coastal landscape.

Socio-Economic Evaluation

As a means to process data for approximately 72,000 census blocks under multiple future scenarios, the LACPR team developed a customized geographic information system (GIS), which utilized remotely-sensed data to assess the damages to residential and non-residential structures, their contents, and vehicles as well as agricultural resources, roads and railroads in the LACPR planning area. The application was also used to determine the number of structures, population, employment, income, and output affected by the stages associated with various frequency flood events. Cultural resources were also placed into a GIS database. These inventories allow the LACPR team to evaluate alternatives and interact with stakeholders using a flexible and meaningful level of outputs.

Scenario Planning

Traditional USACE planning methods rely on a single forecast of the future condition. These forecasts are based partly on the past and partly on expected changes in the future. Most single forecasts lose accuracy the further into the future they project, and therefore strategies based on single projections are likely to be at least partly flawed. Rather than try to predict the future, the LACPR evaluation uses scenarios to evaluate performance of plans. Scenario planning is an approach for dealing with key uncertainties for which no reliable or credible probabilities can be obtained. Scenarios represent futures that can plausibly occur given a set of plausible combinations of future conditions. These conditions represent uncertain values of key drivers that will result in different futures. The key drivers in the four LACPR scenarios are relative sea level rise (subsidence and sea level rise) and development rates/patterns.

Stakeholder-Based Multi-Criteria Decision Analysis

In order to present alternatives that equitably address the many vital concerns to stakeholders, multiple criteria need to be evaluated and compared. While a number of tools exist to compare the over 100 alternative plans brought forth in this document, there are also many competing interests and varying perceptions of risk. In response to limitations in traditional USACE methods, the LACPR team has begun to use MCDA as a tool for objectively comparing alternatives based on stakeholder values.

Evaluation Criteria for Ranking and Comparing Plans

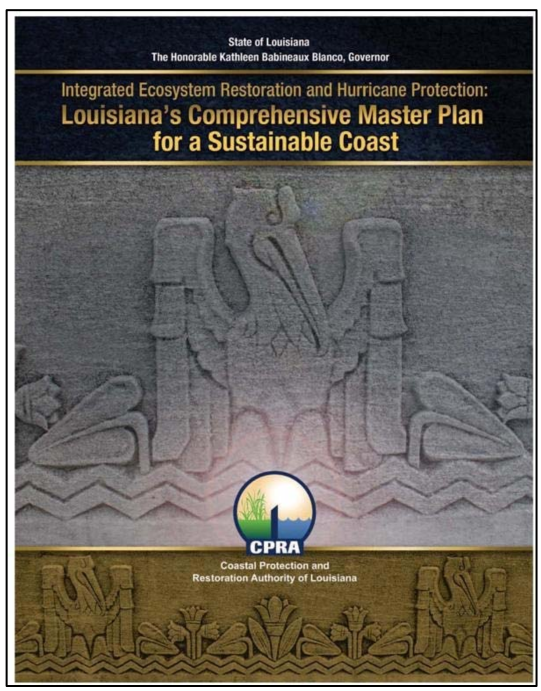
To provide a comprehensive view of decision tradeoffs, the risk-informed decision framework includes several different evaluation criteria in addition to the stakeholder-based MCDA results. These additional evaluation criteria are similar to those produced by the type of decision criteria that have been traditionally applied for water resources planning. The complete set of evaluation criteria for LACPR includes consideration of the stakeholder MCDA results, environmental impacts, cost efficiency, risk reduction efficiency, and total costs.

Louisiana's Comprehensive Master Plan for a Sustainable Coast

At the same time that Congress directed the LACPR technical report, the Louisiana Legislature restructured the State's Coastal Wetlands Conservation and Restoration Authority to form the Coastal Protection and Restoration Authority (CPRA). The CPRA is the single State entity with the authority to focus development and implementation efforts for comprehensive coastal protection and restoration and to interface with the USACE on LACPR coordination. The Louisiana Legislature called for a comprehensive coastal protection plan that:

- Combines hurricane protection and the protection, conservation, restoration, and enhancement of coastal wetlands and barrier shorelines or reefs; and
- Addresses hurricane protection and coastal restoration efforts from both short-term and long-range perspectives and incorporates structural, management, and institutional components of both efforts.

The State's plan entitled *Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast* was unanimously approved by the Louisiana Legislature with final approval being provided on May 30, 2007. This State Master Plan, which is available at *www.lacpra.org*, presents the State's conceptual vision of a sustainable coast and the overarching vision for LACPR.



Cover of Louisiana's State Master Plan

Although the State Master Plan recommends certain actions, it contains many unanswered questions about specific hurricane risk reduction and coastal restoration measures. The LACPR technical report complements the State Master Plan by presenting detailed technical evaluation of those components within the USACE's mission. The relationship between the State and the USACE facilitates sharing of the best available scientific and engineering information and working closely with each program's partners and the public. Continuing cooperation and partnership with the State of Louisiana is, and should be, an integral part of protection and restoration efforts in Louisiana.

Federal Agency Involvement

Federal agencies have participated in the LACPR effort at the field, regional, and Federal level. At the field level, Federal agencies formed the majority of the LACPR Habitat Evaluation Team, which assisted the Project Delivery Team with coastal restoration plan formulation, as well as development and technical assessment of metrics to evaluate the environmental impacts of alternatives. At the regional and Federal levels, Federal agencies participated in the LACPR Regional Working Group and Federal Principals Group. In any future USACE efforts, Federal agencies are expected to participate in project delivery teams, habitat evaluation teams, an adaptive management and planning program, science and technology program teams, regional working groups, Federal working groups, and advisory panels. The participation of the Federal agencies in these capacities does not in any way limit the prerogatives of the other participating agencies in exercising their statutory authorities and responsibilities. However, this collaborative approach creates strong working relationships and provides early recognition of multiple government priorities. Participating Federal entities included:

- Department of Homeland Security - Office of Gulf Coast Recovery, Federal Emergency Management Agency
- Environmental Protection Agency
- Department of the Interior – U.S. Fish and Wildlife Service, U.S. Geologic Survey, National Park Service, Minerals Management Services
- Department of Commerce – National Oceanic and Atmospheric Administration - National Marine Fisheries Service, National Weather Service
- Department of Agriculture - Natural Resources Conservation Service
- Department of Energy
- Department of Transportation - Maritime Administration, Federal Highway Administration
- U.S. Coast Guard

These and other Federal agencies are also expected to work with the State of Louisiana in implementing the State Master Plan. One of the recommendations of the State Master Plan is to provide an effective structure for Federal partnerships by developing mechanisms for focusing Federal involvement in an effective, problem-solving partnership with the State. The State also recommends developing a process to align the many diverse Federal agency missions related to the protection and restoration of coastal Louisiana.

Parallel Efforts in Louisiana and Mississippi

Concurrent with the LACPR effort, the U.S. Congress directed the Secretary of the Army to develop a similar effort for coastal Mississippi, which is referred to as the Mississippi Coastal Improvements Program (MsCIP). Although Congress authorized two separate efforts with slightly different objectives to address the Louisiana and Mississippi coasts, the USACE has taken a systematic and regional approach and has required that both the LACPR and MsCIP efforts be fully coordinated with each other. To ensure a fully coordinated approach, a systems analysis was conducted to assess potential regional impacts primarily associated with storm surge as it relates to economic damages, environmental/cultural impacts, and other social effects upon plans formulated separately for MsCIP and LACPR. This systems analysis also supports the ultimate development of a comprehensive regional plan, consistent with all planning objectives and metrics and commensurate with the level of detail in the reports.

Peer Review

The LACPR technical report has been and will be further reviewed by independent scientists and engineers prior to submittal to Congress. The purpose of these reviews is to provide the USACE with an independent technical assessment of the report, including an assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, data, and analyses used in the report.

In addition to internal agency technical reviews, the USACE requested the National Academies to convene a committee of experts to review the draft and final LACPR technical reports. In response to this request, the Academies' National Research Council Committee on the Review of the Louisiana Coastal Protection and Restoration Program was established in June 2007. To promote dialogue between the LACPR and National Research Council committee, meetings were held in July and August 2007, and in April 2008. All meetings included open, public sessions, and the 2007 meetings featured several invited guest speakers from academia and non-governmental organizations in the region.

The National Research Council reviewed the February 2008 draft LACPR technical report and provided their comments in a May 2008 report. The committee found both areas of strength and areas that have more work to be done. The committee commended the USACE for recognizing the need for new and systems-based approaches to reduce risk to Louisiana's coastal population and infrastructure. All of the National Research Committee's key findings have been addressed in the final technical report to some extent. Some comments could not be fully addressed in the final technical report but will be addressed in follow-on actions of the USACE. The National Research Committee's key findings (in italics) which have been addressed in full include the following:

- *Consistently refer to relative levels of risk reduction from hurricanes and storm surge, and make it clear that absolute protection is not possible.* This report has adopted the term “hurricane risk reduction” rather than “hurricane protection;” presents plans in terms of residual risks; and contains statements throughout that 100 percent risk reduction is not achievable.
- *Include additional, more explicit information on cost estimates for alternatives.* Estimated Federal costs, non-Federal costs, and total costs for each of the final array of alternatives are presented in Section 16 of the report.
- *Identify and clearly present all major assumptions.* Critical assumptions, their rationales, and the consequences if the assumptions become invalid are presented in Section 4 of the report.

The following key findings have been addressed in part and will be further considered in follow-on USACE efforts:

- *Develop sediment budgets for the wetlands of coastal Louisiana to determine the feasibility of maintaining coastal Louisiana in roughly its present condition.* The USACE is currently developing a Regional Sediment Budget for coastal Louisiana; however, the final budget is not expected to be completed until July 2010. Based on rough calculations, the LACPR team concluded that adequate sediment sources are available to implement proposed coastal restoration plans but acquiring those resources involves tradeoffs (e.g. costs and environmental impacts).
- *If the results of the sediment budget show that it is infeasible to maintain the current coastal landscape, then re-assess the role of the proposed structural and nonstructural designs that are based on the assumption that the current coastal configuration will be maintained.* Risk reduction effectiveness has been recalculated and assessed for all structural, nonstructural, and comprehensive plans assuming a degraded coast. In the Pontchartrain and Barataria basins, failing to prevent continued wetland loss would result in increased total system costs (additional implementation costs plus increased residual damages) as shown in the tradeoff tables in Section 15 of this report. With additional investment, however, the intended level of performance of any alternative could be maintained and the relative rank performance of the alternatives without coastal components would be the same.
- *Explicitly include probabilities of failure or inadequate performance and consider possible effects of human actions such as improper operations during an emergency.* For the final array of alternatives, a qualitative risk and reliability comparison is included in the tradeoff tables in Section 15 of the report. Levee lengths were combined with the type and total numbers of structures to qualitatively assess vulnerability. Detailed quantitative analysis of failure potential and associated residual risk will be undertaken and considered in subsequent planning and design phases.

- *Identify projects of higher priority that promise to yield greater and more immediate benefits in terms of flood risk reduction and ecosystem restoration.* The final array of alternatives narrowed down the 111 alternatives evaluated for LACPR to five or six viable alternatives in each of the five planning units. Any of these plans could be implemented if desired by the Administration and/or Congress, but the USACE recommends a continued dialogue between its Federal and State partners as well as stakeholders prior to Congress taking action. Steps were taken during the technical effort to provide the foundation for refining both the evaluation and the decision process that will support the decisions regarding challenges and tradeoffs.

The remaining key findings can only be fully addressed in conjunction with other Federal, State, and local entities:

- *Give sufficient attention to the need to counter the phenomenon of induced development behind levees and to prevent the future development of high-hazard areas not protected by levees, and present an integrated set of measures that can limit future development in low-lying, flood prone areas.* The problem of induced development is addressed in Section 3 of the report; however, without more specific direction from Congress, the USACE is limited in its ability to set policies that might limit future development. Therefore, other Federal, State, and local entities have an equally important role in reducing these vulnerabilities.
- *Further explore the institutional and administrative needs regarding effective implementation of restoration, structural, and nonstructural measures for hurricane risk reduction, and how state, local, and other bodies can complement the roles of the USACE as part of a systematic and integrated program of hurricane protection.* A comprehensive communication and coordination approach involving the Louisiana CPRA, other State and Federal agencies, and local interests is presented in Section 17 of the report.

The National Research Council will provide an extended review of the final LACPR technical report prior to its submittal to Congress.

Section 2. Hurricanes and Coastal Land Loss in Louisiana

Hurricanes and tropical storms are part of Louisiana's history and culture. The catastrophic losses resulting from the hurricanes of 2005, and the greatest tidal surge to hit the mainland of the United States in recorded history, however, highlighted the need to take a more systematic approach to hurricane risk reduction. Impacts of major storms on communities, natural resources, transportation systems, industries, and strategic economic resources are the subject of growing concern. Even if the populated areas can be made safer through improvements to existing hurricane risk reduction measures, the losses of coastal areas outside of the risk reduction systems pose an increasing threat to the economic and environmental sustainability of the region.

What's at Risk?

When economic assets in the LACPR planning area are totaled, they add up to well over $178 billion. These assets could potentially reach over $268 billion by the year 2075[1]. These economic assets, however, are only part of what's at risk. The value of Louisiana's communities, cultural resources, ecosystem, and industries to the nation cannot necessarily be quantified in terms of dollars.

Communities and Cultural Resources

Communities across South Louisiana are subject to inundation by hurricane storm surges. The coastal region contains 55 percent of the State's population; over 2.4 million people according to a January 2006 Post-Disaster Population Estimates by the Louisiana Department of Health and Hospitals Bureau of Primary Care and Rural Health. Major population centers at risk from hurricane surges include the greater metropolitan area of New Orleans, the Houma – Thibodaux area, and the Lake Charles metropolitan area.

Communities of unique heritage can be found nestled within urban areas and on the rural landscape. The people who reside within this region derive from diverse cultural backgrounds and form numerous ethnic groups including Creole, Cajun, African American, French, Spanish, Native American, South American, Yugoslavian, Isleño (Spanish speaking migrants from the Canary Islands), Filipino, Italian, German, Chinese, and Vietnamese, among others. In addition, the coastal wetlands of Louisiana have been a setting for diverse cultural developments. For example, sustainable fishing communities of Native American, Isleño, Acadian and Vietnamese heritage found within the coastal parishes and such communities are becoming increasingly rare within the Nation.

Cultural assets, such as prehistoric and historic archaeological sites, historic buildings, and historic districts are located throughout the region. The contribution of many of these assets, individually or taken together in groups, is invaluable in defining the character of South Louisiana and the Nation. The architecture of public, religious,

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[1] Value of residential and non-residential structures, their contents and vehicles, as well as agricultural resources, roads, and railways. Source: USACE GIS Economic Application Database.

commercial, and residential buildings within the New Orleans and surrounding parishes reflect the City's historic development and the people and cultures that built the City. Vernacular architecture found in coastal and pastoral communities reflects rural lifeways, contributes to the regional landscape, and creates a sense of place.

Coastal subsidence, wetland losses, and relative sea level rise (the increase in the difference between ground elevations and mean sea level elevations) make these coastal communities increasingly vulnerable to inundation from hurricane-induced storm surges. As these coastal changes continue, inundation could occur more frequently and at greater depths than experienced in recent history. Communities are at risk of dispersion and disintegration following inundation events. The damage to or loss of archaeological/historic resources, parks and neighborhoods could lead to the loss of individual and community connection to a particular geographic place or location. Taken together, these outcomes could lead to a net loss of cultural diversity in South Louisiana. Storm-related disruptions to the populations and work force and their availability impact the entire economy of South Louisiana and portions of the national and international economies.

Wildlife Habitat and Fisheries

The Louisiana coastal plain contains one of the largest expanses of coastal wetlands in the contiguous United States. These coastal wetlands of Louisiana are significant on a national level. Their habitats serve as support to thousands of birds, fish, and other species, making the coastal wetlands of Louisiana among the nation's most productive and important natural assets. Seventeen endangered or threatened species are found in South Louisiana, including the bald eagle, Gulf sturgeon, Louisiana black bear, and several species of sea turtles.

Approximately 70 percent of all waterfowl that migrate through the U.S. use the Mississippi and Central flyways. With more than five million birds wintering in Louisiana, the Louisiana coastal wetlands are crucial habitat to these birds, as well as to neotropical migratory songbirds and other avian species that use them as crucial stopover habitat. Additionally, coastal Louisiana provides crucial nesting habitat for many species of water birds, such as the brown pelican.

Louisiana's vast coastal area serves as important fish habitat, functioning as a nursery, feeding, spawning, and growth area for many aquatic organisms. The ecosystem is the nation's largest shrimp, oyster, and blue crab producer. Louisiana produces an estimated 25 percent of North America's seafood off its coast (LED, 2007). Three out of the top ten commercial fishery ports in terms of pounds are located in coastal Louisiana.

The fish, wildlife, and boating resources of Louisiana generate substantial benefits. Hundreds of thousands of people depend on these resources for recreation, employment, and as a source of food for their families. The total economic effect of Louisiana's fish, wildlife and boating resources in 2006 is estimated at $6.75 billion (LDWF, 2008). These valuable resources are at risk; wetlands erosion in the State accounts for 90 percent of the total coastal marsh loss in the Nation.

Industries

Louisiana's industries have a significant role in the nation's economic health. Louisiana is abundant in natural resources and a top producer of rice, sugar cane, and forestry products. Louisiana is the largest importer of rubber, coffee, and steel in the United States and a major exporter worldwide, totaling $23.5 billion – an all-time record – in worldwide merchandise exports in 2006 (LED, 2007). Louisiana also exports sulfur, salt, chemicals, and seafood. Coastal Louisiana provides an integral national-security function by supporting energy independence, balance of trade, defense construction, and the efficient and effective transportation of commodities.

Energy/Oil and Gas - Louisiana is the nation's energy hub. From the first well in the early 1900s, to the first offshore platform in the 1940s, to the deepest sub-sea production system in the world in 2002, Louisiana has been at the forefront of technical innovation in the energy business. According to the State's Economic Development Department, including offshore production, Louisiana is the number one producer of crude oil and the number two producer of natural gas among the 50 states. The State also serves as entry point for critical foreign oil imports. In addition, Louisiana is home to many strategically important energy production and distribution facilities.

Transportation Routes and Port Facilities - Ten major navigation routes are located in South Louisiana; these routes and their integrated transportation systems are critical to regional, national, and international trade. Louisiana is home to the largest port complex in the world including seven deep-water ports, with 460 million tons of cargo shipped annually through the lower Mississippi River (LED, 2007). The Louisiana Offshore Oil Port (LOOP) provides tanker offloading and temporary onshore storage services for crude oil transported on some of the largest tankers in the world. Most of the tankers offloading at the LOOP are too large for U.S. inland ports. This network of port facilities supports the oil and gas industry and forms a critical hub for international trade. The combination of waterborne commerce, trunkline railroads, highways, and trucking connections accommodate the movement of grain, petroleum, natural gas, and a wide range of other products important to both national and international commerce.

Shipbuilding - According to the State's Economic Development Department, more than a quarter of the nation's transport ships are built in Louisiana. Louisiana's manufacturing strengths and strategic import/export location make it a logical site for shipbuilding activities. Louisiana is also home to the top shipbuilding school in the nation at the University of New Orleans.

Tourism - Tourism is the second largest industry in Louisiana. According to the Department of Culture, Recreation, and Tourism, prior to the storms of 2005, the annual tourism industry was a $9.9 billion industry, which employed 178,000 workers, and attracted over 24 million national and international visitors. Louisiana is home to many attractions such as the French Quarter, plantations, Cajun country, and outdoor activities.

The Hurricanes of 2005: Katrina and Rita

By many measures the 2005 hurricane season was the worst in the nation's history. Across the United States and around the world people were shocked by the images of destruction along the Gulf Coast. The hurricanes took over 1,800 lives, destroyed billions of dollars of residential, commercial, and public property, and changed the landscape of the coast. Hurricanes Katrina and Rita were two of the most costly national disasters to occur in the United States. The Congressional Budget Office estimated the total losses of physical capital from Hurricanes Katrina and Rita to be between $70 and $130 billion.

Federal disaster declarations for Hurricane Katrina covered 90,000 square miles of the United States—an area almost as large as the United Kingdom. During Hurricane Katrina, over 80 percent of New Orleans alone flooded—an area seven times the size of Manhattan. Approximately 1.3 million residents were displaced immediately following the storm, and 900,000 residents remained displaced as of October 5, 2005—the largest displacement of people since the great Dust Bowl migrations of the 1930s. However, unlike the Dust Bowl migrations which took place over a five to six year period, the displacement of people from the storms of 2005 was immediate. Also, unlike the Dust Bowl migrations where people knew that they would not be returning for some time, if ever, most of those fleeing the storms of 2005 fully expected to be returning to their homes no longer than two or three days later. In Louisiana alone, over 200,000 homes sustained major or severe damage.

The Hurricanes of 2008: Gustav and Ike

Three years after Hurricane Katrina, Gustav made landfall on the Gulf Coast in central Louisiana as a Category 2 storm. Two weeks later Hurricane Ike, which had at one point been a Category 4 hurricane, made landfall on Galveston Island, Texas. Hurricane Ike was one of the most destructive hurricanes to ever hit the United States. While Hurricane Gustav caused widespread moderate physical damage across a broad swath of Louisiana, Hurricane Ike had a devastating impact focused in large part on several parishes in South Louisiana. The Louisiana Recovery Authority estimates damages from Gustav and Ike in Louisiana to include approximately 12,000 flooded homes; approximately $750 million in agricultural losses; more than $1 billion in infrastructure damages; and business losses totaling approximately $2.5 to $5 billion.

Coastal Wetland Loss

The Louisiana coast is unique among the Gulf Coast states in that its coastal population centers are all buffered from the Gulf of Mexico by an expansive, although rapidly eroding coastal wetland system. Hurricanes Katrina and Rita resulted in the destruction of more than 217 square miles of coastal wetlands during their landfalls. The loss attributed to these storms exceeds the wetland losses that had been projected to occur in the entire State over the next 20 years. Viewed in relation to New Orleans alone, all of the wetlands that were expected to erode in the New Orleans area over the next 50 years were lost in a single day during the landfall of Hurricane Katrina. In addition, Hurricane Katrina destroyed or substantially damaged about one half of the State's barrier islands along the Gulf of Mexico.

The loss of Louisiana's coastal lands has been ongoing since at least the early 1900s with commensurate harmful effects on the ecosystem and future negative impacts to the economy of the region and the Nation. The USACE, the State of Louisiana, and others, under the authorization of the U.S. Congress, have been working for several years to combat coastal land loss, not only because of the role of coastal lands in storm protection, but also because of their vital contribution to the health of the natural environment, the regional and national economy, as well as the culture of South Louisiana. The alarming rate of land loss in coastal Louisiana has been raised as a national concern because it represents approximately 90 percent of the total coastal marsh loss occurring in the Nation. Of the hundreds of miles of shoreline, over 95 percent are suffering some form or level of erosion (USACE, 2004).

Land change is not the same in all coastal areas. Historical changes in land area across coastal Louisiana can be broken into three physiographic provinces including the Deltaic Plain on the east, the Marginal Deltaic Plain between the Atchafalaya River and Freshwater Bayou, and the Chenier Plain to the west of Freshwater Bayou. The term Marginal Deltaic Plain is sometimes used interchangeably with the Chenier Plain but is used here to describe the central Louisiana coast and its unique land change patterns. **Figure 2-1** illustrates the land change trends and projections in the three physiographic provinces as well as for the entire coast. Negative or downward trends indicate land loss while positive or upward trends indicate land gain.

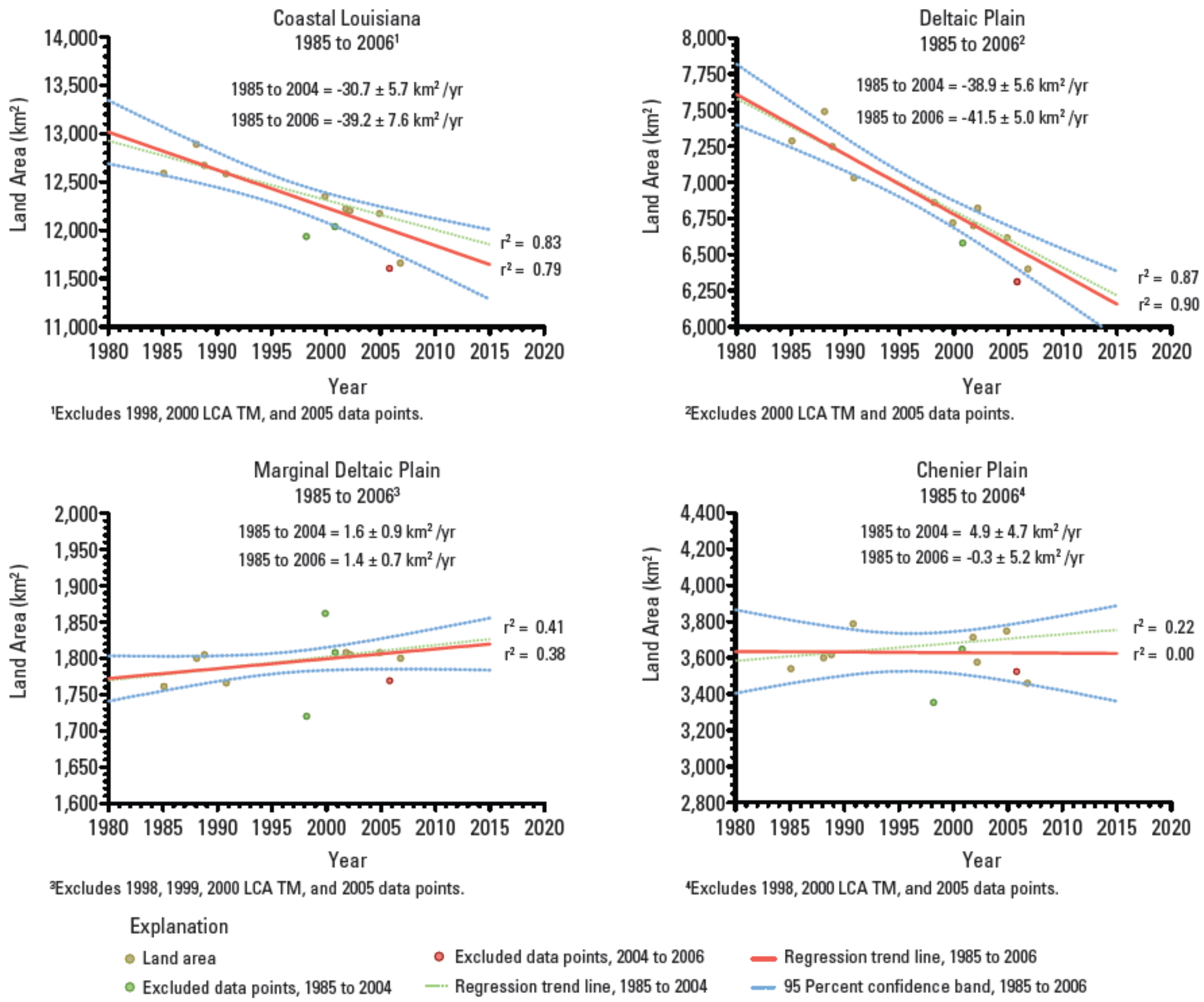


Figure 2-1. Land area change trends and projections in coastal Louisiana by physiographic province, 1985 - 2006.
Source: Barras et. al. 2008

These graphs show that the majority of coastal land loss since 1985 occurred on the Deltaic Plain. Over the same period, the Marginal Deltaic Plain showed a slight land area increase, primarily the result of growth in the Atchafalaya River and Wax Lake delta complexes, and the Chenier Plain was relatively stable. These trends in small land gains slightly offset the trends of land loss in the Deltaic Plain, thus reducing the overall rate of coastal land loss (Barras et. al., 2008). **Figure 2-2** shows the areas of land loss or land gain within the Deltaic, Marginal Deltaic, and Chenier plains over a 50-year period from 1956 to 2006.

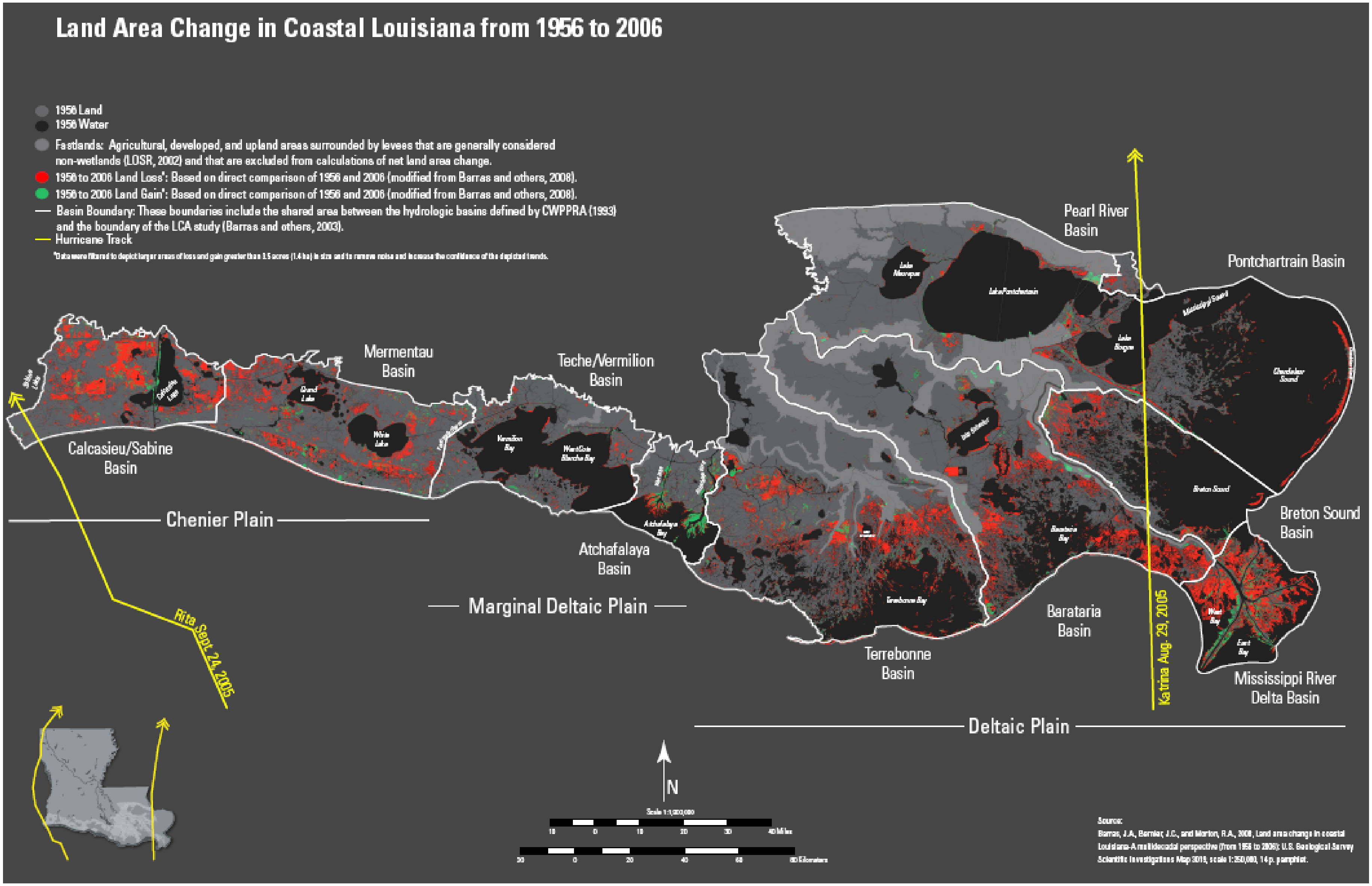


Figure 2-2. Land area change in coastal Louisiana: a multi-decadal perspective (from 1956 to 2006).
Source: Barras et.al. 2008

Land loss and the degradation of the coastal ecosystem are the result of both natural and human induced factors. Establishing the relative contribution of natural and human-induced factors is difficult. In many cases, the changes in hydrologic and ecologic processes manifest gradually over decades and in large areas, while other effects occur over single days and impact relatively localized areas as was the case after Hurricanes Katrina and Rita.

Natural factors of coastal land loss and ecosystem degradation include geologic faulting, compaction of sediment, river floods, global sea level change, wave erosion, and tropical storm events. These factors have shaped the coastal Louisiana landscape for thousands of years. Human activities have impacted land loss both directly and indirectly. Wetlands have been lost in the construction of navigation channels, canals, and flood control structures. Levees, that confine flood flows to their rivers, have contributed indirectly to wetland loss. Subsurface fluid withdrawal (oil, gas, water) may also be a major contributor to relative subsidence and resulting wetland loss. Developing a better understanding of these natural and human influences on land loss will lead to better engineered solutions to combat this problem which continues to reshape Louisiana.

Section 3. New Hurricane Risk Reduction Approaches

The enormity of Hurricane Katrina is staggering. Post-hurricane analysis places Katrina in the range of a 400-year storm, in terms of storm surge generation. A storm as large and intense as Katrina was difficult to reliably predict from a local sample that did not contain this type of storm. Prior to Hurricane Katrina, no historical storm combined both Katrina's intensity and size. The lessons learned from the hurricanes of 2005, and the intense hydromodeling effort that the USACE has undertaken since that time, have advanced the understanding of hurricane risk to South Louisiana. That knowledge sets the stage for improving the USACE's planning, analysis, design, and decision making.

Actions for Change

Since 2005, the USACE has embarked on an ambitious "Actions for Change" initiative to incorporate the lessons learned from Hurricanes Katrina and Rita into its future programs. The Actions for Change initiative began with an extensive internal and external review of USACE methodologies, assumptions, design standards, and decision-making processes related to the Southeast Louisiana hurricane risk reduction system. It concluded with a key element that the level of risk (either success of the expected outcome or reduced risk from damages) associated with a proposed plan should guide the decision-making process as well as inform all stakeholders of the remaining risks. The four themes from this initiative are:

- Comprehensive Systems Approach
- Risk Informed Decision Making
- Communication of Risk to the Public
- Professional and Technical Expertise

The LACPR technical report contains these four themes. Additional information can be obtained in the Interagency Performance Evaluation Task Force (IPET) Report and the Hurricane Protection Decision Chronology Report.

Overcoming Misconceptions about Hurricanes and Storm Surge

For decades, the USACE, the National Oceanic and Atmospheric Administration (NOAA), and the National Weather Service have used the Saffir-Simpson Hurricane Scale for categorizing hurricane strength. The Saffir-Simpson scale serves the public as to the advisability of evacuation from areas where winds may prove dangerous to lives and property; however, it is not an adequate tool for the design of hurricane surge risk reduction systems. In many cases, and especially in coastal Louisiana, the greatest threat to lives and property and the environment from storms is the storm surge flooding.

Coastal Louisiana has been hit by hurricanes with higher Saffir-Simpson ratings than Hurricane Katrina, a Category 3 storm at landfall, but none left anywhere near the destruction of Hurricane Katrina. Subsequently, Congress directed the LACPR effort to address "Category 5 protection." In order to meet this Congressional mandate, the

Federal government had a lot more to learn about hurricanes, in particular their potential storm surge elevations along the coast.

All Hurricanes are Not Created Equal

Hurricanes Camille, Audrey, Carla and Charley all had higher wind speeds at landfall than Hurricane Katrina. Then why did Hurricane Katrina produce at least five more feet of storm surge than even Camille, a Category 5 storm at landfall? The reason has to do with storm size. Scientists have concluded that the two primary parameters for estimation of maximum storm surges along the coast are storm intensity (related to the Saffir-Simpson scale) and storm size (*not* related to the Saffir-Simpson scale).

Hurricane Katrina was a very large Category 3 storm when it passed over the New Orleans area on the morning of August 29, 2005. Twenty-four hours earlier this storm had been the largest Category 5 and most intense (in terms of central pressure) storm on record within the northern Gulf of Mexico (see **Figure 3-1**). Due east of the Mississippi River Delta, a deepwater buoy recorded the highest significant wave height (55 feet) ever measured in the Gulf of Mexico. The large size of Katrina throughout its history, combined with the extreme waves generated during its most intense phase, enabled this storm to produce the largest storm surges (reliable observations up to 28 feet) that have ever been observed.

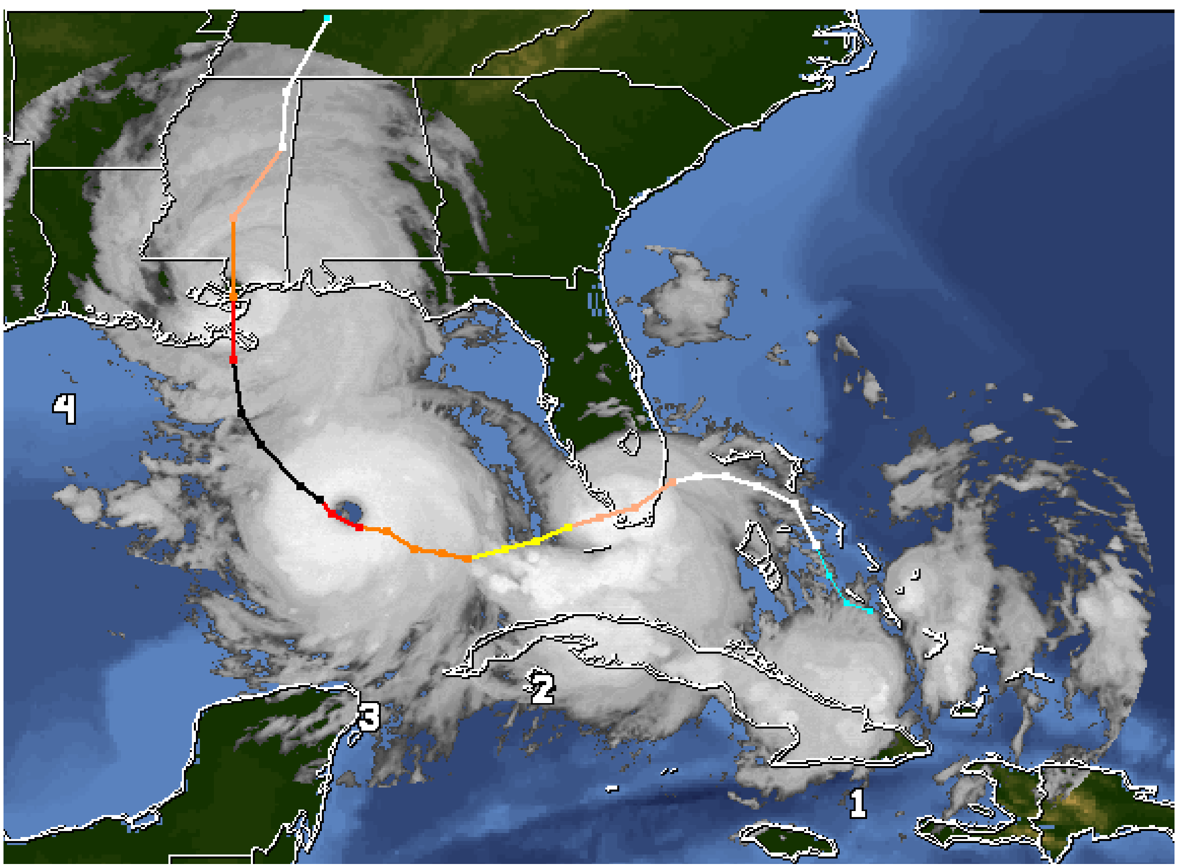


Figure 3-1. Time-lapsed satellite photo showing Hurricane Katrina's path and growth. Source: National Oceanic and Atmospheric Administration

Table 3-1 shows where Hurricane Katrina's characteristics fit within the Saffir-Simpson Hurricane Scale (shaded blocks represent Hurricane Katrina at landfall). Note that based on three physical characteristics, wind speed, central pressure and surge height, Hurricane Katrina displayed attributes from three different categories on the Saffir-Simpson Hurricane Scale.

Table 3-1. How Hurricane Katrina at landfall in Louisiana fits within the Saffir-Simpson Hurricane Scale.

Scale Number (Category)	Winds (miles per hour)	Pressure (millibars)	Approximate Surge (feet)	Damage
1	74-95	980	4 to 5	Minor
2	96-110	965 – 979	6 to 8	Considerable
3	111 – 130	945 – 964	9 to 12	Extensive
4	131 - 155	920 - 944	13 to 18	Extreme
5	> 155	< 920	> 18	Catastrophic

At landfall on August 29, 2005, Hurricane Katrina was a Category 3 storm with 125 mile per hour winds and a pressure of 920 millibars; however, on August 28, 2005, Hurricane Katrina was a Category 5 storm with 175 mile per hour winds and a pressure of 902 millibars.

Figure 3-2 shows the relationship between storm intensity, storm size, and peak surge heights. The larger the storm and the greater the intensity, the larger the surge that can be anticipated. The surge heights were calculated at a common point from numerical simulation of the various historical events. The scale at the top represents the calculated surge heights. The scale on the left called the *pressure deficit* is the change in atmospheric pressure from normal pressure as measured at the outer edge of the storm minus the pressure measured at center of storm circulation. The pressure deficit is a measure of the storm's intensity and is related to the maximum windspeed. The bottom scale is the distance from the center of storm circulation to the location of maximum wind speed, which is a measure of the storm size. Thus, wind is accounted for but in an indirect fashion.

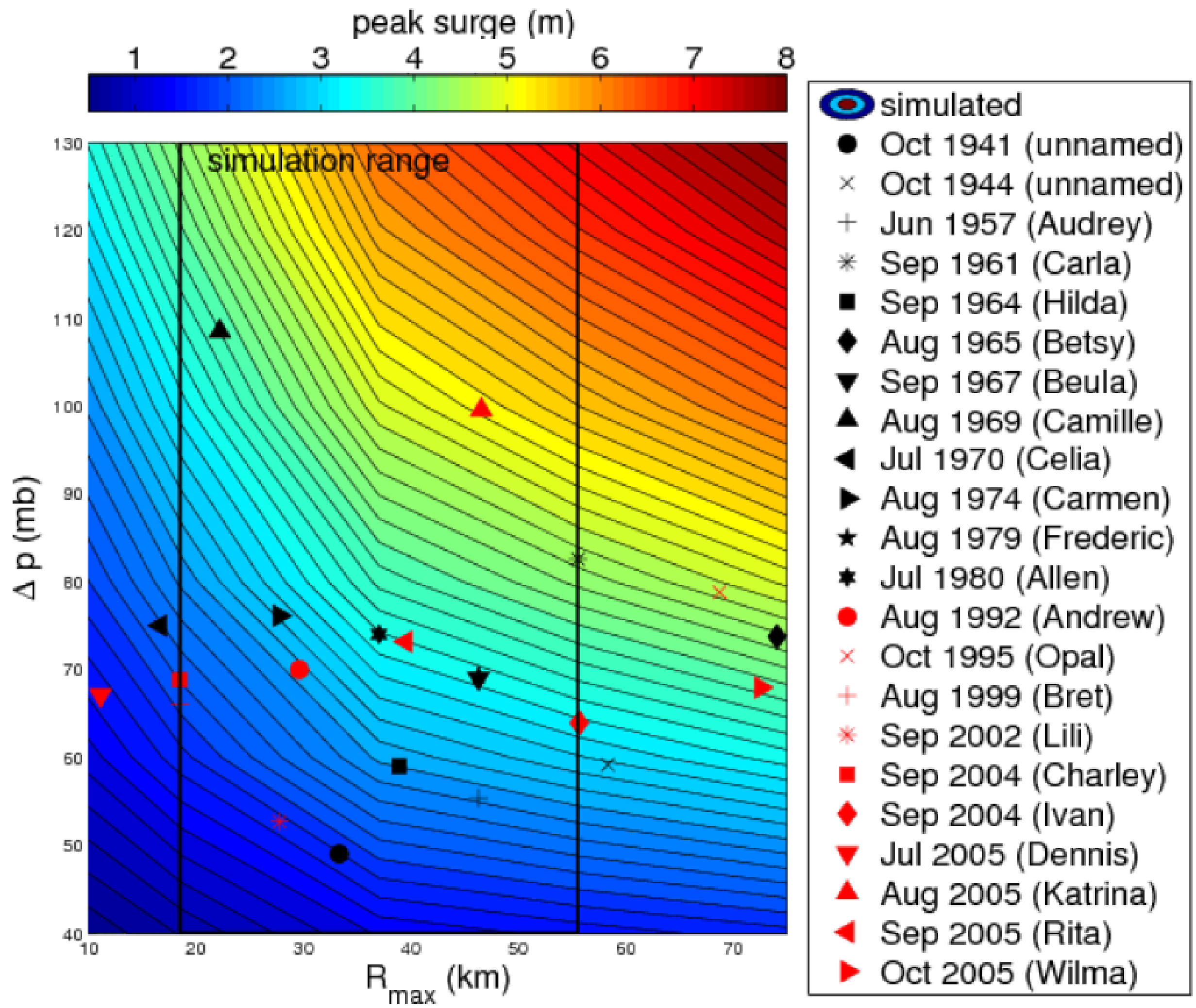


Figure 3-2. Relationship between hurricane size, intensity, and surge heights.

All Areas of the Gulf Coast Do Not Have the Same Chance of Experiencing Powerful Hurricanes

Until recently, weather scientists believed that all areas along the Gulf Coast have an equal chance of being hit by a major hurricane or high storm surge. What has been determined since 2005 is that certain areas of the Gulf of Mexico are more likely to experience higher intensity storms. **Figure 3-3** shows the relatively higher probability of severe hurricane occurrence for southeastern Louisiana, Mississippi, and western Alabama relative to the probability of occurrence elsewhere along the Gulf of Mexico. For example, the New Orleans, Louisiana area is twice as likely to be hit by a Category 2 or larger storm than the Galveston, Texas area. These probabilities were calculated based on the historical record from 1950 to 2005.

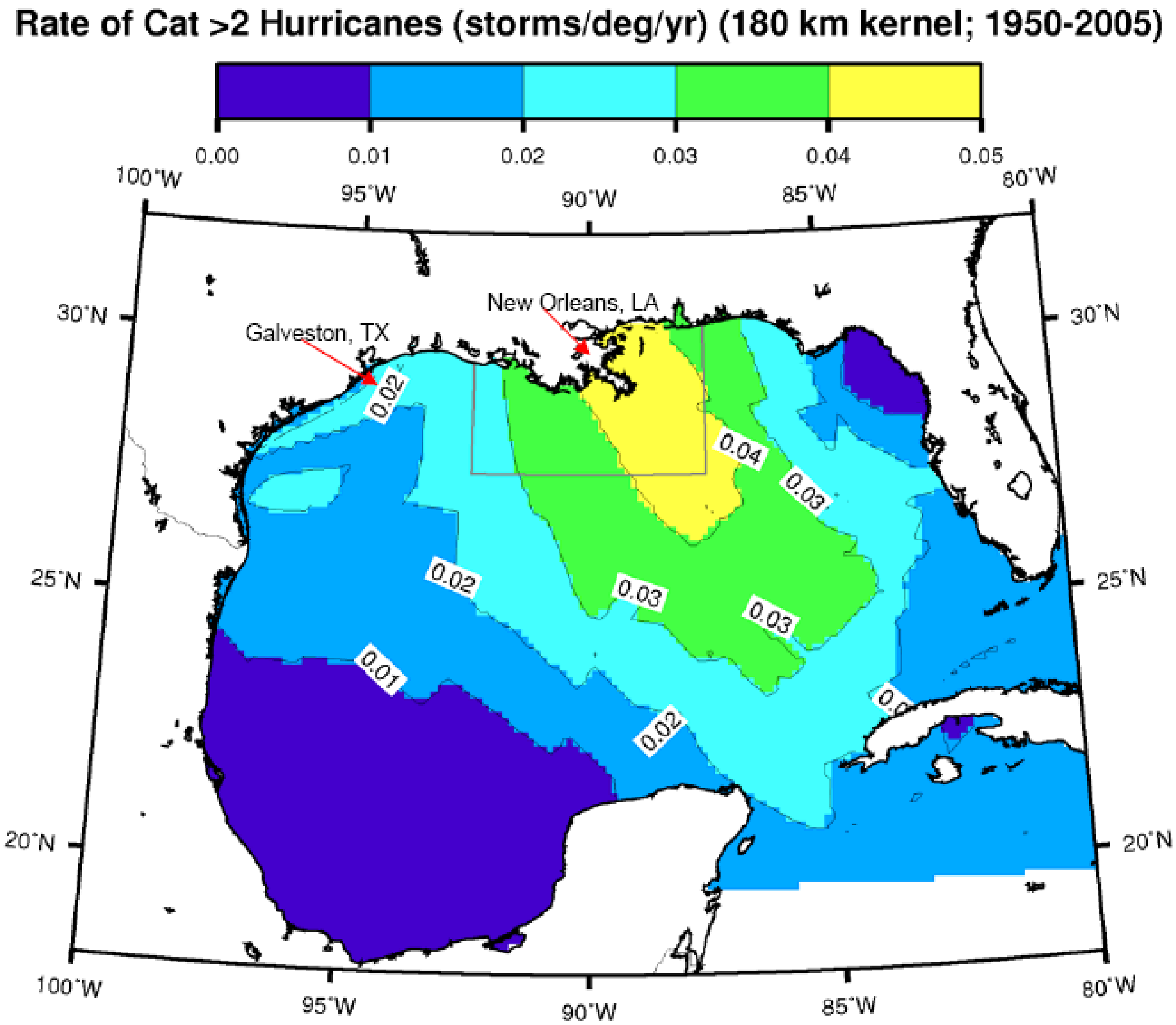


Figure 3-3. Rate of hurricanes greater than Category 2 by area within the Gulf of Mexico.
Source: Risk Engineering, Inc.
Note: “Kernel” refers to a measurement of water area, i.e. square kilometers.

The 100-Year Storm Surge Can Occur More Than Once Every 100 Years

A common misconception is that the 100-year storm surge will only occur once every 100 years. Just as there is a 50 percent chance of getting heads each time a coin is flipped, but it is still possible to flip heads several times in a row, it is possible to experience the 100-year storm surge in consecutive years. Statistically, over thousands of years the 100-year storm surge should occur, *on average*, once in 100 years. However, within a *given* period of 100 years, the 100-year storm statistically has a 63 percent chance of occurring. Given the average lifespan of a Louisiana resident—between 70 and 75—each person living within the 100-year floodplain has a 50 percent chance of experiencing the 100-year flood event within his or her lifetime. For those same individuals with a 30-year mortgage, the chance of experiencing a 100-year storm surge during the life of that mortgage is over 25 percent.

Proactive Risk Management and Communication

In addition to the threat imposed by natural forces, human decisions and policies contribute to the risk equation. Flood risk management in the City of New Orleans and coastal communities through the twentieth century generally was not founded on proactive approaches, but rather developed reactively in response to specific catastrophic floods. **Figure 3-4** shows areas on the East Bank of New Orleans affected by four major storm surge events. Dark blue areas represent flooding and red arrows indicate the direction of flooding.

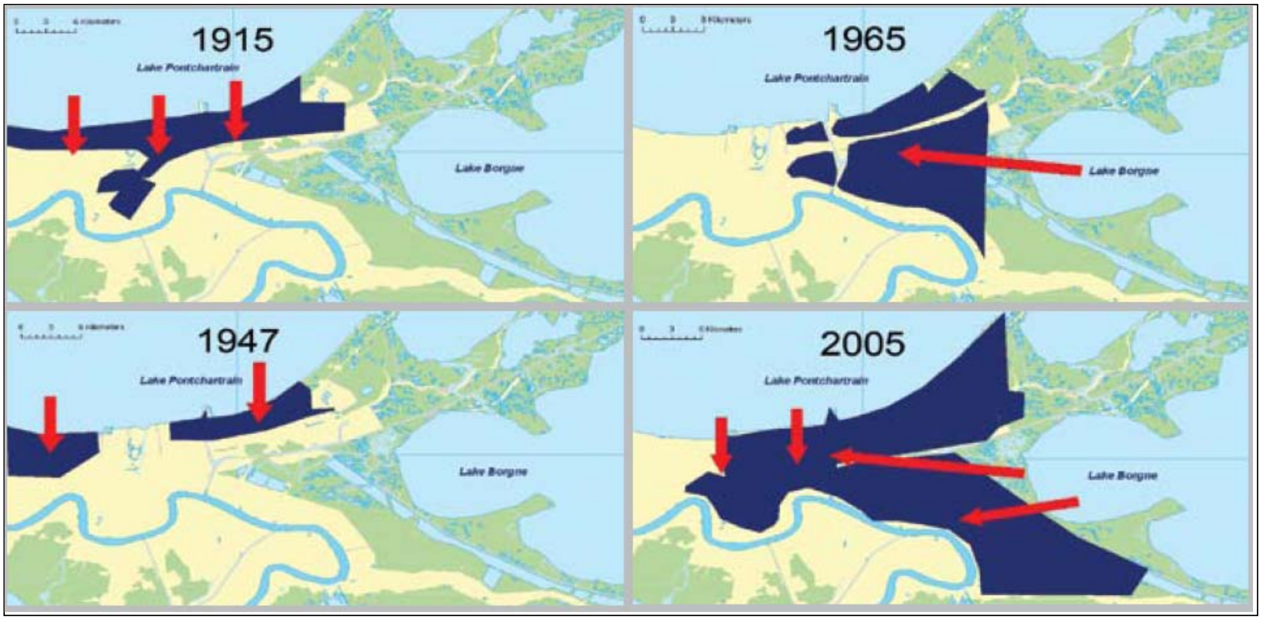


Figure 3-4. Historical flooding in New Orleans due to hurricane storm surges in 1915, 1947, 1965, and 2005.
Source: Grossi and Muir-Wood 2006

After each flood, modest investments were made in improved defenses that reduced the immediate risk of flooding. However, each investment in improved flood defenses prompted additional development in the partially protected floodplain and thus increased the number of people and structures at risk. In the absence of proactive communication of risk to residents, many adopt a false sense of safety, which becomes inherently more dangerous in the face of potential increases in storm intensity. One of the lessons learned from Hurricane Katrina is that **no system is 100 percent effective at eliminating risk.** Weaknesses in individual components can threaten the entire risk reduction system. As concluded in the IPET report:

"Risk is increasing significantly along the nation's coastlines, in part because natural hazards such as hurricanes appear to be more severe, but even more so because increasing numbers of people and property are being allowed to reside in harm's way. There is little that governments or individuals can do about the changing hazard, but there is much that can be done to manage risk by reducing exposure to the hazard. The simplest approach in principle is managing land use to avoid placing more people and

property in areas vulnerable to hazards. While simple in principle, the dichotomy of land-use authorities between levels of government, the lack of adequate standards, and the dependence on continued development has made this the correct path seldom taken."

Risk is difficult to communicate because it means different things to different people and involves statistical probabilities that may not be easily understood. A risk assessment must answer the following four questions: 1) What can go wrong? 2) How can it happen? 3) What is the likelihood? and 4) What are the consequences? The LACPR report only begins to answer to these questions in terms of hurricane-related flood risk. Much work is left to be done in terms of quantifying risk of failure; communicating risks to the public; and determining acceptable risk. Determining what levels of risk are acceptable involves balancing the fundamental competing principles of equity, the right of individuals and society to be protected, and efficiency, the need that society has to distribute and use its available resources in such as way as to gain maximum benefit.

To improve risk communication, the LACPR report uses the phrase "hurricane risk reduction" to replace what has previously been referred to as "hurricane protection." For LACPR, residual risk is defined as the flood risk that remains after a hurricane surge risk reduction project has been implemented. Although wind damage is often associated with hurricanes, this report primarily addresses damages from floods, not wind damage. Residual risk should be quantified and effectively communicated to the public and decision makers. The LACPR effort attempts to assess flood risk and to effectively communicate that risk to policy makers and to the general public so that informed decisions can be made. As an example, the LACPR report provides discussion of the residual risk for various alternatives rather than a discussion of benefits as is normally done in flood damage reduction studies.

Preventing Induced Development

The USACE recognizes that certain proposed levee alignments have the potential to induce development. In the context of a levee project, the term "induced development" refers to the potential to facilitate or inadvertently encourage residential, recreational, and/or commercial development in high risk areas enclosed within the levee alignment. Coastal wetlands are by definition high risk areas prone to flooding. When enclosed within a levee system, however, these areas are theoretically less prone to flooding from storm surges and thus more susceptible to development. Many examples of the potential for levees to induce development can be seen in coastal Louisiana.

The potential for a levee project to induce development is a concern for many reasons. Most obviously, encouraging development in wetlands would be directly counter to the wetland restoration goals of LACPR and the other Federal and State efforts to restore coastal Louisiana. The destruction of wetlands within levee systems can result in the loss of natural flood attenuation functions, while at the same time putting people and properties at greater risk of flooding during heavy rains and/or in the event of levee overtopping or failure. The concern with induced development was eloquently expressed in the State's Master Plan:

"The most state of the art hurricane protection system can actually increase the assets at risk if it encourages development in wetlands or areas near the levee footprint. Such action would not only be risky from a safety and economic standpoint, but it would also degrade wetlands and eliminate interior flood storage capacity." (State Master Plan, page 68)

The LACPR report addresses induced development in three ways:

(1) Different levee alignments were evaluated to assess the potential to induce development in wetlands. Among other potential indirect effects, this analysis includes a qualitative comparison of the relative potential for levee alignments to induce commercial, residential, and/or recreational development in coastal wetlands. A negative score indicates that the given alignment has a relatively greater potential to encourage future development in wetlands (thereby leading to further wetland loss and increased assets at risk of flooding). A positive score indicates a potential to encourage or direct future development towards higher and safer ground. The results of this analysis are reflected in the plan rankings and tradeoff discussions.

(2) Levee alignments that minimize the potential for induced development in wetlands were developed. For example, the ridge alignment in the Barataria Basin would direct development away from wetlands, towards the relatively higher and safer ground along the natural distributary ridges. This alignment would also facilitate coastal restoration by reducing flood concerns associated with large-scale river re-introduction projects.

(3) Section 17, Collaboration and Coordination, acknowledges that additional actions by other Federal, State, parish, and municipalities are necessary to ensure consistency between coastal restoration efforts, regulatory decisions, and other civil works projects. The term "consistency" refers to the need to make sure that coastal restoration and protection efforts are not undercut or otherwise diminished by adverse environmental impacts from other civil works projects and/or regulatory decisions. The LACPR report references a consistency plan developed in the LCA Ecosystem Restoration Study, which includes a discussion of induced development and actions which could help address this and other concerns.

Future increases in vulnerability can only be limited by an integrated set of measures; however, without more specific direction from Congress, the USACE is limited in its ability to set policies that might limit future development in low lying areas. Therefore, other Federal, State, and local entities have an equally important role in reducing these vulnerabilities. For example, local governments must strictly enforce appropriate floodplain management, land use, and zoning regulations to ensure that the constructed levee system contributes to the long-term sustainability of the region; that enclosed wetland areas remain intact and undeveloped; and that unwise development in flood-prone areas is discouraged.

Storm Modeling Overview

Based on lessons learned since 2005, the USACE has adopted a risk-based probabilistic approach to predicting and evaluating a range of possible hurricane storm surge events. At the outset of LACPR, no single model or set of models existed to meet the needs of this rigorous type of analysis. Therefore, a group of international, government, academic, and private sector scientists and engineers were assembled to develop a model that could simulate hurricane surge and wave elevations and show these in terms of return probabilities. This analysis is critical to the evaluation of alternatives in a risk-informed decision framework.

> **Advanced Computer Modeling**
>
> For the LACPR modeling effort, the ADCIRC program was run on two supercomputers; it would take 4,000 desktop computers linked together to equal the computing power available in each supercomputer. In terms of human labor, it would take 1,000 scientists 535 years of working around the clock to do the same computations that one of these machines can do in one second. This use of advanced technology has vastly improved the ability of the USACE to evaluate hurricane threats along the northern Gulf Coast.

In assessing hurricane threats and risks the team employed advanced computer storm simulation software to evaluate a full range of hurricanes that could make landfall in coastal Louisiana. ADCIRC (ADvanced CIRCulation) is a physics-based computer model that can simulate the storm surge response to a powerful storm once it forms in the Atlantic and bring it to its coastal landfall. The computer simulations allowed planners to evaluate storm surge responses to different storm tracks, landfall speeds, and wind fields. Coupling this program with wave generation software and other tools enabled technical analysts to develop assessments of hurricane impacts which can then be used to evaluate different risk reduction strategies and alternatives.

The computer simulation models reflect storm characteristics and storm tracks relative to the coast. The IPET concluded that relying solely on historic storms to help design risk reduction measures for future threats is inadequate. Using the characteristics of past storms to predict future storms, IPET, along with the American Society of Civil Engineers and the National Research Council, used advanced hydromodeling to create hypothetical storms and their paths that could potentially develop in the future.

The models are capable of fluctuating storm strength as a storm approaches the coast in order to estimate the surge at the coast. This capability is important because storms often decay as they make landfall. A sufficient number of different computer simulated storms had to be run on different tracks to develop a statistically significant database. A total of 304 storms (152 in the east side of the State and 152 in the west side) were run for the entire Louisiana coast as shown in **Figure 3-5**.

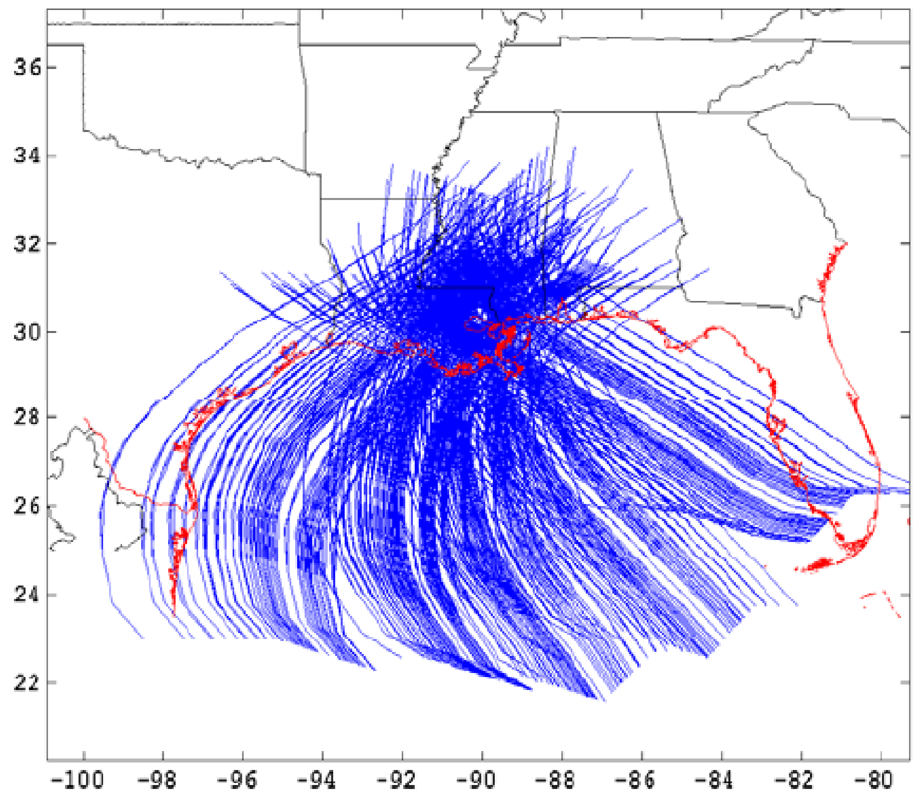


Figure 3-5. Simulated storm paths.

After running all 304 storms, over 3 million data points were analyzed to derive the surge and wave heights across the Louisiana coast. The maximum stage at each of the ADCIRC grid points was used to compute the stage frequency at each of the grid points. The planning area contains thousands of these stage frequencies relationships covering a frequency domain from about one in 50 years to about one in 3,500 years. This range of stage frequencies was used to generate statistical water surfaces that could be mapped to illustrate existing flood risk as shown in Section 7. These same state-of-the-art models are also being applied to the design for the 100-year hurricane risk reduction system around New Orleans.

Evolving Science, Engineering, Policy, and Planning

The academic community has reviewed the LACPR modeling approach described above and it has been adopted by other U.S. government agencies. These significant advancements in surge and wave modeling techniques will be used for years to come. Although the storm modeling presented in this report represents the best in current science and technology, it has not answered all of the questions or uncertainties that exist in developing a set of risk reduction and coastal restoration plans for Louisiana over the next century, or even the next few decades. For example, climate change, sea level rise, and future hurricane patterns are critical issues surrounded by large uncertainties. The USACE is committed to pursuing the best science and engineering available in order to adapt to changing conditions in South Louisiana.

Climate Change and Sea Level Rise

The current USACE Actions for Change initiative includes creation of interim guidance on incorporating sea level change in USACE procedures. In addition, the USACE has set up four new committees to address climate change and sea level rise issues. The committees include planning, engineering, science, and policy. The specific objectives of the planning and policy committees will be to revise the current USACE's regulations and guidance on coastal projects to address both planning and policy issues associated with climate change, including storm frequency and intensity, shifts in precipitation, sea level rise, etc. The results of these efforts will change both USACE planning and policy and all future USACE coastal efforts. The LACPR analysis acknowledges sea level rise and takes into consideration two increasing sea level rise scenarios based on projections by the Intergovernmental Panel of Climate Change and the National Research Council.

Hurricane Frequency and Intensity

The USACE has developed a rigorous, conservative storm modeling approach by taking into consideration the characteristics of a maximum intensity storm for the Gulf of Mexico and basing the storm surge analysis on the most intense hurricane activity period on record (1940 to 2005). By simulating the possible range in size and intensities up to the Maximum Possible Intensity storm, surge levels that can be associated with Category 5 storms were effectively covered. The frequency for these surges will depend on the specific storms simulated but can be expected to range from around one in 100 years to at least one in 3,500 years. This approach was used for LACPR to satisfy the directive by Congress to consider "Category 5 protection" for the Louisiana coastal area.

To consider climate change and its possible impact on storm surge probabilities, the LACPR risk team conducted a sensitivity analysis to simulate possible future increased storm activity by doubling the number of high activity storm years for the (1941 -2005) period of record. At selected locations, the average effect on waves and surge heights at the 100-year return period was an increase in significant wave height of about 12 percent and an increase in surge height of about 15 percent. At the 500-year return period, wave and surge levels increased on average about 10 percent and 9 percent, respectively.

Updating Design Standards

Post-Hurricane Katrina studies that have examined the hurricane risk reduction system for the East Bank of New Orleans using the latest modeling technologies showed that surge levels used in the original designs were in most cases grossly underestimated. These studies compared surge levels generated by the original (circa 1969) windfields used for the "Standard Project Hurricane" to design levees and floodwalls to surge levels generated by new, updated windfields for the Standard Project Hurricane. The updated Standard Project Hurricane windfields were developed at the request of the New Orleans District by NOAA at the National Climatic Data Center. The update extended the period of record used to derive the Standard Project Hurricane from the 1975 hurricane season (contained in the National Weather Service Report 23) to include all storms occurring through the 2005 hurricane season. These studies revealed that modeling the Standard Project Hurricane in ADCIRC, using either the old or new windfields, generates water levels that exceed the 2000-yr return interval as computed using the new statistical frequency methodology used in the LACPR, FEMA and MsCIP studies. Any attempt to design for these water levels would obviously encompass the "Category 5" directive for LACPR and greatly exceed the level of risk reduction afforded by the ongoing 100-year design level for post-Katrina work.

Advanced Engineering Techniques

As part of the ongoing hurricane damage risk reduction work, as well as the LACPR effort, an evaluation of a hollow core concrete levee concept was undertaken. The concept of the hollow concrete levee system is such that the section fills with water from the bottom as the storm surge rises. The combined weight of the concrete frame and its water-filled voids inside the frame result in a gravity structure designed to resist hydrostatic forces and impact forces from waves and vessel collision. This type of levee has potential as a replacement for more typical earthen levee construction, especially in isolated areas with poor foundations as well as in highly developed areas with limited rights-of-way. This type of measure and opportunities for application will be investigated more thoroughly in subsequent design phases.

Contribution of the Coastal Landscape to Risk Reduction

The coastal landscape and the restoration and maintenance of that landscape are an important consideration in a comprehensive system for risk reduction. The detailed ADCIRC modeling enabled the analysis of the performance and contribution of the coastal landscape in limiting storm surges. The magnitude of the modeling effort required for this effort, however, limited the extent of this assessment since the modeling of any modification to the landscape requires a complete modification of the model grid and remodeling of all storms and tracks. The assessment of coastal landscape effect was developed by modeling and comparing model runs made for the base condition landscape to a set of runs made with a grid representing the degraded coastal condition if no action were taken. This assessment enabled the quantification of a value for risk reduction attributable to the maintenance of the existing landscape. The actual value identified by the modeling, however, is really the potential increased risk over time. This assessment does not fully investigate the potential risk reduction that might be possible by strategically locating coastal landscape restoration features nor does it capture the potential in restoring landscape features that have already been lost. Additional detailed modeling through available authorities will be needed to fully optimize coastal planning for risk reduction.

Section 4. Planning Considerations

The following sections provide an overview of the planning considerations for LACPR including problems in the South Louisiana area, planning objectives set out to solve those problems, division of the planning area into planning units and subunits, plan formulation strategies, and the assumptions and methodologies used to perform the LACPR technical evaluation.

Problem Statement

The nature of risk to the planning area is identified in the following problem statement:

> The people, economy, environment, and culture of South Louisiana, as well as the Nation, are at risk from severe and catastrophic hurricane storm events as manifested by:
>
> - Increasing risk to people and property from catastrophic hurricane storm events.
> - Increasing vulnerability of coastal communities to inundation from hurricane induced storm damages due to coastal subsidence, wetland losses, and sea level rise.
> - National and regional economic losses from hurricane flooding to residential, public, industrial, and commercial infrastructure/assets.
> - Losses to high levels of productivity and resilience of South Louisiana coastal ecosystem due to natural conditions and coastal storm disturbances.
> - Risks to historic properties and traditional cultures and their ties and relationships to the natural environment due to catastrophic hurricane storm events.

The risks associated with the problem can never be eliminated or entirely prevented. Thus, residual risks that will remain after plan implementation must be considered.

Objectives

The following planning objectives were established to help solve the problems defined above and to develop the full range of flood damage reduction, coastal restoration, and hurricane risk reduction measures:

- Reduce risk to public health and safety from catastrophic storm inundation.
- Reduce damages from catastrophic storm inundation.
- Promote a sustainable coastal ecosystem.
- Restore and sustain diverse fish and wildlife habitats.
- Sustain the unique heritage of coastal Louisiana by protecting historic sites and supporting traditional cultures.

LACPR Planning Area and Planning Units

The LACPR planning area (see **Figure 4-1** below) stretches across Louisiana's coast, including offshore islands, from the Pearl River on the Mississippi border to the Sabine River on the Texas border. The northern planning area boundary roughly follows Interstates 10 and 12 since hurricane surges are not expected north of these physical boundaries. Based on 2000 U.S. Census Bureau data, the planning area contains approximately 2.4 million people.

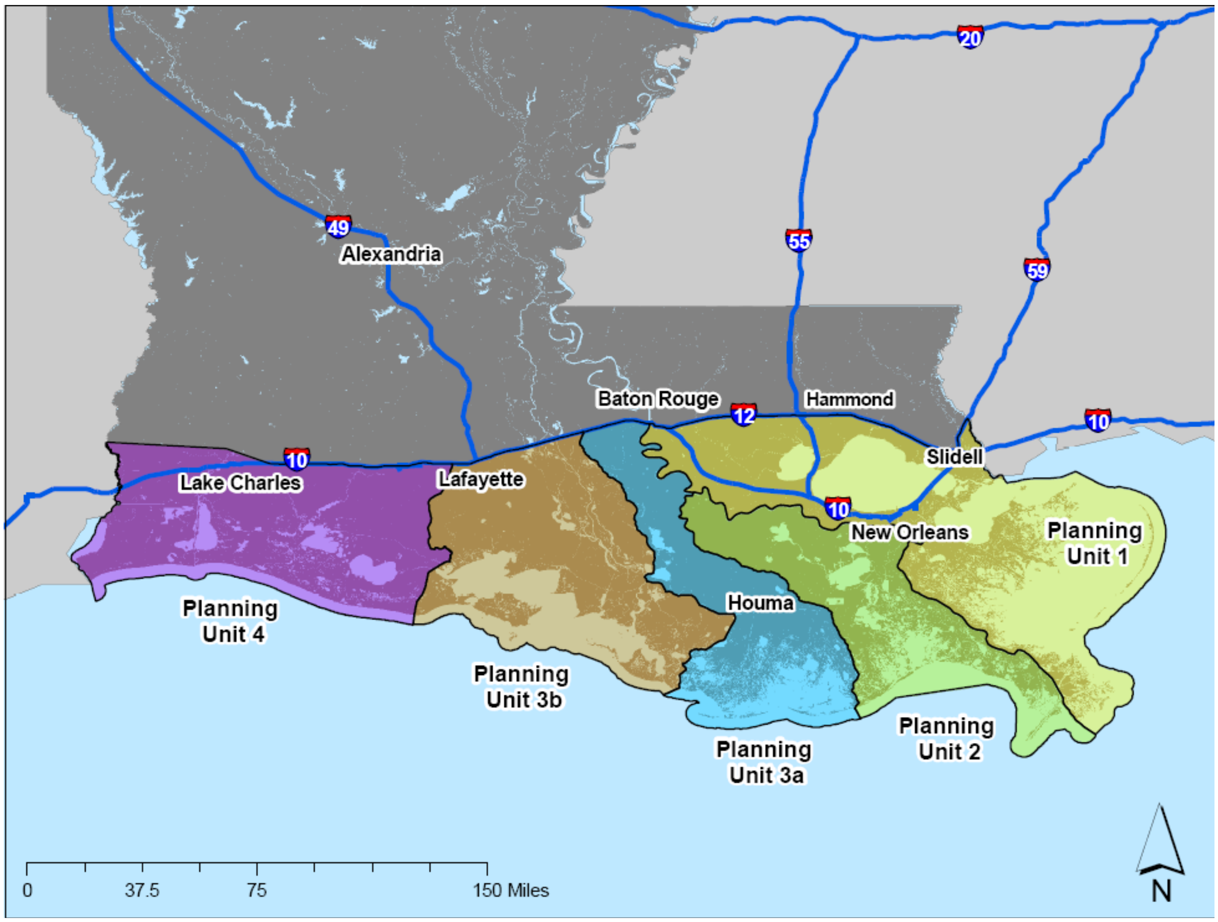


Figure 4-1. Map showing LACPR planning area and planning units.

The LACPR planning units have been divided based on hydrologic basins and watersheds as previously established in other efforts such as the Louisiana Coastal Area study, Coast 2050 plan, and recent State Master Plan. The resulting five LACPR planning units are similarly defined as four sub-provinces in the Louisiana Coastal Area (LCA) study and four corresponding regions in the Coast 2050 plan; however, for LACPR and the State Master Plan, Sub-province or Region 3 was divided into Planning Units 3a and 3b. The team added a boundary between Planning Units 3a and 3b because system disruptions, as well as the opportunities for restoration, are different in these areas.

The five LACPR planning units are listed below:

- **Planning Unit 1 – Lake Pontchartrain Basin**, or the area east of the Mississippi River. Planning Unit 1 includes approximately 51 percent of the planning area population. The major portion of greater New Orleans is located within the planning unit.
- **Planning Unit 2 – Barataria Basin**, or the area from the Mississippi River west to Bayou Lafourche. Planning Unit 2 contains approximately 15 percent of the planning area population, including a portion of greater New Orleans.
- **Planning Unit 3a – Eastern Terrebonne Basin**, or the area west of Bayou Lafourche to Bayou de West. Planning Unit 3a includes approximately 10 percent of the planning area population.
- **Planning Unit 3b - Atchafalaya Influence Area**, or the area west of Bayou de West to Freshwater Bayou. Planning Unit 3b includes approximately 14 percent of the planning area population.
- **Planning Unit 4 – Chenier Plain**, or the area west of Freshwater Bayou to the Sabine River. Planning Unit 4 includes approximately 10 percent of the planning area population.

For detailed economic analyses, the planning units were further divided into approximately 900 planning subunits based on consistent topographical and hydrological characteristics. Planning Units 1 and 2 consist of approximately 200 subunits and Planning Units 3a, 3b, and 4 consist of approximately 700 subunits.

Stakeholder Involvement in Plan Formulation

Once planning objectives were identified, the next phase in the plan formulation process was to identify potential risk reduction measures that could be implemented to address one or more of the planning objectives. Stakeholder involvement was critical in this phase of plan formulation. The inventory of risk reduction measures was collected through extensive public involvement in partnership with the development of the State Master Plan. The USACE, in conjunction with its State of Louisiana partners, held scoping meetings across the State to provide information to the public and stakeholders, and to solicit feedback. Through this partnership, the State developed the State Master Plan to provide a long-term vision for hurricane risk reduction and coastal restoration.

Numerous risk reduction measures were identified during the development of the State Master Plan. In addition, the team gathered measures from several sources, including other coastal area plans and programs; local, parish, and landowner plans; planning workshops; the National Environmental Policy Act (NEPA) scoping process; and other public input (Note: Although NEPA scoping was conducted, no NEPA document is included as part of this technical report). Broad, multi-disciplinary organizational team representatives from coastal parishes, levee districts, State and Federal agencies, non-governmental agencies, and academia, as well as concerned citizens, provided guidance and ideas for identifying measures. The LACPR team engaged the non-government organization/science community in five workshops to solicit their input on overall concerns, alternative proposals, and project evaluations. Many groups and individuals had already been working together on Federal wetland restoration initiatives including the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Program and the Louisiana Coastal Area (LCA) Study. These relationships facilitated gathering interested parties at many public meetings and workshops held across coastal Louisiana.

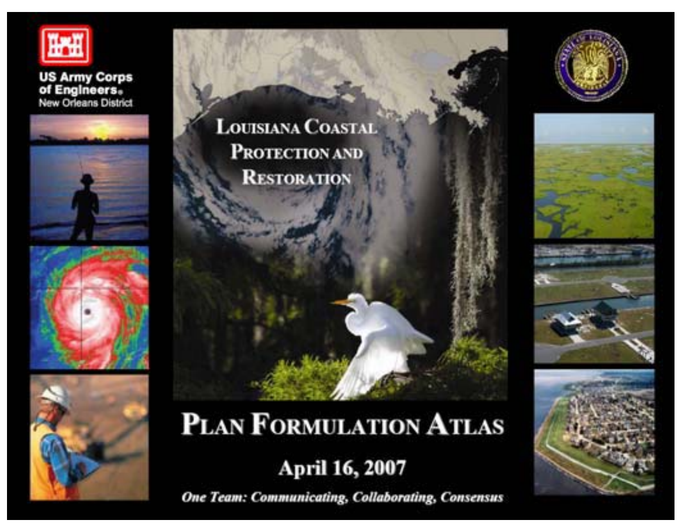
Though extensive, the LACPR effort by no means reflects the entire set of ideas to be considered for risk reduction in South Louisiana. Independent groups have produced information, letters, reports, and articles related to the recovery, restoration, and protection of coastal Louisiana after the 2005 hurricanes. See Section 19 for a brief description of some these other independent plans. Organizations that have contributed plans or ideas to the LACPR and the State Master Plan teams include:

- Bring New Orleans Back Committee
- Flood Protection Alliance
- Interagency Performance Evaluation Task Force
- Federal Emergency Management Agency
- American Society of Civil Engineers
- Barataria-Terrebonne National Estuary Program
- Coalition to Restore Coastal Louisiana
- Lake Pontchartrain Basin Foundation
- Biloxi Marshlands Corporation
- Independent scientists and engineers both nationally and internationally

The USACE plans to continually engage and consult stakeholders in individual project planning and implementation, and conduct similar efforts at the appropriate scale to constantly improve the planning process.

Plan Formulation Atlas

The Plan Formulation Atlas (dated April 16, 2007) documents the extensive, collaborative plan formulation effort undertaken for LACPR by providing an inventory of the hundreds of coastal protection and restoration measures identified for further consideration in developing a comprehensive risk reduction plan for South Louisiana. The Atlas was also used to engage stakeholders in the LACPR effort. The complete LACPR Plan Formulation Atlas is available online at *www.lacpr.usace.army.mil*.



Cover of the LACPR Plan Formulation Atlas

Developing and evaluating all of the potential alternatives that are possible from the combination of measures is not realistic. In order to combine the measures into a reasonable set of alternatives, these options needed to be inventoried and screened. The Plan Formulation Atlas functioned as a reference manual to initiate this screening as well as to continue stakeholder involvement. Since April 2007, the team has continued to refine the measures and alternatives presented in the Plan Formulation Atlas to develop the array of alternatives for evaluation and comparison.

Multiple Lines of Defense Strategy

Storm risk reduction measures can be formulated in two ways, either by reducing the probability of adverse consequences from a hurricane event or by reducing exposure to the event, thereby reducing the consequences themselves. **No alternatives can be formulated that will provide total protection to the entire planning area against all potential storms.** The reason is a matter of practicality, feasibility, and uncertainty. Therefore, the best strategy is to rely on multiple lines of defense. The multiple lines of defense strategy involves using environmental features such as barrier islands, marshes, and ridges to complement structures such as highways, levees, and flood gates as well as nonstructural measures such as raised homes and evacuation (see **Figure 4-2**).

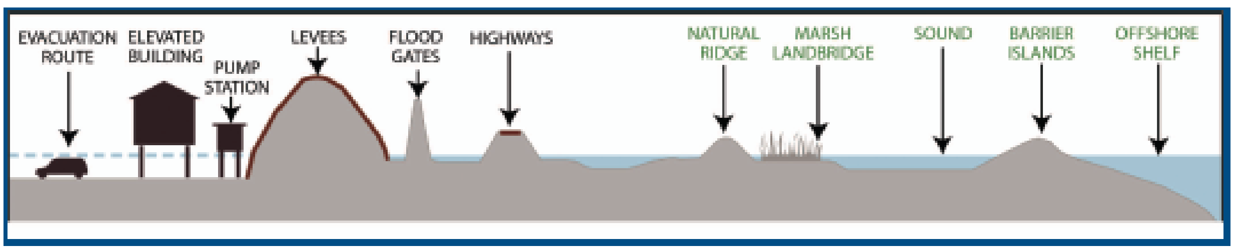


Figure 4-2. Depiction of multiple lines of defense strategy.
Source: Lake Pontchartrain Basin Foundation

Another extension of the multiple lines of defense approach, which has been considered in the LACPR plan formulation and analysis, is the use of overtopping levees, or weirs, that would move the primary structural line of defense away from populated areas and allow storage of storm surge behind them, reducing the required height of levees closest to populated areas.

The multiple lines of defense approach avoids reliance on single risk reduction measures, which, if compromised, would leave vulnerable areas without recourse. Residents of coastal Louisiana have used a multiple lines of defense strategy for hundreds of years, building homes and settlements on high ground protected by natural ridges, barrier islands, and more recently, levees.

Within the context of a multiple lines of defense or comprehensive system, numerous risk reduction measures can be combined to form alternative plans. Each type of measure provides unique opportunities to reduce risk of hurricane-induced flooding. Combining these different types of measures provides opportunities to develop comprehensive solutions to the flooding and habitat loss problems of the Louisiana coast. These combined approaches produce a multiple lines of defense system against storm surge.

For the LACPR effort, alternatives were developed using three concurrent plan development/formulation activities (coastal, nonstructural, and structural) resulting in the following categories of alternatives:

- **Coastal restoration alternatives** consist of hundreds of coastal restoration measures, which may include land/marsh-building river diversions, freshwater redistribution, mechanical marsh creation, barrier island/shoreline restoration, bank/shoreline stabilization, and/or ridge restoration.
- **Structural measures and alternatives** reduce flood risk using features that are designed to withstand the forces of storm events, such as surge-reduction weirs, floodgates, continuous earthen levees, floodwalls, and ring levees.
- **Nonstructural measures and alternatives** reduce the exposure to risk by removing vulnerable populations and assets from the threat through measures such as buyout of properties or raising structures in place. Additional nonstructural measures include wet and dry flood-proofing of critical facilities.
- **Comprehensive alternatives** contain combinations of at least two types of risk reduction measures—nonstructural, structural, and/or coastal restoration—in a multiple lines of defense strategy, providing comparable levels of risk reduction to all economic assets in the surge impacted areas.

Period of Analysis

The period of analysis for all alternatives is the 65-year period from 2010 to 2075. Metric values (e.g. costs, impacts, etc.) are compounded or discounted to 2025 as the common base year for comparison of alternatives. Year 2025 generally represents the end of the implementation period for most alternatives considered. The implementation period is the number of years to construct the plan after which benefits can be expected. For staged construction, the implementation period is the time needed to install the first phase. On average, plans were assumed to take at least 15 years to implement, so the start date for most benefits would be year 2025. In order to evaluate plan performance over a minimum of 50 years which is standard USACE policy, future damages were calculated out to year 2075. **Figure 4-3** illustrates how two hypothetical alternatives (Plan Alternative 1 and Plan Alternative 2) of differing implementation periods are compared. In the illustration, Plan Alternative 1 has an implementation period terminating before the common base year – just the opposite of Plan Alternative 2.

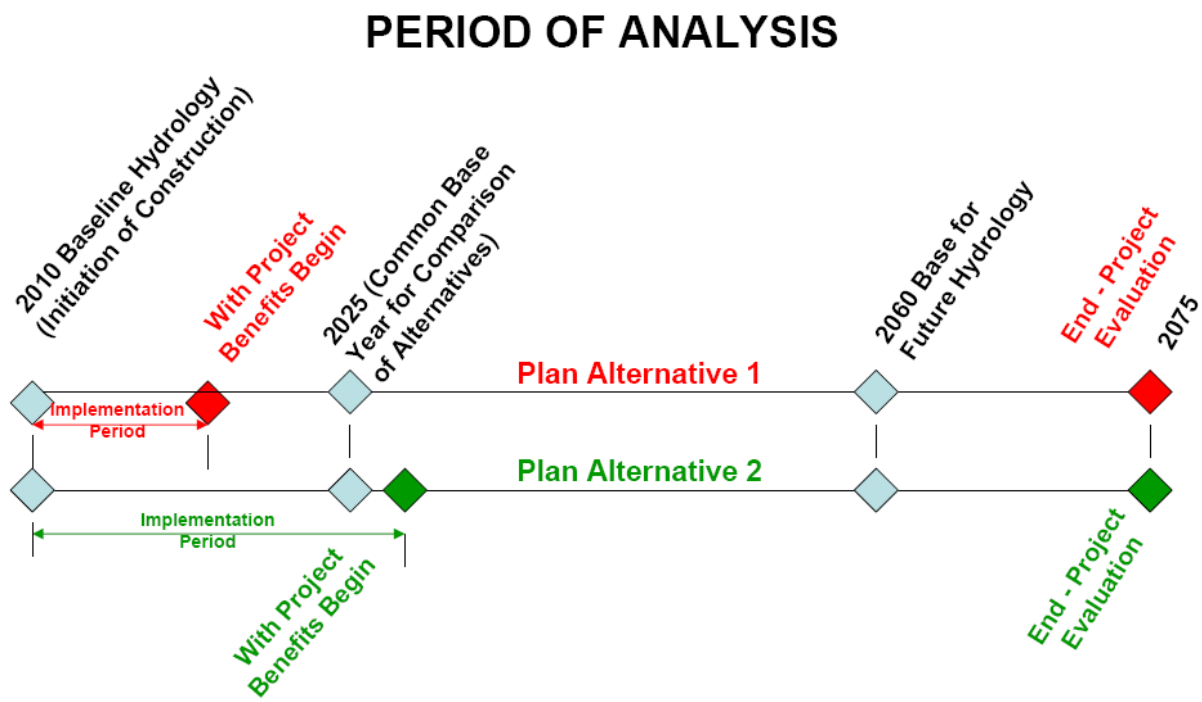


Figure 4-3. Hypothetical period of analysis for plan alternatives.

Baseline hydrology used for the LACPR analysis assumes that the 100-year Greater New Orleans Hurricane Storm Damage and Risk Reduction System is in place. Originally that work was supposed to be completed by 2010 but is currently scheduled for 2011. When referring to the existing base condition, the years 2010 and 2011 can be used interchangeably throughout this report. The future hydrology developed for a degraded coastal landscape is based on Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) results from the LCA study which predicted what the coast would look like approximately 50 years into the future. Because of the level of uncertainty in these predictions, it was assumed that the 2060 hydrologic conditions could be applied through year 2075.

For the purposes of screening coastal restoration alternatives, performance was evaluated over a 100-year period from 2010 to 2110. The reason a longer period was used in this case was that some of the coastal alternatives were predicted to perform well at the end of the period of analysis but then poorly after that point in time. This 100-year period for consideration of coastal sustainability is in compliance with USACE Principles and Guidelines, which states that “appropriate consideration should be given to environmental factors that extend beyond the period of analysis.” Once the coastal alternatives were screened, each remaining alternative was then evaluated for performance in year 2075.

Future Scenarios

Scenario planning is a purposeful examination of a range of potential futures that addresses the uncertainty inherent in long-term planning. Unlike forecasts, scenarios do not indicate what the future *will* look like so much as what the future *could* look like. Scenario construction helps planners, decision makers, and stakeholders better adapt to a rapidly changing and complex future.

The first and major thread of scenario planning is developing several without project conditions rather than a single most likely future without a project. This method, developed for strategic planning by industry, recognizes large uncertainties in the future. Different realizations of the future could lead to quite different views about the best actions to take in the present. Scenario planning acknowledges the critical influence of a few uncertainty drivers on the future condition that provides the base condition for evaluation.

Flood risk to the economy, society, and the environment reflects the cumulative effects of environmental and socio-economic change over decades. Long-term scenarios are therefore required in order to develop robust and sustainable flood risk management policies (Hall et. al., 2003). For the LACPR analysis, relative sea level rise (global sea level rise and subsidence) and development rates/patterns were identified as the most important environmental and socio-economic scenario drivers that affect the performance of hurricane risk reduction plans. Four scenarios, or alternative futures, were defined by combining two levels of relative sea level rise with two levels of regional development. **Figure 4-4** presents the four LACPR scenarios, which capture a wide range of possible futures.

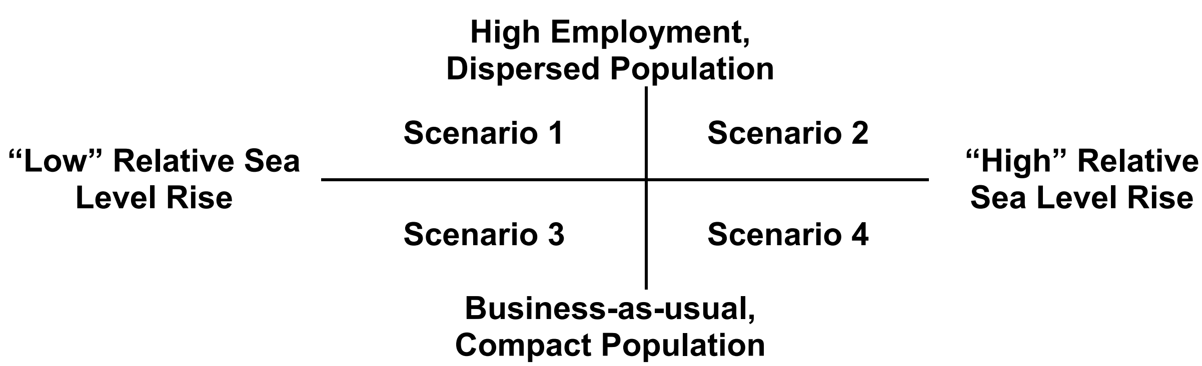


Figure 4-4. LACPR future scenarios.

Each alternative plan was evaluated for each of four future scenarios. The following sections provide more detail on how the relative sea level rise and development/redevelopment projections were developed.

Relative Sea Level Rise Projections

Planning within coastal Louisiana must consider the trends and variations between sea level and land elevations. *Relative sea level rise* as applied to the LACPR analysis is composed of both an increase in water level (sea level rise) and a drop in local land elevation (subsidence) (see **Figure 4-5**). Though the causes of climate change and future projections of climate change are uncertain, scientists have generally concluded that relative sea level has been rising across coastal Louisiana and will continue to do so in the future.

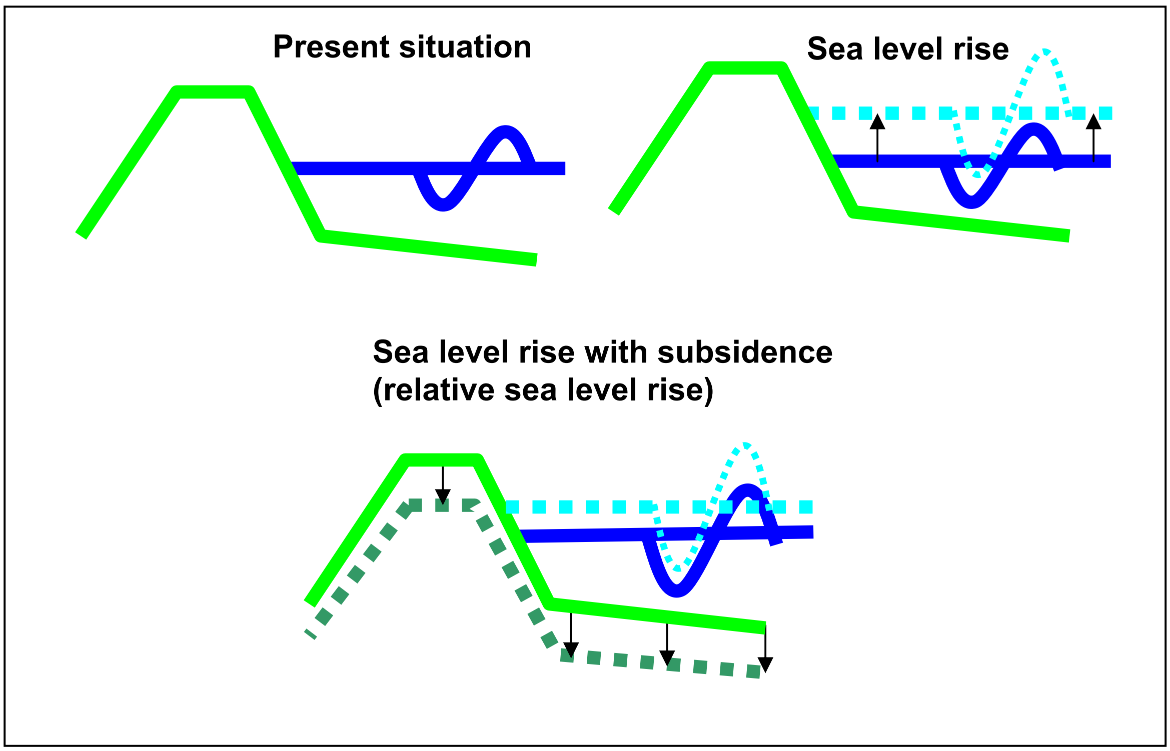


Figure 4-5. Illustrations of future sea level rise and subsidence.

Future projections for rates of relative sea level rise are highly variable and contain a large amount of uncertainty. Throughout the 20th century, the global average sea level rise has been approximately 1.8 millimeters per year (Meehl, 2007), or 0.07 inches per year. Both the National Ocean Service and the USACE have maintained long-term water-level gauges that can be used to calculate historic relative sea level rise rates across coastal Louisiana. Tide gauges installed on geologically stable platforms in the northern Gulf of Mexico indicate a regional average sea level rise of approximately 1.8 to 2.0 mm/year (or 0.07 to 0.08 inches/year). Throughout coastal Louisiana the rates of subsidence exceed the rate of sea level rise by varying amounts, resulting in relative sea level rise rates significantly higher than the global and regional rates. Considering the rate of subsidence and the mid-range estimate of sea level rise during the next 100 years (480 mm), the areas of New Orleans and vicinity that are presently 1.5 to 3 meters below mean sea level will likely be 2.5 to 4.0 meters or more below mean sea level by 2100 (Burkett et. al., 2003).

Since quantifying the rates of sea level rise that may occur in different areas of Louisiana is uncertain, the LACPR scenario analysis includes two different relative sea level rise projections to address how differences in relative sea level rise would impact project designs and costs for maintaining a given level of risk reduction over time. Projection 1 estimates are based on Intergovernmental Panel of Climate Change (IPCC) estimates (Meehl, 2007) and Projection 2 estimates (which are higher than Projection 1 estimates) are based on National Research Council (NRC) estimates (NRC, 1987). **Table 4-1** summarizes the relative sea level rise values developed for the scenarios.

Table 4-1. Relative sea level rise projections used in the future scenarios.

	Relative Sea Level Rise Increase in meters (in feet)		
Basis for Value	**Pontchartrain Basin (Planning Unit 1)**	**Delta Plain (Planning Units 2, 3a, and 3b)**	**Chenier Plain (Planning Unit 4)**
Historic rate (for comparison only)	0.2 m (0.7 ft)	0.4 m (1.3 ft)	0.2 m (0.7 ft)
Future Projection 1 (based on Intergovernmental Panel of Climate Change values)	0.4 m (1.3 ft)	0.6 m (1.9 ft)	0.4 m (1.3 ft)
Future Projection 2 (based on National Research Council values)	0.8 m (2.6 ft)	1 m (3.2 ft)	0.8 m (2.6 ft)

Development/Redevelopment Projections

Despite the fact that many of South Louisiana’s residents have not yet returned after the hurricanes of 2005, and some coastal areas are experiencing rapid rates of degradation and subsidence, the population of South Louisiana is expected to increase. Coastal land loss and other factors, however, may impact the distribution of people and buildings.

The location of populations and economic assets vulnerable to flooding will depend on two factors: (1) development rates and (2) development patterns. These two factors are addressed in the LACPR development projections used in the four scenarios. These without project projections do not account for the implementation of any of the LACPR alternatives. Indirect impacts, such as the potential to induce development in a high risk area, have not been accounted for in the scenarios; however, to meet the stated objectives of reducing risk to public health and safety and reducing damages from catastrophic storm inundation, these indirect impacts should be closely assessed and mitigated before implementing alternatives.

For the LACPR analysis, two future development rates, high employment and business-as-usual, were used to project the amount of assets that could be damaged. Both of these rates assume continued growth rather than population decline. The business-as-usual rate reflects continued employment opportunities in industries traditionally found in South Louisiana, while the high employment rate assumes employment growth in industrial sectors new to South Louisiana.

In addition, two land use allocation patterns, dispersed and compact, were used to spatially locate the development in the planning area. These two patterns represent the two extremes for land use allocation. Dispersed land use means development is spread over a greater land area and is typically composed of single-family homes. Compact means development is concentrated, for example a town center with multi-story buildings.

These development rates and patterns were combined as follows for the future scenario analysis:

- ***High Employment, Dispersed Population*** – Based on the high employment development rate and used in future scenarios 1 and 2.
- ***Business-as-usual, Compact Population*** – Based on the business as usual development rate and used in future scenarios 3 and 4.

These two development types bracket the high and low end of the range of possible damages and were chosen as representative of several ways in which development could occur. The difference in damages for each of these projections can be used to measure the uncertainty in damages due to development. The high employment, dispersed population projection would result in the most damages and the business-as-usual, compact population projection would result in the least damages.

Critical Assumptions

In order to evaluate alternatives, the LACPR team had to make certain assumptions or simplifications. **Table 4-2** provides a brief summary of the major assumptions, the scientific basis or rationale behind each assumption, and an indication of the consequences if the assumption turns out not to be valid.

Table 4-2. Critical assumptions.

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
Projects Included in the Base Conditions		
For New Orleans, the without project conditions assume that the 100-year improvements to the hurricane risk reduction system as authorized in Public Laws 109-148, 109-234, and 110-28 are in place.	These improvements are anticipated to be completed by 2011. The without project conditions would not change regardless of whether funds are sufficient to complete the authorized projects.	If the 100-year improvements were not completed, the risks to the New Orleans area would be higher than estimated by the LACPR analysis.
The without project conditions include Federally-authorized navigation, flood risk management, hurricane risk reduction, and environmental restoration projects in the planning area, except for projects recently authorized by WRDA 2007, i.e. Morganza to the Gulf hurricane protection and LCA ecosystem restoration projects.	At the beginning of the analysis, it was not certain that the projects proposed in WRDA would be authorized, so those projects were considered as part of the with project conditions.	Although the WRDA 2007 projects have been authorized, they have yet to be constructed and including them in the with project conditions does not have a significant impact on the LACPR analysis.
Future Conditions		
Without action, the coastal landscape will continue to degrade except in areas where active delta building is taking place; for example, the Atchafalaya River is building land at the Wax Lake Outlet.	In areas without active delta building, historical trends show a degrading landscape. The CLEAR model predictions of coastal wetland land loss by the year 2060 are consistent with these past trends. The CLEAR model 2060 landscape was used for evaluation of future conditions under LACPR.	Future risks may be less than expected.
Design elevations of existing levees are assumed to be maintained over the period of analysis. Maintenance costs are assumed to part of the existing program and are not included in the LACPR without project conditions.	This assumption is consistent with existing authorizations in order to account for soil compaction, subsidence, etc.	If soil compaction or subsidence is greater than expected or funding is not available to maintain levees to design elevation, this assumption could become invalid resulting in higher levels of risk than anticipated.
If no action is taken other than maintaining design elevations (as described in the above assumption), the level of risk reduction	Even if design elevations are maintained, sea level rise and loss of wetlands in front of levees would likely cause the level of risk	Future risks may be less than expected.

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
provided by existing levee systems will decline over time.	reduction to decline over time. This no action or without project condition represents the "worst-case scenario."	
The four future scenarios capture a sufficient range of futures so that plans can be properly formulated and evaluated to allow decision makers to make informed and rationale decisions.	The four future scenarios capture two increased levels of relative sea level rise and two increasing development rates with different land use assumptions. These scenarios are designed to capture a range of worst-case to best-case damage estimates. No scenarios are included for decreasing relative sea level rise or decreasing population because those scenarios are not considered to be realistic based on historical or projected trends.	Failure of this assumption could result in under-estimated, or more likely, over-estimated damages and could result in risk reduction measures being built in the "wrong" locations or measures that fail to meet their objectives.
Future without project conditions for year 2060 can be applied through year 2075.	The future hydrology developed for a degraded coastal landscape is based on Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) results from the LCA study which predicted what the coast would look like approximately 50 years into the future. Because of the level of uncertainty in these predictions and well as the uncertainty in relative sea level rise predictions, it was assumed that the 2060 hydrologic conditions could be held constant through year 2075 for planning purposes.	Even if coastal land loss or relative sea level rise is worse than predicted, it should not affect the relative comparison of alternatives at this planning stage.
Relative sea level rise can be added to levee heights and exterior water levels after running the ADCIRC model.	Adding relative sea level rise to the bathymetry in the ADCIRC models and rerunning the models for the two relative sea level rise scenarios would have tripled the number of model runs required. Because of the large uncertainties in predicting future water levels, this approach is sufficient for planning purposes.	The results of sea level rise sensitivity analyses in the Lake Pontchartrain basin where sea level rise was added to the model before storm runs were made indicate that actual water levels could be higher or lower depending on the location.

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
Structural Plan Component		
Structural measures can be built to perform reliably to specified risk reduction levels. Therefore, hydrologic stages assume no failure or breaching of levees. Overtopping is assumed above the 90 percent confidence stage of the design level of performance.	Levees and structures are designed based on a 90 percent confidence limit, which is consistent with current USACE hurricane system design work. A true performance or failure risk assessment that delves into the factors that could cause any alternative to fail has not yet been conducted because of the large number of alternatives and the level of detail. The tradeoff tables in Section 15 include a brief risk and reliability comparison based on levee lengths and number of structures (the longer the levee length and the higher the number of structures, the higher the risk of failure).	If structural measures do not perform as designed, the level of flood risk increases. Some of the alternatives may be more susceptible to poor performance, especially when their design is exceeded. Performance can depend on the specific design or site conditions. For example, a levee built in an area with poor soils may not perform as well as a levee built on good soils under the same surge conditions.
The design level (level of risk reduction) for with project levees are assumed to be maintained over the period of analysis. Additional construction lifts and associated future costs to maintain design elevations of improved and proposed levees are included in the cost estimates.	This assumption is consistent with current design standards in order to account for soil compaction, subsidence, sea level rise, etc.	If soil compaction, subsidence, sea level rise, etc. is greater than expected or funding is not available to build future lifts and/or maintain levees, this assumption could become invalid resulting in higher levels of risk than anticipated.
Nonstructural Plan Component		
Nonstructural plans are presented as voluntary participation; however, associated risk reduction for nonstructural alternatives is assumed for this stage of analysis to be based on 100 percent participation. The assumption that participation is voluntary for planning purposes does not preclude future projects being designated as non-voluntary.	This assumption is consistent with the performance assumption of structural measures, i.e., 100 percent performance with full reliability, and therefore allows for an unbiased comparison of performance and cost effectiveness with structural measures. The intent of this initial high-level, broad-brush approach to nonstructural plan formulation was to test the maximum contribution that nonstructural measures can make to an overall risk reduction strategy.	If actual participation in nonstructural measures is less than 100 percent, the benefits from the nonstructural alternatives would be less. A sensitivity analysis has been performed to determine the minimum percentage of participation that would be required before the nonstructural alternatives would start significantly slipping in the alternatives rankings.

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
The nonstructural analysis assumes that all new development, during the reconstruction post-2005 hurricanes, conforms to base flood elevations established for compliance with the National Flood Insurance Program (NFIP). Therefore, if a nonstructural measure proposes a level of risk reduction greater than the 100-year level, only the cost of the height increment above the 100-year was included as an economic cost of raising-in-place for future growth.	The assumption of full local compliance with NFIP base flood elevation building standards assumes that local governance is in place and active. This assumption is consistent with USACE and LACPR planning in that an assumption otherwise would call into question local governments' integrity in the NFIP program.	Were this assumption untrue, the costs of the nonstructural measures considered would be underestimated by some increment of cost to raise between the ground elevation and the 100-year base flood elevation. The cost estimate would be marginally affected but not significantly so when compared with other costs considered and the timing during which these incremental costs occur during the project life.
Nonstructural measures are expected to be implemented incrementally and will accrue pre-base year benefits.	Because of the uncertainty of the actual implementation sequencing, this is a legitimate assumption that is consistently and conservatively applied. Because nonstructural measures accrue benefits as soon as they are constructed, it is correct to allow pre-base benefits to accrue during the assumed uniform project construction period of 15 years.	Benefits may be greater or lesser based on the actual implementation funding, sequencing, and participation.
Relocation assistance is included as a cost component of the nonstructural buyout measures.	As a conservative cost-estimating approach, both permanent and temporary relocation assistance costs are included in the cost of nonstructural measures; however, P.L. 91-646 benefits may be applied differently during implementation of actual projects.	Costs and participation would be lower without the inclusion of relocation assistance.

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
Coastal Restoration Plan Component		
Coastal landscape features and vegetation in South Louisiana have the potential to reduce storm surge elevations and to absorb wave energy. As such, a coastal restoration component is included in all LACPR alternatives.	An initial hydromodeling sensitivity analysis conducted in Planning Unit 1 to address potential impacts of coastal marsh on storm surge showed that an improved marsh had little impact on surge elevations but did show an increase in surge landward of degraded marsh. These results indicated a need for sustaining the coastal landscape in South Louisiana to reduce surge potential.	Final hydromodeling results provide an indication of whether future damages could be prevented through coastal restoration; however, since the magnitude of surge reduction potential is variable along the coast, significant uncertainty exists regarding the effectiveness of specific landscape features to mitigate flooding. To address uncertainties associated with this assumption, a sensitivity analysis has been conducted to evaluate structural alternatives without a coastal component to address potential impacts on plan formulation.
Extensive coastal landscapes in Louisiana can be constructed and maintained at a pace sufficient to offset expected future landscape degradation.	Although it is impossible to maintain all coastal wetlands in the exact location and configuration as they are today (some existing wetlands are most likely unsustainable), the goal of coastal restoration for LACPR is to theoretically achieve sustainability while protecting some key elements of the existing landscape. Sediments needed for wetland creation have to meet a minimum volume and rate availability through some combination of dredging and Mississippi River diversions. See the following two assumptions below.	Ecosystem objectives might still be met even if the complete goals for coastal restoration are not met. The USACE is currently developing a Regional Sediment Budget for coastal Louisiana. The conceptual phase of the sediment budget development is underway. The final budget is not expected to be completed until July 2010.
Diversion capacity assumption: Up to 525,000 cfs can be diverted from the Mississippi River. The total Mississippi River discharge needed to sustain LACPR marsh creation/restoration measures is within the 525,000 cfs limit.	The 525,000 cfs limit is based on LCA total diversion limitations and has been set until more detailed assessments can be completed to assess the diversion capacity with regard to associated flooding, navigation, and environmental impacts. The	If constraints reduce this limit, then a revision of the diversion sizes, locations, and operations may be necessary to maximize restoration benefits from the available river water. Consideration of variable diversion limits should also be

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
	525,000 cfs amount represents 42% of the 1.25 million cfs design flood capacity of the Mississippi River below the Bonnet Carre Spillway.	needed, especially during river flood conditions when significantly more water is potentially available and diversion constraints may be reduced.
Dredging capacity assumption: In addition to material availability, the total number of dredges available and the production rate for any single dredge were considered limiting factors. Because of Jones Act restrictions, it was assumed that the number of available dredges would be limited to nine. An average production rate per dredge (900 acres of created marsh per year) was applied to each marsh creation measure.	Assumed dredge production for offshore and back-bay work = 20K cyds/day x 365 days = 7.3M cyds/yr; 1.0 M cyds assumed to equal 124 acres x 5 feet of fill (3 feet of water). Therefore: 7.3M cyds/yr x 124 ac/M cyds = 900 ac/yr production for one dredge (in shallow water locations). In all cases, annual dredging is highly variable, but the number of required dredges is never greater than six, and the maximum volume dredged in any single year is less than 44 million cubic yards.	If the production rate is too low, or more dredges are available, then more acres of marsh might be created per year. Conversely, if the assumed production rate is too high, or if the assumed number of dredges is not available, then it may not be possible to construct the proposed marsh creation acreage. Other measures might be substituted to partially compensate for benefits that would otherwise have been provided through mechanical marsh creation.
Discharges of proposed diversions from the GIWW in PUs 3a and 3b were determined as maximum practical amounts.	Best professional opinion.	If discharges are underestimated, then benefits of those measures may be underestimated. If GIWW diversion discharges are overestimated, then associated benefits may be overestimated.
Shoreline protection measures were assumed to be maintained throughout the project life.	Maintenance of such measures is needed to achieve coastal wetland sustainability.	Failure to maintain such features would allow once protected land acres to erode.
Linear land loss rates are appropriate for predicting future performance of the coastal restoration alternatives.	Fifty years (1956-2006) of USGS land area change data show very linear losses for the great majority of coastal wetlands. Future land loss was predicted using 1978-2006 land loss rates applied in a linear manner for comparison of coastal restoration alternatives. Areas that have experienced historic land gains were projected under LACPR to continue gaining at that rate to avoid making highly subjective loss rate change decisions. These land loss/gain	If actual land loss rates were greater than the predicted rates, then the extent of coastal restoration necessary to achieve sustainability and maintain existing protection would be greater. If actual land loss rates were less than the predicted rates, then the extent of coastal restoration necessary to achieve sustainability and maintain existing protection would be less. Should those currently stabile areas experience future land loss then the

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
	rates were only used for relative comparison of the coastal restoration alternatives.	projected wetland loss rates have been underestimated.
All wetlands created and/or protected are of equal quality and are ecologically justified.	The LCA study, which preceded LACPR, considered ecological quality. Rather than try to recreate LCA, the LACPR technical evaluation was focused on risk reduction and therefore did not differentiate between or evaluate the ecological quality of wetlands.	The comprehensive plan directed by WRDA 2007 provides the opportunity to integrate LCA with LACPR and the State Master Plan.
Social and Economic Factors		
LACPR uses a 65-year period of analysis from 2010 to 2075. The base year is 2025 and the performance of alternatives was evaluated from 2025 to 2075.	Planning guidance states that the period of analysis should be consistent for economic comparisons of all plans. Year 2025 was chosen as the common base year for comparison of alternatives since it generally represents the end of the implementation period for most alternatives considered.	If a longer period of analysis were used, the relative ranking of plans would probably not change.
The fiscal year 2008 discount rate of 4.875% applies to the LACPR analysis.	This discount rate is provided by USACE Economic Guidance Memorandum, 08-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2008.	If the interest rate goes down, then the project costs and residual damages would be lower. If the interest rate goes up, the project costs and residual damages would be higher.
Regional and local economies will remain strong and viable.	Regional and local economic recoveries have shown steady growth.	Failure of this assumption could affect all alternatives through lack of State and local funding for projects or the potential overemphasis on structural or restoration instead of nonstructural measures (e.g. relocation).

Assumption	Rationale for the Assumption	Consequences if Assumption Becomes Invalid
Interior Drainage		
Evaluation of all alternatives assumes a 10-year rainfall event regardless of the storm surge frequency (100-year, 400-year, etc).	A coincident frequency assessment was not performed, which is consistent with other USACE interior drainage studies. It is not likely that an extreme hurricane event coincides with a rare rainfall event. Therefore, a relatively mild rainfall event (10-year) has been selected for this evaluation which has rainfall intensity comparable to the historical rainfall during some major hurricanes.	If a more infrequent rainfall event occurs simultaneously with a hurricane event, the damages could be higher than expected.
Cost Estimates		
Costs of alternative plans are sufficiently predictable and accurate to recognize differences for planning purposes.	The preliminary costs provided in this technical report are used only for screening and comparing plans and not for funding or construction. Considerable additional design will be required before final costs of an implementable plan are determined.	If costs are much higher than expected, failure of the assumption could limit ability to provide desired levels of risk reduction given future cost constraints.
Funding		
Sufficient funding streams would be available to construct plans over the assumed construction periods and to provide long-term operation and maintenance of proposed risk reduction measures.	USACE planning policy states that plans should be developed without funding constraints. Federal and State funding priorities are difficult to project decades into the future.	Failure of this assumption would likely lead to a failure to meet objectives and to achieve the projected levels of risk reduction. The March 2008 report "Decision-Making Chronology for the Lake Pontchartrain and Vicinity Hurricane Protection Project" is a detailed case study which includes the potential implications of funding constraints (Woolley, 2008).
Federally supported flood insurance will remain available and in its current form throughout the period of analysis.	Although it is unlikely that a Federal program will remain unchanged over the next 50 years, the LACPR team currently has no way to predict these changes to another Federal program.	This assumption could fail in light of recent debate about reformulating flood insurance to shift risk away from the federal taxpayer. Reactions of individuals or local communities in threatened areas could be different and plans may need to be reformulated and costs recalculated.

Section 5. Hydromodeling Analysis

As briefly described in Section 3, state-of-the-art hydromodeling was used to simulate conditions for a range of storm events. This highly-complex hydromodeling process involves many variables. Static inputs to the hydromodeling process included ground elevations, bathymetry, and pumping/storage capacity inside the levee system. Variable inputs included: storm intensity, path, and frequency; storm surge height and duration; wave characteristics; rainfall volume and duration; levee system height and location; base and future degraded conditions of the coastal landscape outside the levee system; and relative sea level rise (subsidence plus sea level rise). Hydromodeling outputs were used to determine the probability of damage inside and outside of alternative levee systems as well as the desired height and related cost of structural improvements for each of the alternative plans. These outputs were used to develop metrics for the evaluation and comparison of the alternative plans.

The Step-Wise Hydromodeling Analysis

The step-wise procedure used for the LACPR hydromodeling analysis is outlined in "Elevations for Design of Hurricane Protection Levees and Structures," prepared by the USACE New Orleans District dated October 9, 2007. Each step is intended to ensure that individual designers follow procedures that will provide consistency in design when different designers work on various reaches of a large project. This procedure was used by a team of designers in the New Orleans District for the post-Katrina restoration and the 100-year levee designs specified by Congress in connection with the levee restoration work. The LACPR 100-year frequency automated design process produced design results that are consistent with work done by the restoration design team that used the step-wise procedure.

Figure 5-1 provides an illustration of the 4-step approach to capturing the hydraulic processes within the LACPR effort:

1. Modeling of surge levels and wave characteristics;
2. Determination of stage frequencies outside existing or proposed levees;
3. Determination of levee heights and overtopping volumes; and
4. Determination of interior flooding from overtopping and rainfall.

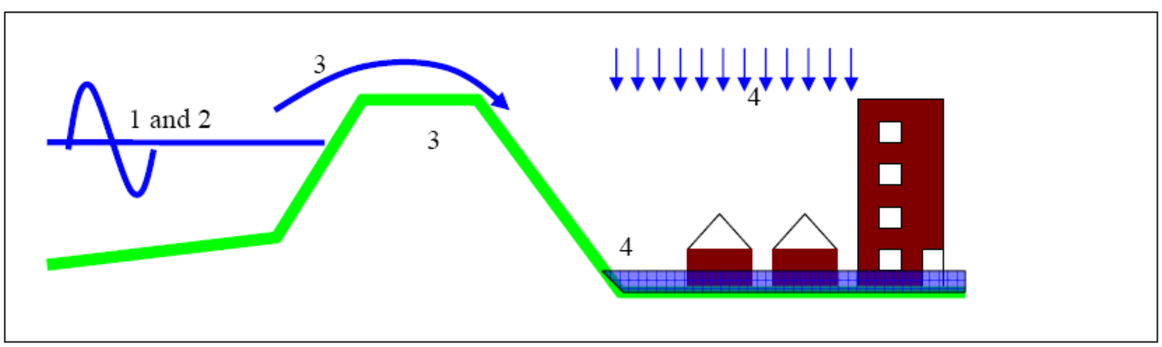


Figure 5-1. Illustration of the four major steps in the hydraulic analysis.

An additional step outlined in the October 2007 design guide, which calls for a check for design resiliency for the 500-year exceedence event, was eliminated in the LACPR work. This check was not necessary for the level of design detail needed for plan comparisons for LACPR. The LACPR design effort was based on a simplification of the process. Levee design was composed of a wave berm located at the still water level with a 1 on 4 slope for that portion of the levee above the still water level. The process that was used for the 100-year design effort was much more rigorous and involved different levee slopes, floodwalls, and slope protection; therefore, being sure that each component of the system provided the same resiliency was a necessary step.

Step 1: Modeling of Surge Levels and Wave Characteristics

Surge levels and wave characteristics were carried out using two models: ADCIRC for surge levels and WAM/STWAVE for the wave characteristics. Multiple storms were modeled against various levee alignments to evaluate the behavior of the surge levels and waves. In addition, the no action alternative was modeled to evaluate the effects of future changes in the coastal landscape, including marsh degradation.

Initially, two wave conditions were modeled: with friction and without friction. After completion of the surge and wave modeling, an independent analysis examined results from several nearshore wave models and a variety of conditions with a focus on wave energy dissipation effects. Careful review of simulated wave heights at some locations inshore of coastal marsh areas indicates that the with-friction STWAVE results may underestimate the wave height. In the interest of conservatism and in the absence of field-verified values for friction coefficients due to bottom and vegetation interaction, the design process applied STWAVE simulations without frictional dissipation. Uncertainty in future location and density of coastal marshes, in part due to local subsidence and lack of appropriated funding for marsh restoration, provides additional rationale for excluding the effects of friction in the nearshore wave simulations. Future planned efforts to obtain the necessary field data along with more accurate estimates of future wetland conditions should provide improved quantitative estimates of friction coefficients suitable for design purposes.

Step 2: Determination of Stage Frequencies

Based on the results from Step 1, a frequency analysis was performed to determine the surge levels and wave characteristics for different return periods. The method adopted for the frequency analysis is the Joint Probability Method with Optimal Sampling (JPM-OS) that takes into account the joint probability of forward speed, size, minimum pressure, angle of approach, and geographic distribution of the hurricanes. In order to establish the frequency curves for surge and waves, 304 storms were modeled for the base condition. For the alternatives, storm subsets were modeled and the remaining storms were then established using correlation techniques in order to carry out the frequency analysis with the JPM-OS method.

The frequency analysis has resulted in stage frequencies for the exterior areas, i.e. the areas that are not protected by the levees. Furthermore, this analysis has provided the surge levels and the wave characteristics for different return periods along the levee system as needed for the levee design and overtopping volumes in Step 3.

Step 3: Determination of Levee Heights and Overtopping Volumes

After predicting storm surge and waves for existing conditions, the team created a series of simplified levee designs at the 100-year, 400-year, and 1000-year design levels. These three design levels were chosen to illustrate “Category 5” risk reduction potential. The 400-year flood event was chosen as an approximation of Hurricane Katrina.

Levee heights were established in such a way that the overtopping rate would be less than 0.1 cubic feet per second per foot with a 90 percent confidence level. Stages were provided for three confidence levels: 10 percent, 50 percent, and 90 percent. Confidence levels quantify the uncertainty inherent in the hydrologic model and reflect the likelihood that the actual stage associated with a storm event will be less than or equal to the stage predicted by the hydromodel. As an example, at the 90 percent confidence level, there is at least a 90 percent chance that the actual stage will be less than or equal to the stage predicted by the hydromodel in any given year. Alternatively, there is a 10 percent chance that the actual stage will be greater than the stage predicted by the hydromodel in any given year.

The team then calculated quantities of water that would theoretically overtop the levees under various conditions including 100-year, 400-year, 1000-year and 2000-year surge events accompanied by the 10-year rainfall event. The 2000-year surge event was added in order to determine overtopping volumes with the 1000-year levee in place. The overtopping volumes were computed using the information on the surge level hydrographs from ADCIRC. Based on a statistical analysis, a correlation was established between the duration of the surge and the maximum surge level. This correlation was applied to compute the overtopping rate during the storm assuming that the wave characteristics are constant around the peak of the storm.

Step 4: Determination of Interior Flooding

The last step in the modeling approach was to determine interior flooding of alternative plans due to levee overtopping and rainfall volumes. The interior stage frequency has been based on the sum of the overtopping volume from Step 3 together with the 10-year rainfall for a particular area. The 10-year rainfall is a relatively mild rainfall event which has intensity comparable to the historical rainfall during major hurricanes; it is not likely that an extreme hurricane event coincides with a rare rainfall event. The effect of pumping has been taken into account if applicable.

Stage-storage relationships, relationships that effectively approximate flood levels based on these incoming volumes, were used to assess levels of damage and residual risk for various alternative plans. Stage-storage relationships only approximate flood levels by filling the lowest areas first but not taking into account how the water is internally routed within the levee system after overtopping occurs. Therefore, when using stage-storage flood level predictions to estimate flood damages, the precision of the estimate necessarily suffers when compared to a more rigorous modeling approach. When comparing alternative plans with structural measures against each other in terms of risk reduction, however, risk associated with the rainfall event is constant for all plans and does not bias the comparison. This use of stage-storage routing relationships to estimate flood levels behind the levees due to overtopping and rainfall was adopted to parallel the IPET risk and reliability approach.

Table 5-2 indicates where interior flooding was quantified for the various levee designs at the various stage frequencies.

Table 5-2. Relationship between levee designs and evaluation frequencies.

	Interior Flooding from Overtopping at Various Stage Frequencies				Interior Flooding from 10-year Rainfall
Levee Design	100-year	400-year	1000-year	2000-year	
100-year	Yes	Yes	Yes	Yes	Yes
400-year	No	Yes	Yes	Yes	Yes
1000-year	No	No	Yes	Yes	Yes

As shown in the table above, a coincident frequency analysis was not performed; instead, the 10-year rainfall was simply added to the overtopping volumes regardless of the event frequency.

Relative Sea Level Rise Effects on Levee Heights and Surge Levels

For the evaluation of alternatives for future conditions, statistical water surfaces were created to include the added effects of relative sea level rise, i.e., eustatic plus local subsidence. This was accomplished by adding the relative sea level rise increases from Table 4-1 to the statistical water surfaces developed from the ADCIRC modeling of surge levels from Step 1 above. No additional ADCIRC modeling was done for future conditions. This relative increase in water surface elevation impacted only areas exterior to the with project levees since the design level for such levees was assumed to be maintained over the period of analysis (see Table 4-2 Critical Assumptions). To maintain the design level, the relative sea level rise increases from Table 4-1 were added to the calculated levee heights from Step 3 above and cost estimates revised accordingly. Under future project conditions, the interior stages were assumed to remain the same as for the 2010 conditions and no new overtopping rates needed to be recalculated. For the no action alternative, existing levee heights were assumed to be kept at a constant elevation, and new overtopping rates and interior stages were calculated for each of the relative sea level rise scenarios.

Vertical Controls and Datum

The effects of subsidence have created issues with the vertical datum that has plagued the engineering and surveying community in Southern Louisiana. Fortunately, in the last few years the National Geodetic Survey has developed a new method for updating vertical datum epochs to take into account subsidence and movement in control monuments. This new method has led to the creation of Vertical Time Dependent Positioning which requires the datum and its epoch to be listed together. At the time the LACPR effort began, the vertical datum in use was the NAVD 88 (2004.65) where 2004.65 is the datum epoch. This epoch has been superseded by a 2006.81 adjustment but to maintain continuity, the 2004.65 epoch will continue to be used for this effort. There are still many problems associated with trying to convert historical data such as gauge data, high water mark data, etc. into the new datum and epoch since the historical data is tied to older datum spanning numerous leveling epochs. The NAVD 88 (2004.65) datum will be used as the reference datum for all elevations in this report unless otherwise noted.

Design elevations referenced in this report were created using the same modeling, methodology, and data used to design the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS) work and to perform the FEMA flood insurance studies for South Louisiana (reference USACE/FEMA Louisiana and Texas Joint Coastal Storm Surge Study). Elevations used in developing the models incorporated the latest information on the relationship between water level reference surface (local mean sea level) and geodetic datum. All elevations are provided in NAVD88 (2004.65) which is the datum currently being used for all HSDRRS work.

Future detailed design and construction will be done using the most current HSDRRS design procedures and standards. During the design phase, gaging requirements will be established and gage(s) will be installed as required. The gage(s) will be used for determining the tidal datum local mean sea level prior to construction. Additional temporary gages may be required depending on vertical accuracy requirements. The gage(s) can also be used to monitor future hydrologic conditions in the area. The datum of the gage(s) has been established to comply with criteria contained in the Vertical Control Requirements for Engineering, Design, Construction, and Operation of Flood Control, Shore Protection, Hurricane Protection, and Navigation Projects (Engineering Division Policy Memo #2).

The relationship between NAVD88 2004.65 and local mean sea level for the gage(s) will be reevaluated and reviewed by NOAA every 5 years (or more frequently if warranted based upon rate of subsidence). Vertical Datum Reports for each current HSDRRS polder are currently being prepared and will contain specific information on the gage network and the relationship between local mean sea level and NAVD 88 2004.65 for the project area. As new areas with HSDRRS projects are added reports for those areas will be produced.

Section 6. Economic Application

A customized GIS framework, or application, similar to the one previously developed for IPET, was used for the LACPR economic evaluations. **Figure 6-1** is a flowchart that displays the inputs and outputs of the LACPR GIS economic application. Further details on the economic application and evaluation can be found in the *Economics Appendix*.

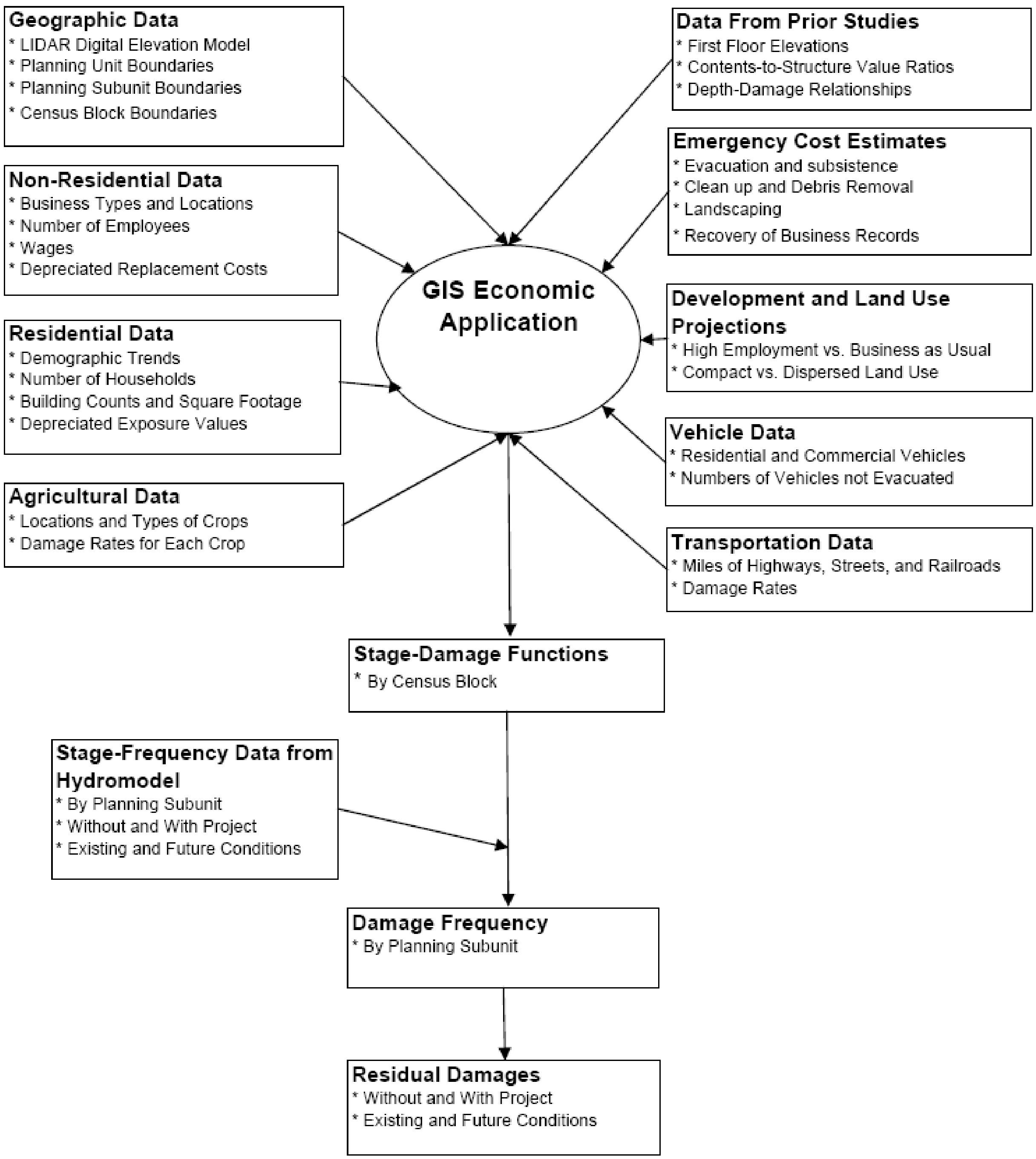


Figure 6-1. LACPR GIS economic application flowchart.

The following sections provide a brief description of each of the components shown in the flowchart. Unless otherwise stated, dollar amounts are in 2007 price levels.

Geographic Data

The GIS application includes boundaries for the five planning units; approximately 900 planning subunits (which were established based on hydraulic data); and approximately 72,000 census blocks within the LACPR planning area. Topographical data obtained from the LIDAR Digital Elevation Model were combined with census block boundaries obtained from the 2000 Census to determine the mean ground elevation for each census block.

Data from Prior Studies

Some of the data used for the LACPR economic evaluation was obtained from prior USACE studies, such as determination of first floor elevations, contents-to-structure ratios, and depth-damage relationships.

First Floor Elevations - First floor elevations were based either on existing first-floor elevation surveys or were estimated after interviewing parish emergency management personnel. This data was used to estimate the percentage of residential structures with pier foundations vs. slab foundations and the percentage of one-story vs. two-story residential structures. An average height of 1.5 feet above ground was assigned to all non-residential properties in the planning area based on information obtained during the interviews with parish emergency management personnel.

Contents-to-Structure Value Ratios – The contents for residential and non-residential structures were determined based on limited field surveys and previous feasibility studies. The value of contents of each structure category were totaled and then compared to the total value of a structure in order to develop contents-to-structure value ratios.

Depth-Damage Relationships – Damages from flooding were calculated for residential and non-residential buildings, their contents, and vehicles based on the depth-damage relationships for previous feasibility studies. Saltwater, long-duration (1-week) depth damage curves were used to indicate the percentage of the structural value that was damaged at each depth of flooding.

Development and Land Use Projections

As discussed in Section 4, projections of population growth and land use were included in the future scenarios. Projections of population, number of households, and total non-agricultural employment were provided by Calthorpe Associates, an urban planning agency contracted by the State of Louisiana. These projections were based on the results of a custom application of the U.S. Macro Model, a macro-economic model prepared by Moody's Economy.com. The Economy.com model used factors such as net migration of population, employment demand by sectors of the economy, distribution of personal income, and residential construction patterns to project future development patterns. Calthorpe also developed land use allocation scenarios to show the location and type of development expected to take place throughout southern Louisiana. Out of several possible combinations of population growth and land use, the following two were chosen to bracket the high and low end of the range of possible damages: high employment/dispersed population and business-as-usual/compact population.

Structure Inventory and Valuation

The LACPR planning area includes over one million residential and non-residential structures. Aerial photography was used to identify the locations of the residential and non-residential structures in each census block. A point was then placed on the GIS maps to show these locations and to assign a ground elevation to each structure using LIDAR data.

Residential – The residential structure inventory was obtained from HAZUS-MH, a GIS-based multi-hazard loss estimation tool developed by FEMA and the National Institute of Building Sciences. The building stock data, which were based on the 2000 Census, were then updated to represent the second quarter of 2005 (pre-Katrina) based on census block group data obtained from Calthorpe Associates. The updated HAZUS-MH database was used in the GIS application to provide the total square footage, building count, and the total depreciated exposure value for residential occupancies by census block.

Non-residential – The non-residential inventory was compiled using databases from the Louisiana Department of Labor (LDOL) and the Louisiana State University GIS Department. The LDOL database provided a latitude/longitude coordinate for each business property in the planning area that had been registered for unemployment insurance. The Louisiana State University database provided additional information on the locations of schools, post offices, and churches. Average depreciated replacement costs were assigned to each non-residential occupancy category in the GIS application. The LDOL database also describes the type of business occupancy at each location, the number of employees, and the total wages paid for second quarter 2005 for each business unit.

Vehicle Data

Approximately 1.4 million privately-owned vehicles and 135,000 vehicles associated with businesses were estimated for the 23 parishes subject to surges from hurricanes in the LACPR planning area. Damages to residential automobiles were based on the number of automobiles not used by their owners during the evacuation process. It was assumed that the average household would use 70 percent of its vehicles to evacuate during a storm event, while the remaining 30 percent would remain parked at the residence. These percentages are based on data from the Hurricane Katrina evacuation, during which between 65 and 80 percent of privately-owned vehicles in Southeast Louisiana were used for evacuation. It was assumed that since business owners would likely use their privately-owned vehicle for evacuation, all commercial vehicles would remain parked at the business.

The elevation of each automobile is determined by the corresponding elevation near either the residential or commercial structure. Damages are then calculated by correlating the depth of flooding to the depth-damage relationship for vehicles. An average retail replacement value of $12,217 was used for both residential and commercial vehicles.

Emergency Cost Estimates

A flooded community typically incurs a variety of flood-related costs not associated with structural damages. The emergency costs associated with inundated residential properties include evacuation and subsistence, clean up and reoccupation costs, debris removal, and landscaping costs throughout the necessary duration for recovery. The emergency costs associated with inundated non-residential properties include clean up and restoration costs, recovery of business records, and landscaping. These costs are incurred either by the Federal, State, and local government, the occupants of inundated residential properties, or the owners of inundated non-residential properties.

An emergency cost depth-damage relationship for residential and non-residential properties was developed for each increment of flooding up to 15 feet above the first floor elevation. These depth-damage relationships were then combined in the GIS framework with the number of residential and non-residential structures inundated at each 1-foot increment of flooding to develop a stage-damage relationship for the total of all residential and non-residential emergency cost categories.

Agriculture

Stage-damage relationships were developed for the agricultural resources in the planning area. The National Agricultural Statistics Service GIS database for the year 2005 (pre-Katrina and Rita) was used to provide the location of each of the various crops farmed in the LACPR planning area. These crops include corn, cotton, rice, sorghum, soybeans, winter wheat, small grains (alfalfa, oats, millet, and rye) and hay, sugar cane, fallow cropland, pecans, and pasture. The number of citrus acres in Plaquemines Parish was provided by the Louisiana State University Agricultural Center (LSU AgCenter) and their location was estimated based on the location of fallow cropland in the area. The LSU AgCenter provided the number of acres of crawfish farming for each parish, and it was assumed that these acres were located in the same area as the rice acres. The total damage rate developed for each crop, including both crop loss and non-crop loss, was multiplied by the number of cleared acres inundated in order to calculate the total loss from inundation for each crop.

Transportation

The GIS framework was used to determine the number of miles of highways, streets, and railroad tracks that would be inundated by the stages associated with each 1-foot increment of flooding. Data obtained by USACE New Orleans District staff were used to revise the depth-damage relationships for highways, streets, and railroad tracks that had been developed as part of a Mississippi River and Tributaries study entitled Economic Data Survey New Orleans District, which was conducted for the Lower

Mississippi Valley Division in September 1980. These depth-damage relationships were then combined in the GIS framework with the number of residential and non-residential structures inundated at each 1-foot increment of flooding to develop a stage-damage relationship for the total of all highways, streets, and railroad tracks.

Stage-Damage Functions

Flood damages were calculated at 1-foot increments from the beginning damage elevation to an elevation where damages for all the structural categories have reached a maximum.

Stage-Frequency Data

As previously discussed, stage-frequency data were developed through the hydromodeling effort for each planning subunit under existing and future without project and with project conditions. Stages associated with the five storm frequency events (10- to 2000-year) were then combined with the stage-damage functions to create damage-frequency relationships used to calculate expected annual damages.

Section 7. Base Conditions

The base conditions are the no action or without project conditions assuming none of the LACPR alternatives are implemented. In general, the base conditions assume completion of Federally-authorized navigation, flood risk management, hurricane risk reduction, and environmental restoration projects in the planning area. The base conditions also include non-Federal levees at existing design levels.

The base conditions include outputs of the hydromodeling analysis, which statistically predict the hurricane threat; an inventory of economic and environmental assets; and descriptions of existing projects designed to reduce risk to those assets. The base conditions have been evaluated at two points in time over the period of analysis as explained in Section 4. This inventory of existing and future conditions is contained within an extensive GIS database, which can be queried down to the census-block level.

Existing Hurricane Risk Reduction Projects

The following sections describe existing hurricane risk reduction projects and explain which projects either were or were not included in the LACPR base conditions. If any of the projects included in the base condition are not completed, then the actual risks could be higher than estimated by the LACPR analysis.

2007 Water Resources Development Act

Although the Water Resources Development Act 2007 authorized the following projects, they are not included in the base conditions since they were not authorized at the time the analysis was conducted:

- Louisiana Coastal Area projects,
- Coastal Impact Assistance Program projects, and
- Morganza to the Gulf project.

Many or all features of the above projects, however, are included in the with project conditions in various alternatives.

Emergency Supplemental Improvements for New Orleans

For New Orleans, the base conditions assume that improvements to the hurricane risk reduction system as authorized in Public Laws 109-148, 109-234, and 110-28 are in place. These laws provided funds to raise levee heights or otherwise enhance the West Bank and Vicinity and the Lake Pontchartrain and Vicinity projects to a 100-year design level.

Implementation of the 100-year standard will be accomplished through improvements to levees, floodwalls, armoring, and associated structures in Jefferson, Orleans, portions of Plaquemines, St. Charles, and St. Bernard Parishes. Improvements are anticipated to be completed by 2011. Appropriations were also provided to accelerate completion of previously authorized hurricane and storm damage reduction and flood risk management projects in South Louisiana. For the purpose of this analysis, the base conditions assume that funds provided by these laws are sufficient to complete the authorized improvements.

Hurricane Risk Reduction and Flood Control Projects and Studies

Figure 7-1 shows the locations of existing Federal and non-Federal levees as well as existing flood control structures in Planning Units 1, 2, 3a, and part of Planning Unit 3b. The western portion of Planning Unit 3b and Planning Unit 4 do not contain any significant existing levees or hurricane flood control structures.

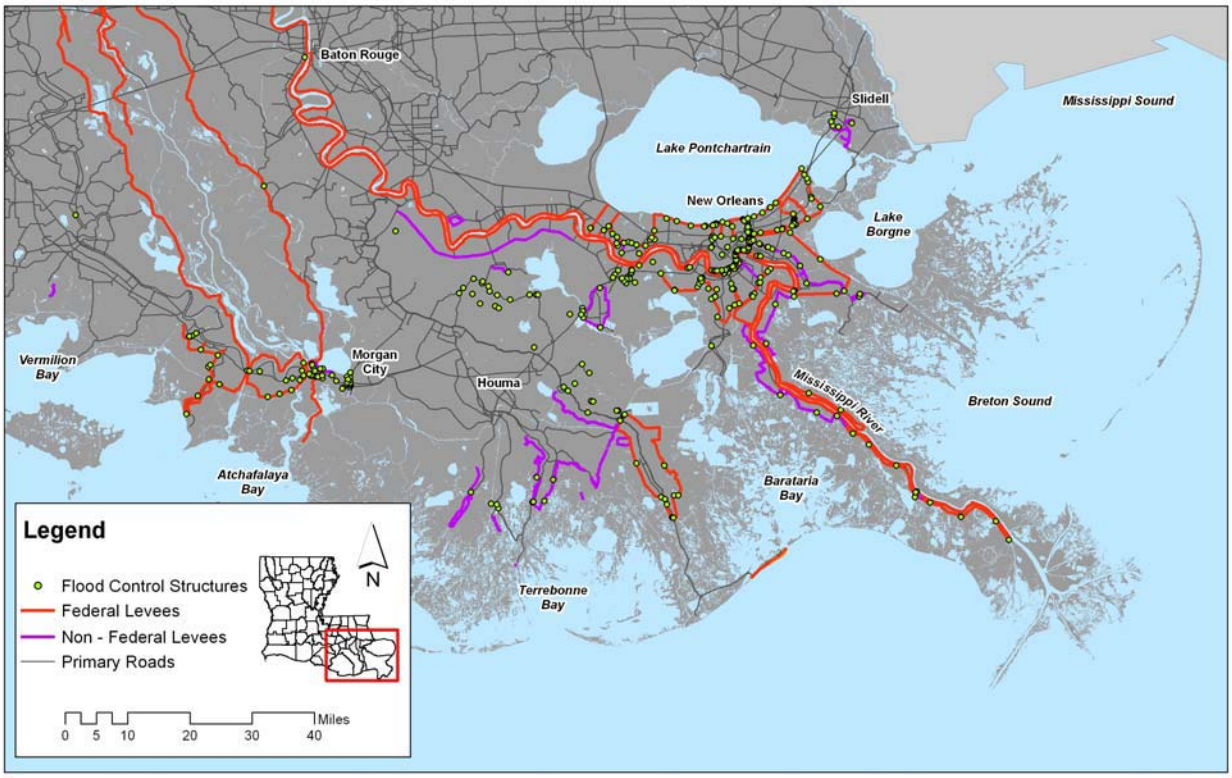


Figure 7-1. Existing Federal levees, non-Federal levees, and flood control structures.

The hydromodeling effort captured local (non-Federal) levees for the with and without project conditions through available LIDAR information reflecting pre-Katrina and Rita design levels. These design levels (although providing relatively low levels of risk reduction) have been assumed to be maintained at the current levels for the LACPR evaluation. In addition, some of the local levees have been restored by the USACE in response to emergency restoration efforts after Katrina, e.g. the St. Bernard Parish back levee was restored to an elevation of 10ft. The LACPR base condition reflects these repairs.

Table 7-1 and **Figure 7-2** display major existing USACE hurricane and flood control projects and studies by individual project or study name. Section 205 projects and studies are not shown in the table or on the map.

These projects and studies have evolved over different periods of time and are at various stages of completion. The LACPR analysis considers all authorized projects as part of its base condition, except for those recently authorized under the Water Resource Development Act as described above. Studies are evaluated as components of the overall LACPR comprehensive system.

Table 7-1. Major USACE hurricane and flood risk reduction projects and studies.

Common Project Name	Design Standard	Status
Lake Pontchartrain and Vicinity*	Standard Project Hurricane/ 100-year design	Construction phase
West Bank and Vicinity*	Standard Project Hurricane/ 100-year design	Construction phase
New Orleans to Venice	100-year design	Construction phase
Larose to Golden Meadow	100-year design	Construction phase
Morganza to the Gulf	100-year design	Authorized by WRDA 2007; not yet appropriated
Grand Isle and Vicinity	50-year design	Construction phase
Morgan City and Vicinity	Standard Project Hurricane	Morgan City area was deferred in 1987 and the Franklin area was de-authorized in 1997.
Mississippi River Levees	Mississippi River and Tributaries Project Design Flood	Construction phase
Atchafalaya Basin Levees	Mississippi River and Tributaries Project Design Flood	Construction phase
Common Study Name	**Design Standard***	**Status**
West Shore Lake Pontchartrain Study	To be determined	Feasibility phase
Southwest Coastal Louisiana Feasibility Study**	To be determined	Feasibility Cost Share Agreement currently being negotiated with the State of Louisiana.
Donaldsonville to the Gulf Study	To be determined	Feasibility phase
La Reussite to St. Jude Study (would be part of New Orleans to Venice project)	100-year design	Revised decision report needed
Lower Atchafalaya Basin Reevaluation Study	Mississippi River and Tributaries Project Design Flood	Study phase

Notes: See Glossary for explanation of design standards.
*Originally authorized for Standard Project Hurricane; however, Public Laws 109-148, 109-234, and 110-28 authorize improvements to reach the 100-year design. IPET's *Decision Making Chronology for the Lake Pontchartrain and Vicinity Hurricane Protection Project* report details the history of the Standard Project Hurricane as applied to the designs for that project.
**Not shown on map.

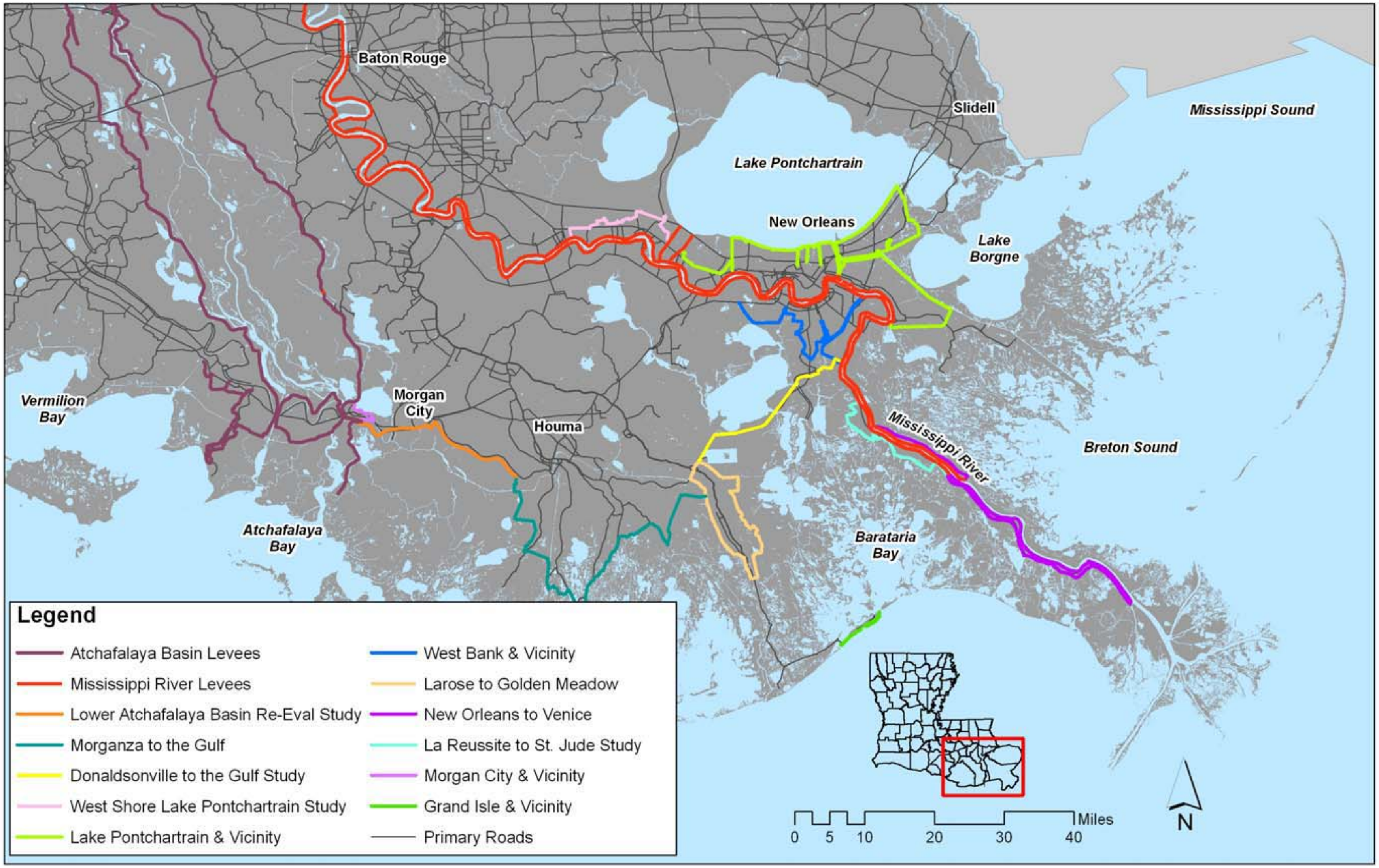


Figure 7-2. Existing hurricane and flood risk reduction projects and studies.

In general, within the LACPR planning area authorized hurricane risk reduction projects fall into two categories of risk reduction. The first category applies a Standard Project Hurricane design standard for urban areas. The Standard Project Hurricane was established as the design storm to be used for highly populated areas where there is a chance for loss of life and great economic impact due to loss of property. A second category of risk reduction has been applied to less developed areas where property protection was the primary emphasis and loss of life was addressed by imposing mandatory evacuation of residents; in general benefit/cost analysis dictated the level of risk reduction, e.g. 50-year or 100-year level of risk reduction.

Existing Hurricane Threat

The following sections include the limits of hurricane surge inundation for the 1000-year event across the coast and the statistical water surfaces for the 100-year, 400-year, and 1000-year events in each of the planning units.

Base Condition Surge Inundation Limits

Figure 7-3 illustrates the extent of the 1000-year hurricane surge inundation (hatched area). The 100-year and 400-year limits are not shown on the map because they generally extend to similar limits but at lower elevations.

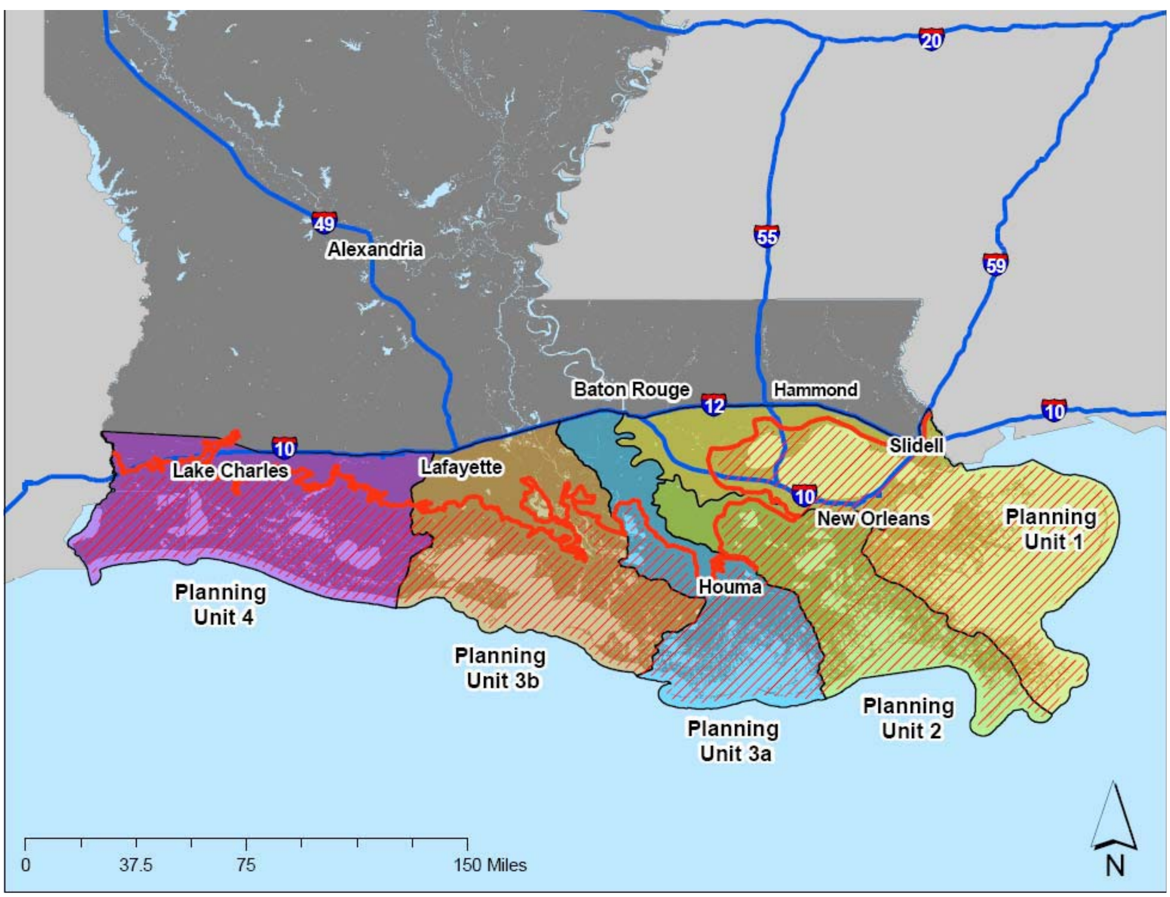


Figure 7-3. LACPR planning area map showing the extent of the 1000-year hurricane surge inundation (hatched area).

Base Condition Water Surface Elevations

Each of the planning units contains literally thousands of grid points which translate into thousands of stage frequencies from which statistical surfaces can be prepared. To create the 100-year surface, the 100-year surge value is extracted from each of the frequency curves. Since the ADCIRC grid is geo-referenced, each 100-year stage can be plotted at its correct point in space; by connecting to the 100-year points a 100-year statistical surface can be mapped. Statistical water surfaces for other frequencies (e.g. 400-year) can be produced using the same procedure.

Figure 7-4 through **Figure 7-18** show statistical water level surfaces for the 100-, 400- and 1000-year return periods in each planning unit. The 100-, 400- and 1000-year surfaces were chosen since those return intervals were used to design proposed protective works and levees for this effort. Additional maps showing future conditions are located in the *Evaluation Results Appendix*.

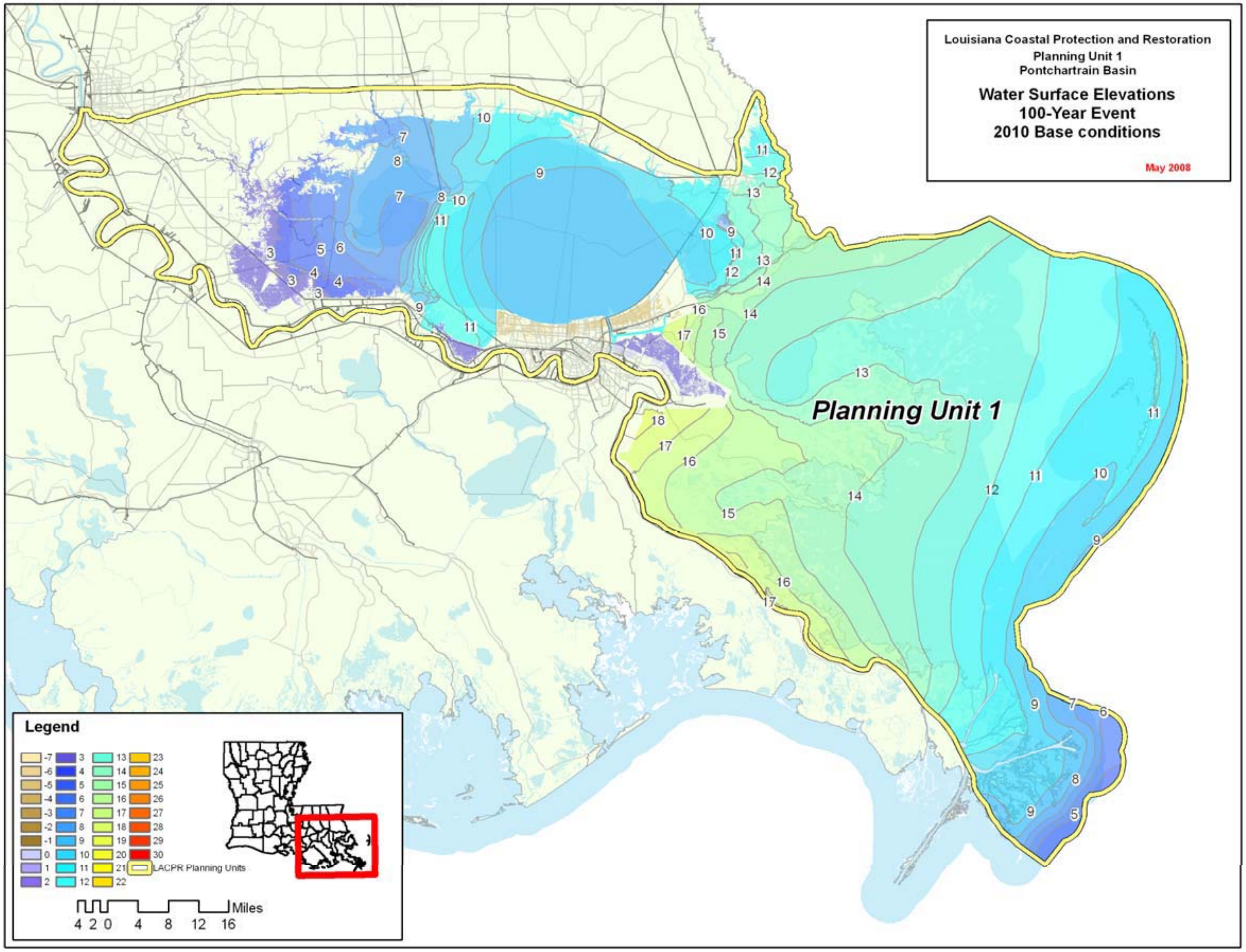


Figure 7-4. Statistical water surface for the 100-year event in Planning Unit 1.

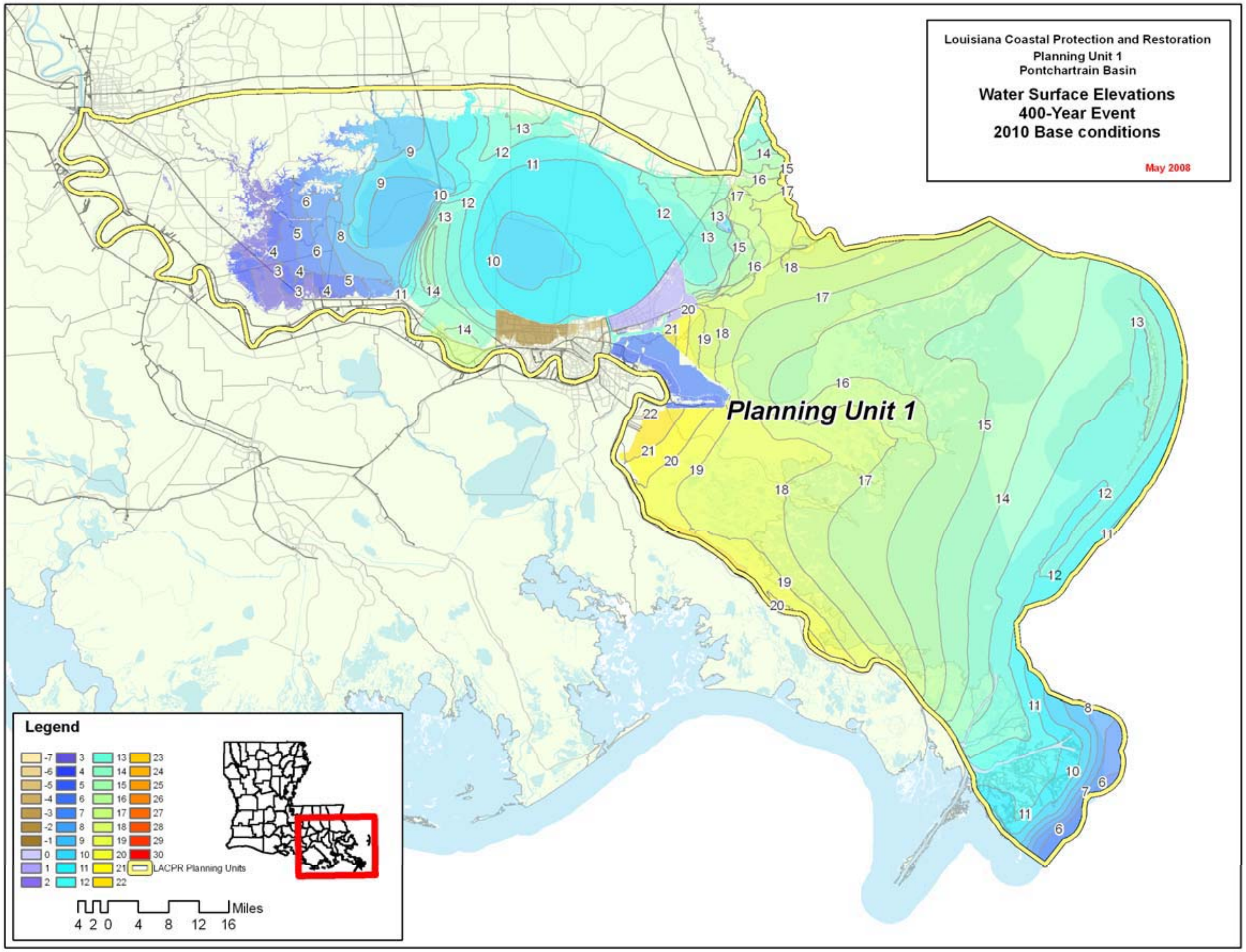


Figure 7-5. Statistical water surface for the 400-year event in Planning Unit 1.

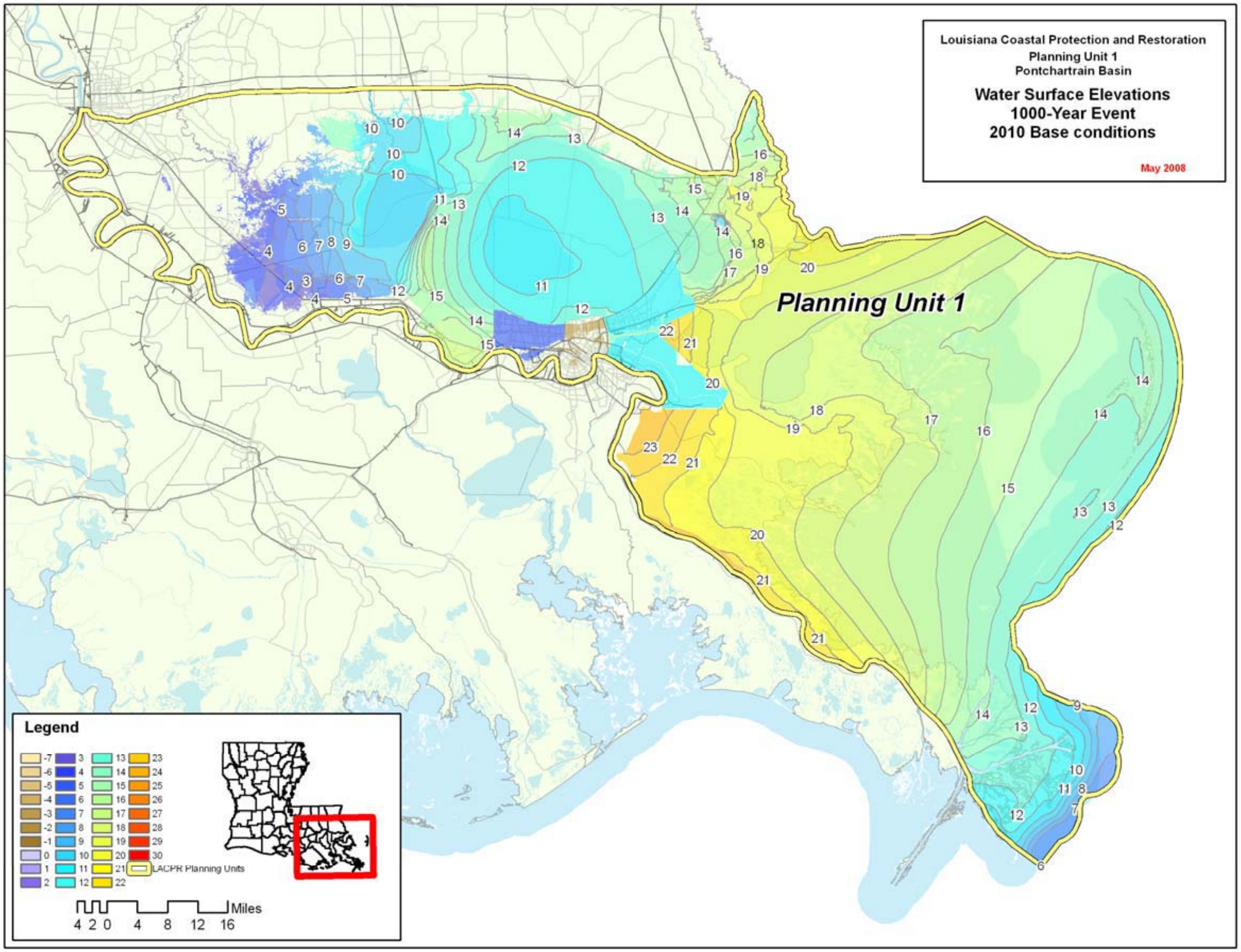


Figure 7-6. Statistical water surface for the 1000-year event in Planning Unit 1.

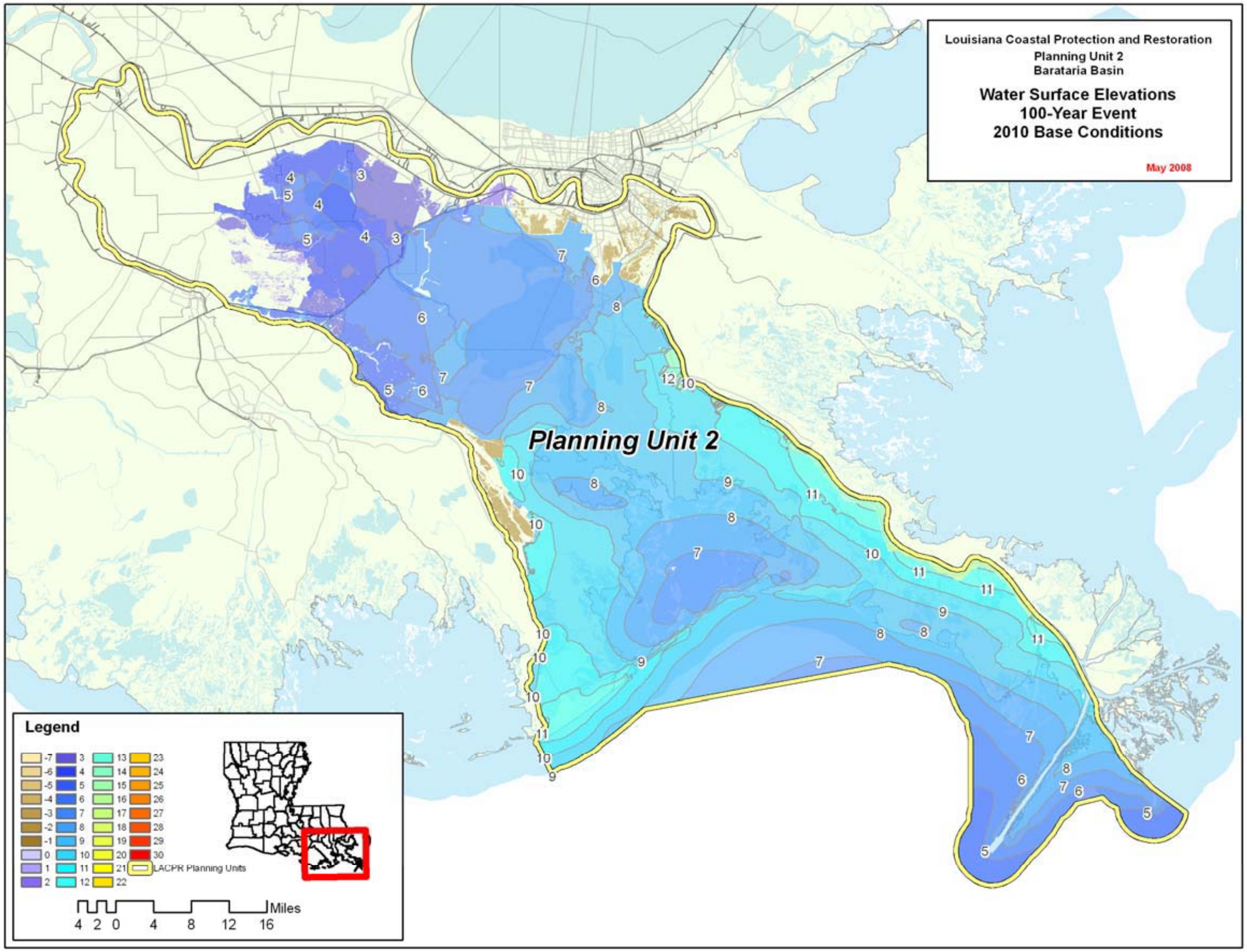


Figure 7-7. Statistical water surface for the 100-year event in Planning Unit 2.

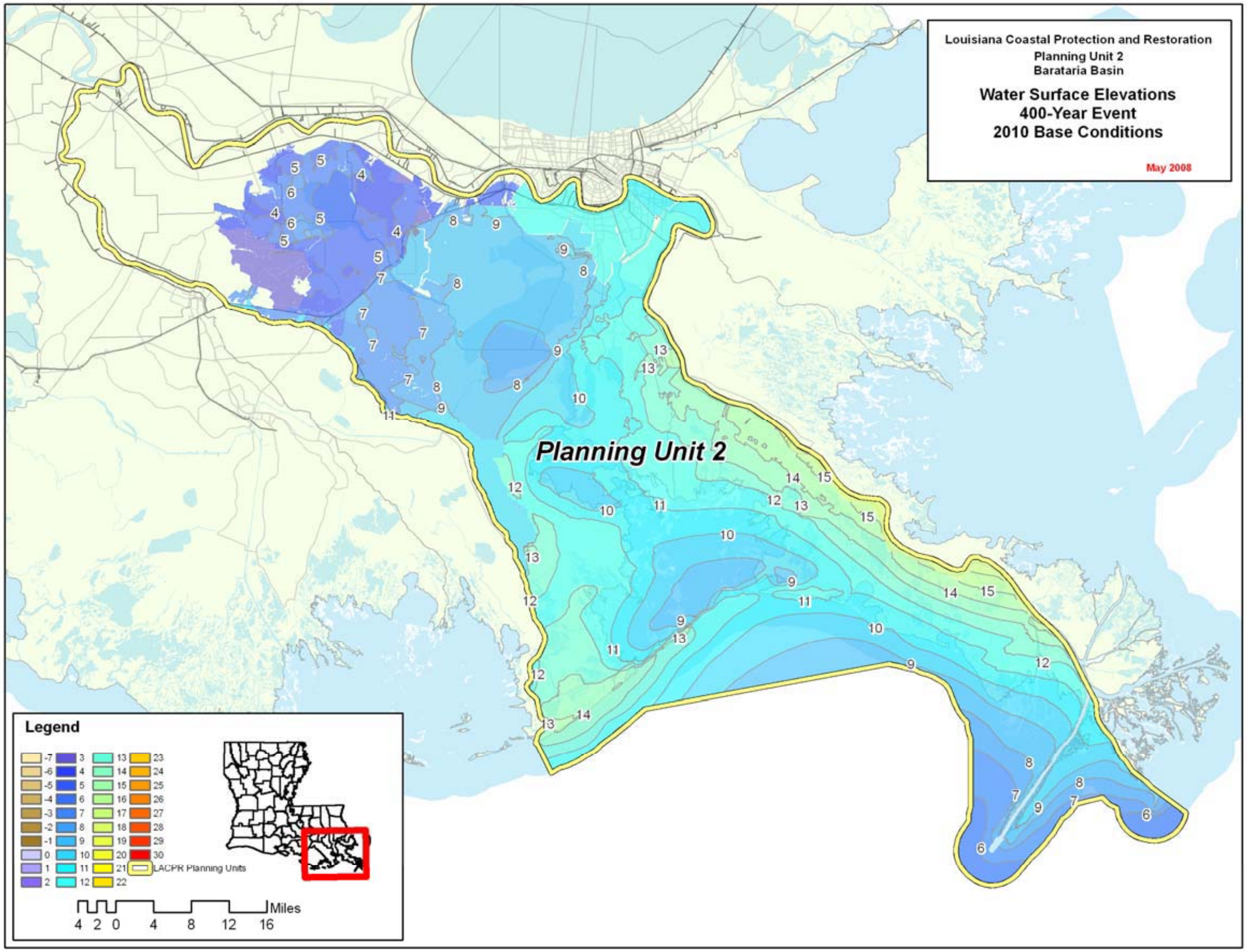


Figure 7-8. Statistical water surface for the 400-year event in Planning Unit 2.

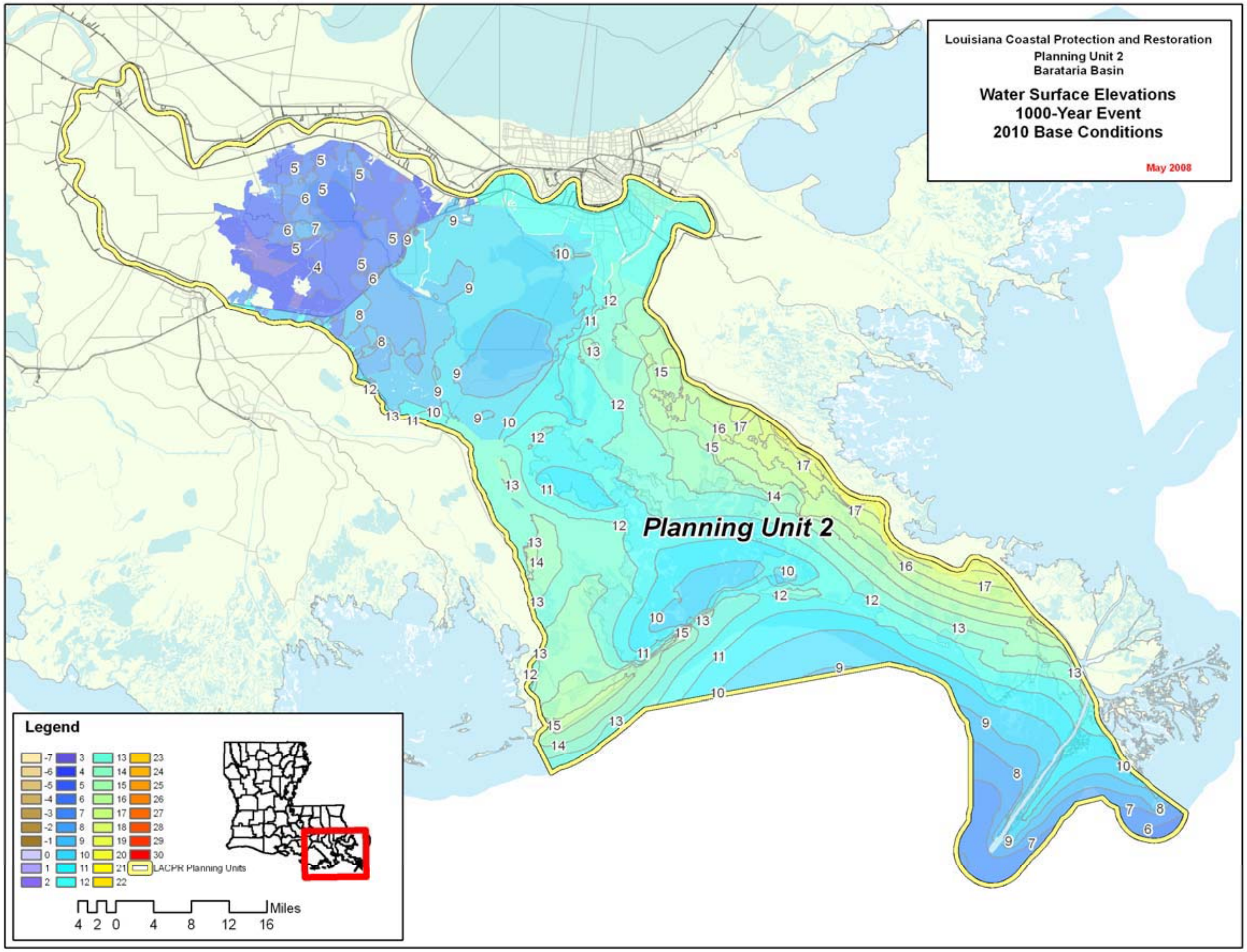


Figure 7-9. Statistical water surface for the 1000-year event in Planning Unit 2.

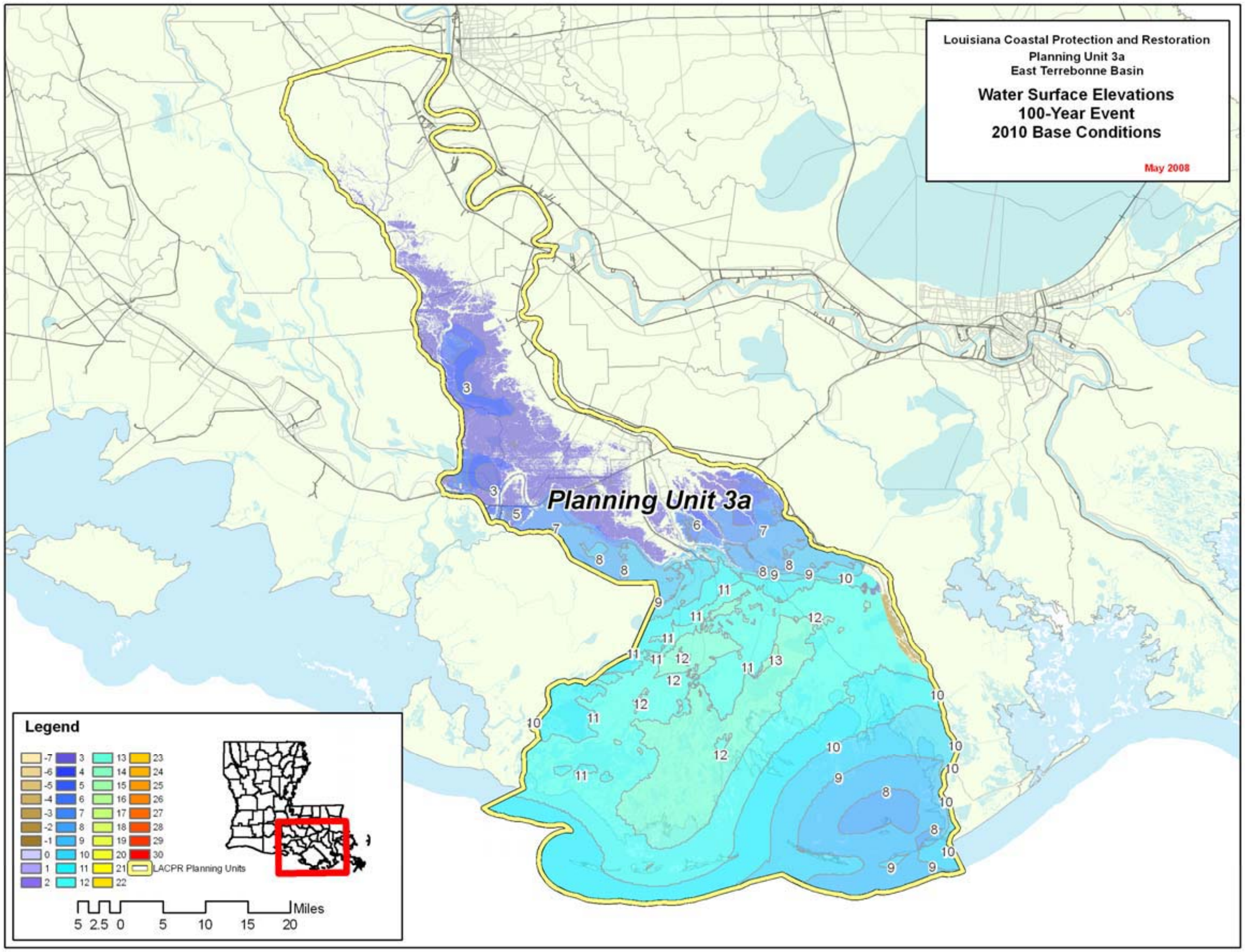


Figure 7-10. Statistical water surface for the 100-year event in Planning Unit 3a.

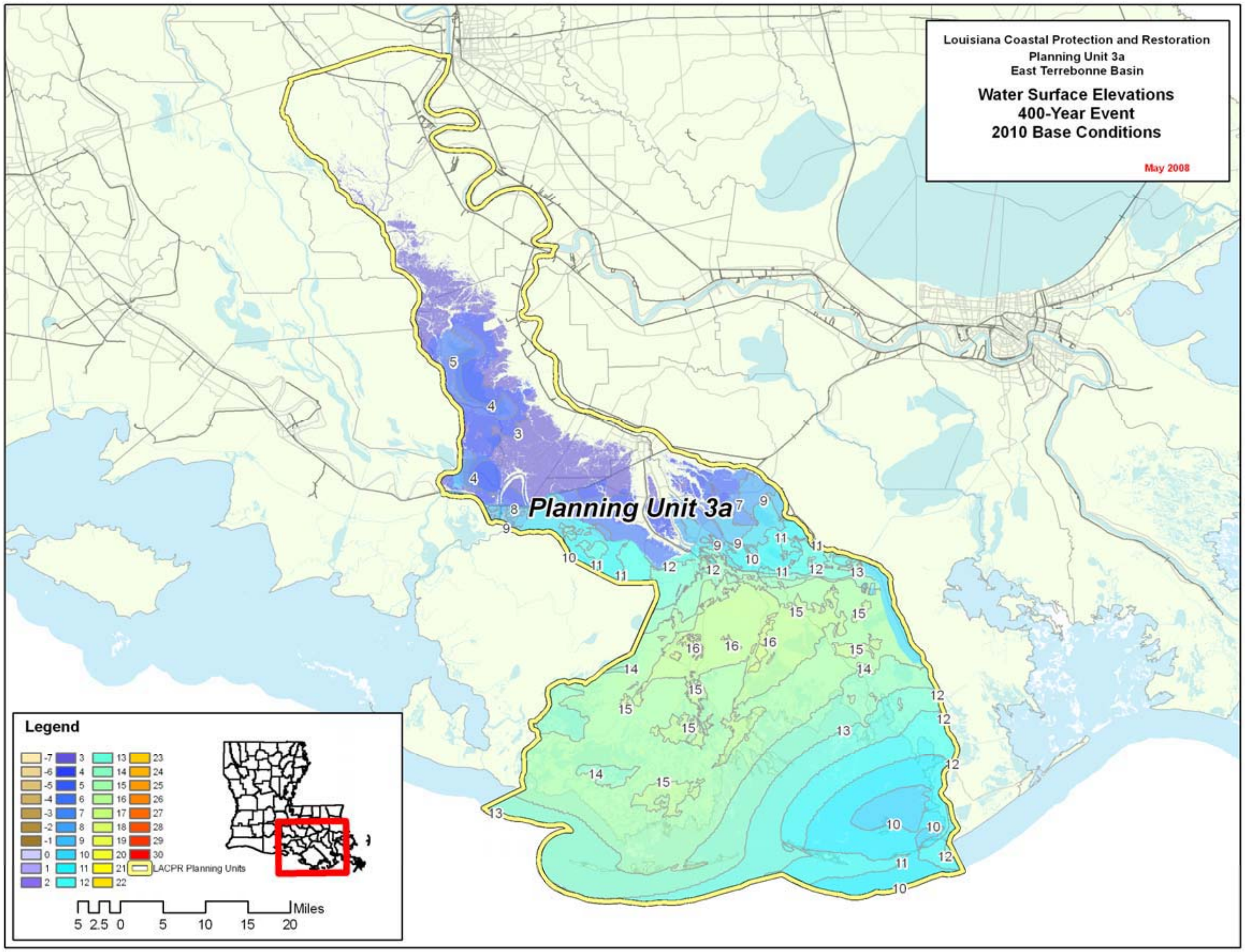


Figure 7-11. Statistical water surface for the 400-year event in Planning Unit 3a.

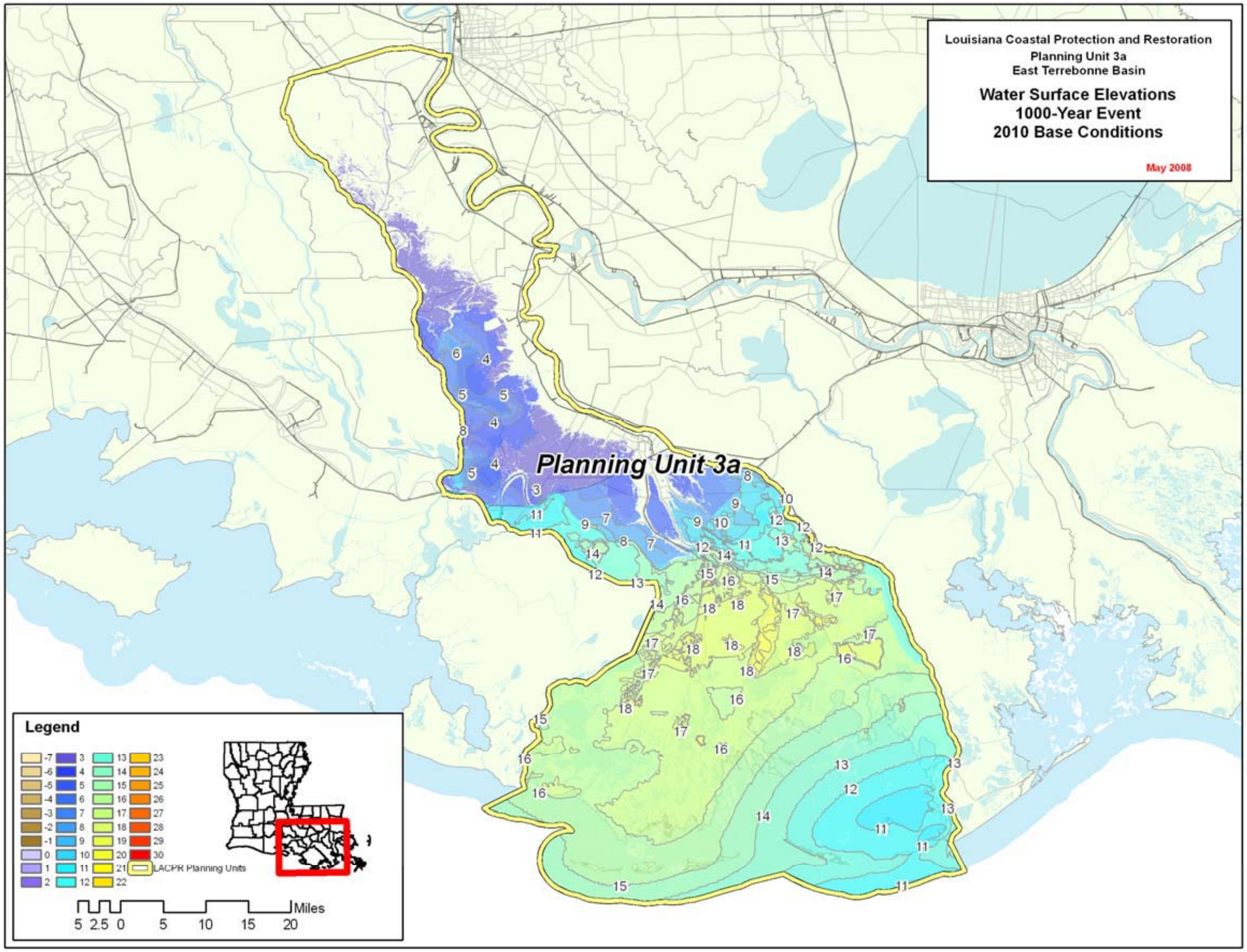


Figure 7-12. Statistical water surface for the 1000-year event in Planning Unit 3a.

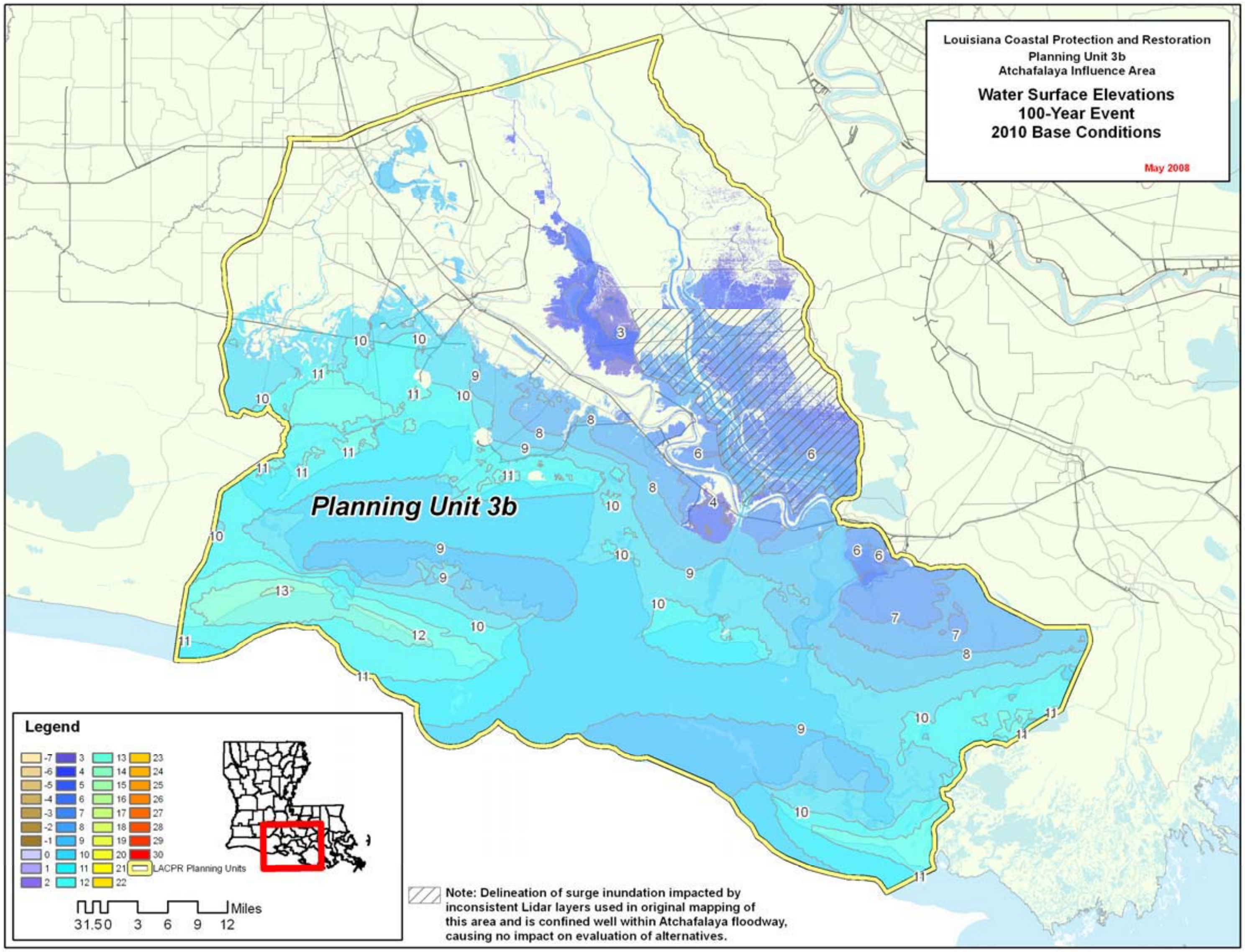


Figure 7-13. Statistical water surface for the 100-year event in Planning Unit 3b.

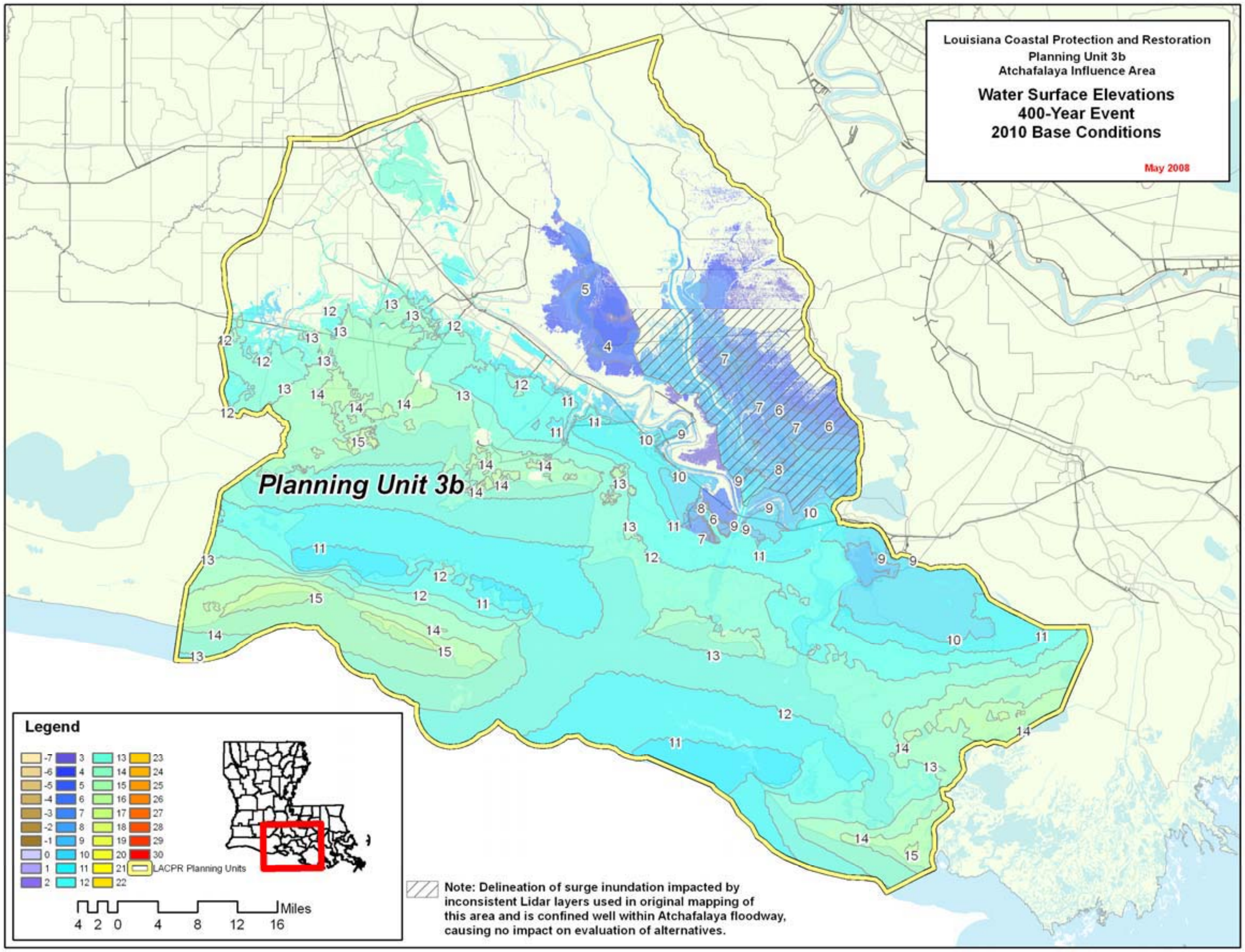


Figure 7-14. Statistical water surface for the 400-year event in Planning Unit 3b.

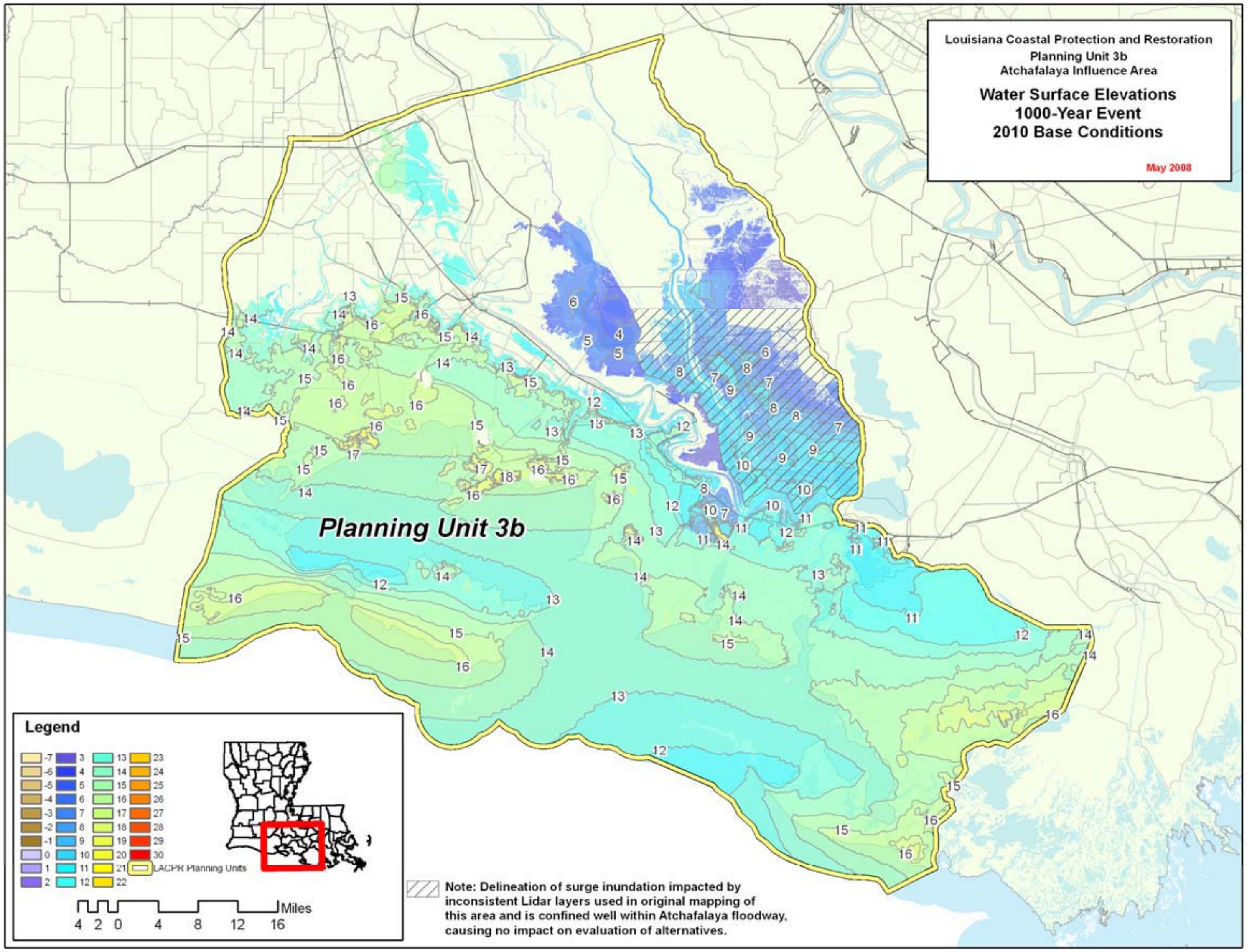


Figure 7-15. Statistical water surface for the 1000-year event in Planning Unit 3b.

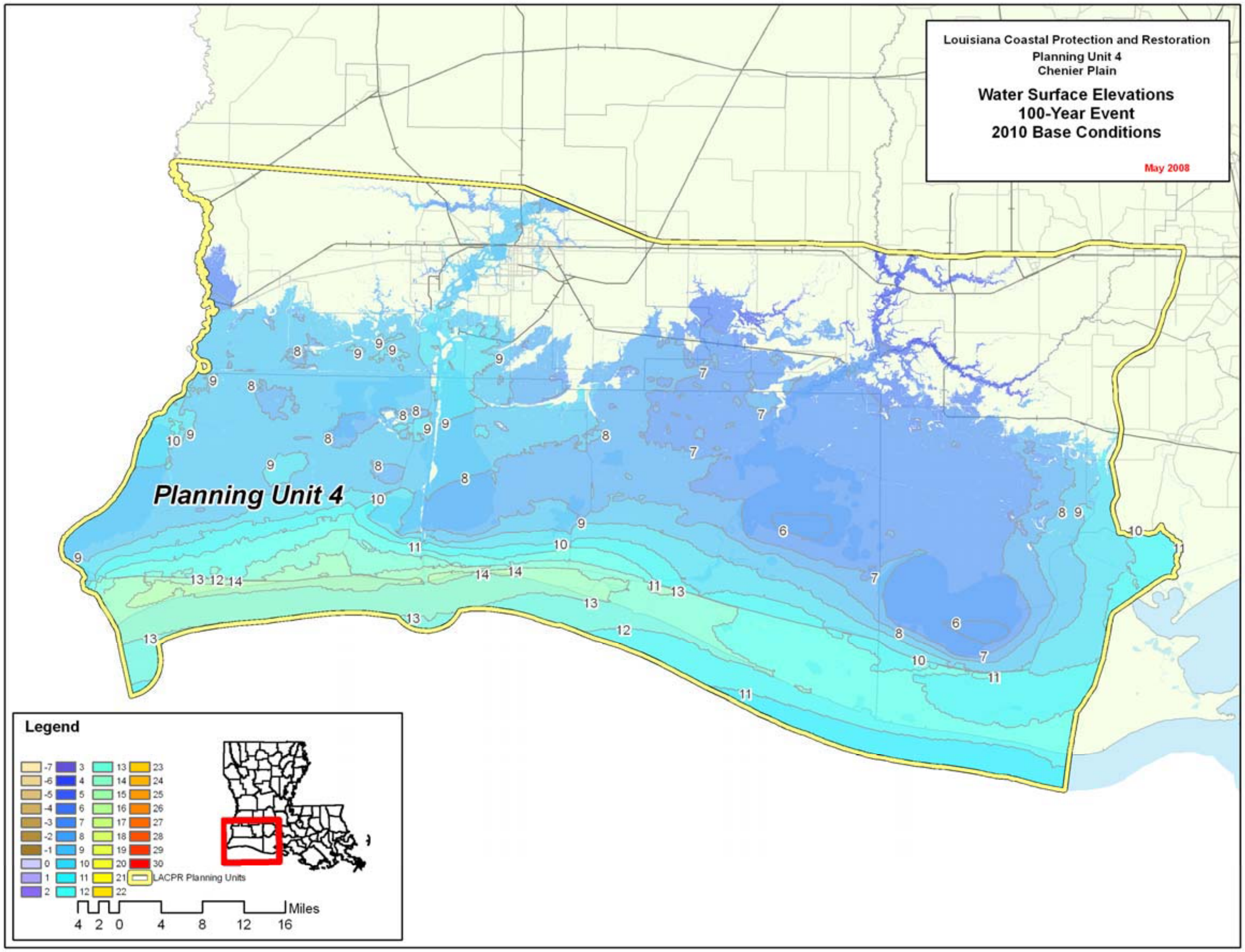


Figure 7-16. Statistical water surface for the 100-year event in Planning Unit 4.

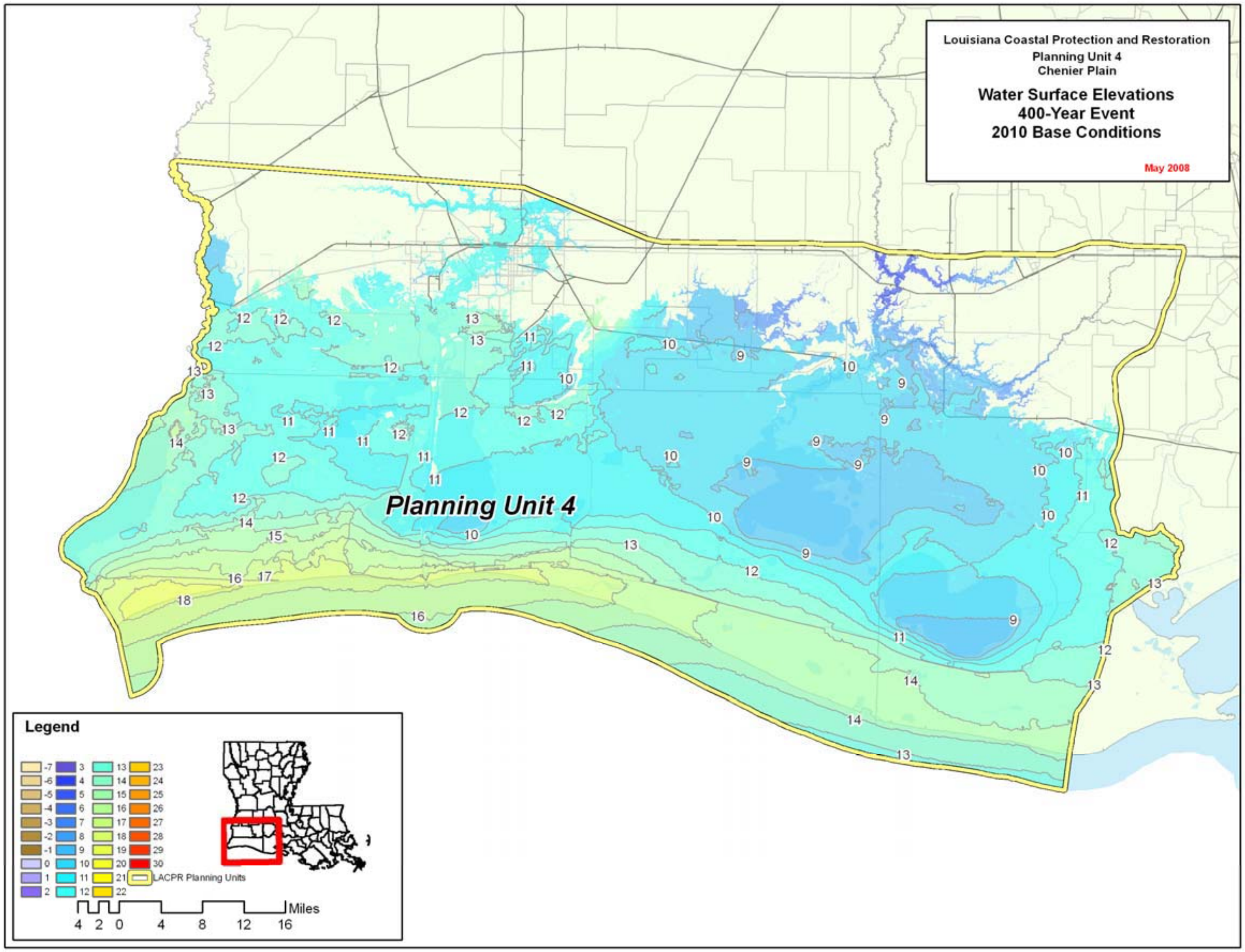


Figure 7-17. Statistical water surface for the 400-year event in Planning Unit 4.

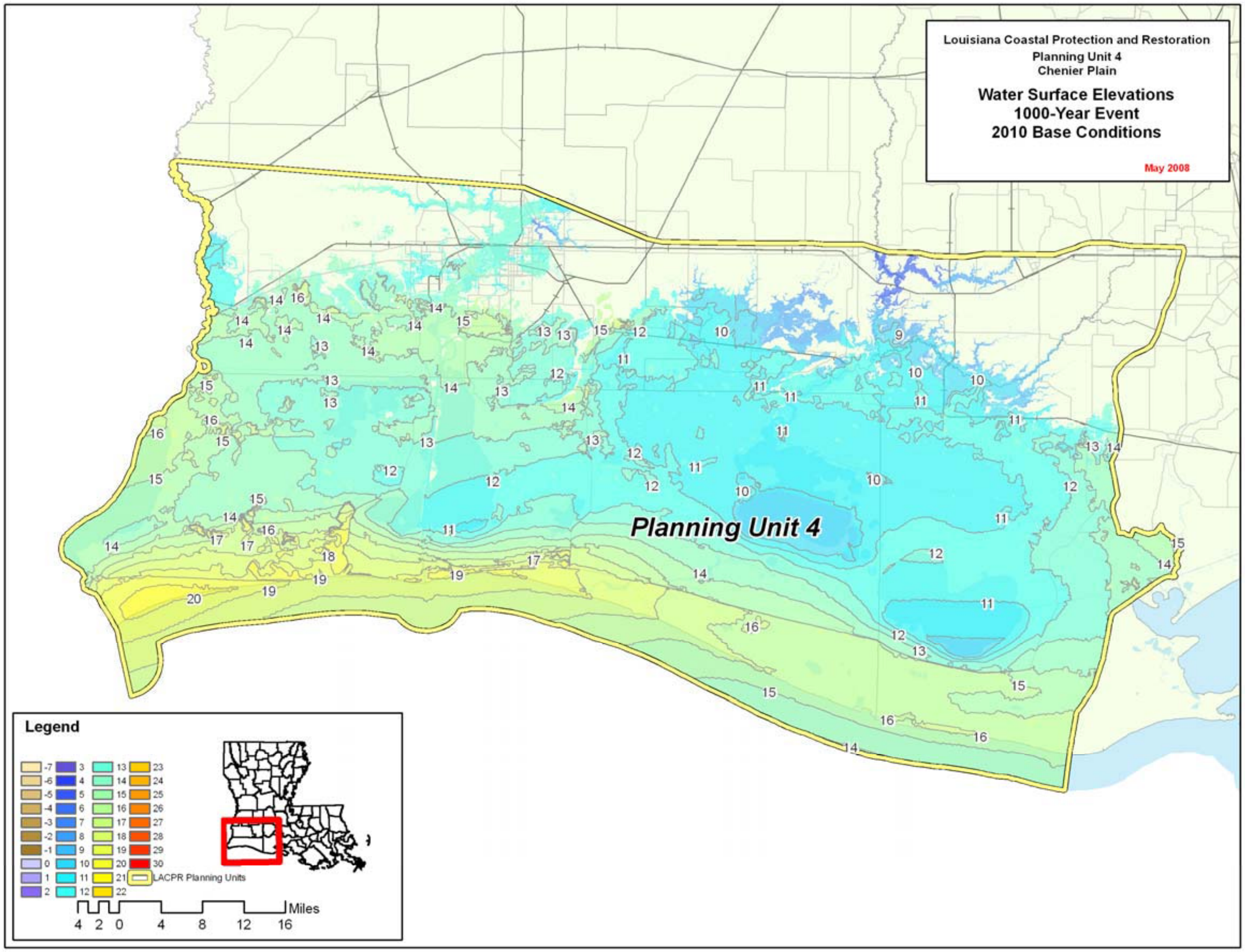


Figure 7-18. Statistical water surface for the 1000-year event in Planning Unit 4.

Critical Landscape Features

Review of the LACPR ADCIRC storm surge modeling output for the 100-year, 400-year, and 1000-year base conditions allows the identification of landscape components that tend to produce significant effect on surge. These landscape features currently exist independent of any proposed alternative action. While some of these features may be incorporated into alternative risk reduction plans, the fact that they are already existing contributors to systemic risk reduction demonstrates that there are landscape benefits being derived even with no action. This also indicates that maintenance of these features, independent of any proposed alternative plan, would be beneficial to a system of comprehensive risk reduction.

The observable effects of the features identified in **Figure 7-19** are generally either a relatively rapid decrease in, or a pronounced “stacking” preceding a decrease in, the forecast surge elevation. It appears reasonable to suggest that these marked changes in surge elevation, and the landscape components associated with them, represent a beneficial restriction to the movement of water toward areas further inland. These landscape effects are based on modeling multiple storm tracks and intensities and represent statistical water surfaces. The actual performance of landscape features varies widely when considering the impacts of individual storm tracks and intensities.

In many cases, the identified landscape features are intrinsically integrated into all proposed alternative structural protection alignments by virtue of being part of the existing conditions applied in the model grid. It is important to therefore identify these features and consider the relationship of potential actions on or near them. These landscape features would merit priority or focus for restoration based on their identifiable contribution to risk reduction wherever they have been incorporated into an alternative plan, or for maintenance wherever they represent elements of existing publicly-supported projects. The features identified through this review range from critical wetland segments to natural ridges to manmade embankments. The features identified generally demonstrated performance in altering storm surge across all of the mapped surge conditions (100-year, 400-year, and 1000-year).

Planning Unit 1

In Planning Unit 1, critical landscape features include the Maurepas land bridge/Highway 51, the Pontchartrain land bridge/Highway 90, and the Biloxi marshes. Decreases in surge elevation are forecast to occur across each of the major land bridges in the Pontchartrain basin for every surge condition. The Pontchartrain land bridge is also the location of a potential structural risk reduction alignment. The Biloxi marshes are observed to alter the surge pattern such that elevations are reduced around the southeastern most point of the St. Bernard hurricane risk reduction system. However, due to extreme amplification of surge elevation in the Golden Triangle and Caernarvon areas, which flank this point, the value of the effect from these marshes is limited.

Planning Unit 2

In Planning Unit 2, the observed critical features include Highway 90 and the band of wetlands immediately south of the GIWW. There is a significant reduction in surge elevation to the north of this highway embankment for all conditions. For the marshes south of the GIWW, the effect appears to be limiting of surge stacking along the Mississippi and Lafourche ridges although the progression of surge elevation through the center of the basin appears unaltered. There is a noticeable diminishing of the stacking effect north of the GIWW.

Planning Unit 3a

In Planning Unit 3a, critical landscape features include Highway 90, Highways 24 and 182, the Bayou Terrebonne ridge/Highway 56, and lower Highway 1. The effect of Highway 90 is pronounced in reducing surge but is limited to the extreme western portion of this planning unit where stacking appears to occur against the north bank of the GIWW. Highway 24 from the Lafourche ridge into Houma and Highway 182 west from that point appear to effect a rapid reduction in surge elevations although continued reduction beyond these embankments is mild. The Bayou Terrebonne ridge and Highway 56, due to their southeastern facing exposure tend to create stacking of surge that is then flattened to west beyond it. Highway 1 south of the Larose to Golden Meadow ring levee also creates mild stacking of surge to the east. The result is a measureable drop in surge elevation immediately to the west. However, most of this area is the undeveloped open water of Timbalier Bay. It is possible that Port Fourchon may benefit from the influence of Highway 1 and Highway 3090 entering the port.

Planning Unit 3b

In Planning Unit 3b, the critical landscape features consist of wetlands of Point Au Fer island and the Penchant Basin, wetlands east and west of Wax Lake Outlet, Cypremont Point, and the wetlands between the GIWW and the western extent of Vermilion Bay. The combined wetland areas of Point Au Fer Island and the Penchant basin create a significant reduction of surge elevation in the area around the mouth of the Atchafalaya River and upstream. The three wetland areas from the mouth of the Wax Lake Outlet to Cypremort Point to the western extent of Vermilion Bay inland to the GIWW create a zone of surge stacking that allows a continuous mild decrease of the surge further inland toward the developed communities.

Planning Unit 4

In Planning Unit 4, the critical landscape features include the entire barrier-shoreline, Grand Chenier, and the wetland area between Freshwater Bayou and Highway 82. In this planning unit, the modeling indicates consistent stacking of surge at the coast with significant reduction of surge elevation inland from that point. Grand Chenier contributes to this effect along the entire eastern portion of the planning unit. The wetland area between Freshwater Bayou and Highway 82 at the eastern end of the planning unit provides a similar effect and results in significant reduction of surge elevation in the interior of the basin.

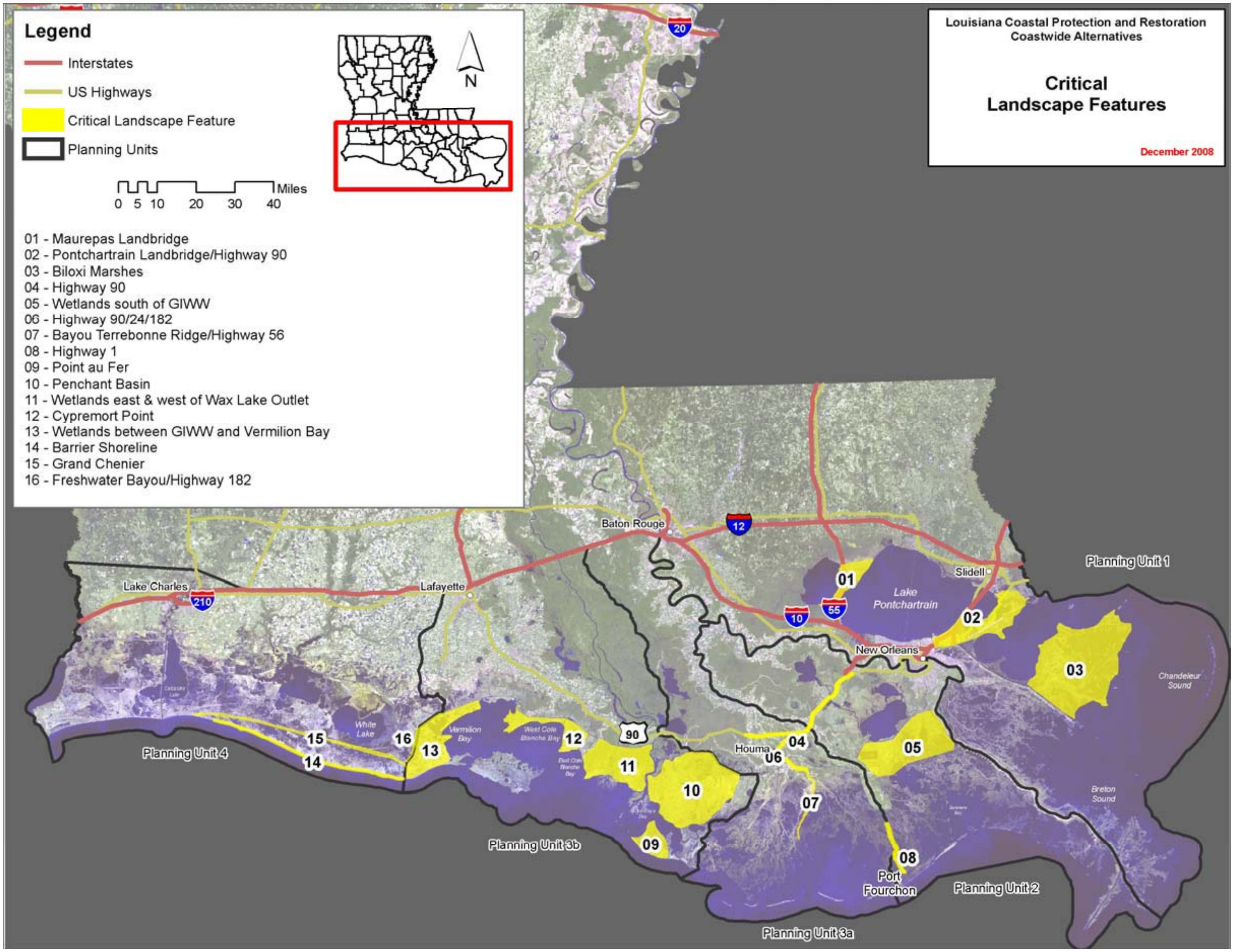


Figure 7-19. Critical landscape features.

Navigation Projects

One of the primary missions of the USACE New Orleans District is to provide navigation in South Louisiana that benefits the Nation. As part of that mission, the New Orleans District currently maintains the waterways shown in **Figure 7-20**, except for the Mississippi River Gulf Outlet, which was de-authorized in June 2008.

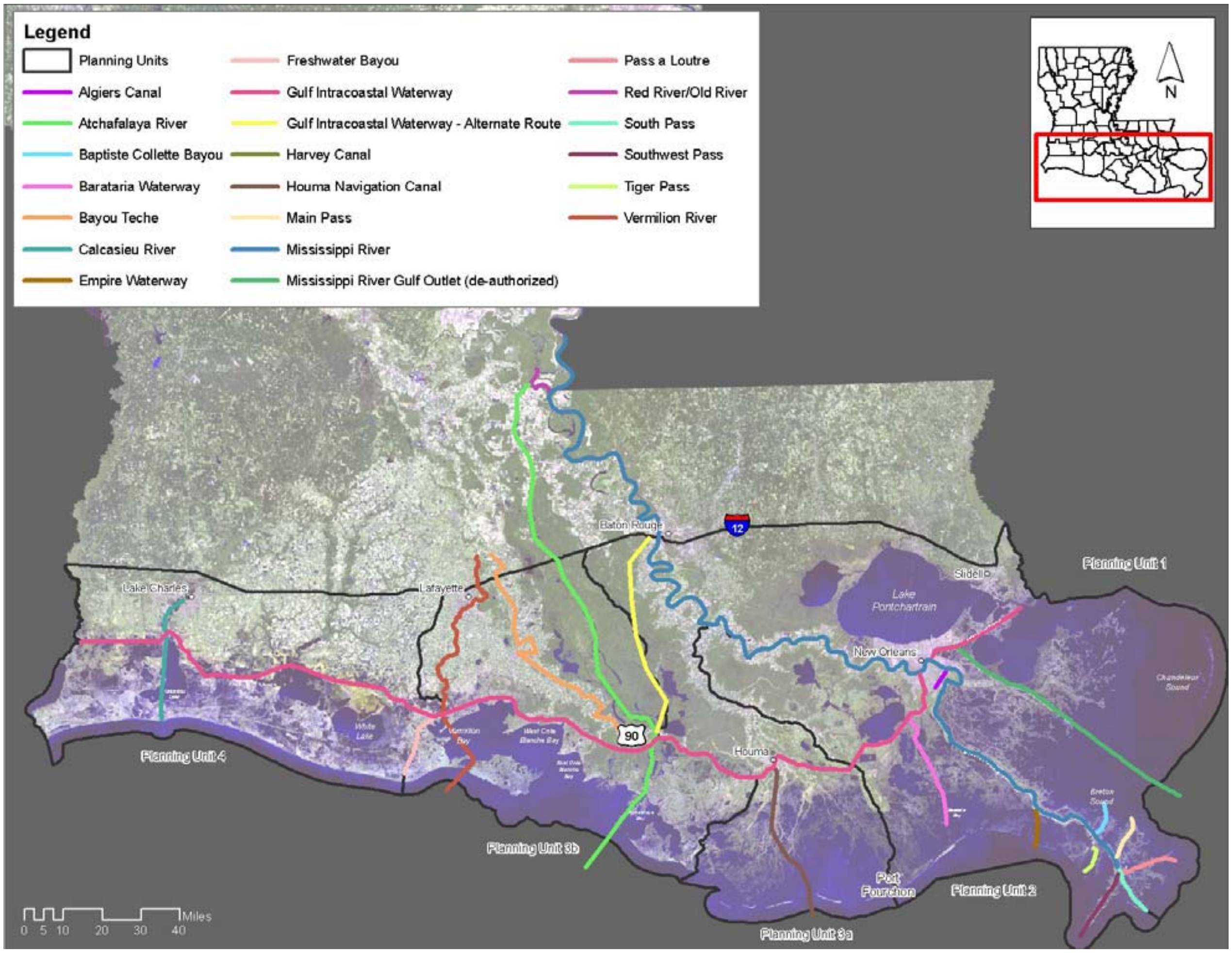


Figure 7-20. Navigation routes in South Louisiana.

Section 8. Coastal Restoration Measures and Alternatives

Coastal features are the first line of defense against hurricane surge and waves. Preliminary model analyses of storm surge levels and wave magnitudes demonstrate the potential value of coastal features to lowering storm damage risks. The role of coastal features in reducing hurricane storm-surge effects depends on a variety of factors, including the physical characteristics of the storm, coastal geomorphic setting, and the track of a storm when it makes landfall. While the models show benefits from additional marsh, island, and landbridge habitat in some areas, the effects of allowing existing features to degrade in these areas are even more pronounced. Thus, sustaining the integrity of the estuarine environments in coastal Louisiana is a key component of a comprehensive storm risk reduction strategy for the region. A range of features can be used to maintain or restore natural deltaic processes and hydrology in coastal Louisiana, including diversions of the Mississippi River, marsh creation, and maintenance or restoration of ridges, cheniers (oak ridges), and barrier islands.

Ecosystem Restoration Planning

Ecosystem restoration planning by the USACE dates back to the 1960s with surveys of coastal processes and problems for purposes of water resources development. Efforts now focus on the integration and implementation of plans for coastal restoration as identified in the 1998 Coast 2050 Plan and further defined in the 2004 Louisiana Coastal Area (LCA) Plan. Other restoration programs and plans such as the Coastal Wetlands Planning, Protection and Restoration Act (Breaux Act), the Coastal Impact Assistance Program (CIAP), the State of Louisiana's Master Plan for Coastal Protection and Restoration, must work in unison towards the common goal of promoting a sustainable coastal Louisiana ecosystem.

Louisiana Coastal Area Ecosystem Restoration Study

In 2000, the USACE and State of Louisiana initiated the Louisiana Coastal Area (LCA) Ecosystem Restoration Study to address Louisiana's severe coastal land loss problem. The goal of LCA is to achieve and sustain a coastal ecosystem that can support and protect the environment, economy, and culture of coastal Louisiana and thus, contribute to the economy and well-being of the Nation.

The Water Resources Development Act (WRDA) of 2007 authorized the LCA near-term plan, including the following five near-term critical restoration projects for construction contingent on the final construction reports: the Mississippi River Gulf Outlet (MRGO) environmental restoration, a small river diversion at Hope Canal, Barataria Barrier shoreline restoration, a small Bayou Lafourche river reintroduction, and a medium river diversion at Myrtle Grove with dedicated dredging. An additional 10 near-term critical restoration projects were authorized contingent upon feasibility and Chief of Engineers reports. Programmatic authorization also included a Science and Technology Program and associated demonstration projects, beneficial use of dredged material, and studies to modify existing water control structures.

The LCA near-term plan and other authorizations are an integral, complementary part of LACPR. In addition, WRDA 2007 Section 7002 directed the development of a long-term comprehensive plan "for protecting, preserving, and restoring the coastal Louisiana ecosystem." The comprehensive plan must be integrated with the LACPR hurricane risk reduction analysis and design and consistent with the State Master Plan.

River Diversions

Diversion of Mississippi River freshwater, nutrients, and sediment is essential for the restoration of natural deltaic processes that sustain coastal wetlands. Therefore, projects to divert freshwater and sediments from the Mississippi River into adjacent estuaries are integral components of coastal protection and restoration plans. Currently, over 20 diversions are either being studied or constructed along the Mississippi River. These projects and studies, all developed through various authorizations, require strategic coordination with other Mississippi River management efforts to ensure success in construction and operation. The USACE is working to implement a near-term plan for diversions as well as a comprehensive plan that will include significant scientific developments to better understand the hydrodynamics of the system and the potential long-term configuration of the river delta system.

Coastal Restoration Plan Formulation

As part of the overall LACPR team, a Habitat Evaluation Team, consisting of USACE, State of Louisiana, and various Federal resource agency members, developed a suite of coastal restoration alternatives. The Habitat Evaluation Team evaluated multiple restoration alternatives in addition to the future without project condition to achieve coastal restoration goals. The coastal restoration goal for LACPR could be summarized as *"achieve ecosystem sustainability in coastal Louisiana to the greatest degree possible."* To accomplish this goal, the Habitat Evaluation Team considered and/or evaluated:

- Coastal restoration strategies that contribute to sustainable hurricane risk reduction;
- Individual measures of varying sizes to restore and maintain landscape features and essential wetland maintenance processes;
- Combinations of individual measures which provide ecosystem-level synergistic benefits;
- Alternative plans that maintain or enhance the extent of coastal wetlands;
- The potential for trade-offs associated with various restoration alternatives (e.g. near-term protection vs. long-term sustainability and fisheries changes vs. deltaic processes).

The process used to develop the coastal restoration alternatives involved the following steps: inventorying measures from the State Master Plan and other sources; screening individual measures; formulating alternatives; evaluating performance of those alternatives; selecting the best performing alternatives for further evaluation; and finally, selecting a representative coastal restoration alternative for combination with the structural and nonstructural measures.

Inventorying and Screening Measures

The Habitat Evaluation Team started by assembling the set of measures identified during the development of the State Master Plan. Since sediment availability was a concern, the Habitat Evaluation Team subdivided many of the marsh polygons from the State Master Plan into smaller units that could be separately prioritized. The Habitat Evaluation Team also added some marsh creation areas or erosion reducing measures that were not included in the State Master Plan. These features were prioritized according to the degree of basin-level benefits they would provide. Factors considered for prioritization included (in no particular order):

- Potential for flood and infrastructure protection
- Distance to sediment sources, both riverine and offshore
- Availability of freshwater
- Existing structures to aid in sediment confinement during construction
- Average depth of open water areas
- Land/water distribution
- Need for shoreline protection
- Preferred sediment grain size for restoration
- Processes responsible for wetland loss
- Measure of local subsidence
- Potential fisheries impacts
- Proximity of pipeline right-of-ways and access for construction
- Overlap with LCA/CWPPRA projects

Ultimately, screening was based primarily on the contribution of measures to sustaining the coast. Those marsh creation measures assigned the lowest priority were excluded from further analysis. High-priority measures that would restore and/or maintain critically important landscape features or marsh areas were combined into alternatives.

Formulation of Coastal Alternatives

Five alternatives were developed or identified for further analysis as briefly described below. Each alternative focuses on the use of measures that contribute to estuarine maintenance at a basin scale, namely freshwater diversions, marsh creation using dredged material, ridge/chenier restoration, and barrier island restoration. The specific similarities and differences between the combinations of measures in each alternative, however, can best be understood by examining the list of measures and maps for each alternative by planning unit included in the *Coastal Restoration Plan and Structural Impacts Appendix*.

The Habitat Evaluation Team developed two alternatives (R1 and R2) with the specific aim of sustaining the wetland area over a 100-year timeframe. Both alternatives achieve this aim through the restoration of coastal features (barrier islands, ridges, land bridges and marsh) in combination with Mississippi River diversions in Planning Units 1, 2, and 3a. One major difference between the alternatives is in the design and operation of the diversion structures. Alternative R1 incorporates the use of small to medium diversions operated on a relatively consistent basis, whereas Alternative R2 uses medium to large diversions with the capability for periodic (every four or five years) large pulsed flows. In Planning Unit 3a, Alternative R2 includes an additional diversion that involves the management and re-distribution of seasonally available Atchafalaya River fresh water from various points along the GIWW. Another major difference between the two alternatives is the use of shoreline protection measures. In Planning Units 3b and 4, Alternative R1 includes shoreline protection to reduce shoreline erosion. In contrast, Alternative R2 does not employ shoreline protection which significantly impacts the aim of reaching sustainability. Both alternatives employ heavy use of dedicated dredging to restore or sustain marsh.

In addition to alternatives R1 and R2 which were specifically developed with the LACPR objectives in mind, the Habitat Evaluation Team also evaluated two other alternatives that were previously developed external to LACPR—the State Master Plan (R3) and the Louisiana Coastal Area Plan (R5)—to compare their performance to R1 and R2 in terms of long-term sustainability. The Habitat Evaluation Team also developed Alternative R4 as a variation on the State Master Plan alternative.

The five coastal restoration alternatives are summarized below:

- ***R1 - Steady State Diversions/Shoreline Protection*** - In Planning Units 1, 2, and 3a, Alternative R1 relies primarily on Mississippi River diversions. In PUs 1 and 2, the diversions are steady state; in PU3a, the alternative includes diversions that could be either steady state or pulsed. In Planning Units 3b and 4, Alternative R1 includes bankline stabilization combined with dedicated marsh creation.

- ***R2 - Pulsed Diversions/Without Shoreline Protection*** - In Planning Units 1 and 2, Alternative R2 relies primarily on Mississippi River diversions that are pulsed. In Planning Unit 3a, Alternative R2 relies primarily on diversions or water management off of the Gulf Intracoastal Waterway. In Planning Units 3b and 4, Alternative R2 includes dedicated marsh creation without bankline stabilization.

- ***R3 - State Master Plan*** - Alternative R3 is a set of measures representing the coastal restoration plan presented in the final State Master Plan.

- ***R4 - Variation on the State Master Plan*** - Alternative R4 was created from other coastal restoration measures not identified in the State Master Plan or modified from the State Master Plan.

- ***R5 - Louisiana Coastal Area Study Plan*** - Alternative R5 is the "Plan that Best Meets the Objectives" from the 2004 Louisiana Coastal Area (LCA) study. Of all the plans developed for the LCA study, this combination of measures (diversions, marsh creation, shoreline protection, etc.) was found to best meet the LCA planning objectives as well as critical needs criteria defined by the LCA study; however, unlike LACPR, the primary objectives for the LCA study were ecological, not hurricane risk reduction.

Evaluation and Screening of Alternatives

Each of the five coastal restoration alternatives was subjected to a performance analysis over a period of 100 years. The value generated was not a habitat value, but rather a simple gross maximum acreage of wetlands created and/or protected for each alternative for each planning unit over 100 years. From the analysis, the acreages calculated at various points in time were used to develop performance trends for each alternative. Those plans that resulted in negative acreages (based on the continuation of existing sea level rise rates), indicating an inability to achieve coastal restoration goals, were dropped from further consideration.

Figure 8-1 is an example performance graph for Planning Unit 1. The worst performer is the future without project (FWOP). The dashed lines indicate performance trends based on a higher level of relative sea level rise (SLR) than existing rates. Additional graphs for other planning units are located in the *Coastal Restoration Plan and Structural Environmental Impacts Appendix*.

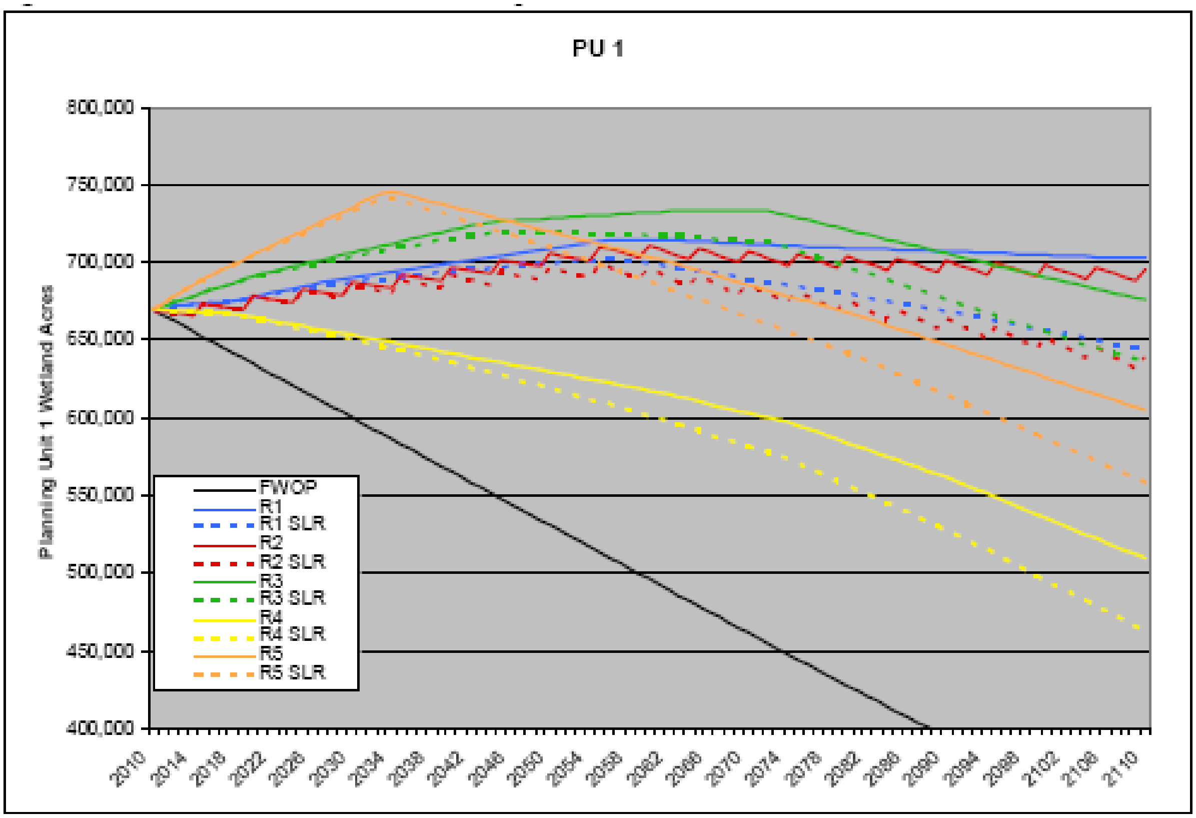


Figure 8-1. Predicted Planning Unit 1 wetland restoration plan results.

After predicting the performance results in each planning unit, the alternatives found to meet restoration goals included R1, R2, and R3 in Planning Units 1 and 2; R1 was the only alternative found to meet restoration goals in Planning Units 3a, 3b, and 4.

Representative Coastal Restoration Alternatives

Since the three remaining alternatives in Planning Units 1 and 2 showed similar performance, one was chosen in each planning unit as a representative landscape in order to reduce the number of possible combinations of coastal restoration, structural, and nonstructural measures. R2 was chosen as the representative landscape in Planning Units 1 and 2 because it contains pulsed diversions that may be more acceptable than continuously operated diversions. **Figures 8-2** through **8-6** are map depictions of measures contained within the representative landscapes: Alternative R2 in Planning Units 1 and 2 and Alternative R1 in Planning Units 3a, 3b, and 4. Lists of measures in each planning unit follow the set of maps.

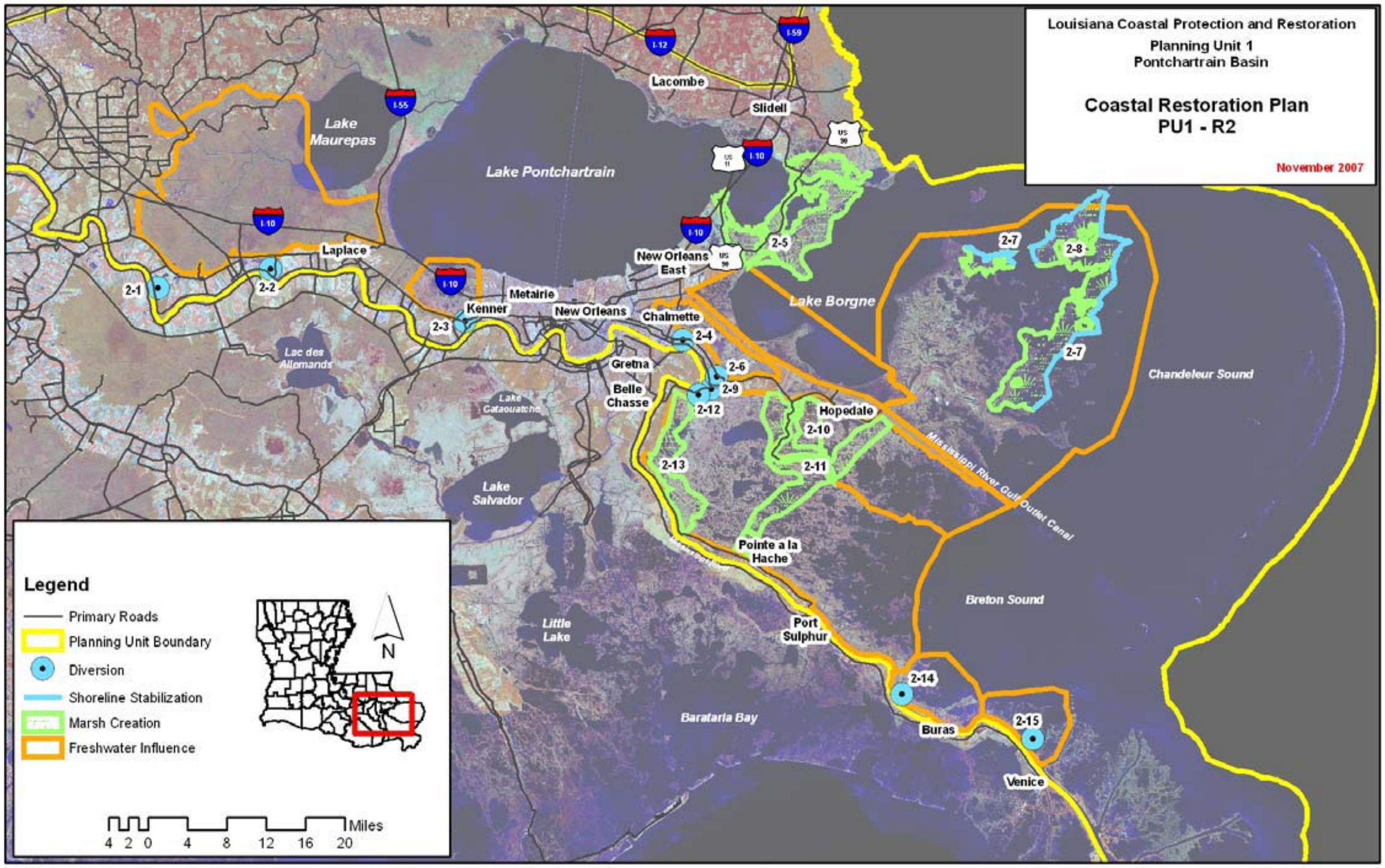


Figure 8-2. Representative coastal restoration plan in Planning Unit 1.

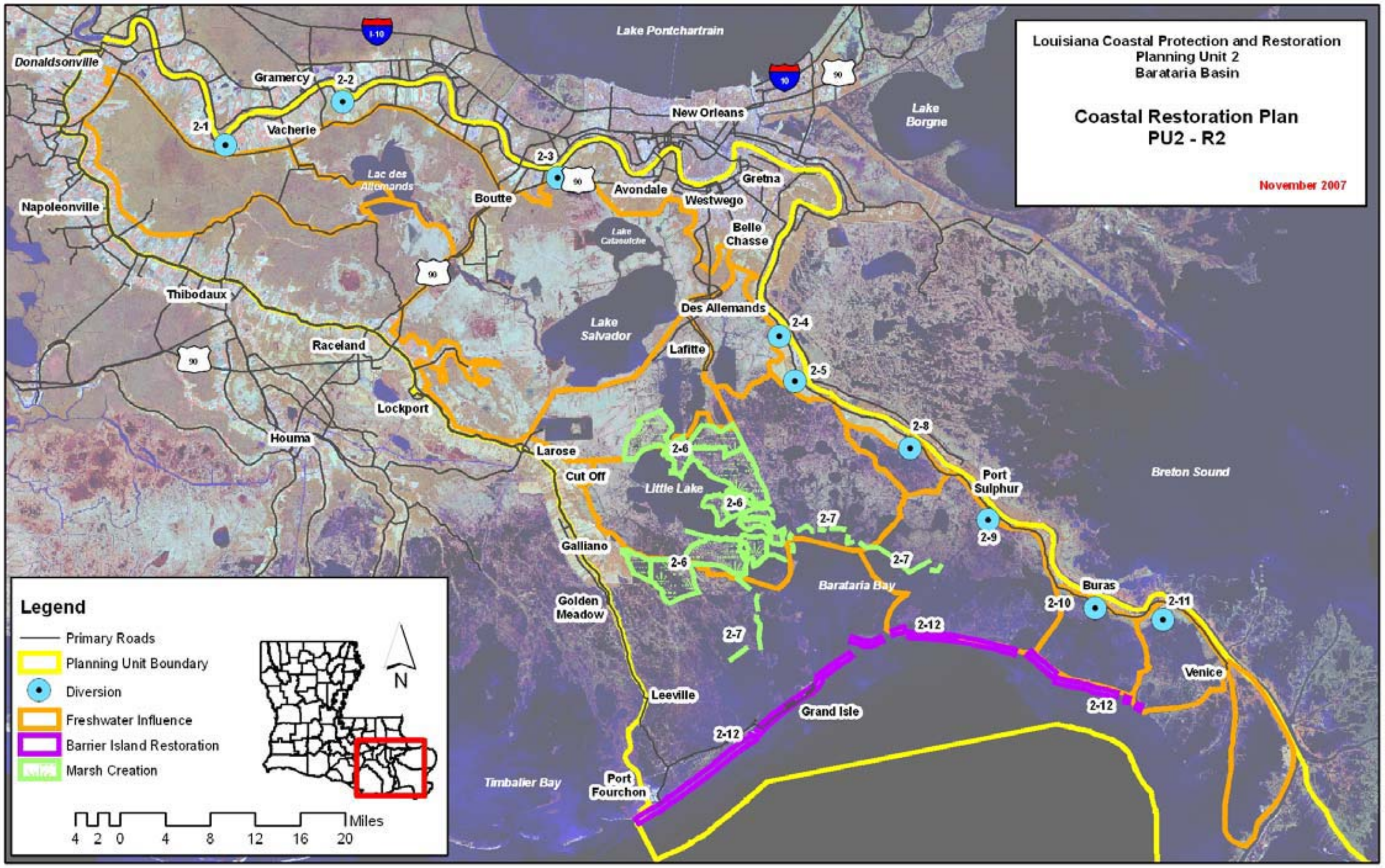


Figure 8-3. Representative coastal restoration plan in Planning Unit 2.

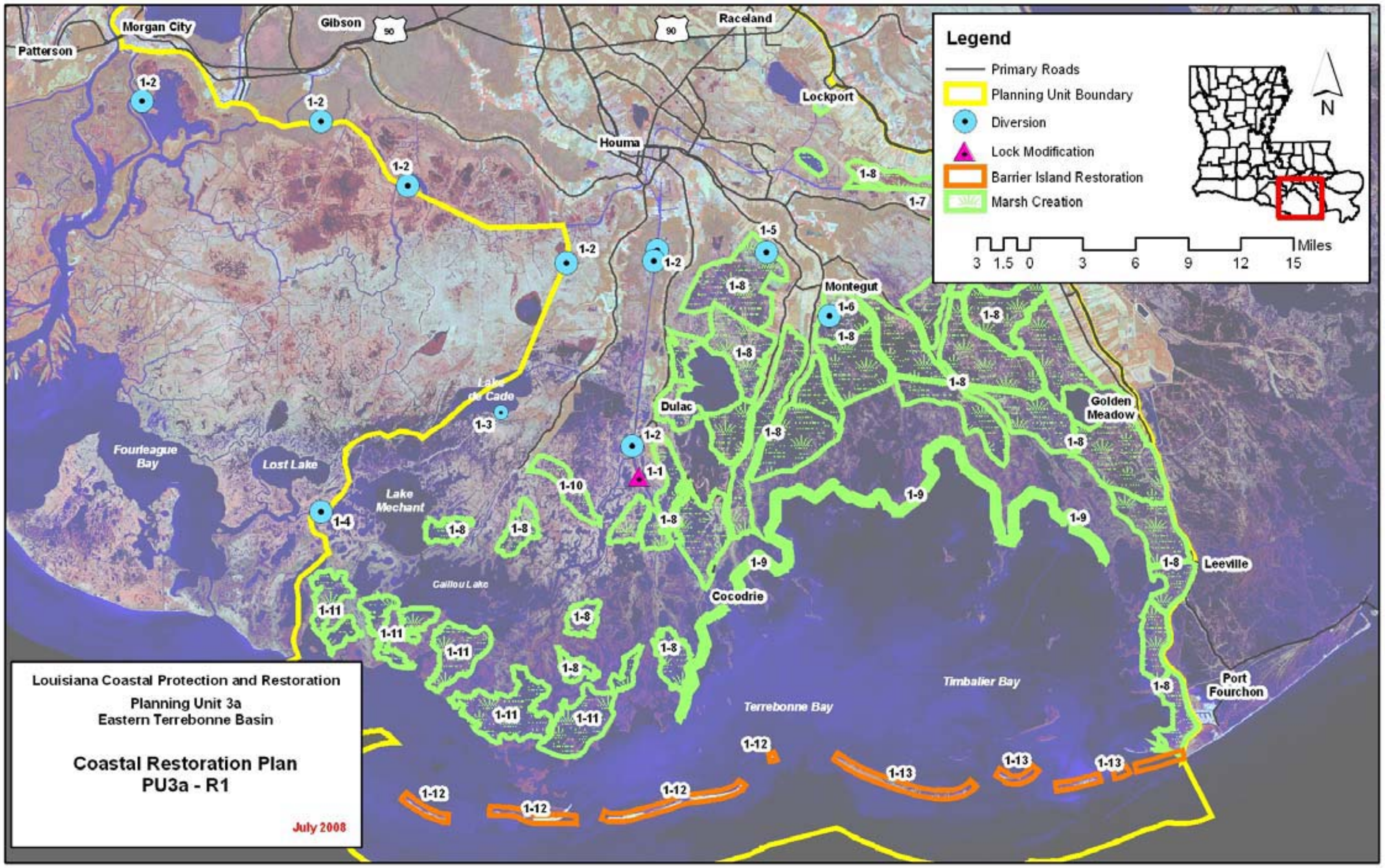


Figure 8-4. Representative coastal restoration plan in Planning Unit 3a.

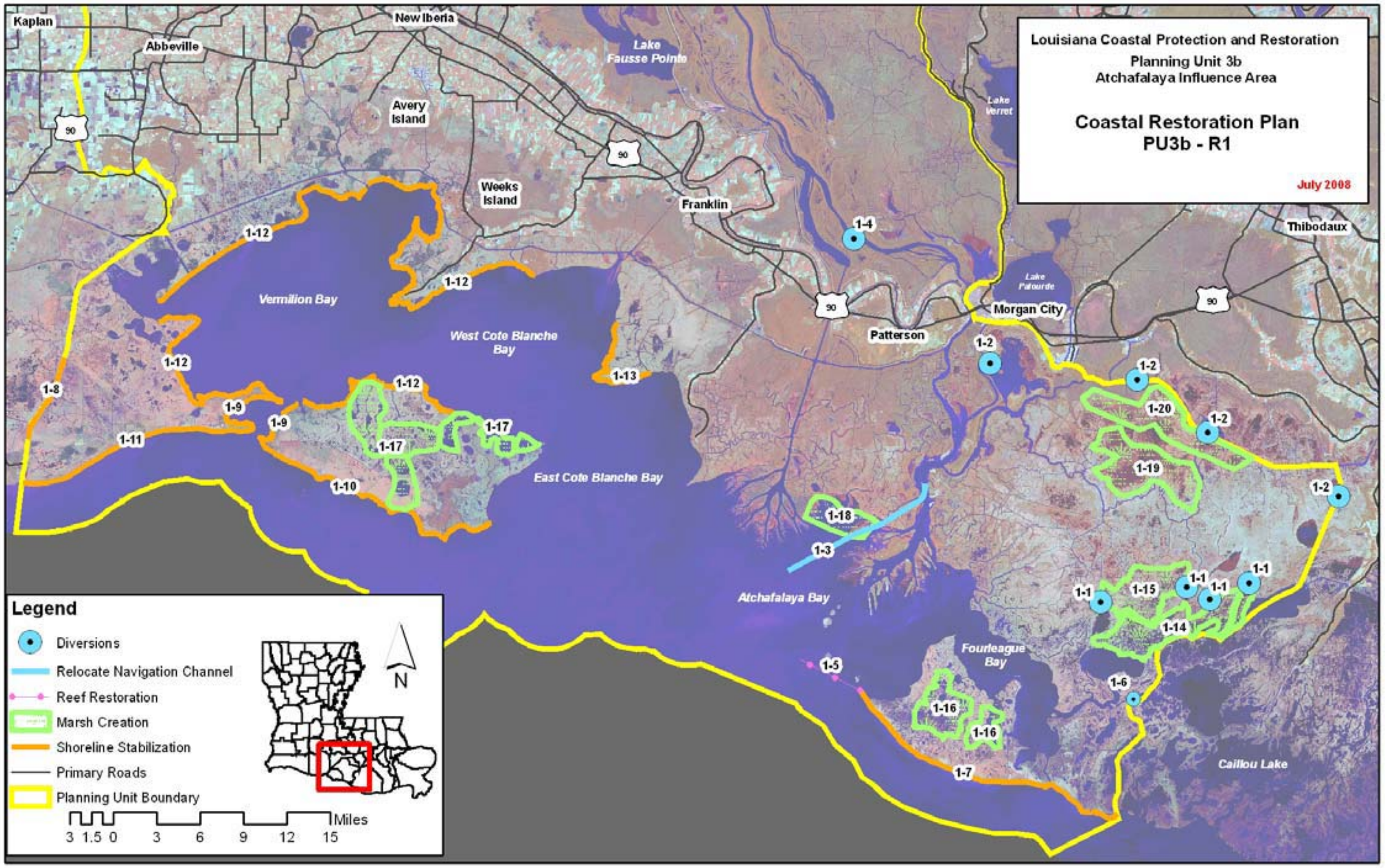


Figure 8-5. Representative coastal restoration plan in Planning Unit 3b.

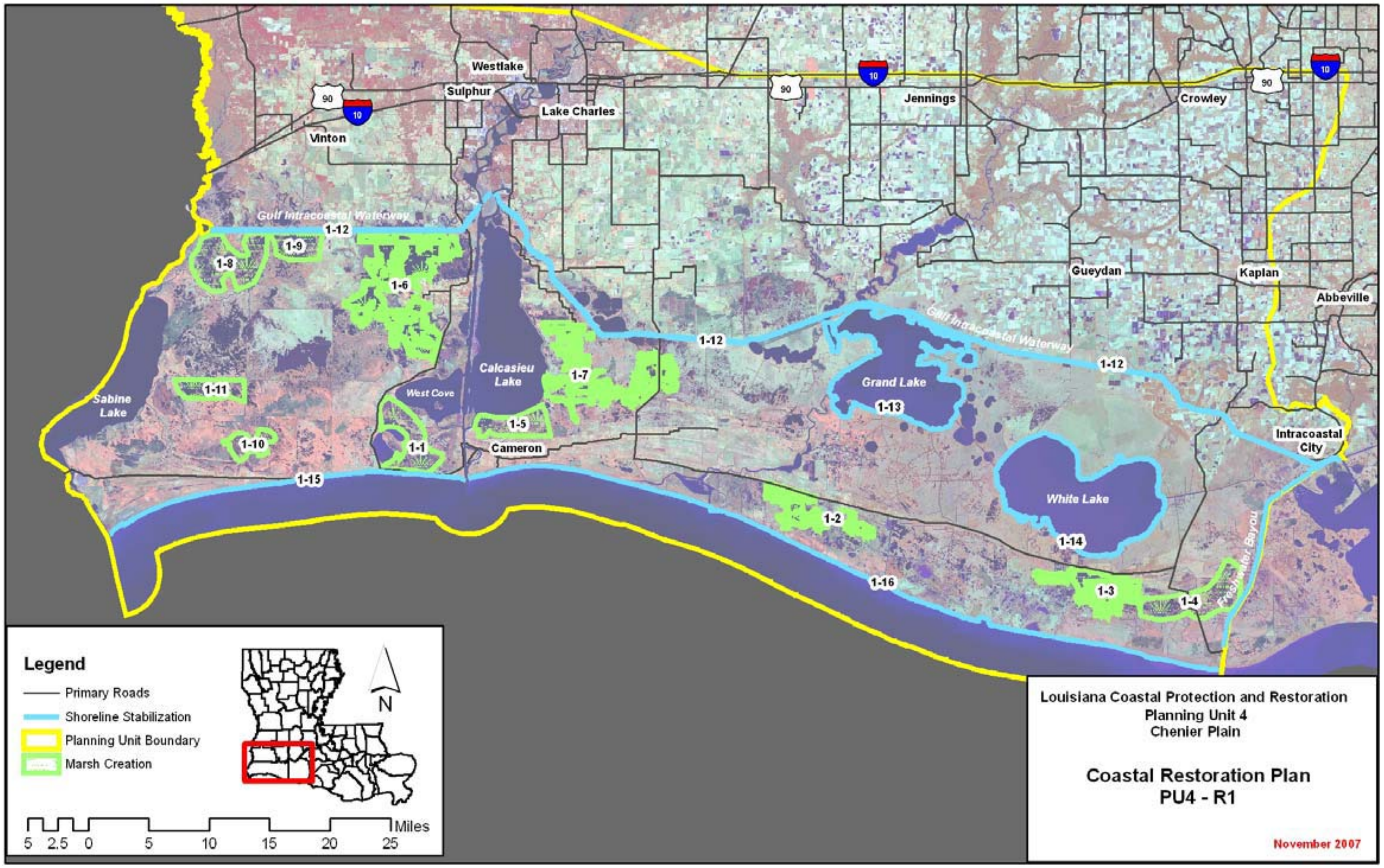


Figure 8-6. Representative coastal restoration plan in Planning Unit 4.

Planning Unit 1 Alternative R2 – Pulsed Diversion (one heavy flow year out of 5)

- 2-1 Blind River Diversion - flows for sustaining entire south Maurepas swamp split between Blind River and Hope Canal
- 2-2 Hope Canal Diversion - flows for sustaining entire south Maurepas swamp split between Blind River and Hope Canal
- 2-3 LaBranche Diversion – diversion directly into LaBranche wetlands to sustain those wetlands
- 2-4 Bayou Bienvenu Diversion – to reduce East New Orleans landbridge loss rates by 50%
- 2-5 East New Orleans land bridge Marsh Creation – 7,996 acres @ 900 acres/year
- 2-6 Bayou LaLoutre Diversion – (In lieu of Violet) sized to sustain the Biloxi Marshes
- 2-7 Biloxi Marshes Shore Protection – 254,500 linear feet of protection around outer perimeter
- 2-8 Biloxi Marshes Marsh Creation – 33,553 acres of marsh creation with armored containment dikes where not already provided by Biloxi Marshes Shore Protection measure
- 2-9 Bayou Terre aux Boeufs Diversion - flows to sustain marshes between MRGO and Bayou Terre aux Boeufs
- 2-10 Bayou Terre aux Boeufs Marsh Creation – 2,591 acres in upper basin
- 2-11 Breton Sound Strategic Land Bridge – a band of marsh from MRGO to Miss. River (14,579 acres) plus marsh creation along either side of Bayou LaLoutre
- 2-12 Caernarvon Diversion – sized to sustain all marshes between Bayou Terre aux Boeufs and the Miss. River
- 2-13 Caernarvon Area Marsh Creation – Marsh creation along protection levee from Big Mar south to Phoenix (4,936 acres)
- 2-14 Bayou Lamoque Diversion – to sustain receiving area marshes
- 2-15 Grand Bay Diversion – sized to sustain receiving area marshes

Planning Unit 2 Alternative R2 – Pulsed Diversion (one heavy flow year out of 5)

- 2-1 Lagan Diversion – sized to sustain a portion of upper basin swamps
- 2-2 Edgard Diversion - sized to sustain remaining Lac des Allemands portion of upper basin wetlands
- 2-3 Davis Pond Freshwater Diversion reauthorization - run full discharge one year out of 5 years
- 2-4 Naomi Diversion – sized to sustain receiving area
- 2-5 Myrtle Grove Diversion – sized to sustain receiving area
- 2-6 Strategic Marsh Creation in lower basin – 22,573 acres @ 900 ac per year
- 2-7 North Bay Rim Marsh Creation/Protection – 3538 acres along northern border of Barataria Bay @ 900 acres per year
- 2-8 West Point a la Hache Diversion – sized to sustain receiving area
- 2-9 Port Sulphur Diversion – sized to sustain receiving area
- 2-10 Buras Diversion – sized to sustain receiving area
- 2-11 Fort Jackson Diversion – sized to sustain receiving area
- 2-12 Barrier Islands Restoration – 15,029 acres @ 900 acres per year

Planning Unit 3a Alternative R1 – Mississippi River Diversions

- 1-1 HNC Lock Multi-purpose Operation
- 1-2 Convey Atchafalaya River water via GIWW
- 1-3 Lapeyrouse Canal diversion
- 1-4 Blue Hammock diversion
- 1-5 Upper Lake Boudreaux Basin Mississippi River Diversion
- 1-6 East Terrebonne Mississippi River Diversion
- 1-7 Grand Bayou and Jean LaCroix Basins Mississippi River Diversions
- 1-8 Pipeline Conveyance Marsh Creation (92,174 acres)
- 1-9 North Terrebonne Bay Rim Marsh Creation (3,158 acres)
- 1-10 DuLarge to Grand Caillou Landbridge Marsh Creation (1,170 acres)
- 1-11 South Caillou Lake Landbridge Marsh Creation (19,964 acres)
- 1-12 Isles Dernieres Restoration
- 1-13 Timbalier Islands Restoration

PU3b Alternative R1 – Marsh Creation with Shoreline Protection

- 1-1 Penchant Basin Plan
- 1-2 Convey Atchafalaya River water via GIWW
- 1-3 Relocate the Navigation Channel through Lower Atchafalaya River Delta
- 1-4 Increase Sediment Transport down the Wax Lake Outlet
- 1-5 Barrier Reef from Eugene Island to Pointe au Fer Island
- 1-6 Blue Hammock Bayou Freshwater Introduction (benefits in PU3a)
- 1-7 Gulfshore Protection at Pointe au Fer Island
- 1-8 Freshwater Bayou Bank Protection, Belle Isle to Lock
- 1-9 Southwest Pass Bank Protection
- 1-10 Marsh Island Shoreline Protection
- 1-11 Gulfshore Protection from Freshwater Bayou to Southwest Pass
- 1-12 Shoreline Protection at Vermilion Bay and West Cote Blanche Bay
- 1-13 East Cote Blanche Bay Shore Protection
- 1-14 Bayou Decade Area Marsh Creation (5,870 acres)
- 1-15 Brady Canal Area Marsh Creation (2,731 acres)
- 1-16 Pointe au Fer Island Marsh Creation (1,462 acres)
- 1-17 Marsh Island Marsh Creation (7,883 acres)
- 1-18 Wax Lake Outlet Delta Marsh Creation (4,736 acres)
- 1-19 Bayou Penchant Area Marsh Creation (6,554 acres)
- 1-20 Terrebonne GIWW Area Marsh Creation (3,977 acres)

Planning Unit 4 Alternative R1 – Marsh Creation with Shoreline Protection

- 1-1 Marsh Creation at Mud Lake (5,669 acres)
- 1-2 Marsh Creation at South Grand Chenier (8,575 acres)
- 1-3 Marsh Creation at South Pecan Island (9,851 acres)
- 1-4 Marsh Creation at East Pecan Island (7,184 acres)
- 1-5 Marsh Creation at No-Name Bayou (2,151 acres)
- 1-6 Marsh Creation at NW Calcasieu Lake (23,187 acres)
- 1-7 Marsh Creation at East Calcasieu Lake (14,141 acres)
- 1-8 Marsh Creation at Black Bayou (4,769 acres)
- 1-9 Marsh Creation at Gum Cove (3,261 aces)
- 1-10 Marsh Creation at Cameron Meadows (1,293 acres)
- 1-11 Marsh Creation at Central Canal (120 acres)
- 1-12 GIWW bank stabilization
- 1-13 Grand Lake bank stabilization
- 1-14 White Lake bank stabilization
- 1-15 Gulf Shoreline Stabilization (Sabine River to Calcasieu River)
- 1-16 Gulf Shoreline Stabilization (Calcasieu River to Freshwater Bayou)

Additional Refinement and Tradeoff Analyses of Restoration Plans

Although representative comprehensive coastal restoration plans have been identified for this technical report, decisions on the precise type, location, and size of individual measures requires additional analysis and refinement of those plans. Each of the alternatives was developed to emphasize a particular strategy for attaining a "sustainable" coastal system and not a specific, well defined plan for authorization and implementation.

A major issue remaining to be fully explored is the tradeoff concerning freshwater diversion size and operability. Diversions would be sized to sustain a particular influence area. Achieving sustainability, particularly in Planning Units 1, 2, and 3a, will require the use of strategically located and operated freshwater diversions that are generally larger than those that have been previously proposed. Large diversions are generally classified as those with a discharge capacity greater than 15,000 cfs. In Planning Units 1 and 2, there are 19 diversions being considered at various locations with design capacities at high flow that range from 2,200 cfs to over 175,000 cfs and 15 of those diversions are over 15,000 cfs.

Larger structures provide not only an increased area of influence but also more flexibility for future operational changes, such as periodic pulsed flows. While the use of freshwater diversions from the Mississippi River as a method of coastal restoration has great potential, technical issues persist as to how well the diversions would perform and how they would be operated. Seasonal, "steady state" diversions would be operated on a relatively consistent basis. Depending on their size, steady flow diversions could have a long term adverse impact by over-freshening of brackish to saline habitats and the permanent displacement of associated fisheries and wildlife. Seasonal “pulsed” flow diversions would have the capability to be operated with periodic unrestricted flows (once every four or five years), followed by four or five consecutive low-discharge years. This type of diversion operation would require diversion structures to be overbuilt and might cause impacts similar to the steady flow diversions; however, the impacts of pulsed flow diversions are assumed to be short term.

Another significant tradeoff component is resource allocation of freshwater between Planning Units 1, 2, and 3a. For most alternatives, the issue of freshwater allocation for diversions can impose operational difficulties or opportunities and induced shoaling maintenance within the navigation channel of the Mississippi River. The “pulsed” alternative provides the most built flexibility regarding optimal operation through adaptive management opportunities.

Restoration must keep up with loss since all plans rely on sustaining the existing landscape but does not need to occur all at once. Implementation of any of the complete restoration alternatives will require several decades, which allows for implementation to advance in an adaptive fashion and permits the formulation and testing of hypotheses regarding the effectiveness of various restoration measures and strategies. Given this adaptive approach, any of the alternatives could serve as a starting point for restoration and would be expected to evolve over time as a consequence of improved understanding of the effectiveness of the various measures.

Section 9. Structural Measures and Alternatives

Structural measures include raising existing levees and/or building new levees, floodwalls, pumps, gates, and weirs. Levees protect limited portions of the coast that have intense economic development. These measures are intended to significantly reduce risk from the surge and waves associated with a hurricane. Pumping stations reduce flood risk from rainfall, but historically cannot pump out floodwater in the case of a levee breach or significant overtopping. Floodgates crossing water courses and tidal passes are designed to withhold floodwater during storm events, but are generally left open during non-flood events so that navigation or natural ebb and flow of tides and aquatic organisms are not impeded.

Screening Structural Measures and Alternatives

Considering the millions of possible combinations of structural measures and alternatives across the coast, it was essential that the LACPR team reduce the list of measures under consideration to a manageable number. Early screening helped to refine the number of measures that would be investigated in greater detail and eventually included in alternative plans. A three-tiered screening process was used to reduce possible structural measures, alignments and alternatives to a more manageable number for further evaluation and consideration across a wide range of stakeholder interests. The screening of structural measures and alternatives, as discussed below, should not be confused with the evaluation, comparison and selection of the final alternative plans.

- **Tier 1 – Initial Screening of Structural Alignments.** Alignments from the Plan Formulation Atlas were screened considering preliminary construction costs, constructability, and environmental impacts.
- **Tier 2 – Initial Hydromodeling of Structural Measures.** Initial hydromodeling results were used to further screen the number of alignments and strategies.
- **Tier 3 – Final Screening of Structural Alternatives.** The final step set each remaining alignment at three design heights, 100-year, 400-year, and 1000-year, to create a set of structural alternatives, which were then screened using six attributes: cost effectiveness, present value costs, average annual flood damages, population exposed, construction period, and direct wetland impacts.

Tier 1 – Initial Screening of Structural Alignments

In April and May 2007, the USACE and State teams screened the structural measures identified in the Plan Formulation Atlas. Each measure either “passed” (moved on to the next screening level) or “failed” (dropped from further consideration) based on consideration of potential performance of each compared to other similar measures. Typical to planning efforts, criteria used at this screening level to assess measures and potential performance were mostly subjective with limited quantitative data available. Screening included consideration of the following:

- Extraordinarily high construction costs

- Constructability issues
- Potential for significant induced flooding
- Highly disrupted to existing hydrology (local drainage)
- Significant direct and/or indirect environmental impacts (e.g. wetland loss)
- High interference with potential restoration plans
- Excessive real estate acquisition issues
- Excessive operations and maintenance costs

The goal in using such criteria is to identify those measures that clearly stand out as poor choices with respect to a particular criterion. Again, the aim of applying these initial screening criteria was to eliminate clearly inferior choices from further consideration. Representative alignments of strategically different structural measures were maintained in order to evaluate tradeoffs through the multi-criteria decision analysis.

The initial screening of structural measures was less formal than the process used to evaluate and identify the final array of alternative plans. This initial screening primarily compared alignments without consideration to the level of risk reduction (e.g. 100-year vs. 1000-year). Alignments were eliminated when another similar alignment could theoretically provide the same level of risk reduction but at a lower cost, with less potential adverse environmental impacts, less real estate requirements, and/or fewer challenges, etc. For example, in Planning Unit 1, the Plan Formulation Atlas presented six different alignments for structures (barriers) to be placed at the Lake Pontchartrain passes (see **Figure 9-1** below).

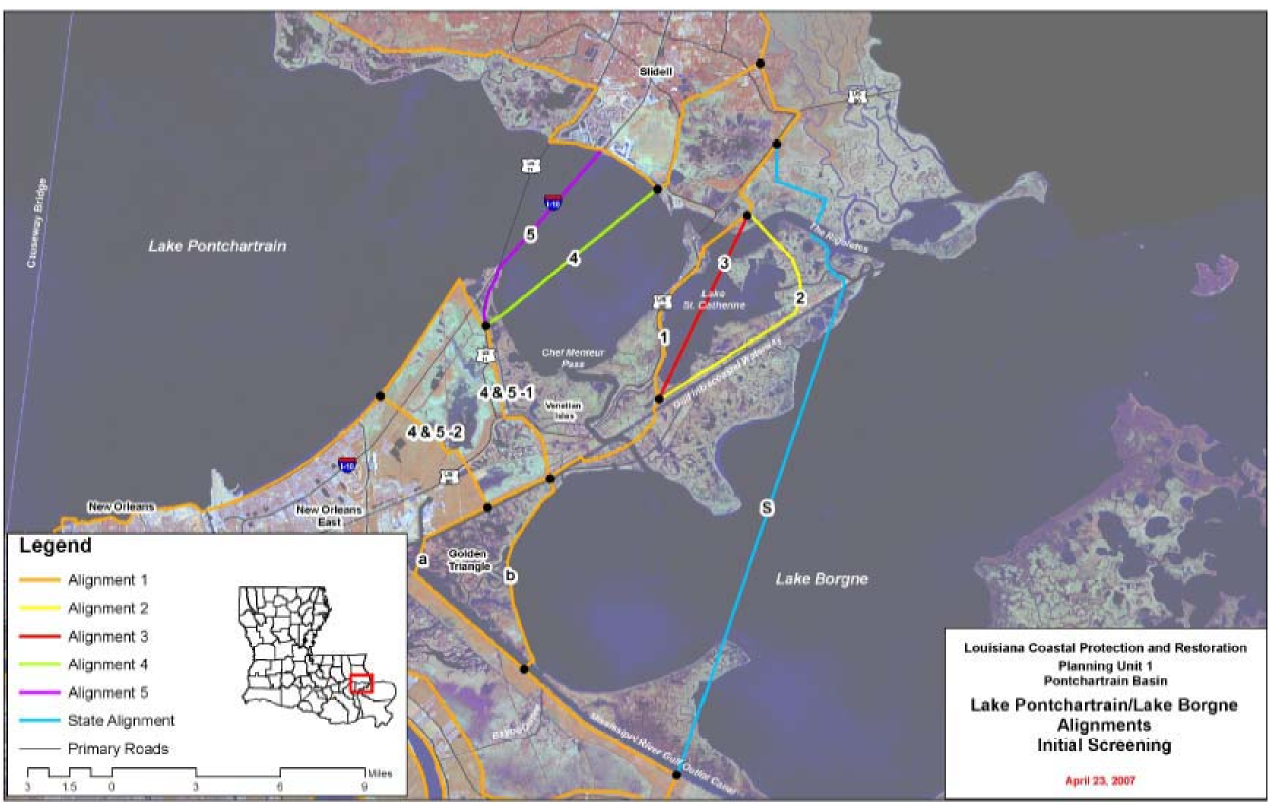


Figure 9-1. Initial screening alignments in Planning Unit 1.

Each of the six barrier alignments could be combined with alignments ‘a’ or ‘b’ in the Golden Triangle area. Alignment ‘a’ refers to the levee alignment that would cross the Golden Triangle wetlands at the confluence of the Gulf Intracoastal Waterway and the Mississippi River Gulf Outlet. Alignment ‘a’ is part of the base conditions scheduled to be in place around 2011. Alignment ‘b’ follows along the edge of the Golden Triangle and Lake Borgne and would provide a secondary line of defense to Alignment ‘a.’ Through the Tier 1 screening process, three of the six barrier alignments were eliminated from further consideration, i.e. alignments 3, 4, and 5. The remaining barrier alignments 1, 2, and S (from the State Master Plan) were carried forward into the next screening tiers along with both segments ‘a’ and ‘b.’

Tier 2 – Initial Hydromodeling of Structural Measures

Structural measures that passed the initial screening underwent a second screening once results of the hydromodeling analysis became available and a measure of hurricane surge risk reduction performance could be evaluated. The alternative alignments that passed the Tier 1 screening were further defined by setting design levels (i.e. 100-year, 400-year, and 1000-year). The hydromodeling analysis helped make design comparisons such as open versus closed (gated) tidal passes at The Rigoletes and Chef Menteur, overtopping versus non-overtopping barriers, etc.

The same general criteria as were used in the Tier 1 screening were used in the Tier 2 screening, but could be measured with more detailed quantitative data. For example, open tidal passes were screened out because they performed poorly in comparison to closed tidal passes. In other cases, non-overtopping barriers were eliminated because of undesired water level increases to adjacent areas, high costs and constructability issues. The Tier 2 screening and associated evaluation process also facilitated the development of specific alternatives for further evaluation, including variances to address specific problem areas.

Tier 3 – Final Screening of Structural Alternatives

The resulting set of alternatives, at the three design levels, was further screened once detailed performance data, including hydromodeling results, cost estimates, economic data, and wetland impacts became available. For the third tier screening, structural alternatives were ranked based on evaluation data for the six attributes shown in **Table 9-1** below.

Table 9-1. Attributes used to screen structural alternatives.

Attribute	Description
Cost Effectiveness	Ratio of present value costs/average annual risk reduction
Present Value Costs	Present value at 2025 for life-cycle costs
Average Annual Flood Damages	With project damages
Population Exposed	People inundated at inundation frequency
Construction Period	Years required to complete initial construction
Direct Impact – Wetlands	Wetland acreage impacted by proposed levees

In order to have comparable scores for each of these attributes across alternatives, values in each were normalized or converted to a scale of 0-1, with a score of 0 being the best performer and score of 1 being the worst performer or having the greatest adverse impact. The normalization method was based on a percent of the maximum value for each screening attribute. The sum of the resulting normalized scores for each attribute for each alternative was then used to produce a relative ranking of alternatives. The alternatives with the lower scores are preferred. However, in identifying the final array of alternatives for detailed evaluation and comparison, not only were the best performers in this analysis selected, but also those alternatives representing a cross section of stakeholder interests in strategically different alternatives or concepts.

The number of alternatives in each planning unit that were selected for further detailed evaluation is as follows: Planning Unit 1, 11 of 34 alternatives (of which 6 were selected from the top 10); Planning Unit 2, 13 of 18 alternatives (of which all of the top 10 alternatives were selected); Planning Unit 3a, 4 of the 8 total alternatives; Planning Unit 3b, 6 of the 9 total alternatives; and Planning Unit 4, 7 of the 11 total alternatives. A complete list of all the alternatives included in the Tier 3 screening is included in the *Structural Plan Component Appendix*. This appendix also includes a detailed discussion on why each alternative in the final array was selected and why other alternatives were eliminated.

Summary of Structural Alternatives Formulation by Planning Unit

The following sections describe (by planning unit) the screening and the identification of structural measures that are combined with nonstructural and coastal restoration measures to form comprehensive hurricane risk reduction strategies. Based on screening, 41 structural alternatives at various design levels (19 alternatives at 100-year, 14 alternatives at 400-year, and 8 alternatives at 1000-year) across the five planning units were selected for detailed evaluation in combination with nonstructural and coastal restoration measures or alternatives. See Attachment 1 for the full list of alternatives and descriptions.

Planning Unit 1

The Plan Formulation Atlas identified two primary structural strategies in Planning Unit 1. One strategy includes raising the existing levees on the south shore of Lake Pontchartrain to a higher level of risk reduction and adding structural protection elements in Laplace and on the north shore of Lake Pontchartrain, referred to as the **High Level alternatives (designated by 'HL').** See **Figure 9-2** on the following page.

By contrast, the second strategy or **Lake Pontchartrain Surge Reduction alternatives (designated by 'LP')** include the construction of a barrier-weir with gated structures across the two tidal passes connecting Lake Pontchartrain with the Gulf of Mexico. Refer to **Figure 9-3**. This alternative also includes consideration of additional structural protection elements in Laplace and on the north shore of Lake Pontchartrain.

Common to both alternatives are structural elements in New Orleans East, portions of St. Bernard Parish, the upper portion of Plaquemines Parish and a floodgate across the Gulf Intracoastal Waterway (GIWW) in the Golden Triangle area. Alternatives in Planning Unit 1 will need to be refined in order to reduce impacts to the coast of Mississippi. Preliminary impacts have been quantified in a coordinated regional analysis that can be found in the *Regional Considerations for LACPR and MsCIP Appendix*.

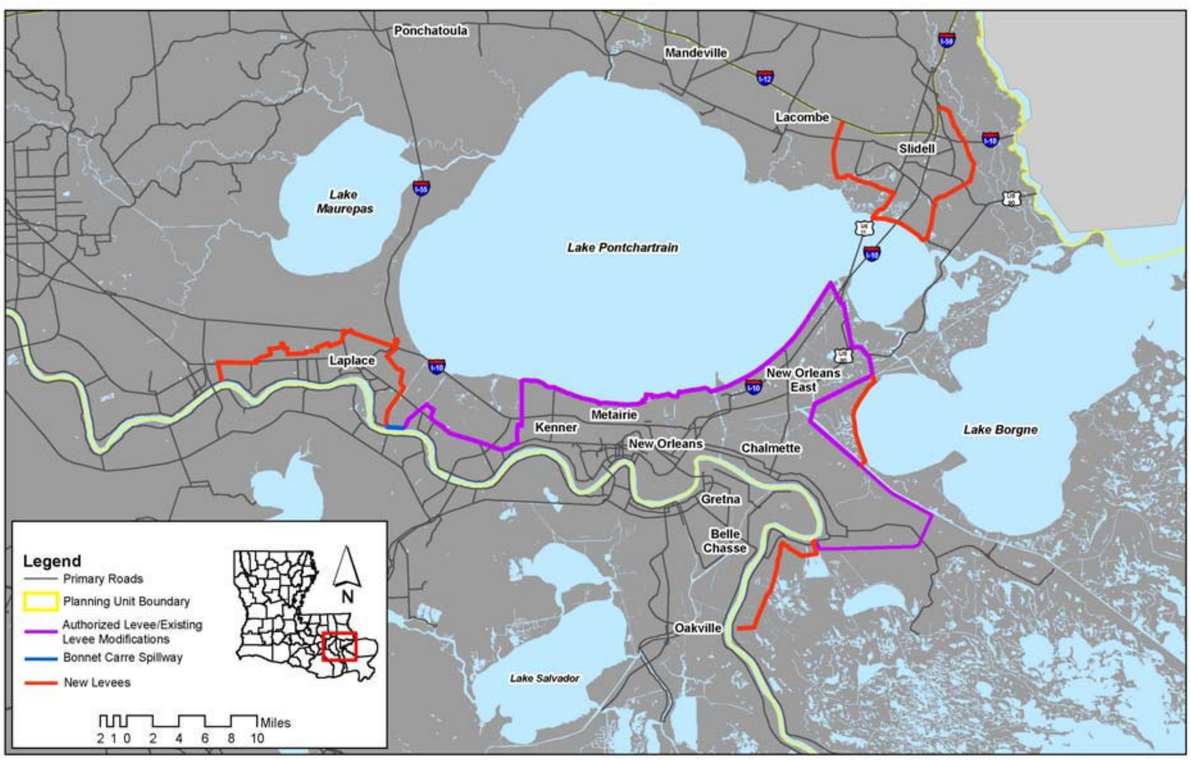


Figure 9-2. Example high level alternative.

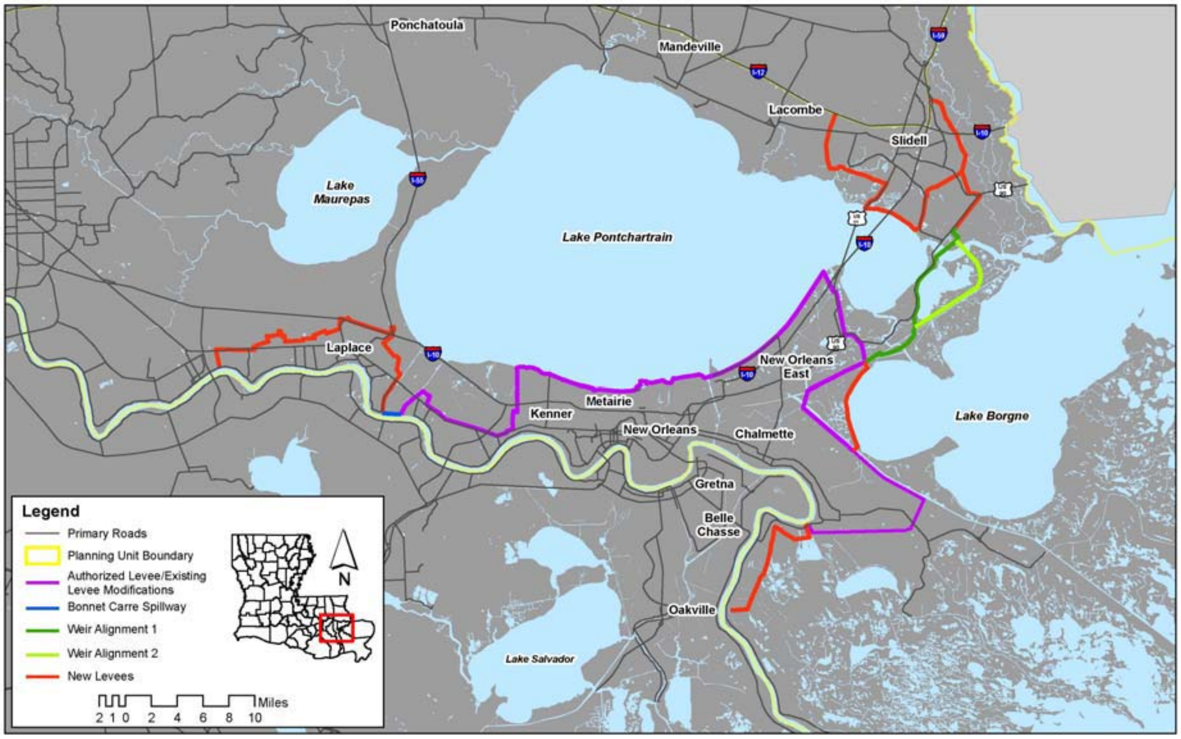


Figure 9-3. Example Lake Pontchartrain surge reduction alternative.

Planning Unit 2

The Plan Formulation Atlas identified four primary strategies for structural risk reduction within Planning Unit 2. The levee alignments included the GIWW levee alignment, Highway 90 levee alignment, swamp alignment, and two alignments along the West Bank interior. Through initial screening, in which preliminary construction costs as well as direct and indirect environmental impacts and hydrologic performance were considered, the number of primary strategies was screened to three, with numerous variants identified.

The most significant change to the initial strategies included modification of the swamp alignment and Highway 90 alignment, combining these to form the **Ridge alternatives (designated by 'R')**. Refer to **Figure 9-4** for an example of a ridge alternative.

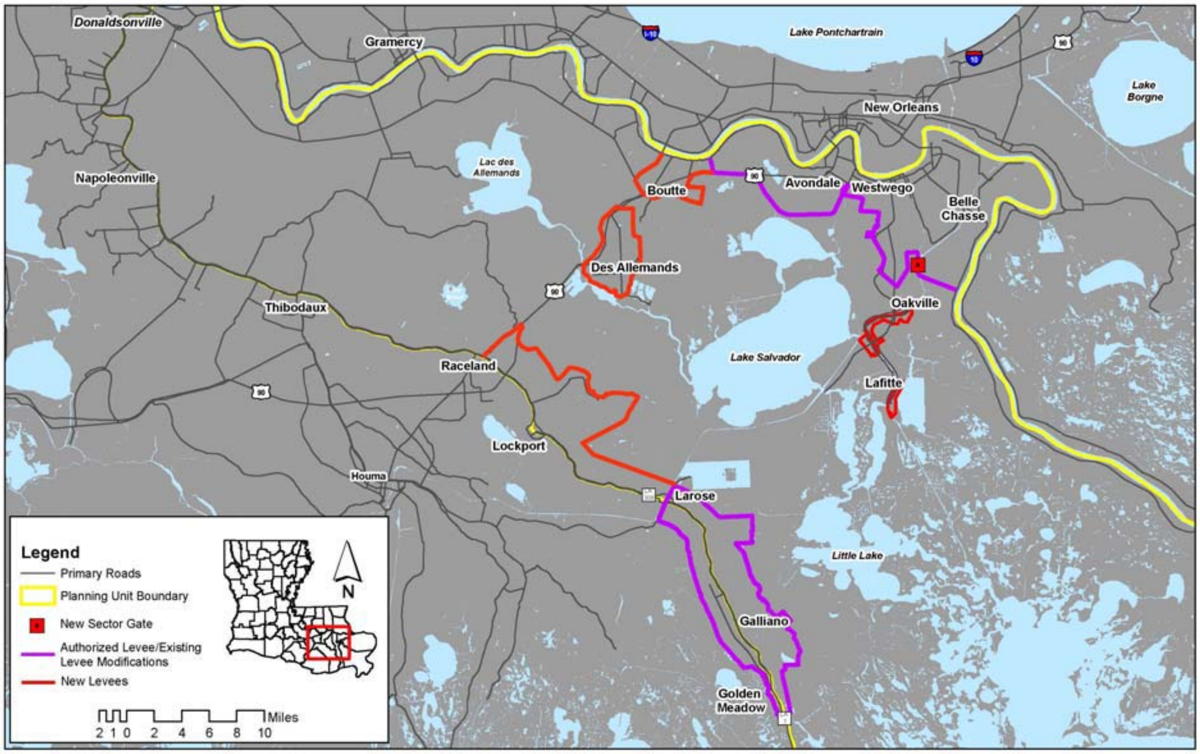


Figure 9-4. Example ridge alternative.

Three variations in the **GIWW levee alternatives (designated by 'G')** were considered including structural risk reduction for Lafitte and variations where the levee ties into the Mississippi River Levee System. Refer to **Figure 9-5** for an example of a GIWW alternative. These alignments follow the Gulf Intracoastal Waterway, which cuts across the Barataria Basin south of Lake Salvador (shown as a weir on Figure 9-5).

The **West Bank alternatives (designated as 'WBI')** include improvement to, or extension of the existing West Bank levee and construction of a sector gate on the GIWW in Bayou Barataria at the confluence with the Algiers and Harvey Canals. Common to the three basic alignments is a ring levee encompassing Golden Meadow and Larose. Refer to **Figure 9-6** for an example of a West Bank alternative.

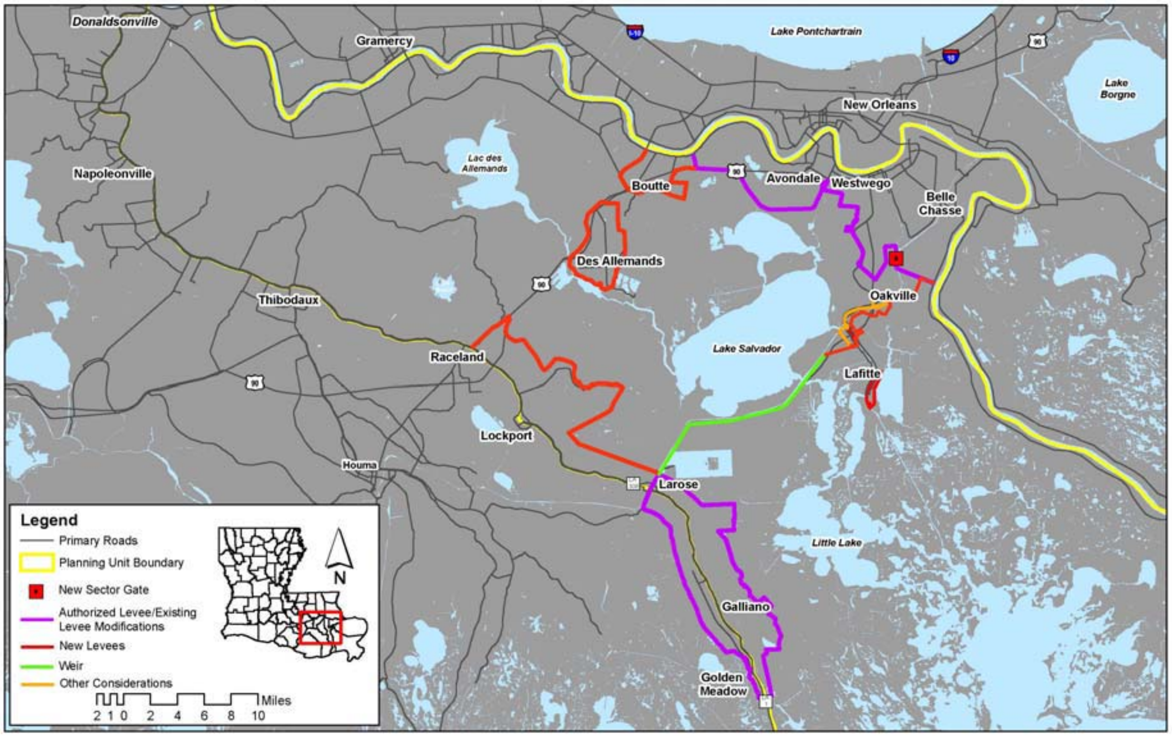


Figure 9-5. Example GIWW alignment.

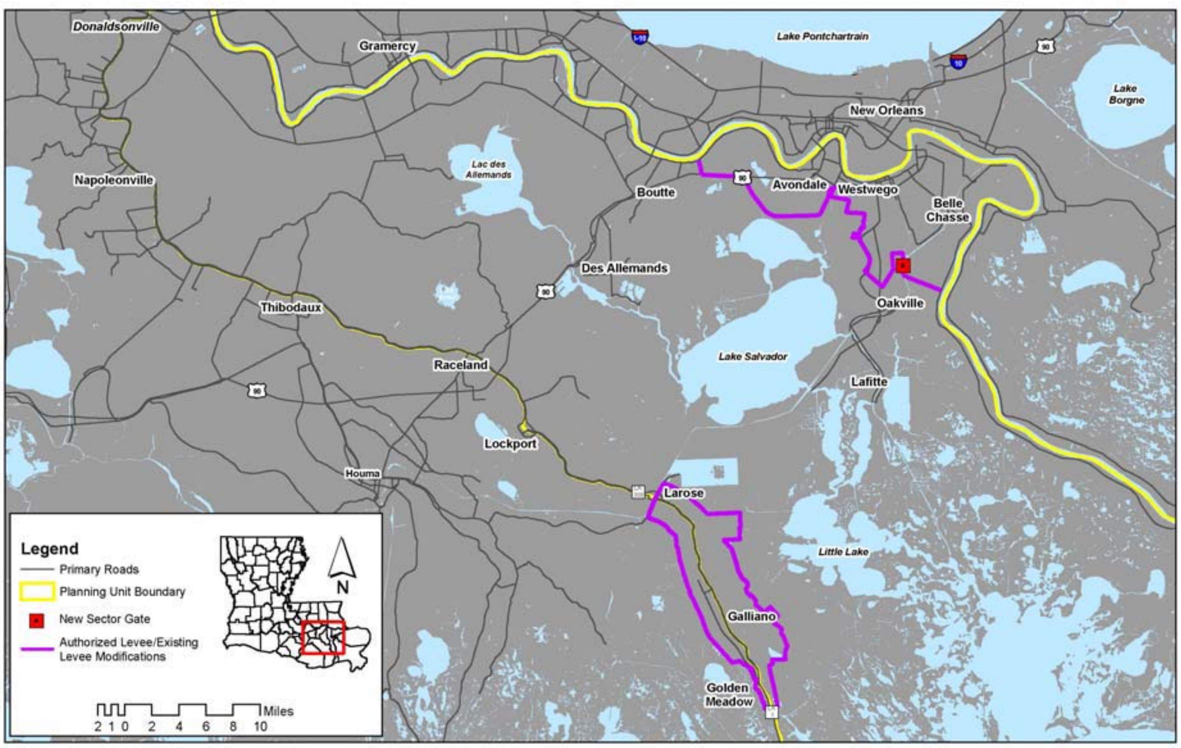


Figure 9-6. Example West Bank alignment.

Lower Plaquemines Parish (Part of both Planning Unit 1 and 2)

The Plan Formulation Atlas presented four options for increased risk reduction in Plaquemines Parish:

1. **Ring Levees/Spillways** – This option proposes spillways in combination with ring levees in multiple locations in Plaquemines Parish. The spillway concept was envisioned to reduce hurricane surge in the New Orleans area and Plaquemines Parish by degrading sections of the existing Plaquemines Parish levees to allow storm surge transfer between Breton Sound and Barataria Bay areas. Highway bridges would be constructed over degraded levee reaches.
2. **Closed Ring Levee System** – This option includes a series of basins (ring levees) that would provide an increased level of risk reduction to critical facilities and more densely populated areas of lower Plaquemines Parish. Levee sections outside the closed ring levee areas would remain at existing height.
3. **Federal Levee Alignment** – This option proposes to raise the height of all Federal levees in lower Plaquemines Parish to the 100-year design level and to leave the non-Federal levees at existing height.
4. **Existing Levee Alignment** – This option would incorporate non-Federal levees in Plaquemines Parish into the Federal levee system and raise the height of all existing levees in lower Plaquemines Parish.

As a result of the high cost, both the State Master Plan stakeholder process and the USACE screening process eliminated options 2 – 4 above. A sensitivity analysis was performed on the spillway concept (option 1); however, results are inconclusive at this time. The spillway concept appears to have some merit but further study is needed; therefore, the spillway option was not carried forward as a risk reduction measure for LACPR.

Planning Unit 3a

The two primary structural strategies considered for Planning Unit 3a are the **Morganza to the Gulf alternatives (designated by 'M')**, which are variations on the currently proposed 100-year Morganza to the Gulf project authorized by the Water Resources Development Act of 2007, and a set of **GIWW alternatives (designated by 'G')**, which would provide a second line of defense further inland along the Gulf Intracoastal Waterway. The first two alternatives are variations on the Morganza to the Gulf alignment as follows:

- Extend the proposed Morganza alignment westward to Morgan City and into the Atchafalaya basin (**Figure 9-7**); or
- Tie the proposed Morganza alignment into high ground to the west of Houma with a ring levee around Morgan City (**Figure 9-8**).

The third alternative would use the Morganza levee as a first line of defense at a 100-year design level and then would provide a second levee alignment further inland, along the GIWW, to prevent inner flooding around Houma at a 400-year and 1000-year frequency design (**Figure 9-9**).

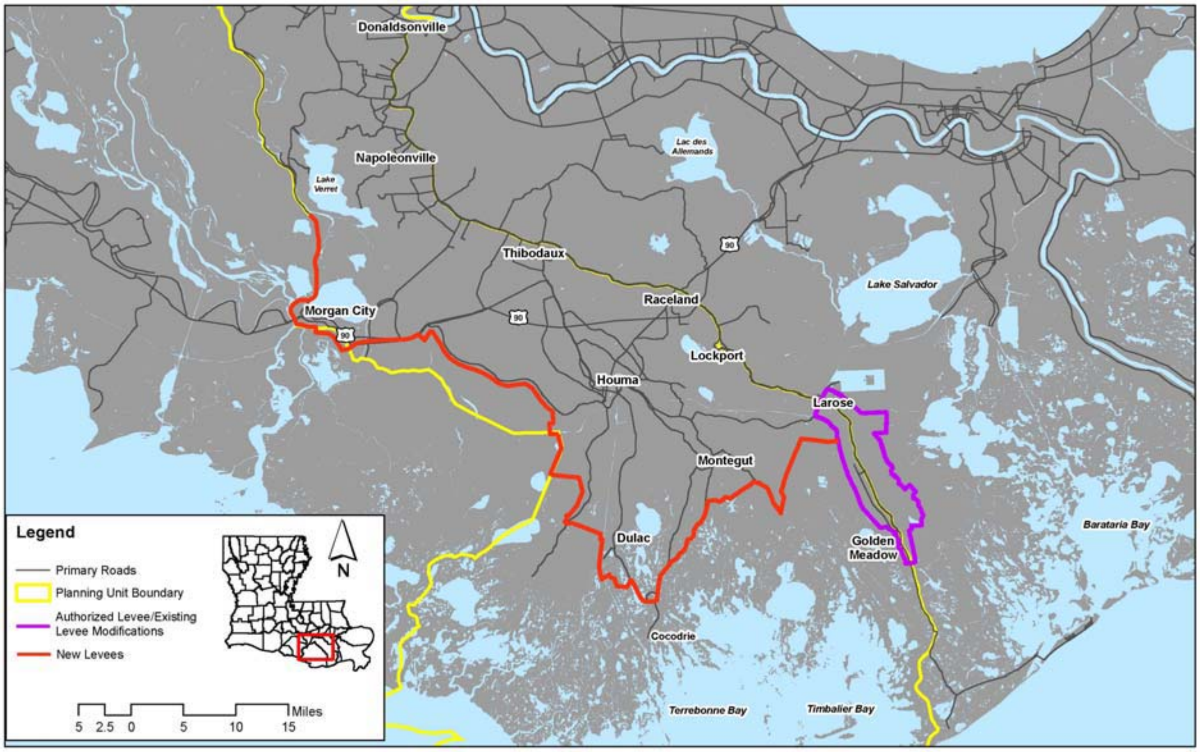


Figure 9-7. Example Morganza to the Gulf alternative.

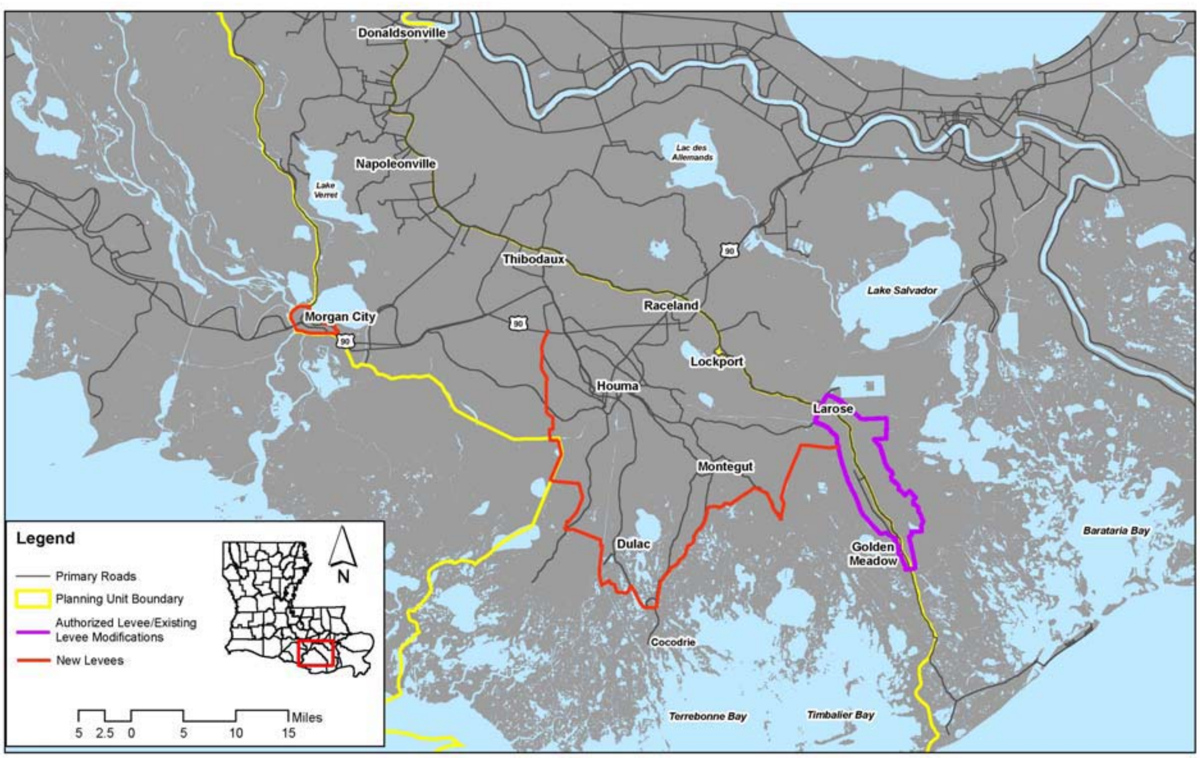


Figure 9-8. Example Morganza alternative with ring levee around Morgan City.

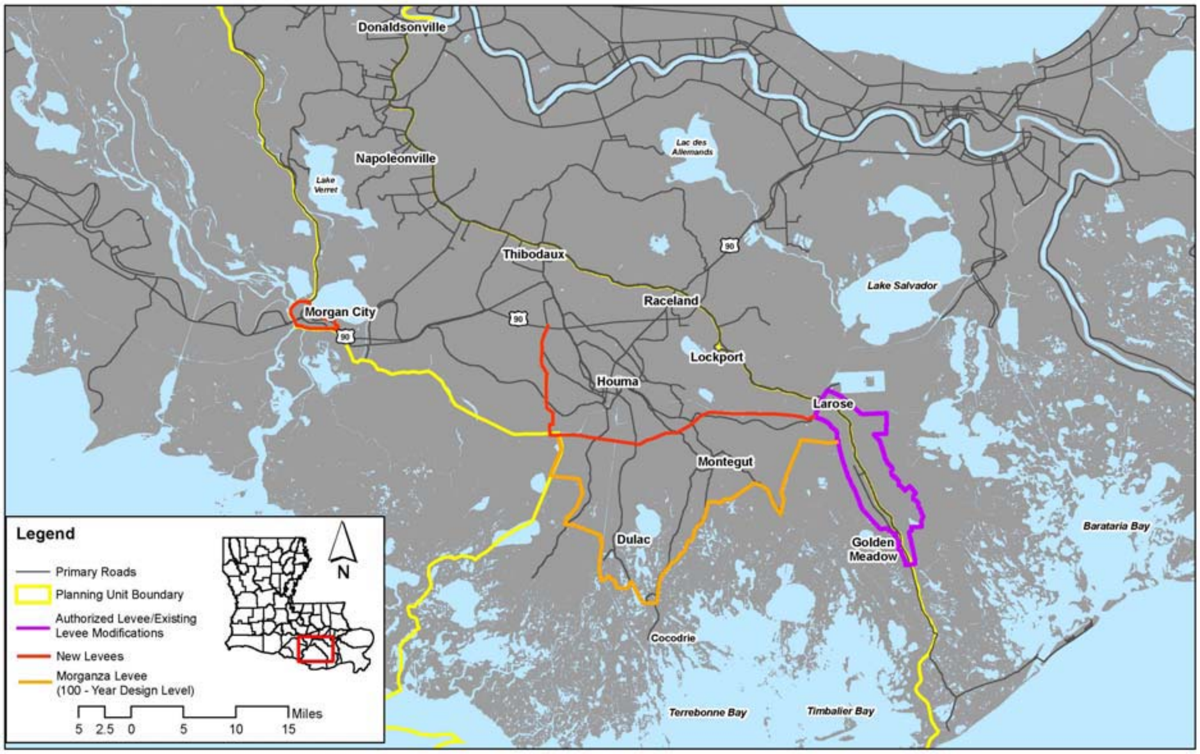


Figure 9-9. Example GIWW alternative with 100-year Morganza to the Gulf.

Planning Unit 3b

The primary levee strategies considered in Planning Unit 3b included two parallel alignments extending from Morgan City west across Vermilion Bay. The southern alignment follows the **GIWW** and extends into Planning Unit 4 (**Figure 9-10**).

The northern alignment, referred to as the **Franklin to Abbeville alternatives (designated by 'F')**, provides a ring levee around Patterson and a continuous levee from Patterson, around Franklin and Baldwin and tying to high ground to the west of Abbeville (**Figure 9-11**).

A third levee alignment strategy considers **ring levees (designated by 'RL')** around concentrated population centers, including Patterson, Franklin, Baldwin, New Iberia, Erath, Delcambre and Abbeville (**Figure 9-12**).

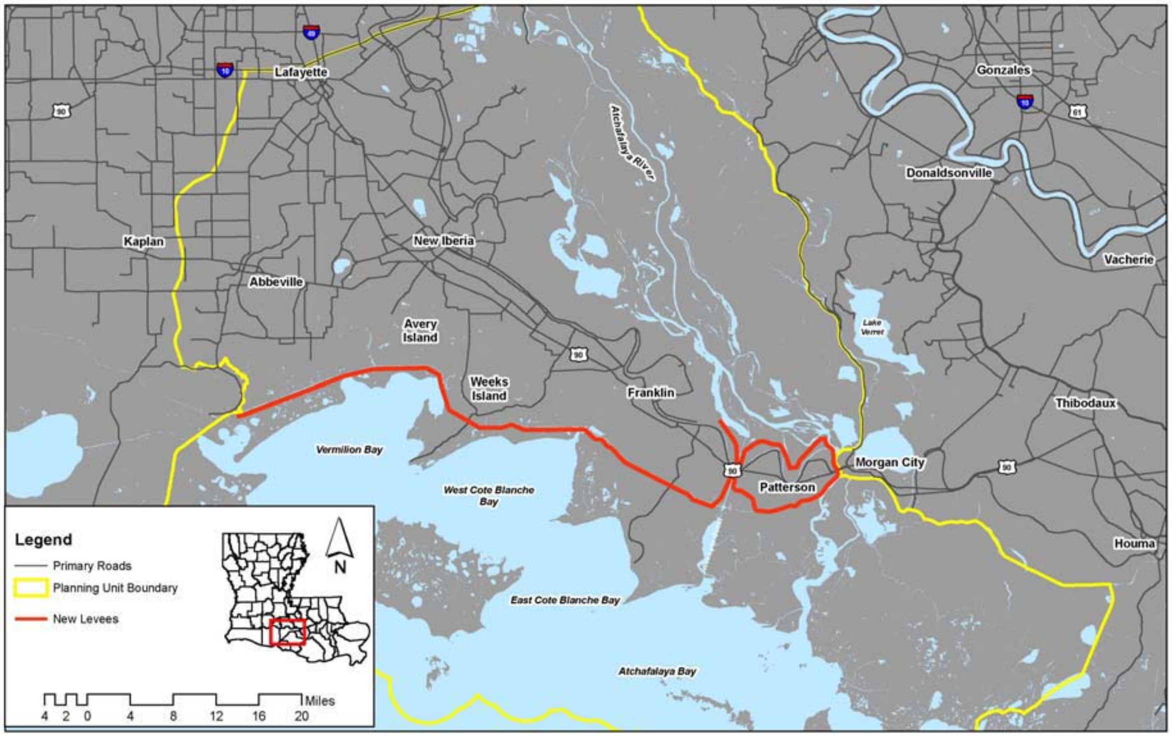


Figure 9-10. Example GIWW alignment in Planning Unit 3b.

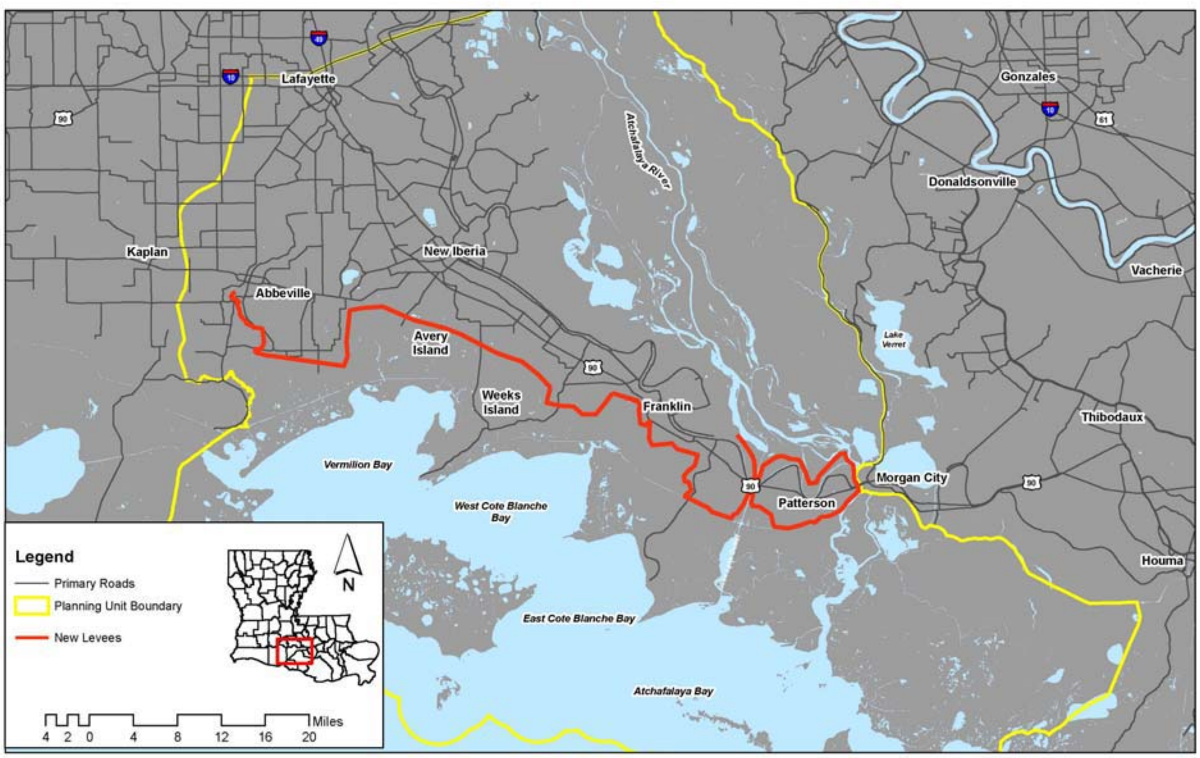


Figure 9-11. Example Franklin to Abbeville alignment.

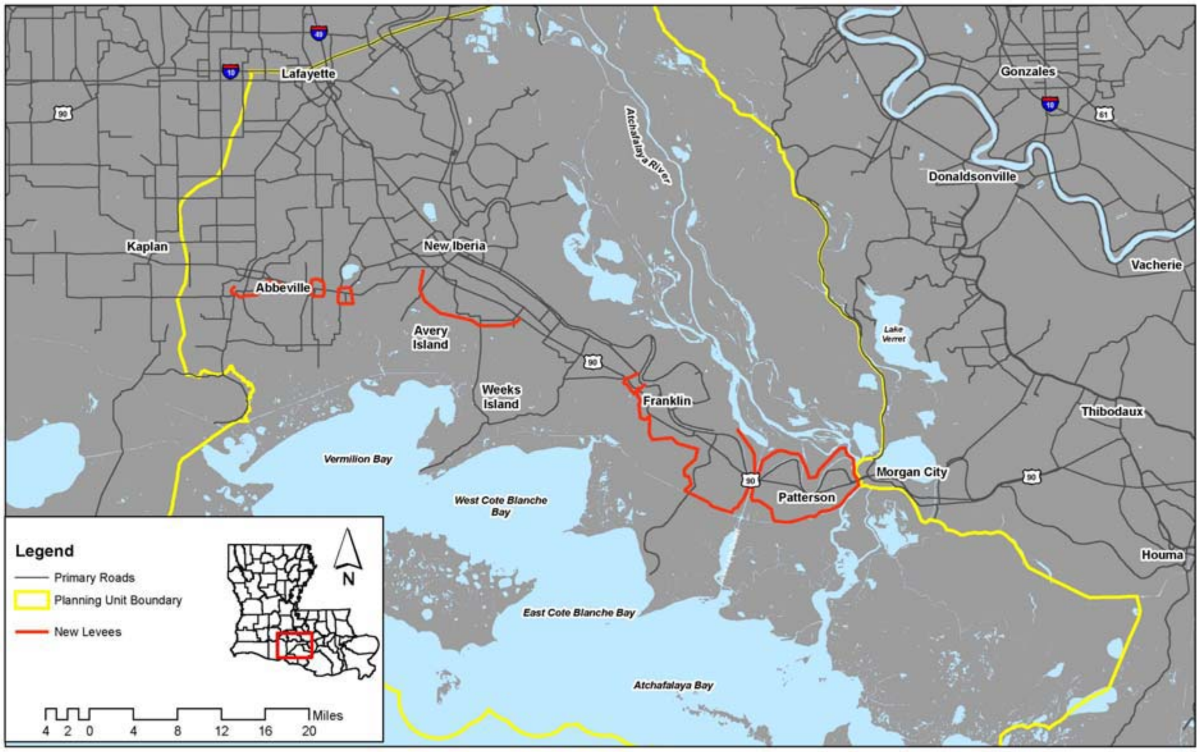


Figure 9-12. Example ring levee alignment in Planning Unit 3b.

Planning Unit 4

The levee alignment strategies for this planning unit are relatively similar for the two continuous levees extending along the GIWW westward from near Vermilion Bay to the Calcasieu River just below Lake Charles, with a separable reach west of the river. The first of these **GIWW alternatives (designated as 'G')** joins with the GIWW alignment in Planning Unit 3b (**Figure 9-13**).

The second GIWW alignment has a return to high ground to the west of the Vermilion River so that this alternative can be evaluated as "stand alone." This alignment has also been evaluated at a 12-foot levee height, performing essentially as an overtopping weir (**Figure 9-14**). An additional alignment strategy consists primarily of a series of **ring levees (designated by 'RL')** to the east and west of Lake Charles (**Figure 9-15**). Common to all three is a series of small levees within Lake Charles to separate the river from the land.

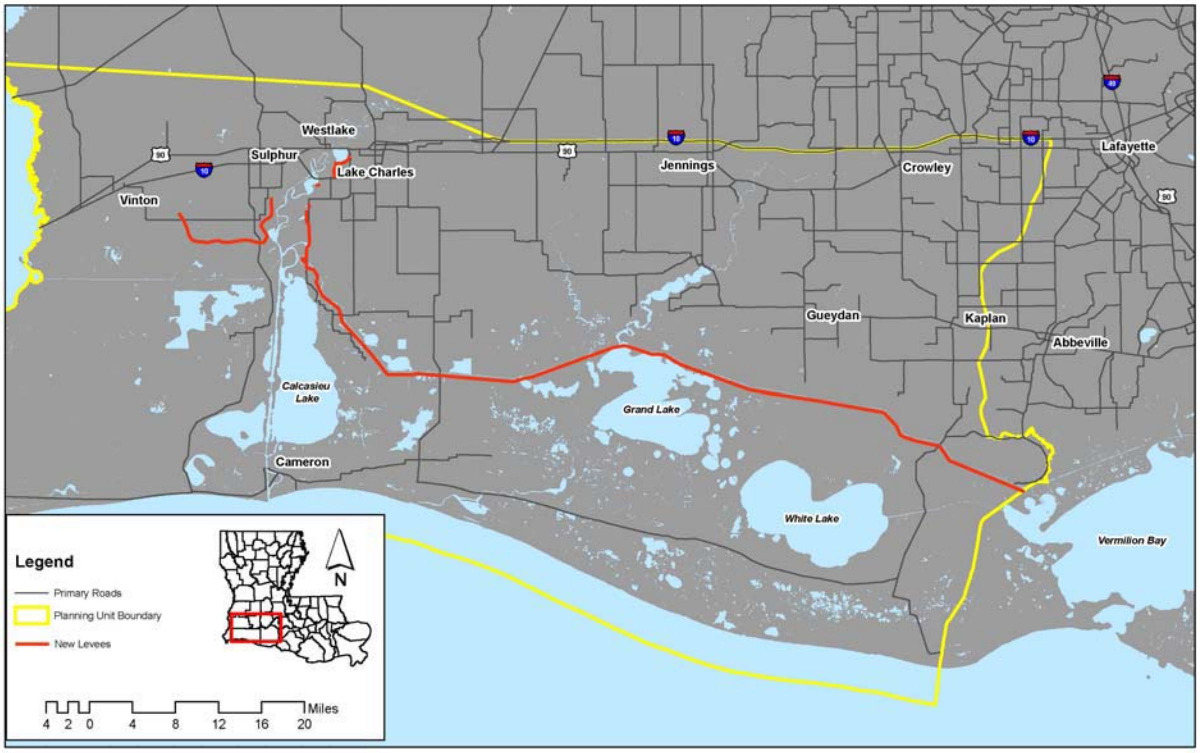


Figure 9-13. Example GIWW alignment in Planning Unit 4.

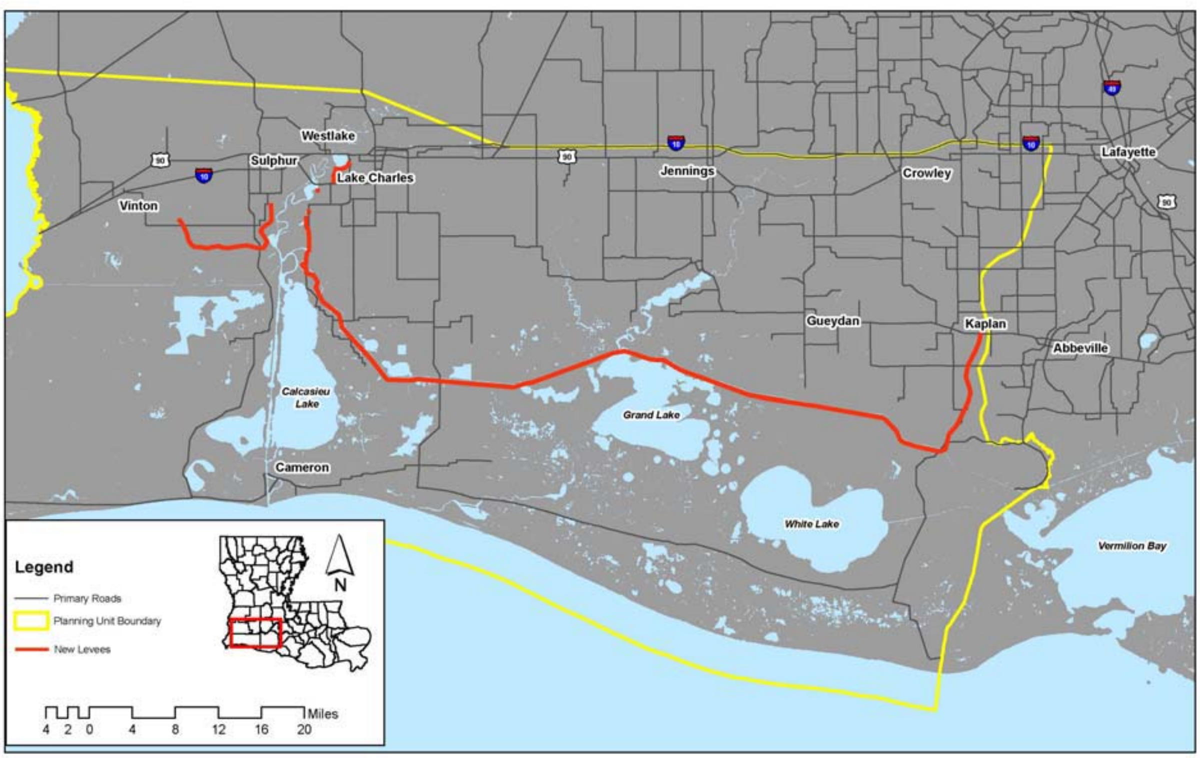


Figure 9-14. Planning Unit 4 – example GIWW alignments 2 and 3 (12-ft levee).

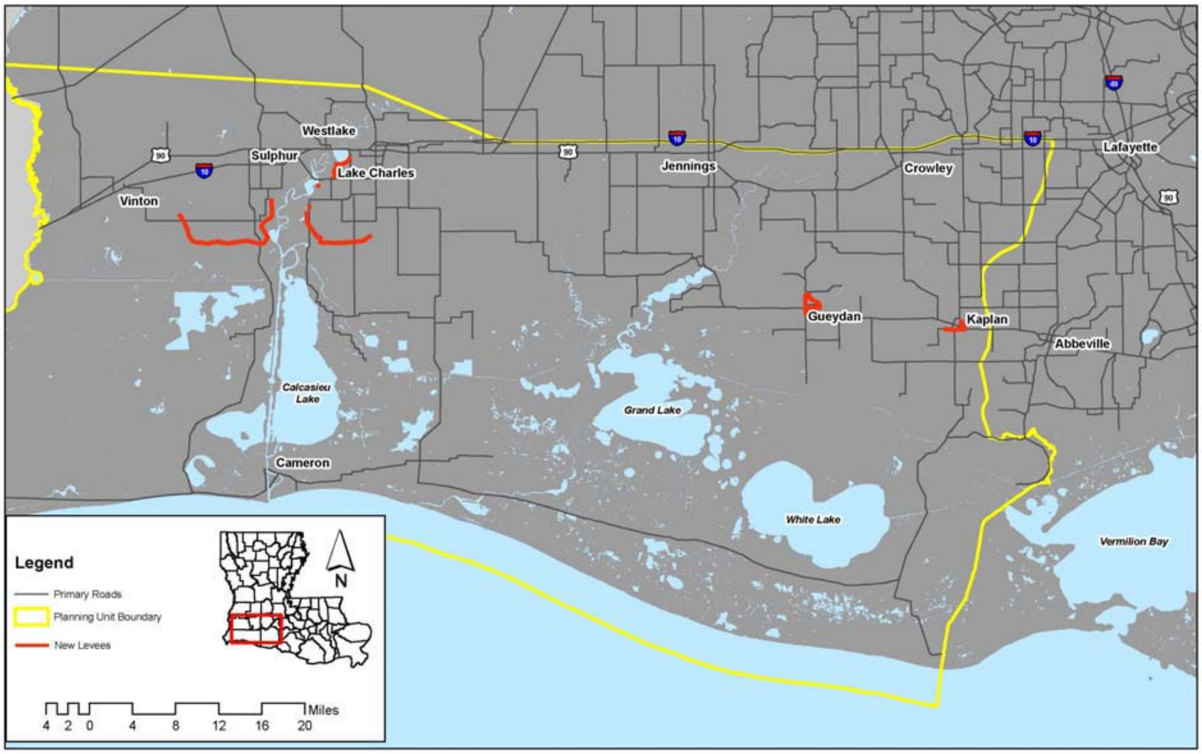


Figure 9-15. Planning Unit 4 – example ring levee alignment.

Section 10. Nonstructural Measures and Alternatives

Nonstructural risk reduction measures do not attempt to change the nature of a storm event or a flood profile. Nonstructural measures reduce the consequences of hurricanes by limiting the exposure of people and/or economic assets to flooding. Types of nonstructural measures include wet and dry flood proofing, flood warning, raising-in-place by lifting on pilings or placing on fill, relocations of property improvements, and buyouts of properties. This group of measures includes risk management land use practices that offer strategies for reducing exposure to storm hazards by influencing development within the floodplain, in combination with, or sometimes instead of, structural measures.

Nonstructural measures, such as buyouts and relocations, can provide opportunities for alternate uses of the vacated flood plain, such as ecosystem restoration, recreational development, or urban green space if sufficient contiguous parcels are purchased for evacuation. Nonstructural measures also contribute to community sustainability and economic recovery where the measures protect existing residential structures, commercial buildings, and especially critical facilities that provide a base for emergency response and a post-storm foothold for recovery.

In comparison to structural and coastal restoration measures, successful implementation of nonstructural measures requires a higher degree of direct participation by individuals and other government agencies besides the USACE. The only way to ensure complete safety from storm or flood risk is through evacuation before the storm. Individuals have a personal responsibility to be prepared to evacuate as directed by local officials or sooner.

Louisiana's Emergency Alert System and Evacuation Planning

The Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) ensures that the State of Louisiana is prepared to respond to, and recover from, all natural and man-made emergencies. GOHSEP provides the leadership and support to reduce the loss of life and property through an all-hazards emergency management program of prevention, mitigation, preparedness, response and recovery. GOHSEP has enabled the Integrated Public Alert and Warning System (IPAWS) which is administered by FEMA for the Department of Homeland Security and addresses the mandate and vision of Executive Order 13407 to create a comprehensive and modern public alert and warning system. The IPAWS components and pilot project work in conjunction with GOHSEP's existing Emergency Alert System. IPAWS will help provide critical and timely information alerts and warning that will save lives and property not only to governmental agencies, but to the general public, business, schools and other groups. This program is an essential element of any risk reduction plans.

Formulation of Buyout/Relocation and Elevation of Structures

For the purposes of the LACPR plan formulation, buyout/relocation of structures and elevation of structures are considered to be the most viable nonstructural measures for broad applicability across South Louisiana. This generalized determination was made on the basis of flood depth and hydrodynamic force associated with hurricane storm surges as well as on the breadth of the study. Participation in these nonstructural measures is assumed to be 100 percent and voluntary for evaluation purposes; however, the assumption that participation is voluntary for planning purposes does not preclude future projects being designated as non-voluntary.

The physical aspects of storms are a major consideration when formulating nonstructural measures at specific sites. Certain nonstructural measures function better given defined flooding conditions or when considering other interests. For example, the only reliable nonstructural measure under high-velocity surge conditions is buyout of property and permanent evacuation of the population at risk. Conversely, flood-proofing, such as raising-in-place either on fill or piers works well for low-velocity flooding conditions. Raising structures in place is effective when an interest exists in maintaining a local tax-base and when flooding conditions and structural integrity warrant its application, so long as elevating does not put the structure at further risk in the wind field. Also, relocation of structures and population into clusters at flood-free sites can address both risk reduction and community cohesion concerns.

An evaluation of the entire southern Louisiana coast was conducted to identify opportunities for risk reduction and to establish areas for further in-depth analysis. Nonstructural measures were formulated at the planning unit level. The intention of this effort was to establish a programmatic approach to implementation of nonstructural measures in a comprehensive and systematic manner.

Nonstructural measures can be developed into stand-alone alternatives or can be combined with other types of risk reduction measures as one line in a multiple lines of defense strategy for reducing and managing hurricane risks. The LACPR team formulated nonstructural measures within the following categories:

- **Stand-alone measures** to compete against structural measures within planning units and at similar levels of risk reduction;
- **Complementary measures** in the residual floodplains of structural measures in order to provide a uniform level of risk reduction throughout the planning unit; and

Formulation Criteria

Formulation of nonstructural measures was based on the following decision criteria, which indicate a high degree of flood risk:

- **Velocity zones (V zones)**: FEMA designated areas along the coast subject to inundation by the 100-year flood event with additional hazards associated with storm-induced waves. These areas were investigated for population and property with the intent of reducing or eliminating exposure using buyout and permanent relocation.

- **Depth of inundation**: Areas of flood inundation were investigated for nonstructural measures such as raising-in-place for depths of inundation less than 14 feet. Where inundation depths are 14 feet or higher, buyout/permanent evacuation measures apply.

V Zones - Areas located within V zones were identified by census block and combined for processing through the geodatabase. Outputs of the processing included an estimate of the number of structures and the population impacted by various flood events, as well as an estimate of damages to economic assets from those flood events. These areas were targeted for relocation/permanent evacuation based on the established decision criteria. Therefore, benefits and costs were developed for relocations to the baseline structure inventory for the designated census blocks falling within FEMA's V zones. Buyouts of these areas would eliminate the risk to people and assets.

Depth of Inundation - Depth of inundation was used as another indicator of risk. The base condition assumes that the improvements to the metropolitan New Orleans levee system as prescribed in the Fourth Emergency Supplemental Appropriation are complete and provide protection from overtopping to the 90 percent confidence level of the 100-year flood stage. Hydrologic stages, upon which some nonstructural measures are formulated based on inundation, assume no failure or breaching. Overtopping is assumed above the 90 percent confidence stage of the design level of performance.

Flood depths from the 90 percent confidence stages of 100-year, 400-year, and 1000-year storm events were aggregated into practical ranges of 1 – 2 feet, 3 – 6 feet, 7 – 13 feet, and depths of 14 feet and higher based on the stage of the event as compared with the mean ground elevation of each census block. The base condition flood stages were referenced for formulation of stand-alone nonstructural measures. Structural and coastal measures' residual floodplain flood stages were the basis for formulation of complementary nonstructural measures.

The areas identified to be flooded from depths of 1 – 2 feet were removed from further consideration with the expectation that first floor corrections, averaging 2 feet in the structure database, would eliminate these areas from actual damage. The areas identified as flooding 3– 13 feet qualified for raising-in-place with the expectation that the structural integrity of the structures would be determined during the implementation phase. Those census blocks that experienced depths of flooding of 14 feet or greater qualified for buyouts/permanent evacuation based on the decision criterion that lifting a structure above 13 feet would elevate it into an undesirable wind field and would violate best practices as set forth in the July 2006, FEMA technical manual, Publication 550, *Recommended Construction for the Gulf Coast, Building on Stronger and Safer Foundations.*

The FEMA Publication 550 offers the rationale for the raising-in-place criterion decision. The following excerpt is taken from the referenced manual: "This manual contains closed foundation designs for elevating homes up to 8 feet above ground level and open foundation designs for elevating homes up to 15 feet above ground level. These upper limits are a function of constructability limitations and overturning and stability issues for more elevated foundations." The nonstructural analysis used an upper limit of 14 feet for elevation because of the uncertainty of where the bottom of the lowest horizontal member of the structure frame might actually be. Using 14 feet as the upper limit was considered to be a conservative approach to the analysis but could be refined in subsequent studies.

Stand Alone Measures

Using the decision criteria previously described, planning units were evaluated for location of V zones and depth of inundation. Stand alone nonstructural plans were formulated with the following measures:

1) Buyout of delineated FEMA V zones across the entire planning unit.
2) Buyout of all structures within census blocks not in V zones which demonstrate a depth of inundation of 14 feet or greater across the entire planning unit.
3) Raise-in-place for all structures in census blocks which demonstrate a depth of inundation between three and 13 feet across the entire planning unit.

Stand alone nonstructural plans with these combined measures were formulated for three levels of risk reduction to the 100-year, 400-year, and the 1000-year risk reduction levels in each planning unit (denoted as NS-100, NS-400, and NS-1000) for a total of 15 nonstructural alternatives across the coast. **Figures 10-1** through **10-5** illustrate the extent and type of nonstructural measures considered for the NS-100 plans.

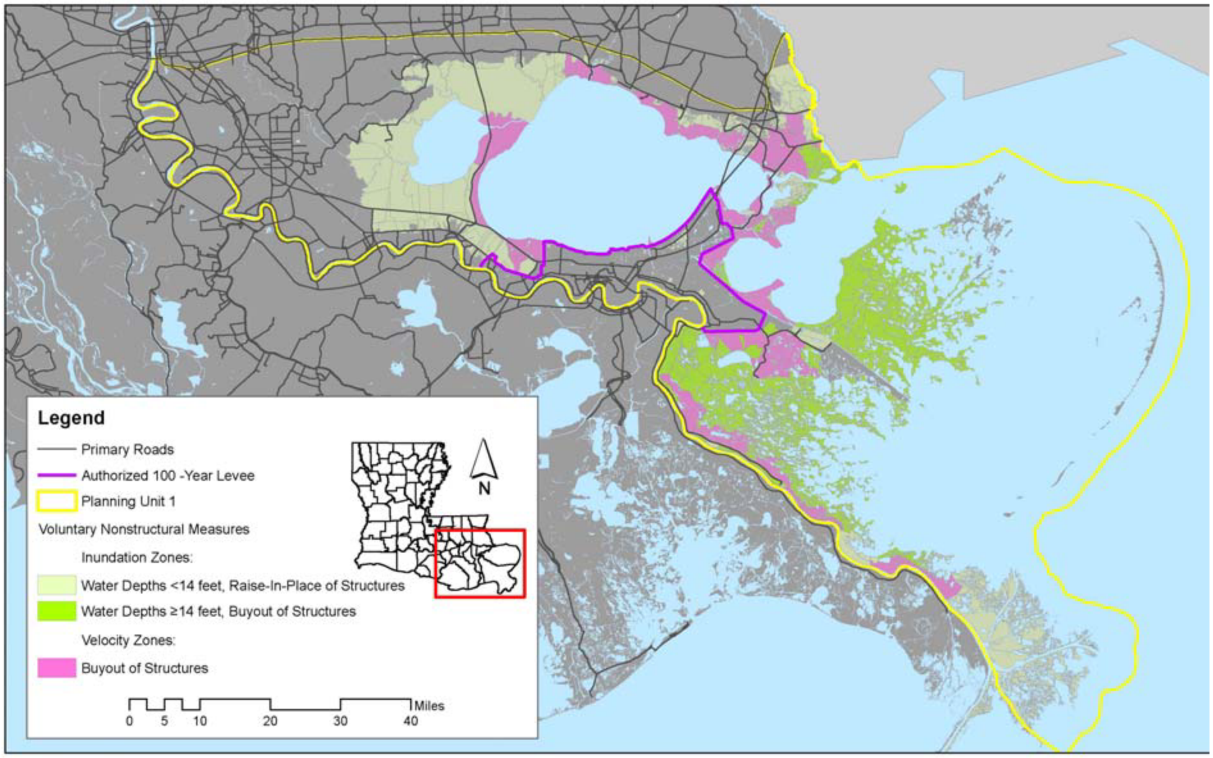


Figure 10-1. Example nonstructural plan in Planning Unit 1.

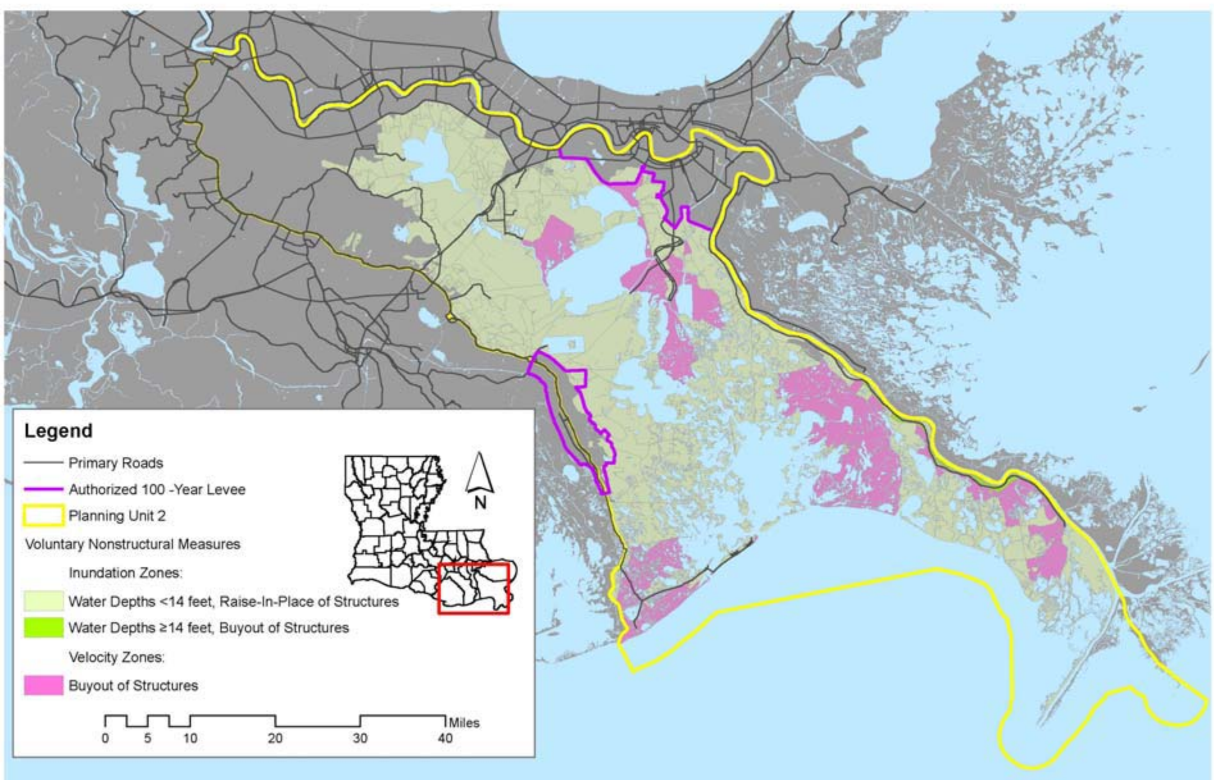


Figure 10-2. Example nonstructural plan in Planning Unit 2.

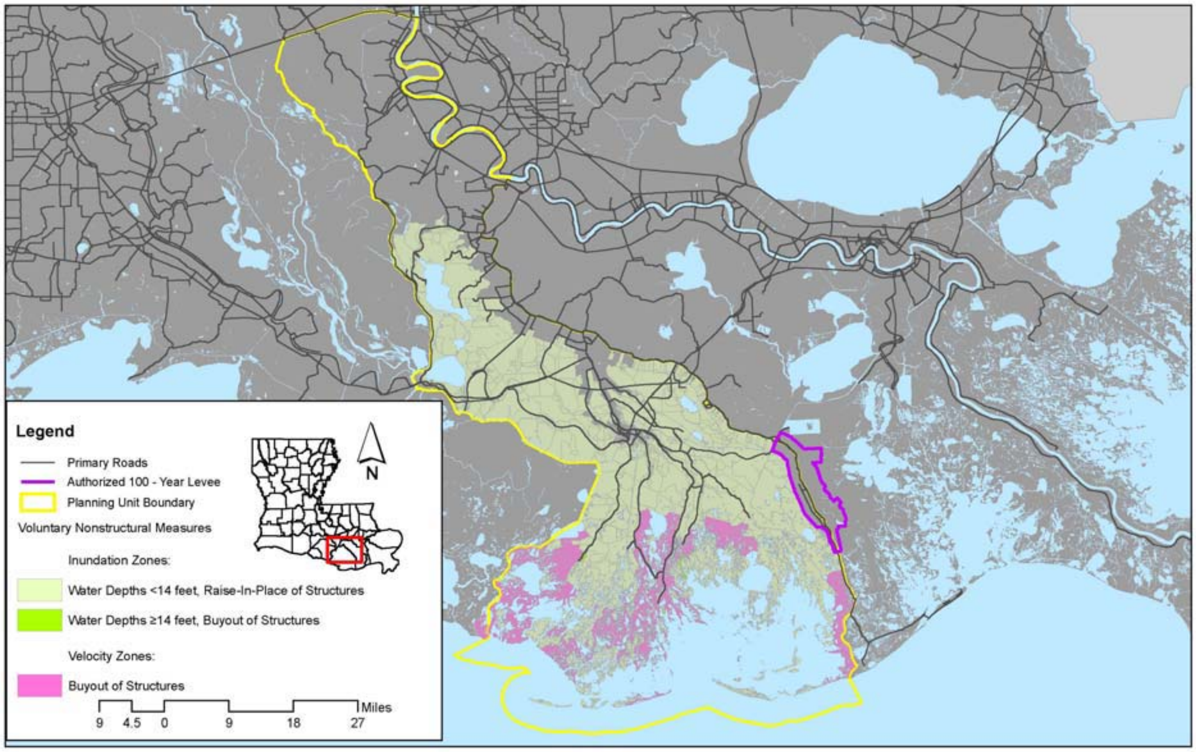


Figure 10-3. Example nonstructural plan in Planning Unit 3a.

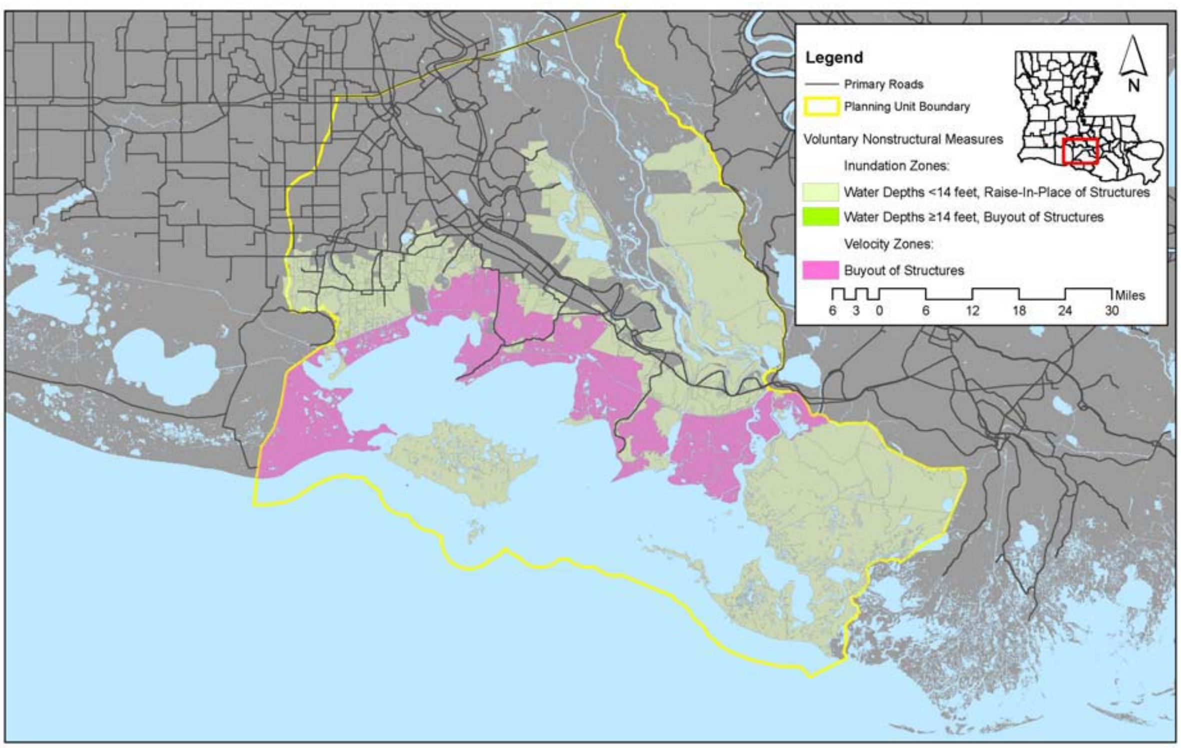


Figure 10-4. Example nonstructural plan in Planning Unit 3b.

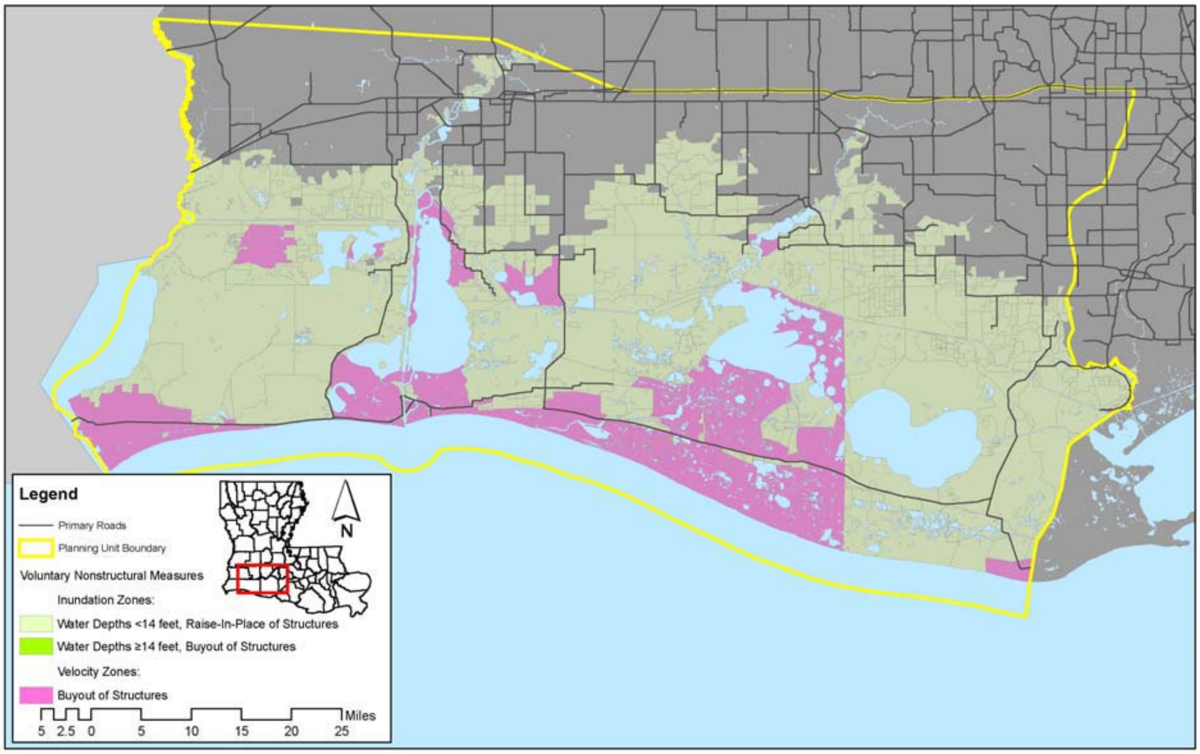


Figure 10-5. Example nonstructural plan in Planning Unit 4.

In Figure 10-1 for Planning Unit 1, all of the nonstructural measures appear outside of the existing levee system; however, the 400-year and 1000-year stand alone nonstructural plans (not shown) include measures within the New Orleans levee system to achieve the desired level of "Category 5" risk reduction across the planning unit. These plans would also have the effect of creating redundancy at the 100-year level of risk reduction.

Complementary Measures

Nonstructural measures were formulated in the residual floodplain of each structural alternative to conform to the level of risk reduction provided by that alternative. Decision criteria were applied in the same way as in the stand alone nonstructural measure formulation. As a result, the nonstructural measures formulated in the residual floodplain of the structural measures share the same components of V zone buyouts, buyout of structures whose census blocks demonstrate deep flooding of 14 feet or greater, and raising-in-place of structures whose census blocks demonstrated flooding between 3 feet and 13 feet. The magnitude and distribution of nonstructural measures based on depth of flooding changes with the structural measure considered.

When the complementary nonstructural measures are combined with the structural alternatives, the comprehensive alternative plans are formed. Comprehensive plans are designated by adding ‘C-’ in front of the structural alternative codes. See Attachment 1 for the complete list of alternatives.

Nonstructural Concept Plans

In addition to evaluation and comparison of nonstructural alternatives to coastal restoration, structural, and comprehensive alternatives throughout the report, the nonstructural analysis included development of a redundancy concept plan for the New Orleans area and an assessment of protecting critical facilities. These concept plans are independent of the other alternatives that were evaluated in detail throughout the rest of this report.

Redundant Measures Concept Plan

Redundancy of risk reduction measures is a critical aspect of creating a highly reliable risk reduction system. As a redundant feature, nonstructural measures contribute to management of the risk of interior flooding, whether from rainfall or from hurricane surges that may exceed the design capacity of the risk reduction system. An added benefit of this redundant system is found in the timing of implementation. Because nonstructural measures can typically be implemented incrementally, they could begin to reduce flood risk prior to completion of structural measures. Upon completion of the structural measures, the combined measures would provide redundancy to the flood control system.

The existing levee system surrounding the New Orleans area allowed the team to apply the concept of redundancy as a multiple lines of defense strategy for risk reduction. The development of a redundant nonstructural concept plan for the New Orleans area addresses the City's expressed interest in achieving a resilient and sustainable economic recovery and provides an example of the magnitude of resources that would be required to affect a more reliable risk reduction system in an urban area such as New Orleans. This concept plan entails raising-in-place of all eligible existing and projected future structures within the New Orleans metropolitan levee system to +1 foot elevation (see **Figure 10-6**).

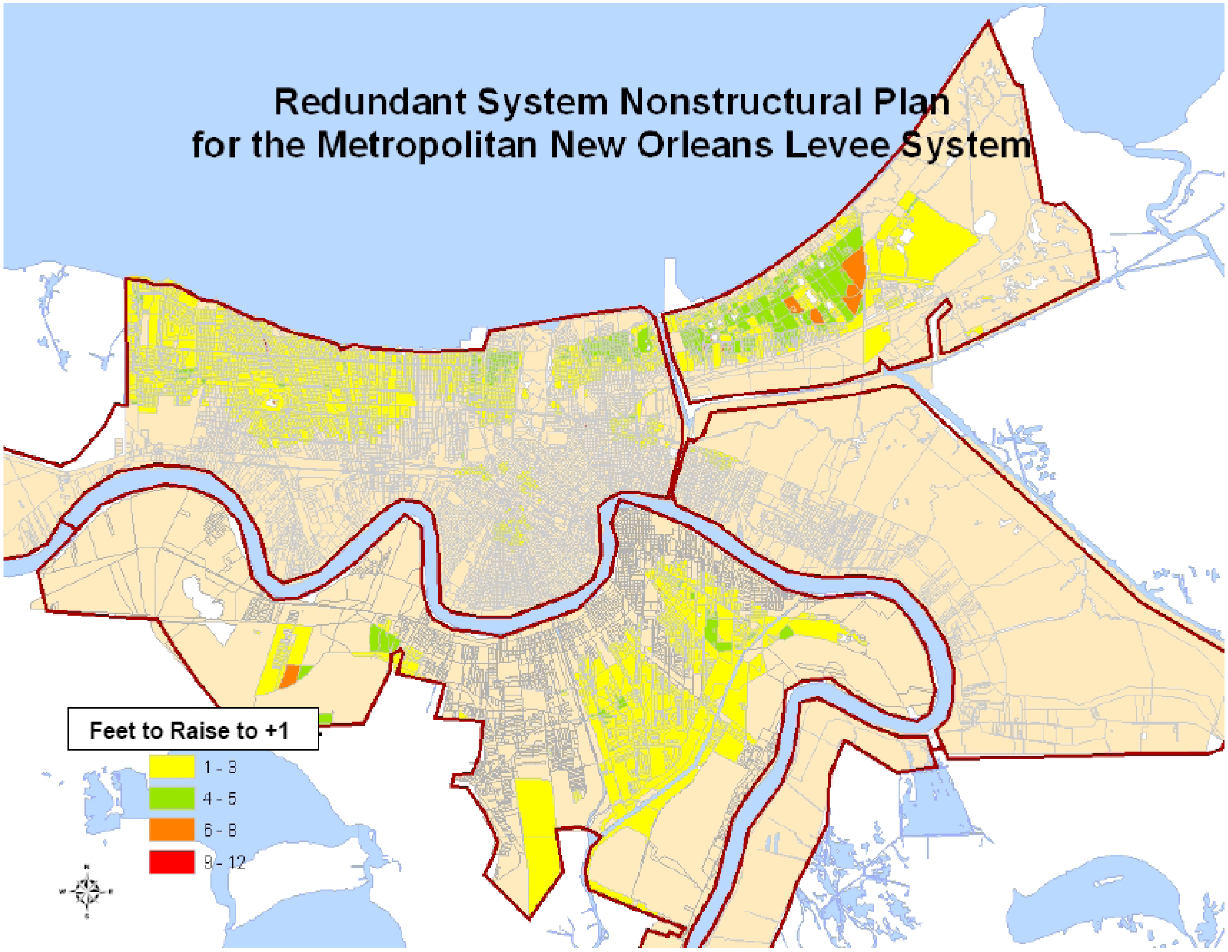


Figure 10-6. Redundant nonstructural concept plan for New Orleans.

Information upon which the analysis was based stems from data developed for the economic analysis. Topographical data obtained from the LIDAR digital elevation model using the NAVD88 (2004.65 epoch), which were used for the IPET study area, were combined with census block boundaries obtained from the 2000 Census using GIS mapping to determine the mean ground elevation for each census block in the New Orleans metropolitan area. The +1 foot value was calculated based on a difference between the mean ground elevations of census blocks, consistent with the reference datum of NAVD 88 (2004.65).

Elevating structures to +1 foot might not be sufficient to guarantee redundancy in a risk reduction system since relative sea level rise and other important considerations were not included in this particular analysis; however, this exercise was not intended to be a precise calculation of benefits and costs, in fact, no benefits were derived for this exercise at all. The derivation of cost for a redundant nonstructural concept plan for the Greater New Orleans levee system was intended to demonstrate the minimum order of magnitude of effort and resources required in creating a back-up or redundant measure for risk reduction in the face of catastrophic failure of the levee system. Actual implementation would require more detailed information than what was available for the

LACPR effort; however, this plan demonstrates conceptually the potential magnitude and cost for achieving a back-up system of risk reduction with the Metropolitan New Orleans area.

In total, a plan for elevating all structures below an elevation of +1 foot within the New Orleans levee system to an elevation of +1 foot would cost between $23 and $28 billion. This plan would impact between 160,000 to 230,000 structures and an associated population between 320,000 and 460,000 residents. The levee system and coastal features would provide risk reduction from storm surge. The redundant nonstructural concept plan would provide redundant security to the City's economic assets from any flooding source.

Protection of Critical Facilities

One way to create resiliency within the communities of South Louisiana is to protect vulnerable public and private facilities that are critical to the health and safety of the resident population, especially in the aftermath of storms. Critical facilities are related to critical actions. The FEMA definition of a critical action is "any action for which even a slight chance of flooding would be too great."

Over 1,500 critical facilities have been identified within the LACPR planning area using FEMA's Hazard U.S.-Multihazard (HAZUS-MH) database. For LACPR, critical facilities are defined as hospitals, police and fire protection facilities, water treatment facilities, city halls, emergency operations centers, and schools that could serve as evacuation centers. The assumption implicit to the critical facilities analysis is that privately-owned, profit-based industries, such as refineries and power plants, have within their basic operating budgets accommodations for emergency response and recovery so that this category of facilities would not require Federal support for protection.

The desired base flood elevation for critical facilities as stated in Executive Order 11988 is outside the 500-year floodplain or protected to the 500-year stage as a minimum requirement. Many critical facilities in southern Louisiana are subject to high velocity storm surge or deep inundation, indicators of a high degree of risk. In order to best serve their surrounding communities, however, it may be important that these facilities remain at their present locations.

Protection of critical facilities can be addressed through either relocation or flood proofing. Depth of inundation and surge velocity were used to determine the preferred measure. Flood proofing was only considered for structures subject to water depths up to 6 feet. For structures that had water depths greater than 6 feet, relocation was selected as the preferred nonstructural measure. Any critical facility that is located within a V zone or extreme high hazard area was subject to relocation and buyout. In total, 600 structures would be eligible for flood proofing or relocation based on depth of flooding at an estimated total cost of $3.2 billion.

Section 11. Alternatives for Evaluation and Comparison

Once the individual plan formulation components described in the previous three sections were complete, the team developed alternative plans with differing combinations of the remaining structural, nonstructural, and coastal restoration components for each of the five planning units. The alternative plans were formulated to present strategically different options for providing solutions to identified flooding problems. Comparison of the outputs and effects of these different types of actions, including the no action alternatives, allow for identification and documentation of tradeoffs to be considered in the decision making process.

Categories of Alternatives

Over 100 alternatives have been evaluated for this technical report, which fall into one of five categories:

1. **No action alternatives** are the future without project conditions.
2. **Coastal restoration alternatives** in which the only action taken is coastal restoration.
3. **Nonstructural alternatives** in which stand-alone nonstructural measures are added to coastal restoration.
4. **Structural alternatives** in which structural measures are added to coastal restoration.
5. **Comprehensive alternatives** are combinations of coastal restoration, structural measures, and complementary nonstructural measures which generally provide a uniform level of risk reduction for hurricane surge throughout all areas in the planning unit. The complementary nonstructural measures were formulated in the residual floodplains not protected by structural measures.

The individual alternatives in each of the five categories are briefly described below. More detailed descriptions are included in Attachment 1.

Note: Each alternative “number” or code (shown in bold) is sometimes preceded by the planning unit number (PU#-) when necessary to distinguish between similar alternatives in different planning units. The numbers 100, 400, and 1000 used in the alternative codes denote the approximate design level of that alternative, e.g. 1000-year level of risk reduction.

No Action Alternatives

Each planning unit has a no action alternative for a total of five no action alternatives across the coast. No action alternatives are denoted by a zero after the planning unit number, e.g. **PU1-0, PU2-0, etc**.

Coastal Restoration Alternatives

Across the coast, there are a total of nine coastal restoration alternatives. Planning Units 1 and 2 each have three coastal restoration (“R”) alternatives: **R1, R2, and R3**. In Planning Units 1 and 2, coastal restoration alternative **R2** is used as the representative landscape for combining with the structural, nonstructural, and comprehensive alternatives. The only coastal restoration alternative in Planning Units 3a, 3b, and 4 is **R1**, which is also used as the representative landscape in those planning units.

Nonstructural Alternatives

Each planning unit has three nonstructural ("NS") alternatives representing the 100-year, 400-year and 1000-year levels of risk reduction, i.e. **NS-100, NS-400, and NS-1000**, for a total of 15 nonstructural alternatives across the coast. The nonstructural alternatives include maintenance of the coast (see Coastal Restoration Alternatives above).

Structural and Comprehensive Alternatives

Structural and comprehensive alternatives can be grouped together because each comprehensive alternative builds on a corresponding structural alternative. A "**C-**" is added to the front of the structural code to denote the corresponding comprehensive alternative. The structural and comprehensive alternatives also include maintenance of the coast (see Coastal Restoration Alternatives above). Structural and comprehensive alternatives are discussed by planning unit and by the primary structural strategies within each planning unit in the following sections.

Planning Unit 1 - In Planning Unit 1, the two primary strategies are the Lake Pontchartrain surge reduction strategy (barrier-weir) and the High Level strategy (perimeter levees along the lake shoreline). Within the Lake Pontchartrain Surge Reduction and High Level strategies, there are a number of options for levees in different areas (e.g. Northshore, Slidell, Laplace, upper Plaquemines Parish, etc.). **Table 11-1** below groups the structural alternatives in Planning Unit 1 by strategy and features.

Table 11-1. Structural alternatives in Planning Unit 1 by strategy and features.

Strategy	Structural Alternatives	Levee Features					
		Weir Barrier	South Shore	North Shore	Slidell	Laplace	Upper Plaquemines
Lake Pontchartrain Surge Reduction (LP-)	LP-a-100-1 LP-b-400-1 LP-b-1000-1	X	X				X
	LP-a-100-2 LP-b-1000-2	X	X	X	X	X	X
	LP-a-100-3 LP-b-400-3	X	X		X	X	X
High Level (HL-)	HL-a-100-2 HL-b-400-2		X	X	X	X	X
	HL-a-100-3 HL-b-400-3		X		X	X	X

In **Table 11-1**, note that the 400-year plan is missing from the second set of barrier-weir plans and the 1000-year plan is missing from the third set of barrier-weir plans. Similarly, the 1000-year plans are missing from both sets of High Level plans. The reason is that these alternatives were screened during the Tier 3 screening of structural measures because of relatively poor performance. Additional information on the screening of alternatives in all planning units can be found in the *Structural Plan Component Appendix*.

Planning Unit 2 *-* In Planning Unit 2, the three primary strategies are the West Bank strategy (no new levees), the Ridge strategy (build on natural ridges), and the GIWW strategy (build along the GIWW). Within the Ridge and GIWW strategies, there are a number of options for levees in different areas (e.g. Boutte, Des Allemands, etc.). All Planning Unit 2 alternatives at the 400-year and 1000-year design levels include raising the existing Larose to Golden Meadow ring levee to the corresponding design level. **Table 11-2** below groups the structural alternatives in Planning Unit 2 by strategy and features.

Table 11-2. Structural alternatives in Planning Unit 2 by strategy and features.

Strategy	Structural Alternatives	Levee Features							
		Sector Gate	West Bank	Larose to GM	Barrier Weir	Boutte	Lafitte	Des Alle-mands	Bayou La-fourche
West Bank (WBI-)									
	WBI-100-1 WBI-400-1	X	X	X					
Ridges (R-)									
	R-100-2 R-400-2	X	X	X		X	X		
	R-100-3 R-400-3	X	X	X		X	X	X	
	R-100-4 R-400-4 R-1000-4	X	X	X		X	X	X	X
GIWW (G-)									
	G-100-1	X	X	X	X		X		
	G-100-4 G-400-4 G-1000-4	X	X	X	X	X	X	X	X

Planning Unit 3a - In Planning Unit 3a, one of the two primary strategies is to extend and/or improve the existing Morganza to the Gulf and Morgan City and Vicinity projects. The other primary strategy is to supplement the authorized Morganza to the Gulf project with a second line of defense along the GIWW. Within the Morganza/Morgan City strategy, the two options are to extend a continuous levee to the west of Morgan City or to tie the Morganza levee to high ground and build a ring levee around Morgan City. **Table 11-3** below groups the structural alternatives in Planning Unit 3a by strategy and features.

Table 11-3. Structural alternatives in Planning Unit 3a by strategy and features.

Strategy	Structural Alternatives	Levee Features			
		Morganza to the Gulf	Houma to Morgan City	Morgan City Ring Levee	Houma GIWW
Morganza and Morgan City (M-)					
	M-100-1	X	X		
	M-100-2	X		X	
GIWW (G-)					
	G-400-2 G-1000-2	X		X	X

The reason there is no G-100-2 GIWW alternative is because the authorized 100-year Morganza to the Gulf levee alignment was considered a likely alternative (even though it wasn't included in the without-project conditions). Therefore, the GIWW alignments were developed as a second line of defense behind the 100-year Morganza levees creating a higher level of risk reduction for the Houma area. As such, a 100-yr level alternative was not developed following this levee alignment. In actuality, the so-called 100-year Morganza to the Gulf levee by itself provides a higher level of risk reduction than 100-year to the Houma area.

The 400-year and 1000-year Morganza/Morgan City alternatives were eliminated from further consideration during the Tier 3 screening of structural alternatives because of relatively poor performance. These alternatives had excessive costs and numerous constructability issues because of poor foundation conditions in this area. Additional information on the screening of alternatives in all planning units can be found in the *Structural Plan Component Appendix*.

Planning Unit 3b - In Planning Unit 3b, the three primary strategies are a continuous levee along the GIWW, a continuous levee inland of the GIWW ("Franklin to Abbeville") and a series of ring levees. **Table 11-4** below groups the structural alternatives in Planning Unit 3b by strategy and features.

Table 11-4. Structural alternatives in Planning Unit 3b by strategy and features.

Strategy	Structural Alternatives	Levee Features					
		Patterson RL	GIWW	Franklin to Abbeville	Franklin RL	New Iberia RL	Abbeville RLs
GIWW (G-)							
	G-100-1	X	X				
Franklin to Abbeville (F-)							
	F-100-1 F-400-1 F-1000-1	X		X			
Ring Levees (RL-)							
	RL-100-1 RL-400-1				X	X	X

Planning Unit 4 - In Planning Unit 4, the two primary strategies are 1. levees along the GIWW 2. a ring levee-only plan or 3. Within the continuous GIWW levee strategy, the three options are as follows:

- A continuous levee that is designed to connect to a similar levee in Planning Unit 3b.
- A continuous levee that can be a stand alone alternative (doesn't depend on what is built in PU3b).
- A 12-foot continuous levee that relies on additional ring levees to reach the desired level of risk reduction.

Table 11-5 below groups the structural alternatives in Planning Unit 4 by strategy and features.

Table 11-5. Structural alternatives in Planning Unit 4 by strategy and features.

Strategy	Structural Alternatives	Levee Features						
		GIWW Levee	GIWW 12-ft Weir	Lake Charles	Vinton/ Sulphur	Kaplan Tieback	Kaplan RL	Gueydan RL
GIWW (G-)								
	G-100-1	X		X	X			
	G-100-2	X		X	X	X		
	G-400-3 G-1000-3		X	X	X	X	X	X
Ring Levees (RL-)								
	RL-100-1 RL-400-1 RL-1000-1			X	X		X	X

Summary of Alternatives Evaluated

Table 11-6 provides a summary of the alternatives that were evaluated in each planning unit by category. A map showing each of the 111 individual alternatives can be found in the *Evaluation Results Appendix*. Attachment 1 at the end of this report contains descriptions of each alternative and an explanation of codes used to refer to the alternatives.

Table 11-6. Summary of LACPR alternatives evaluated.

Category	Planning Unit 1	Planning Unit 2	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
No Action	PU1-0	PU2-0	PU3a-0	PU3b-0	PU4-0
Coastal Restoration	PU1-R1	PU2- R1	PU3a-R1	PU3b-R1	PU4-R1
	PU1-R2	PU2-R2			
	PU1-R3	PU2-R3			
Non-structural*	PU1-NS-100	PU2-NS-100	PU3a-NS-100	PU3b-NS-100	PU4-NS-100
	PU1-NS-400	PU2-NS-400	PU3a-NS-400	PU3b-NS-400	PU4-NS-400
	PU1-NS-1000	PU2-NS-1000	PU3a-NS-1000	PU3b-NS-1000	PU4-NS-1000
Structural*	PU1-LP-a-100-1	PU2-WBI-100-1	PU3a-M-100-1	PU3b-G-100-1	PU4-G-100-1
	PU1-LP-a-100-2	PU2-WBI-400-1	PU3a-M-100-2	PU3b-F-100-1	PU4-G-100-2
	PU1-LP-a-100-3	PU2-R-100-2	PU3a-G-400-2	PU3b-F-400-1	PU4-G-400-3
	PU1-LP-b-400-1	PU2-R-400-2	PU3a-G-1000-2	PU3b-F-1000-1	PU4-G-1000-3
	PU1-LP-b-400-3	PU2-R-100-3		PU3b-RL-100-1	PU4-RL-100-1
	PU1-LP-b-1000-1	PU2-R-400-3		PU3b-RL-400-1	PU4-RL-400-1
	PU1-LP-b-1000-2	PU2-R-100-4			PU4-RL-1000-1
	PU1-HL-a-100-3	PU2-R-400-4			
	PU1-HL-a-100-2	PU2-R-1000-4			
	PU1-HL-b-400-3	PU2-G-100-1			
	PU1-HL-b-400-2	PU2-G-100-4			
		PU2-G-400-4			
		PU2-G-1000-4			
Comp-rehensive* (Structural and Non-structural)	PU1-C-LP-a-100-1	PU2-C-WBI-100-1	PU3a-C-M-100-1	PU3b-C-G-100-1	PU4-C-G-100-1
	PU1-C-LP-a-100-2	PU2-C-WBI-400-1	PU3a-C-M-100-2	PU3b-C-F-100-1	PU4-C-G-100-2
	PU1-C-LP-a-100-3	PU2-C-R-100-2	PU3a-C-G-400-2	PU3b-C-F-400-1	PU4-C-G-400-3
	PU1-C-LP-b-400-1	PU2-C-R-400-2	PU3a-C-G-1000-2	PU3b-C-F-1000-1	PU4-C-G-1000-3
	PU1-C-LP-b-400-3	PU2-C-R-100-3		PU3b-C-RL-100-1	PU4-C-RL-100-1
	PU1-C-LP-b-1000-1	PU2-C-R-400-3		PU3b-C-RL-400-1	PU4-C-RL-400-1
	PU1-C-LP-b-1000-2	PU2-C-R-100-4			PU4-C-RL-1000-1
	PU1-C-HL-a-100-3	PU2-C-R-400-4			
	PU1-C-HL-a-100-2	PU2-C-R-1000-4			
	PU1-C-HL-b-400-3	PU2-C-G-100-1			
	PU1-C-HL-b-400-2	PU2-C-G-100-4			
		PU2-C-G-400-4			
		PU2-C-G-1000-4			

*In Planning Units 1 and 2, coastal restoration alternative R2 was included as the representative landscape in combination with the structural, nonstructural, and comprehensive alternatives. In Planning Units 3a, 3b, and 4, R1 was used as the representative landscape for the evaluation; however, subsequent to the evaluation, the coastal restoration component was removed from the alternatives in the final array because it was not found to contribute to risk reduction.

Section 12. Metrics and Evaluation of Alternatives

In order to illustrate the varying risks and costs associated with different plans, the team evaluated a range of alternatives to assess economic, social, ecological, and cultural benefits and impacts, as well as construction, operations, maintenance, and repair costs. The alternatives help show differences between various inundation frequencies (100-year, 400-year, and 1000-year) and what they mean in terms of levee heights, costs, and residual damages. The following sections describe the methodology and performance metrics used to evaluate the 111 alternatives listed in the previous section. Details on hydrologic and metric results are included in the *Evaluation Results Appendix*. **Table 12-1** presents a summary of plan evaluation considerations, which are described elsewhere in this document and/or the appendices:

Table 12-1. Summary of plan evaluation considerations.

Parameter or Case	Variations
Structural and Nonstructural Design Levels	100-year risk reduction design
	400-year risk reduction design
	1000-year risk reduction design
Flood Events	10-year rainfall event
	100-year surge event
	400-year surge event
	1000-year surge event
	2000-year surge event
Water Level Confidence Limits	10 percent (high uncertainty)
	50 percent (mid uncertainty)
	90 percent (low uncertainty)
Waves	Without friction
Coastal Landscape	Existing/maintain
	Degraded (no action)
Future Relative Sea Level Rise (sea level rise and subsidence)	Projection 1 (“low”)
	Projection 2 (“high”)
Development Rates	High employment growth, dispersed land use
	Business as usual growth, compact land use
Hydrologic Conditions	Existing/base (approximately 2010)
	Future (approximately 2060)
Economic Conditions	Base year (2025)
	End of period of analysis (2075)

Evaluating the Planning Objectives Using Metrics

Metrics are an essential component of the risk-informed decision framework. Metrics were developed and used to evaluate alternative plans to establish the degree to which they satisfy the planning objectives. Metrics involve quantification of a complex array of human and natural system drivers. Therefore, any set of metrics will not be representative of all the decision factors that could be brought to bear on the problem. For this reason, metrics are often referred to as indicators that emphasize the representational relationship between elements of complex systems. They are indicative, but not definitive, gauges and consequently must be interpreted with their limitations in mind.

Effective metrics must be scientifically verifiable, easy to communicate to a wide audience, credible, scalable, relevant, sensitive enough to capture the minimum meaningful level of change, minimally redundant, and transparent. One or more metrics is used to measure performance against each of the five LACPR planning objectives as shown in **Table 12-2**. In selecting this set of metrics, the LACPR team strove to represent the best available information for evaluating alternatives keeping in mind the characteristics of effective metrics. Quantitative values were developed for each of the metrics for each of the 111 alternatives.

Table 12-2. LACPR planning objectives and related metrics.

Planning Objectives	Metrics
Reduce risk to public health and safety from catastrophic storm inundation.	Population Impacted
Reduce damages from catastrophic storm inundation.	Residual Risk/Damages
	Life Cycle Cost
	Non-Federal Share of Life Cycle Cost
	Construction Time
	Gross Regional Output Impacted
	Employment Impacted
	Earned Income Impacted
Promote a sustainable coastal ecosystem. Restore and sustain diverse fish and wildlife habitats.	Direct Wetland Impacts
	Indirect Environmental Impact Score
	Spatial Integrity
	Wetlands Created/Protected
Sustain the unique heritage of coastal Louisiana by protecting cultural resources and supporting traditional and ethnic communities.	Historic Properties Protected
	Historic Districts Protected
	Archaeological Sites Protected

The following sections briefly describe each of the metrics and the important underlying assumptions associated with their use. Metric estimates were derived from mathematical models, empirical data, and/or expert opinion. For most of the metrics, estimates of uncertainty have been quantified in terms of the variance or range associated with the estimate to support risk-informed decisions.

Cost and Construction Time Metrics

The life cycle cost and construction time metrics measure the time and money investment required by each alternative. Details on the construction time metric and the cost assumptions for the structural and coastal restoration plan components can be found in the *Engineering Appendix*. Details on the nonstructural plan cost assumptions can be found in the *Nonstructural Plan Component Appendix*.

Life Cycle Cost

The life cycle cost metric represents the total cost of implementing an alternative plan, which includes first costs plus operation and maintenance, repair, replacement and rehabilitation costs. First costs include engineering and design, facility relocations, real estate, mitigation, and construction costs. Construction costs include the cost of materials and construction of physical structures as well as construction management costs. Construction costs also include costs associated with maintaining the risk reduction levels of structural measures into the future associated with relative sea level rise and/or degradation of the coast, i.e. future levee lifts. The life cycle cost metric does not include adaptive management or monitoring costs.

Life cycle costs are presented both as annual equivalents and present values at year 2025 in millions of dollars. The cost estimates were developed using post-Hurricane Katrina impacts to labor, equipment, materials, and supplies. The estimated costs were based upon an analysis of each line item evaluating quantity, production rate, and time, together with the appropriate equipment, labor, and material costs. All cost estimates used to evaluate and compare alternatives included a 25 percent contingency. Cost estimates for the final array of options are first costs only and include a 50 percent contingency.

Non-Federal Share of Life Cycle Cost

The non-Federal share of the life cycle costs (i.e. State and local costs) would be 35% or more of the total cost. The non-Federal share of life cycle costs are present values at year 2025 in millions of dollars.

Construction Time

The construction time metric represents the length of time required to design and construct an alternative plan so that most of its intended benefits are realized. The following assumptions were applied to the construction time metrics for the various categories of alternatives:

Coastal restoration only plans have a metric value for construction time of 15 years, representing an average time for the following measures:

- 25 years for shoreline protection (Planning Unit 4 only), marsh creation and ridge restoration
- 15 years for diversions, relocation of navigation channels, and bypass channels
- 10 years for shoreline protection (Planning Units 1, 2, and 3b only) and barrier islands
- 5 years for fresh water redistribution

Nonstructural/coastal restoration plans have a metric value for construction time of 15 years, which is based on the nonstructural component.

Structural/coastal restoration plans and *comprehensive plans* have a metric value for construction time which is based only on the structural component of the plans. Construction of structural measures ranges from 6 to 16 years.

Socio-Economic Metrics

The socio-economic metrics measure impacts to people, assets, and the regional economy. Metrics include population impacted, residual damages, employment impacted, gross regional output (sales) impacted, and earned income impacted. Data for each metric were developed for five frequency events (10-year, 100-year, 400-year, 1000-year, and 2000-year) to derive expected annual values. These expected annual values were converted to an equivalent annual value using the Federal discount rate. Further details on these metrics can be found in the *Economics Appendix*.

Population Impacted

The population impacted metric is a measure of the number of residents who would experience any amount of flooding after implementation of an alternative plan. This metric represents part of the residual risk to health and safety of the residential population impacted. The impacted population is defined as the total number of residents in each census block in which the stage associated with a frequency storm event is greater than the mean ground elevation of that census block. The population metric does not consider the portion of the population that would evacuate before a storm event and is not a measure of personal safety.

Residual Damages

The residual damages metric represents the remaining risk to assets from flooding after implementation of an alternative plan. Residual damages include damages to residential and non-residential properties, emergency response costs, losses to agricultural resources, and damages to transportation infrastructure. Residual damages are expressed both in annual equivalent terms and as a total for each of the five frequencies (10-year to 2000-year).

Gross Regional Output, Employment, and Earned Income Impacted

The sales, employment, and wages associated with each commercial property in a census block are assumed to be directly affected whenever the stage associated with a frequency storm event at the planning subunit level reaches or exceeds the first floor elevation of the structure. Indirect regional economic impacts, such as the reduced customer base following a storm event and the closing of related businesses, are not considered in the metric values. The employment impacted metric represents the number of jobs that would be disrupted for one or more days as a direct consequence of flooding after implementation of an alternative plan.

Environmental Metrics

The environmental metrics measure non-monetary effects on ecological resources including both the positive and adverse effects of alternative plans on the environment. The direct wetland impacts and the indirect environmental impact score metrics measure impacts of the structural plan components on the environment. The spatial integrity and wetlands created/protected metrics measure the benefits of the coastal restoration plan components. More details on these metrics can be found in the *Coastal Restoration Plan and Structural Environmental Impacts Appendix*.

Direct Wetland Impacts

The direct wetland impacts metric represents the amount of wetlands that would be displaced by an alternative plan. The acreage impacted includes the levee footprint and adjacent borrow areas used for levee construction. These wetland impacts would be offset by creating more acres of wetlands within the impacted basin.

Many of the proposed levee alignments cross wetlands and result in the direct loss of those wetlands occupied by the footprint of the levee and adjacent borrow areas. The magnitude of the impact is a function of the levee alignment and the levee height, which influences levee base width. The potential direct wetland losses are calculated by simply overlaying the footprint of a given levee and associated borrow areas on the existing coastal landscape, assuming that all construction impacts occur simultaneously. These simplifying assumptions produce acreages of potentially adverse direct wetland impacts.

Indirect Environmental Impact Score

The indirect environmental impact score represents the severity of potential aquatic ecosystem impacts (positive or negative) relative to other alternatives in the planning unit. This metric considers impacts to hydrology, fisheries, the potential to induce development of wetlands, and consistency with coastal restoration goals. Using best professional judgment based on extensive field experience; knowledge of pertinent scientific literature; and experience conducting Wetland Value Assessments for over 150 CWPPRA projects, the multi-agency Habitat Evaluation Team rated the various structural measures within each planning unit for their potential for positive or adverse indirect environmental impacts relative to each other.

Qualitative scores fall within the following ranges: -8 to -5 = Highly adverse impact, -4 to -1 = Moderately adverse impact; 0 = No impact (or sum of positive and negative impacts equal to zero); 1 to 4 = Moderately positive impact; 5 to 8 = Highly positive impact.

This metric compares levee alignments and their potential indirect impacts (both positive and negative) to wetlands and other aquatic resources. Hydrologic impacts are potential changes, such as reduced or increased impoundment; reduced or increased sheet flow; and reduced or increased salinities. In applying rankings, the team considered the amount of wetlands that would be enclosed within a proposed levee system. Other factors being equal, it is assumed that the greater the acreage of wetlands that would be enclosed within a proposed levee system, the greater the potential for adverse indirect impact.

Fishery impacts are potential reductions in fish access due to increased velocities and/or physical barriers; increases in fish access due to removal of obstructions; and/or reductions or increases in fish habitat.

Induced development is the potential increase or decrease in wetland areas with significantly improved hurricane protection and which are susceptible to residential, recreational, and/or commercial development.

Ecological sustainability/consistency (with coastal restoration) is the extent to which the proposed levee is or is not likely to be consistent with existing and future coastal restoration projects, particularly river reintroduction projects, i.e. diversions. This value also refers to the extent to which the proposed levee may or may not be located in a potentially sustainable environment.

Spatial Integrity

Spatial integrity relates to landscape stability or sustainability. A fragmented landscape (one containing several discrete patches of land or many inclusions of water) has less spatial integrity than a landscape containing fewer patches or inclusions. Spatial integrity is measured using a Landscape Stability Index which ranges from 0 to 1, with probability of land retention increasing as the index approaches 1. The Landscape Stability Index places emphasis not only on the amount of land built but the spatial configuration of that land.

Wetlands Created/Protected

The wetlands created/protected metric is a direct measure of the acres of wetlands created and/or restored and those existing wetlands protected from further degradation. Wetlands created and/or restored include both mechanical marsh creation and diversion of sediments and nutrients.

Cultural Resources Metrics

The cultural resources metrics measure non-monetary effects on cultural, prehistoric, and historic resources. More details on these metrics can be found in the *Cultural Resources Appendix.*

Historic Properties Protected

The historic properties protected metric represents the number of historic properties protected by an alternative plan. Historic properties include those listed or eligible for listing on the US Park Service's National Register of Historic Places or register of National Historic Landmarks. Historic properties are protected by hurricane risk reduction alternatives that reduce land loss, erosion, and flooding.

While archaeological sites are included in the number of historic properties, structures form an overwhelming majority. In general, cultural resources in these categories must meet criteria defined at a local or national level to be included. Examples of historic resources in this category include Fort Jackson, Oaklawn Manor, Jackson Square, and the Garden District.

Historic Districts Protected

The historic districts protected metric represents the number of historic districts protected by an alternative plan. Historic districts encompass living communities consisting of clusters of historic buildings and/or other structures that share a similar date or theme. Historic districts are protected by hurricane risk reduction alternatives that reduce land loss, erosion, and flooding.

Historic districts reflect the historic development in an area, help connect people to the past, contribute to the regional landscape, and serve to create a sense of place. Protecting historic districts helps to preserve the unique historic character of towns, neighborhoods, and rural settings, and conserve data that provides information about the past.

Historic districts may be urban neighborhoods, commercial districts, or rural landscapes, helping to define people's sense of place. In general, it's the collection of the properties that make historic districts important, and they can be viewed as the sum being greater than the parts. Examples of historic districts include the French Quarter, the Garden District, and the Abbeville Residential Historic District.

Archaeological Sites Protected

The archaeological sites protected metric represents the number of archeological sites protected by an alternative plan. Archaeological sites include locations with artifacts and other materials from people and cultures from the prehistoric and historic past. Archeological sites may include the remains of buildings, trash pits, hearths, pottery and tools (stone, metal and other materials). Archeological sites are protected by hurricane risk reduction system alternatives that reduce land loss, erosion, and flooding.

Section 13. Risk-Informed Decision Framework Development

The metrics described in the previous section provide the raw data needed to evaluate the performance of plans; however, the evaluation results for the individual metrics do not provide a coherent set of information that decision makers can use to make a decision. The information needs to be presented in such a way that decision makers are faced with the important economic, social, and environmental risks. In order to identify a final array of comprehensive, coastwide plans while considering risks and tradeoffs, the team developed an approach known as the Risk-Informed Decision Framework (RIDF). As an integral part of RIDF, the team performed a comprehensive evaluation of project alternatives through a stakeholder-based multi-criteria decision analysis (MCDA) exercise intended to provide comparable consideration of assets that are difficult to quantify in monetary terms.

Purpose and Limitations of the RIDF/MCDA

Over the course of the LACPR effort, considerable learning regarding the possible approach to, and application of, a risk-informed decision framework has occurred. Unfortunately, it has not yet been feasible to incorporate lessons learned to improve the deterministic elements of RIDF or MCDA. Nevertheless, RIDF/MCDA has been a successful means to inform tradeoffs and is an effective means of communicating the wide spectrum of risks to stakeholders.

The “risk informed” approach to the decision process was conceptualized in response to the performance of existing storm damage reduction system and the contrast between the public perception of their relative risk and the risk designed for in existing or proposed measures. It was clear following Hurricanes Katrina and Rita that the public appreciation of their level of residual risk with some level of storm damage risk reduction in place was, if not inaccurate, inadequate. Additionally, it was evident that traditional decision making criteria (maximizing NED using annualized costs and damages) would generally discount the impact of extreme, “Category 5” events due to their relative rarity, or low probability. While directing an investigation of measures to potentially supply reduction of risk for extreme events, Congress also alluded to that investigation being conducted in a multi- criteria environment.

The decision process should be refined to achieve greater sensitivity to the extreme impacts of relatively rare events and to provide a clearer understanding of both the relative risk reduction provided to, and the residual risk being assigned to, the public. To achieve these outcomes there are several functional needs: to define the number and range of planning criteria; to determine the potential variations and proportions of those criteria within the decision; to gather data in support of the determination and application of those proportions; and to identify or develop evaluation techniques to appropriately gauge performance relative to the criteria and to scale them to the extreme level of event being considered.

Ultimately, the legislatively directed singular purpose of the LACPR effort is the reduction of storm damage risk, particularly from extreme events. For the planning effort, the need for greater sensitivity to extreme events and the better communication of risk information was identified early in the process. The directive to develop a RIDF to effectively integrate all the aspects of the needs and desired outcomes came several months into the LACPR effort. Throughout the plan formulation process, the planning team sought to correctly identify and compare metrics for performance of each alternative, and to involve stakeholders in the evaluation and selection process. However, with the planning objectives, or criteria, already established, performance metrics already identified, and evaluations already underway, certain aspects of this framework were effectively set before the RIDF was developed. Despite these constraints, the planning team sought to develop and implement RIDF, and to integrate it with their prior and ongoing efforts. The resulting steps in the RIDF are as follows: 1. Stakeholder-based MCDA process 2. Comparison of the MCDA results with other individual criteria (efficiency, effectiveness, etc.) 3. Blending of the MCDA results with other criteria to identify final array of alternatives.

The initial objective for the application of MCDA was the full development of preference data through engagement with a diverse range of stakeholders to enable identification of, and to facilitate understanding of, risk reduction based alternatives. The MCDA process provides a platform for stakeholders to express and explore the relative importance of various performance related outputs and tradeoffs. As the planning effort developed, however, stakeholder-based MCDA results were found to discount alternatives that provide greater risk reduction or cost efficiency. While the development of an MCDA approach has made significant strides in pursuit of evaluation of plans in light of performance across broad criteria, it does not yet meet the initial expectations. With additional effort, the MCDA tool could be adapted to better achieve the desired integration of criteria, risk evaluation, and communication. Through iterative MCDA refinement and comparison of the range of individual preference patterns, and the resulting ordering of alternatives to best achieve the desired performance, stakeholders started to gain an understanding of performance, risk, and tradeoffs. Ultimately, the refined preference data and possible alternative choices based on this understanding will inform the decision process.

Over the course of completing alternative performance evaluations, and through iterative engagement and preference elicitation, several issues concerning both the MCDA tool and its application in LACPR surfaced. It first became evident that due to the lengthy duration of the performance evaluation process it would not be possible to adequately iterate the stakeholder elicitation feedback cycle required for an effective MCDA. Although two elicitation cycles were undertaken with stakeholders, the initial lack of final metric data required that two distinctly different elicitation processes be used. The difference in these techniques effectively limited the usefulness of the first cycle to a dry run of the engagement process and data processing, which was presented for internal and external technical review. The results of the second iteration of MCDA, although procedurally more sound, reveal some apparent inconsistency between the plan rankings resulting from the weighted preference patterns and the basic criteria preferences for population protection provided by the stakeholders. This inconsistency would normally be resolved through successive iteration. However, there was not sufficient time left in the LACPR planning process for those additional iterations. Without additional iterations of MCDA, limited confidence must be placed on the preferred alternatives identified through the stakeholder-based MCDA process.

The tested results from the initial MCDA stakeholder elicitation indicated that some potential for the identification of clusters of common stakeholder preference patterns might exist. When the data from the second stakeholder elicitation was similarly tested, no explainable clusters of common value could be identified. As a result, the stakeholder data, resulting preference patterns, and plan utility scores were evaluated entirely on an individual basis. The combinability of the stakeholder results was limited to ordinal rankings (based on utility score) for each individual, for any given plan, as a relative gauge of cumulative preference.

This data indicates that it might be possible to discern trends or consistencies across the individual plan rankings, despite variance in preference patterns. However, the data set is limited by the number and diversity of the stakeholders sampled. The stakeholder group sampled represented a number of public government, non-governmental organizations, and private industry groups. The sample lacks statistical significance relative to the coastal population and the relative diversity is uneven across the planning units. Both numbers and diversity should be improved upon overall. However, it seems unlikely that the present data set will converge on a single common preference pattern, or utility, even with adequate iteration cycles.

Based on these limitations, the planning team concluded that the MCDA tool is not a viable approach for a stand-alone risk based decision process; however, the MCDA still provides a valuable supplement to RIDF by providing a semi-quantitative gauge of stakeholder sentiment regarding performance value and plan preference. The MCDA should be continued to be improved upon as a method of capturing stakeholder input and facilitating the process of communicating value differences, plan tradeoffs, and relative risk. Additional steps must be taken to document the relative significance and diversity of the stakeholder sample, either statistically or through comparative demography.

The LACPR planning team also believes that additional risk informing value can be derived from comparing MCDA results with more traditional decision criteria employed by the USACE. This comparison was initially developed to provide a basis for identifying commonality in plan recommendation between these criteria. However, after further consideration it was concluded that, because of the inherent variation in the decisions they potentially could produce, some reaffirmation of the result based on traditional criteria related to effectiveness, efficiency, and acceptability (represented by the MCDA results) were fundamental to supporting the needs of fiscal decision makers. In addition they provide insight into potential tradeoffs and risk inherent in the decision process itself. Ranking results based on these criteria also provide a basis for the inclusion of alternatives that may be valued by the stakeholders based on their stated preference for plans which protect the population.

The development of evaluation criteria associated with effectiveness and efficiency also affords additional opportunity to better assess sensitivity of the decision process to the impact of extreme events. Utilizing the same basic evaluation data used in MCDA, additional assessment of relative plan effectiveness were performed to contrast the effect of annualized versus episodic (based on the period of analysis) damage probabilities. The percent of cumulative potential damage reduction, based on each of the probabilistic surge events assessed, was also considered as a measure of effectiveness. These values were then be contrasted with expressions of plan costs (annual or present value) to test plan efficiency.

The application of episodic probability for damage serves two potential purposes based on the period of analysis of 65 years employed in LACPR. First, the probabilities associated with the various level surge events (100-yr, 400-yr, 1000-yr, etc.) become more indicative of the chance of an individual experiencing those conditions within a lifetime at one location; and second those longer period probabilities produce a shift in the relative importance of rarer more extreme events in the decision process and therefore illustrate the relative benefit of higher levels of risk reduction. The application of results based on this type of expression of effectiveness could indicate a greater optimal level of protection than the application of traditional, annualized NED data. The result of considering these varied evaluations demonstrates there is observable variation, or potential tradeoff, and resultant risk, associated with possible decision approaches that should be considered.

In an effort to test the sensitivity of overall relative plan ranking to the varied evaluation criteria deemed to be important to decision makers, the effect of combining these criteria was investigated. Multiple combinations of these criteria were tested, aggregating the results for each criteria set. This assessment indicated that by assigning some level of relatively equal importance to each evaluation criteria a tier of consistent optimal plan performance might be identified. As a result, this approach is employed in the report as a method of optimizing across all evaluation considerations, and identifying plans that might merit further, more detailed consideration.

The results of this RIDF analysis provide some insight and may be used as a foundation for further evaluation and development. However additional investigation and refinement of both the MCDA approach for stakeholder value elicitation and the consideration of impacts from extreme storm events is recommended. The Findings, and Conclusions and Recommendations sections of this report identify some of the needs and possible actions that might be utilized to continue to refine and development a risk informed decision approach.

Stakeholder-Based MCDA Process

Multi-Criteria Decision Analysis (MCDA) is a key tool to aid stakeholders in their understanding of risk and plan tradeoffs. The MCDA allows the individual stakeholder to assign importance and weight to each selected plan performance attribute. MCDA using stakeholder values is one of several approaches employed by the LACPR team to support the quantitative comparison and ranking of alternative plans. The MCDA tool provides the means to weigh a plan's performance with respect to planning objectives and the relative value stakeholders place upon those objectives. The MCDA process also provides the means for exploring the implications of variation among stakeholders in these values on plan scoring and ranking. MCDA results provide a basis for examining and discussing differences and similarities, both in the expressed values and their ultimate effect on the comparison and ranking of plans.

A Common Example of MCDA: Buying a Car

Buying a car is a decision problem that is common to the experience of most people. A large SUV has the passenger compartment space and safety rating that you desire but has poor fuel efficiency. At the same time, your spouse would prefer the style and comfort of a luxury sedan and is concerned about the resale value of an SUV having poor fuel efficiency. You and your spouse are both concerned about the initial cost and repair and maintenance costs of any vehicle you choose.

All the basic elements of a complex water resources planning problem, including LACPR, are included in this simple example. Because of a problem or need (lack of a source of transportation), a decision must be made (which car to buy). The decision will be made based on consideration of specific criteria or attributes (cost, resale value, repair/maintenance cost, fuel efficiency, passenger compartment space, style and comfort, and safety rating). Multiple decision makers (you and your spouse) having different values complicates the decision. Tradeoffs cannot be avoided; choosing one thing simultaneously means not choosing another. One attribute may be more important than another and there may not be complete agreement with the weights you and your spouse give to the criteria. Not everyone, and perhaps no one, is going to be perfectly satisfied with the decision making process or the ultimate decision.

MCDA is a method that can quantitatively and objectively show the top ranked cars for both you and your spouse. Perhaps you will discover that one or more cars appear in both you and your spouse's list. Certain cars won't appear at the top of either or your lists and you can discard those options. You may be able to reduce the list of possible options from five to two cars. Now you can begin to negotiate on the remaining options.

In the car buying example, several attributes (fuel efficiency, cost, safety rating, style and comfort, etc.) provided measurements of a car's performance for a range of consumer objectives. Similarly, the LACPR metrics previously described in this report (population impacted, residual damages, direct wetland impacts, etc.) provide the measurement of a plan's performance against the basic objectives identified for LACPR. Unlike the car example, however, stakeholders may not completely understand how components of risk reduction link to one another. Although stakeholders likely understood the metric definitions and could therefore effectively express which metrics they valued, the LACPR team is not confident that the resulting rankings reflect the stakeholders' true preference for risk reduction plans. Without a feedback loop the LACPR team can't be sure whether the MCDA output fully captured stakeholder desires.

Stakeholder Workshops and Participants

In order to gather input from stakeholders for the MCDA process, the LACPR team held a series of workshops in four locations across coastal Louisiana. The purpose of the stakeholder workshops was to collect information on stakeholder preferences by finding out how much importance stakeholders place on the various metrics. Hence, by design, stakeholders did not rank plans. Information about stakeholder preferences was obtained through a series of workshops during which stakeholders participated in assessments that obtained information on their preferences. These preferences were expressed by ranking and then rating the metrics. These values were later used to calculate the score by which decision alternatives were ranked.

Workshops were held July 28 through July 31, 2008 in Abbeville, Lake Charles, New Orleans, and Houma. As part of these stakeholder workshops, the USACE engaged local elected officials, parish governments, various civic organizations, business interests, as well as State and Federal agencies and others. The USACE developed its list of stakeholders based on its past relationships with the stakeholder community, input from its State partner, as well as cooperative efforts with community and civic leaders. A group of 114 stakeholders, representing diverse interests such as business, government, and not-for-profit, participated in the workshops where data was gathered on how stakeholders allocate importance across performance objectives/metrics and define tradeoffs among the metrics.

Swing Weighting Technique

A key component of the MCDA process is determining weights, or values, for each metric in relation to the other metrics. The stakeholder workshop interactions assessed individual stakeholder preferences with respect to a set of performance metrics chosen to evaluate the alternatives using a swing-weighting technique. As part of the swing-weight exercise, stakeholders ranked and rated metrics. Stakeholders did not rank plans.

In the first step, each stakeholder was asked to rank order the metrics taking into consideration each metric's associated value ranges. Assuming that each metric was at its worst possible level, the stakeholder was asked which metrics she or he would most prefer to change from its worst to its best level. This same question was then asked for each of the remaining metrics. The final order of the metrics is assumed to reflect their subjective importance to each stakeholder. In the next step, each participant was shown her or his ranked metrics with 100 points being given to the top ranked metric. Each stakeholder could then allocate from 0 to 100 points for each of the remaining metrics. Weights were later derived from those point allocations.

Table 13-1 was presented to stakeholders at the swing-weight elicitation workshop before they began the swing-weighting exercise. The worst case outcome and best case improvement values shown in this table represent the most extreme metric results generated across the range of all with and without project alternatives within the planning unit for any scenario or any confidence level. If a metric value doesn't vary much between alternatives, then allocating a large proportion of weight to that metric may not affect the ranking of plans as much as allocating a large proportion of weight to a metric that has a wide variation in metric values.

Note: Four of the metrics evaluated and included in an initial iteration of MCDA were not used in the MCDA swing-weighting exercise. The regional economic metrics gross regional output impacted and earned income impacted were not included because they were found to be redundant to the employment impacted metric. The environmental metrics spatial integrity and wetlands created/protected were not included because they had the same value for all plans except for the no action plan and therefore did not influence plan rankings.

Table 13-1. Summary of worst and best case metric results for all alternatives.

Metric	Best/Worst	Planning Unit				
		1	2	3a	3b	4
Population Impacted (# of people/year)	Worst Case Outcome	55,748	31,441	20,522	8,345	5,279
	Best Case Improvement	25,257	7,845	5,049	1,526	1,698
Residual Damages ($ millions/year)	Worst Case Outcome	2,129	2,285	1,221	529	465
	Best Case Improvement	151	110	149	70	87
Life Cycle Cost ($ millions/year)	Worst Case Outcome	3,777	3,147	2,765	1,857	1,388
	Best Case Improvement	0	0	0	0	0
Construction Time* (years)	Worst Case Outcome	16	15	15	15	15
	Best Case Improvement	0	0	0	0	0
Employment Impacted (# of jobs disrupted/year)	Worst Case Outcome	11,040	9,325	6,024	2,358	1,105
	Best Case Improvement	411	300	557	308	225
Indirect Environmental Impact Score (unitless scale: -8 to +8)	Worst Case Outcome	-8	-8	-7	-8	-6
	Best Case Improvement	0	4	0	2	0
Direct Wetland Impacts (acres)	Worst Case Outcome	9,100	9,500	6,600	5,200	2,500
	Best Case Improvement	0	0	0	0	0

Metric	Best/Worst	Planning Unit				
		1	2	3a	3b	4
Historic Properties Protected (# of properties)	Worst Case Outcome	119	11	0	2	0
	Best Case Improvement	159	27	18	20	3
Historic Districts Protected (# of districts)	Worst Case Outcome	38	0	0	0	0
	Best Case Improvement	52	9	1	5	0
Archaeological Sites Protected (# of sites)	Worst Case Outcome	111	42	72	14	29
	Best Case Improvement	363	502	203	312	140

*Although the no action plan requires zero construction time as represented by the "best case" value in the table, the metric value for the multi-criteria decision analysis was adjusted to 15 years so that the no action plan wouldn't rank highly just because stakeholders valued shorter construction times. The purpose of the construction time metric was to measure how fast risk reduction benefits could be achieved, but benefits are never achieved with the no action plan.

Stakeholder Ranking of Metrics

The MCDA results give a good indication of stakeholder preference toward metrics. **Table 13-2** below indicates how survey respondents ranked (but not rated) metrics. The numbers in the table indicates the number of respondents who ranked a particular metric as being most important.

Table 13-2. Number of times stakeholders ranked each metric as most important.

Metric (shown in descending order by total)	Planning Unit					Total
	1	2	3a	3b	4	
Population impacted (people/year)	21	15	17	8	10	71
Direct wetland impacts (acres)	8	4	3	4	6	25
Indirect environmental impact (unit-less scale, -8 to +8)	8	2	5	2	4	21
Residual damages ($, million/year)	3	2	2	3	4	14
Construction time (years)	1	1	3	4	1	10
Employment impacts (jobs disrupted/year)	2	2	0	2	1	7
Life-cycle cost ($, million/year)	1	1	0	1	1	4
Historic properties protected (# of properties)	1	0	0	0	0	1
Historic districts protected (# of districts)	0	0	0	1	0	1
Archeological sites protected (# of sites)	0	0	0	0	0	0
Number of Survey Respondents	**45**	**27**	**30**	**25**	**27**	**154**

The top five most valued metrics (based on the number of times each metric was ranked as a workshop participant's top metric) were (1) population impacted, (2) direct wetland impacts, (3) indirect environmental impact score, (4) residual damages, and (5) construction time. These results indicate that stakeholders are most concerned with reduction of risk to people, followed by concern for the environment, and property damage. Stakeholders are also concerned with obtaining risk reduction as quickly as possible.

The five least valued metrics included (6) employment impacted (7) present value life-cycle cost (8) historic properties protected, (9) historical district protected, and (10) archaeological sites protected. Archaeological sites protected is the only metric that was never selected as the most important metric.

Stakeholders were informed that the non-Federal share of the life cycle costs (i.e. State and local costs) would be 35% or more of the total cost. The fact that stakeholders ranked costs relatively low despite being presented with the possible range of costs is problematic since the traditional USACE cost-benefit ratio for making Federal investment decisions places a high level of importance on cost. The additional evaluation methodologies described in Section 14, however, do give cost more weight in the decision making process.

Plan Rankings using Stakeholder Weights

Following the stakeholder workshops, metric data was combined with metric weights derived from the stakeholder values (i.e. the 0 to 100 ratings given by stakeholders to each metric) to generate an overall score for each plan being considered. These scores allowed direct comparisons across all plans and plans to be ranked in relation to each other. Some stakeholders ranked metrics in more than one planning unit; the 114 stakeholders completed 154 swing-weight surveys. Each set of stakeholder values produced a different set of rankings. These 154 individual sets of rankings were aggregated into a single stakeholder MCDA ranking using a cumulative ranking score. For example, if Plan A ranked 1^{st} for Stakeholder A, 3^{rd} for Stakeholder B, and 10^{th} for Stakeholder C, then the cumulative ranking score would be 1 + 3 + 10 or 14. **Table 13-3** shows the top 10 ranked plans by planning unit with their cumulative ranking scores in parentheses. Rankings are based on the aggregation of ordinal values; therefore the lowest score indicates the highest level of preference.

Table 13-3. Top 10 ranked plans from stakeholder MCDA by planning unit.

Plan Rank	Planning Unit (Plan Rankings for Scenario 1)				
	1	2	3a	3b	4
1	NS-1000 (85)	C-WBI-100-1 (53)	NS-1000 (50)	C-RL-100-1 (71)	NS-1000 (53)
2	NS-100 (106)	C-R-100-2 (111)	NS-400 (84)	C-F-100-1 (78)	NS-400 (76)
3	NS-400 (127)	WBI-100-1 (113)	NS-100 (126)	F-100-1 (132)	C-RL-400-1 (88)
4	C-HL-a-100-3 (227)	C-R-100-3 (138)	C-M-100-2 (134)	RL-100-1 (140)	NS-100 (116)
5	Coastal (283)	C-R-400-3 (189)	M-100-2 (169)	C-RL-400-1 (150)	C-RL-100-1 (135)
6	HL-a-100-3 (297)	R-100-2 (225)	C-M-100-1 (191)	C-G-100-1 (159)	C-RL-1000-1 (145)
7	C-HL-a-100-2 (307)	C-R-100-4 (228)	M-100-1 (229)	G-100-1 (197)	Coastal (236)
8	HL-a-100-2 (373)	R-100-3 (248)	Coastal (248)	C-F-400-1 (197)	RL-100-1 (254)
9	C-LP-a-100-1 (462)	NS-400 (316)	C-G-400-2 (259)	NS-1000 (216)	RL-400-1 (262)
10	C-HL-b-400-2 (470)	R-400-3 (326)	C-G-1000-2 (282)	RL-400-1 (231)	C-G-100-1 (277)

Scenario Sensitivity

As previously described in the table of critical assumptions, design elevations of existing, improved, and proposed levees are assumed to be maintained over the period of analysis. Relative sea level rise would therefore affect areas within levees in terms of the costs required to maintain performance levels. Relative sea level rise would also affect the performance of plans in areas outside of levees in terms of increased damages. Development rates and patterns do not impact plan costs but do impact the level of damages. The greatest damages are typically seen in the scenario with high employment and compact population and the least damages are seen in the scenario with business-as-usual employment and compact population.

One observation from the stakeholder MCDA results, however, is that although the scenarios impact plan performance and costs, plan rankings appears to be relatively insensitive to the uncertainty in relative sea level rise or to the potential patterns of development. As shown in **Table 13-4** for Planning Unit 1, the same plans appear in the top rankings in each scenario but in slightly different orders. The same trend occurs in the other planning units. Therefore, for the rest of the report results are only presented for Scenario 1.

Table 13-4. Planning Unit 1 MCDA rankings by scenario.

Plan Rank	Scenario 1 Low RSLR High Employment Disperse Population	Scenario 2 High RSLR High Employment Disperse Population	Scenario 3 Low RSLR Business-as-Usual Compact Population	Scenario 4 High RSLR Business-as-Usual Compact Population
1	NS-1000	NS-1000	NS-100	NS-1000
2	NS-100	NS-400	NS-1000	NS-100
3	NS-400	NS-100	NS-400	NS-400
4	C-HL-a-100-3	C-HL-a-100-3	C-HL-a-100-3	C-HL-a-100-3
5	Coastal	HL-a-100-3	Coastal	Coastal
6	HL-a-100-3	Coastal	HL-a-100-3	HL-a-100-3
7	C-HL-a-100-2	C-HL-a-100-2	C-HL-a-100-2	C-HL-a-100-2
8	HL-a-100-2	HL-a-100-2	HL-a-100-2	HL-a-100-2
9	C-LP-a-100-1	C-LP-a-100-1	C-LP-a-100-1	C-LP-a-100-1
10	C-HL-b-400-2	C-HL-b-400-2	C-HL-b-400-2	C-HL-b-400-2

Conclusions about the Stakeholder MCDA Results

The MCDA as performed for LACPR provides insight as to what the most important performance attributes are for most stakeholders which in turn provides valuable input to the risk-informed decision framework and provides an indication of stakeholder plan preferences or acceptability. For the LACPR participants, protecting population was frequently the most important attribute followed by the reduction of direct and indirect environmental impacts.

The confidence in the stakeholder preference for these performance attributes, however, is higher than the confidence in the resultant MCDA rankings, since inconsistencies were apparent between the attribute values and the plan ranking produced by the attribute weights. For example, in most cases, the resultant ranking of plans appears to have emphasized the avoidance of environmental impacts at the expense of higher levels of risk reduction. In some cases, selecting the top ranked MCDA plans would mean paying substantially more to get less risk reduction. This result indicated that further iterations of the MCDA process would be necessary to reassess the metrics and to assure complete stakeholder understanding of the potential tradeoffs implied by the provided weights. For instance, stakeholders and decision makers may choose to accept some environmental impacts to get higher levels of risk reduction with the potential cost savings being applied towards environmental mitigation.

Even with the identified limitations, the MCDA plan rankings still provide a reflection of stakeholder values and preliminary plan preferences that is useful for comparison with other methods of performance-based plan ranking. The comparison of the results for different ranking criteria provides insight for decision makers and stakeholders on the tradeoffs that result directly from the decision criteria.

Additional Criteria for Ranking and Comparing Plans

The outputs of the stakeholder MCDA analysis indicate that the MCDA process, as conducted to date, could potentially eliminate plans that may best meet stakeholder preferences for reducing risk to people. Although the applied MCDA process provides insights to local and regional stakeholder preferences, the resulting ranking of plans for LACPR seemed to place less emphasis on alternatives that provide the highest levels of risk reduction and/or cost efficiency. Therefore, other methods for ranking and comparing plans are necessary to address the wide range of objectives important to decision makers and, in general, to a broader range of taxpayers nationwide.

To assure that such plans were not prematurely or inappropriately eliminated from further consideration, a comparison was made incorporating additional evaluation criteria that included (1) the stakeholder input on preferences; (2) direct and indirect environmental impacts; (3) cost efficiency; (4) effectiveness in reducing risk; as well as (5) project costs and the realities of future funding requirements for both Federal and non-Federal interests. These rationale and descriptions of these criteria are provided below. By comparing these criteria, a more fully risk-informed assessment can be made among alternatives, considering specific tradeoffs and similarities across these evaluation criteria.

Stakeholder Multi-Criteria Decision Analysis

As described earlier in this section, stakeholder MCDA results were used to create a cumulative ranking score of plans based on the aggregation of plan rankings derived from individual stakeholder weights. The cumulative ranking score based on the MCDA trend analysis was used as one of the criteria for ranking plans.

Minimizing Environmental Impacts

The criteria used to consider environmental impacts are identical to the direct wetland impact metric and the indirect environmental impact metric used in the stakeholder MCDA and previously described in Section 12.

Direct Wetland Impacts - The direct wetland impacts metric represents the amount of wetlands that would be displaced by an alternative plan. The acreage impacted includes the levee footprint and adjacent borrow areas used for levee construction.

Indirect Impacts - The indirect environmental impact score represents the severity of potential aquatic ecosystem impacts (positive or negative) relative to other alternatives in the planning unit. This metric considers impacts to hydrology, fisheries, the potential to induce development of wetlands, and consistency with coastal restoration goals.

Investment Decision

The following three criteria combine cost and damages into different measurements of investment risk to help in making investment-based decisions. The first two approaches, Cost Efficiency and Total System Costs, include annualized costs and/or damage measurements as are normally calculated for USACE cost-benefit analyses. Annualized approaches to expressing cost and potential damage reduction, however, are heavily influenced by those costs whose relative occurrence, or more appropriately in the case of potential damage—likely occurrence, is in the near term. Implementation costs are generally certain and immediate. Potential damage from a given storm event is uncertain and is weighted by its probability of occurring in a given year. This means that the effects of larger less frequent events, which represent greater potential damage, carry significantly less weight in comparison with implementation costs. Since the risks the LACPR effort is principally attempting to address are those related to larger, less frequent events and exposure to these risks is perpetual rather than discrete from year to year, a third approach was employed, Period of Analysis Cost Efficiency.

Cost Efficiency - Cost Efficiency is measured as the equivalent annual risk reduction, or reduction in damages, divided by the present value life cycle costs.

Total System Costs - Total System Costs are calculated as the annualized life cycle costs of an alternative plus the expected annual residual damage that remains for that alternative. Total System Costs can be minimized to identify the most efficient actions.

Period of Analysis Cost Efficiency - A third measurement of cost efficiency is a ratio of the summed residual damage for each frequency event, weighted by the probability of its occurrence during the 65-year period of analysis, to the present value life cycle cost of the alternative. The probability of the events used in the analysis occurring based on this period is presented in **Table 13-5** below. This assessment places more weight on the potential damages by beginning to account for the long-term nature of the proposed actions. The same summing of period of analysis residual damage can be used as a measure of plan effectiveness over a longer-term.

Table 13-5. Occurrence probabilities for LACPR analysis events.

Event (years)	Annual Probability (over 1 year)	Period of Analysis Probability (over 65 years)
10	0.10 (10%)	1.0 (100%)
100	0.01 (1%)	0.48 (48%)
400	0.0025 (0.25%)	0.15 (15%)
1,000	0.001 (0.1%)	0.063 (6.3%)
2,000	0.0005 (0.05%)	0.032 (3.2%)

Minimizing Remaining Risk

The effectiveness of plans was measured using pure damage reduction as a criterion without blending in costs. The residual risk/damage for alternatives relative to no action provides a gauge of plan effectiveness. The effectiveness of plans in achieving risk reduction was considered in three ways as described below.

Annualized Residual Damages - The Annualized Residual Damages criterion is identical to the equivalent annual residual damages metric used in the stakeholder MCDA and previously described in Section 12.

Period of Analysis Risk Reduction - The Period of Analysis Risk Reduction criterion is as described for the Period of Analysis Cost Efficiency but without dividing risk reduction value by present value life cycle costs.

Average Percent Risk Reduction - The Average Percent Risk Reduction criterion is similar to the Period of Analysis Risk Reduction but it excludes the 10-year frequency event to focus on the less frequency, potentially more catastrophic events. The value is expressed as a percentage of the no action damages rather than as a dollar amount.

Present Value Life Cycle Costs

In addition, life cycle cost is employed as a ranking method that further differentiates those actions that are efficient as a result of being least costly from those that are highly effective. This ranking also allows a comparison of how a purely cost based decision criteria relates to the MCDA.

Section 14. Comparison of Plan Rankings using MCDA and Other Evaluation Criteria

This section provides a continuation of the RIDF process described in Section 13, Risk-Informed Decision Framework Development. As previously described, comparing results from the MCDA with more traditional USACE decision criteria reveals the inherent variation in possible alternative rankings. Therefore, some comparison of MCDA (used as an indicator of acceptability) to traditional criteria related to effectiveness and cost efficiency is fundamental to supporting the needs of fiscal decision makers. In addition, it provides insight into potential tradeoffs and risk inherent in the decision process itself. Ranking results based on these criteria also provide a basis for the inclusion of alternatives that may be valued by the stakeholders absent the necessary iteration and refinement of the MCDA results. More details on the comparison of alternatives can be found in the *Risk-Informed Decision Framework Appendix.*

Indexed Scoring Tables

To display the plan performance results in a method that would convey the tradeoffs involved, a “Consumer Reports” type rating index was created (**Tables 14-1** through **14-5)**. This format provides a presentation of rank as well as relative strength of performance within that ranking. The data for each ranking criteria were normalized, i.e. data for a particular criterion were adjusted to fit on a zero to one scale with 0.0 being the worst and 1.0 being the best, so that criteria with different units could be compared on a uniform scale.

In comparing the plan rankings produced by each criterion, areas of tradeoff that would occur if selections were made based on any single method become evident. While there is generally some commonality between the MCDA, cost efficiency, and even life cycle cost rankings, typically the most effective alternative plans did not correlate with the other rankings. This is true even when the period of analysis residual damage is employed. This approach does result in plans with higher effectiveness rising toward the top in these ranking however. It is therefore clear that some tradeoff of effectiveness must be made in making a multi-criteria, cost efficiency, or purely cost based decisions. To a lesser degree we can see that tradeoffs in general acceptability or efficiency may be required when comparing possible multi-criteria versus efficiency based decisions.

Table 14-1. Indexed scoring table for Planning Unit 1.

Plan #	Planning Unit 1 Alternatives	Stakeholder (Multi-Criteria Decision Analysis)	Minimizing Environmental Impacts		Investment Decision (Efficiency)			Minimizing Remaining Risk (Effectiveness)			Year 2025 Present Value Life Cycle Costs (2010-2075) ($Millions)
Evaluation Criteria		Cumulative Ranking Score MCDA Trend Analysis	Direct Wetland Impact	Indirect Impacts	Cost Efficiency	Total System Costs	Period of Analysis Cost Efficiency	Annualized Residual Damages	Period of Analysis Risk Reduction	Average % Risk Reduction	
(Units)		*(Unit-less Scale)*	*(Acres)*	*(Unit-less Scale)*	*Ratio: Risk Reduction / Present Value Life Cycle Costs (PV LCC)*	*Annualized Life Cycle Costs + EA Residual Damages ($Millions)*	*Cost Efficiency Ratio: Event Freq Risk Reduction X Probability of Occurrence (2010-2075) / PV LCC*	*Average Annual Remaining Risk ($ Millions)*	*Event Freq Risk Reduction X Probability (2010-2075) ($Millions)*	*2075: 100-yr to 2,000-yr Frequency Events (Avg % of No Action Damages)*	
2	Coastal (R2)	◎	●	●	❍	◉	◉	⊙	⊙	⊙	●
3	NS-100	◉	●	●	●	●	❍	○	⊙	⊙	◉
4	NS-400	◉	●	●	❍	❍	⊙	◉	❍	○	❍
5	NS-1000	●	●	●	⊙	○	⊙	●	◎	❍	⊙
6	HL-a-100-2	❍	○	❍	⊙	❍	⊙	⊙	⊙	⊙	❍
7	HL-a-100-3	◎	❍	◎	⊙	❍	⊙	⊙	⊙	⊙	❍
8	HL-b-400-2	○	⊙	❍	⊙	⊙	⊙	○	◎	◎	⊙
9	HL-b-400-3	○	○	❍	⊙	⊙	⊙	○	◎	◎	⊙
10	LP-a-100-1	○	◎	⊙	❍	◉	●	⊙	○	⊙	◎
11	LP-a-100-2	⊙	○	⊙	⊙	❍	⊙	⊙	○	○	❍
12	LP-a-100-3	⊙	○	⊙	⊙	❍	⊙	⊙	○	⊙	❍
13	LP-b-400-1	⊙	○	⊙	⊙	❍	○	⊙	❍	❍	○
14	LP-b-400-3	⊙	⊙	⊙	⊙	⊙	⊙	○	◎	◎	⊙
15	LP-b-1000-1	⊙	○	⊙	⊙	○	⊙	⊙	❍	❍	○
16	LP-b-1000-2	⊙	⊙	⊙	⊙	⊙	⊙	○	◉	◉	⊙
17	C-HL-a-100-2	❍	○	❍	⊙	❍	⊙	⊙	⊙	⊙	❍
18	C-HL-a-100-3	◎	❍	◎	⊙	❍	⊙	⊙	⊙	⊙	❍
19	C-HL-b-400-2	❍	⊙	❍	⊙	⊙	⊙	○	◉	◉	⊙
20	C-HL-b-400-3	○	○	❍	⊙	⊙	⊙	○	◉	◉	⊙
21	C-LP-a-100-1	❍	◎	⊙	❍	◉	◎	○	○	○	◎
22	C-LP-a-100-2	○	○	⊙	⊙	❍	⊙	○	○	○	❍
23	C-LP-a-100-3	○	○	⊙	⊙	❍	⊙	○	○	○	❍
24	C-LP-b-400-1	⊙	○	⊙	⊙	○	⊙	○	◎	◎	○
25	C-LP-b-400-3	⊙	⊙	⊙	⊙	⊙	⊙	○	◉	◉	⊙
26	C-LP-b-1000-1	⊙	○	⊙	⊙	○	⊙	❍	◉	◉	⊙
27	C-LP-b-1000-2	⊙	⊙	⊙	⊙	⊙	⊙	○	●	●	⊙

Scoring based on normalized values determined within each evaluation criteria as shown:	● 1.0 Best	◉ .9 - .99 ___	◎ .8 - .89 ___	❍ .6 - .79 ___	○ .4 - .59 ___	⊙ 0 - .39 Worst

Table 14-2. Indexed scoring table for Planning Unit 2.

Plan #	Planning Unit 2 Alternatives	Stakeholder (Multi-Criteria Decision Analysis)	Minimizing Environmental Impacts		Investment Decision (Efficiency)			Minimizing Remaining Risk (Effectiveness)			Year 2025 Present Value Life Cycle Costs (2010-2075) ($Millions)
Evaluation Criteria		Cumulative Ranking Score from MCDA Trend Analysis	Direct Wetland Impact	Indirect Impacts	Cost Efficiency	Total System Costs	Period of Analysis Cost Efficiency	Annualized Residual Damages	Period of Analysis Risk Reduction	Average % Risk Reduction	
(Units)		*(Unit-less Weight)*	*(Acres)*	*(Unit-less Scale)*	*Ratio: Risk Reduction / Present Value Life Cycle Costs (PV LCC)*	*Annualized Life Cycle Costs + EA Residual Damages ($Millions)*	*Cost Efficiency Ratio: Event Freq Risk Reduction X Probability of Occurrence (2010-2075) / PV LCC*	*Average Annual Remaining Risk as % of No Action Damages*	*Event Freq Risk Reduction X Probability (2010-2075) ($Millions)*	*2075: 100-yr to 2,000-yr Frequency Events (Avg % of No Action Damages)*	
2	Coastal	⊙	●	⭘	●	◉	◉	⊙	⊙	⊙	●
3	NS-100	○	●	⭘	◉	●	⭘	○	⊙	⊙	◉
4	NS-400	⭘	●	⭘	⭘	◎	⭘	◉	◎	⭘	⭘
5	NS-1000	○	●	⭘	⊙	○	⊙	●	◉	◉	⊙
6	G-100-1	○	◎	⊙	⭘	◎	●	⊙	⭘	⭘	◎
7	G-100-4	⊙	⭘	⊙	○	⭘	⭘	⊙	⭘	⭘	⭘
8	G-400-4	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⭘	◎	⊙
9	G-1000-4	⊙	⊙	⊙	⊙	⊙	⊙	⊙	◎	◎	⊙
10	R-100-2	⭘	◉	●	○	⭘	○	⊙	⊙	⊙	◎
11	R-100-3	⭘	◎	●	○	⭘	○	⊙	⊙	⊙	⭘
12	R-100-4	⭘	◎	●	⊙	⭘	⊙	⊙	⊙	⊙	⭘
13	R-400-2	⊙	○	●	⊙	⊙	⊙	⊙	⭘	⭘	○
14	R-400-3	⭘	○	●	⊙	⊙	⊙	⊙	⭘	⭘	⊙
15	R-400-4	⊙	○	●	⊙	⊙	⊙	⊙	⭘	⭘	⊙
16	R-1000-4	⊙	⊙	●	⊙	⊙	⊙	⊙	⭘	◎	⊙
17	WBI-100-1	◉	●	◎	◉	◉	◉	⊙	⊙	⊙	◉
18	WBI-400-1	⊙	⭘	◎	⊙	○	⊙	⊙	○	⭘	⭘
19	C-G-100-1	○	◎	⊙	⭘	◎	◎	○	◎	◎	⭘
20	C-G-100-4	○	⭘	⊙	○	⭘	⭘	○	◎	◎	⭘
21	C-G-400-4	⊙	⊙	⊙	⊙	⊙	⊙	○	◉	◉	⊙
22	C-G-1000-4	⊙	⊙	⊙	⊙	⊙	⊙	○	●	●	⊙
23	C-R-100-2	◉	◉	●	○	⭘	○	⊙	⊙	⊙	⭘
24	C-R-100-3	◎	◎	●	○	⭘	○	⊙	⊙	⊙	⭘
25	C-R-100-4	⭘	◎	●	⊙	⭘	⊙	⊙	⊙	⊙	⭘
26	C-R-400-2	○	○	●	⊙	○	⊙	○	◎	⭘	⊙
27	C-R-400-3	◎	○	●	⊙	○	⊙	⭘	◉	⭘	⊙
28	C-R-400-4	○	○	●	⊙	⊙	⊙	○	◉	⭘	⊙
29	C-R-1000-4	⊙	⊙	●	⊙	⊙	⊙	○	●	◉	⊙
30	C-WBI-100-1	●	●	◎	◎	◉	◎	⊙	⊙	⊙	◎
31	C-WBI-400-1	⭘	⭘	◎	⊙	⭘	○	○	◎	⭘	○

Scoring based on normalized values determined within each evaluation criteria as shown:	●	◉	◎	⭘	○	⊙
	1.0 Best	.9 - .99	.8 - .89	.6 - .79	.4 - .59	0 - .39 Worst

Table 14-3. Indexed scoring table for Planning Unit 3a.

Plan #	Planning Unit 3a Alternatives	Stakeholder (Multi-Criteria Decision Analysis)	Minimizing Environmental Impacts		Investment Decision (Efficiency)			Minimizing Remaining Risk (Effectiveness)			Year 2025 Present Value Life Cycle Costs (2010-2075) ($Millions)
Evaluation Criteria		Cumulative Ranking Score from MCDA Trend Analysis	Direct Wetland Impact	Indirect Impacts	Cost Efficiency	Total System Costs	Period of Analysis Cost Efficiency	Annualized Residual Damages	Period of Analysis Risk Reduction	Average % Risk Reduction	
(Units)		*(Unit-less Weight)*	*(Acres)*	*(Unit-less Scale)*	*Ratio: Risk Reduction / Present Value Life Cycle Costs (PV LCC)*	*Annualized Life Cycle Costs + EA Residual Damages ($Millions)*	*Cost Efficiency Ratio: Event Freq Risk Reduction X Probability of Occurrence (2010-2075) / PV LCC*	*Average Annual Remaining Risk as % of No Action Damages*	*Event Freq Risk Reduction X Probability (2010-2075) ($Millions)*	*2075: 100-yr to 2,000-yr Frequency Events (Avg % of No Action Damages)*	
2	Coastal (R1)	⊙	●	●	⊙	◎	⊙	⊙	⊙	⊙	●
3	NS-100	❍	●	●	◎	●	○	❍	⊙	⊙	❍
4	NS-400	◎	●	●	◎	●	◎	◉	❍	○	❍
5	NS-1000	●	●	●	●	◎	●	●	◎	◎	❍
6	M-100-1	⊙	⊙	⊙	❍	⊙	❍	❍	◎	❍	⊙
7	M-100-2	○	⊙	○	○	○	❍	❍	❍	○	⊙
8	G-400-2	⊙	⊙	⊙	○	⊙	❍	❍	◎	❍	⊙
9	G-1000-2	⊙	⊙	⊙	○	⊙	❍	❍	◎	◉	⊙
10	C-M-100-1	○	⊙	⊙	❍	⊙	❍	◉	◉	❍	⊙
11	C-M-100-2	❍	⊙	○	❍	○	❍	❍	❍	○	⊙
12	C-G-400-2	⊙	⊙	⊙	❍	⊙	❍	◉	◎	◎	⊙
13	C-G-1000-2	⊙	⊙	⊙	○	⊙	❍	◉	●	●	⊙

Scoring based on normalized values determined within each evaluation criteria as shown:	●	◉	◎	❍	○	⊙
	1.0 Best	.9 - .99	.8 - .89	.6 - .79	.4 - .59	0 - .39 Worst

Table 14-4. Indexed scoring table for Planning Unit 3b.

Plan #	Planning Unit 3b Alternatives	Stakeholder (Multi-Criteria Decision Analysis)	Minimizing Environmental Impacts		Investment Decision (Efficiency)			Minimizing Remaining Risk (Effectiveness)			Year 2025 Present Value Life Cycle Costs (2010-2075) ($Millions)
Evaluation Criteria		Cumulative Ranking Score from MCDA Trend Analysis	Direct Wetland Impact	Indirect Impacts	Cost Efficiency	Total System Costs	Period of Analysis Cost Efficiency	Annualized Residual Damages	Period of Analysis Risk Reduction	Average % Risk Reduction	
(Units)		*(Unit-less Weight)*	*(Acres)*	*(Unit-less Scale)*	*Ratio: Risk Reduction / Present Value Life Cycle Costs (PV LCC)*	*Annualized Life Cycle Costs + EA Residual Damages ($Millions)*	*Cost Efficiency Ratio: Event Freq Risk Reduction X Probability of Occurrence (2010-2075) / PV LCC*	*Average Annual Remaining Risk as % of No Action Damages*	*Event Freq Risk Reduction X Probability (2010-2075) ($Millions)*	*2075: 100-yr to 2,000-yr Frequency Events (Avg % of No Action Damages)*	
2	Coastal	⊙	●	⦿	⊙	◉	⊙	⊙	⊙	⊙	●
3	NS-100	⊙	●	⦿	◉	●	◯	◯	⊙	⊙	◉
4	NS-400	○	●	⦿	●	◉	⦿	◉	◯	○	⦿
5	NS-1000	○	●	⦿	◉	◉	●	●	⦿	◯	⦿
6	G-100-1	○	○	⊙	○	○	○	⦿	◉	⦿	○
7	F-100-1	⦿	○	●	⊙	◯	⊙	◯	○	⊙	○
8	F-400-1	○	⊙	●	⊙	⊙	⊙	◯	⦿	◉	⊙
9	F-1000-1	⊙	⊙	●	⊙	⊙	⊙	◯	⦿	◉	⊙
10	RL-100-1	◯	⦿	●	⊙	◯	⊙	○	○	⊙	◯
11	RL-400-1	○	◯	●	⊙	○	⊙	○	○	○	○
12	C-G-100-1	◯	○	⊙	○	○	○	◉	◉	⦿	○
13	C-F-100-1	◉	○	●	○	◯	○	◯	◯	⊙	○
14	C-F-400-1	○	⊙	●	⊙	⊙	○	⦿	◉	◉	⊙
15	C-F-1000-1	⊙	⊙	●	⊙	⊙	⊙	⦿	●	●	⊙
16	C-RL-100-1	●	⦿	●	○	◯	○	◯	○	⊙	◯
17	C-RL-400-1	◯	◯	●	⊙	○	○	⦿	⦿	◯	○

Scoring based on normalized values determined within each evaluation criteria as shown:	●	◉	⦿	◯	○	⊙
	1.0 Best	.9 - .99	.8 - .89	.6 - .79	.4 - .59	0 - .39 Worst

Table 14-5. Indexed scoring table for Planning Unit 4.

Plan #	Planning Unit 4 Alternatives	Stakeholder (Multi-Criteria Decision Analysis)	Minimizing Environmental Impacts		Investment Decision (Efficiency)			Minimizing Remaining Risk (Effectiveness)			Year 2025 Present Value Life Cycle Costs (2010-2075) ($Millions)
Evaluation Criteria		Cumulative Ranking Score from MCDA Trend Analysis	Direct Wetland Impact	Indirect Impacts	Cost Efficiency	Total System Costs	Period of Analysis Cost Efficiency	Annualized Residual Damages	Period of Analysis Risk Reduction	Average % Risk Reduction	
(Units)		*(Unit-less Weight)*	*(Acres)*	*(Unit-less Scale)*	*Ratio: Risk Reduction / Present Value Life Cycle Costs (PV LCC)*	*Annualized Life Cycle Costs + EA Residual Damages ($Millions)*	*Cost Efficiency Ratio: Event Freq Risk Reduction X Probability of Occurrence (2010-2075) / PV LCC*	*Average Annual Remaining Risk as % of No Action Damages*	*Event Freq Risk Reduction X Probability (2010-2075) ($Millions)*	*2075: 100-yr to 2,000-yr Frequency Events (Avg % of No Action Damages)*	
2	Coastal	○	●	●	⊙	◉	⊙	⊙	⊙	⊙	●
3	NS-100	⊚	●	●	◉	●	○	◯	○	⊙	⊚
4	NS-400	◉	●	●	●	◉	⊚	◉	◯	◯	◯
5	NS-1000	●	●	●	◉	⊚	●	◉	◉	◉	◯
6	G-100-1	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	○	⊙
7	G-100-2	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
8	G-400-3	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
9	G-1000-3	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	○	⊙
10	RL-100-1	○	◉	●	⊙	◯	⊙	⊙	⊙	⊙	⊚
11	RL-400-1	○	◉	●	⊙	◯	⊙	⊙	⊙	⊙	◯
12	RL-1000-1	○	◉	●	⊙	◯	⊙	⊙	⊙	⊙	◯
13	C-G-100-1	○	⊙	⊙	○	⊙	○	⊚	◯	◯	⊙
14	C-G-100-2	○	⊙	⊙	○	⊙	○	⊚	◯	◯	⊙
15	C-G-400-3	⊙	⊙	⊙	○	⊙	○	◉	◯	◯	⊙
16	C-G-1000-3	⊙	⊙	⊙	○	⊙	◯	●	●	●	⊙
17	C-RL-100-1	⊚	◉	●	◯	◉	◯	◯	○	○	◯
18	C-RL-400-1	◉	◉	●	⊚	◉	◯	◉	◯	◯	◯
19	C-RL-1000-1	◯	◉	●	⊚	◯	◉	◉	◉	●	○

Scoring based on normalized values determined within each evaluation criteria as shown:	●	◉	⊚	◯	○	⊙
	1.0 Best	.9 - .99	.8 - .89	.6 - .79	.4 - .59	0 - .39 Worst

Ranking Sensitivity Analysis using Multiple Evaluation Criteria

The indexed scoring tables provide some insight into relative strengths and weaknesses of the alternative plans for the various evaluation criteria. Ultimately, however, the identification of a final array of viable plans based on the comparison of this information is somewhat subjective and difficult. Based on the results of this comparison, the team returned to the underlying evaluation criteria data to further evaluate and compare the performance of alternative plans. The team developed additional rankings of the alternative plans to test whether balancing overall plan performance using different combinations of the previously compared evaluation criteria could aid in identifying consistently effective plans. This test assumes that the various criteria applied in any ranking are generally of equal importance. An effort was made to test the possible sensitivity of rankings to multiple criteria reflecting acceptability, effectiveness, or efficiency, and by comparison of rankings, identify any skewing that might occur in the results.

Normalized values were previously used for each criteria to develop the indexed scores used in ranking plans (i.e. data for a particular criterion adjusted to fit on a zero to one scale with 0.0 being the worst and 1.0 being the best). Using these normalized data for each evaluation criteria, alternatives were scored based on the sum of the total value for the various combinations of the evaluation criteria. This sensitivity analysis helps to identify plans that rate optimally considering all or most criteria. The analysis also allows the identification of significant breaks between plans in the overall rating.

In addition to the stakeholder MCDA trend analysis rankings described in Section 13, eight different combinations of evaluation criteria were used to rank alternative plans. This approach included applying and adjusting weights to the various evaluation criteria as shown in **Table 14-6**. These adjustments provided a means of testing for possible bias in the overall ratings from application of multiple efficiency and effectiveness values. The following variations were used to test plan ranking sensitivities:

- NVR-1 included all 10 criteria weighted equally to test rankings based on the full set of criteria.
- NVR-2 included six criteria weighted equally. Rather than using all three efficiency and three effectiveness criteria as in NVR-1, it only used one efficiency criterion and one effectiveness criterion.
- NVR-3 included eight criteria weighted equally. Rather than using all three efficiency and three effectiveness criteria as in NVR-1, it used two efficiency and two effectiveness criteria.
- NVR-4 included the same set of criteria as NVR-3 but doubled the MCDA weight.
- NVR-5 included all criteria except direct and indirect environmental impacts.
- NVR-6 equally weighted the same criteria as NVR-2 minus the direct and indirect environmental impacts.
- NVR-7 equally weighted the same criteria as NVR-3 minus the direct and indirect environmental impacts.
- NVR-8 included the same criteria as NVR-7 but doubled the MCDA weight.

Observation of the results from this comparison indicates that there is potential for the identification of some reduced set of alternative plans that would consistently provide an optimal performance for multiple criteria sets.

Table 14-6. Criteria included in each of the normalized value rankings (NVR-).

Evaluation Criteria		Normalized Value Rankings							
		NVR-1	NVR-2	NVR-3	NVR-4	NVR-5	NVR-6	NVR-7	NVR-8
Stakeholder MCDA		Y	Y	Y	Y (x2)	Y	Y	Y	Y (x2)
Minimizing Environ-mental Impacts	Direct Wetland Impacts	Y	Y	Y	Y				
	Indirect Impacts	Y	Y	Y	Y				
Efficiency	Cost Efficiency	Y				Y			
	Total System Costs	Y	Y	Y	Y	Y	Y	Y	Y
	Period of Analysis Cost Efficiency	Y		Y	Y	Y		Y	Y
Effectiveness	Annualized Residual Damages	Y		Y	Y	Y		Y	Y
	Period of Analysis Risk Reduction	Y	Y	Y	Y	Y	Y	Y	Y
	Average % Risk Reduction	Y				Y			
Present Value Life Cycle Costs		Y	Y	Y	Y	Y	Y	Y	Y

Note: For each ranking combination, criteria are treated equally, except as noted in the table.

Table 14-7 provides an example of one of the above ranking methods (NVR-8) using the normalized scoring of criteria. From this scoring, the top six plans were identified as the best performing for this ranking combination.

Table 14-7. Example ranking in Planning Unit 1 for NVR-8.

Plan #	Alternative	Total Score	Rank
4	NS-400	5.2330	1
3	NS-100	5.1955	2
5	NS-1000	5.0209	3
21	C-LP-a-100-1	4.9617	4
10	LP-a-100-1	4.6453	5
2	Coastal	4.5274	6
18	C-HL-a-100-3	3.8332	7
23	C-LP-a-100-3	3.6320	8
7	HL-a-100-3	3.5897	9
22	C-LP-a-100-2	3.5846	10
24	C-LP-b-400-1	3.5348	11
17	C-HL-a-100-2	3.5108	12
6	HL-a-100-2	3.2956	13
12	LP-a-100-3	3.2777	14
11	LP-a-100-2	3.2718	15
20	C-HL-b-400-3	3.2094	16
19	C-HL-b-400-2	3.2058	17
13	LP-b-400-1	3.0430	18
26	C-LP-b-1000-1	3.0410	19
8	HL-b-400-2	2.8902	20
9	HL-b-400-3	2.8461	21
15	LP-b-1000-1	2.4602	22
25	C-LP-b-400-3	2.3633	23
14	LP-b-400-3	2.0259	24
27	C-LP-b-1000-2	1.7027	25
16	LP-b-1000-2	1.4174	26
Total Score = Sum of normalized values for MCDA X 2, Total System Costs, Period of Analysis Cost Efficiency (Frequency Risk Reduction/Present Value Costs), Annualized Residual Damages, Period of Analysis Risk Reduction, and Present Value Costs			

Comparison Ranking Tables

After the normalized value rankings were compiled for each alternative, they were compared to the MCDA rankings as shown in **Tables 14-8** through **14-12**. Comparing the top rated plans for each combination of evaluation criteria revealed a consistent group of optimally rated plans in each planning unit. While the order of these plans varies based on the criteria combination, the composition of this group of optimally rated plans is generally consistent. Based on this consistency a final array of viable alternative plans has been identified for each planning unit. The color-coding in these tables illustrates the commonalities found in the top-ranked plans included in the final array.

Table 14-8. Comparison ranking table for Planning Unit 1.

Plan Rank	Stakeholder MCDA Trend Analysis	NVR - 1	NVR - 2	NVR - 3	NVR - 4	NVR - 5	NVR - 6	NVR - 7	NVR - 8
1	NS-1000	NS-100	NS-100	NS-400	NS-400	C-LP-a-100-1	NS-100	C-LP-a-100-1	NS-400
2	NS-100	NS-400	NS-400	NS-100	NS-100	NS-100	NS-400	NS-400	NS-100
3	NS-400	NS-1000	Coastal	NS-1000	NS-1000	NS-400	C-LP-a-100-1	NS-100	NS-1000
4	C-HL-a-100-3	C-LP-a-100-1	NS-1000	Coastal	Coastal	NS-1000	Coastal	LP-a-100-1	C-LP-a-100-1
5	Coastal	Coastal	C-HL-a-100-3	C-LP-a-100-1	C-LP-a-100-1	LP-a-100-1	LP-a-100-1	NS-1000	LP-a-100-1
6	HL-a-100-3	LP-a-100-1	HL-a-100-3	LP-a-100-1	LP-a-100-1	C-LP-b-400-1	NS-1000	Coastal	Coastal
7	C-HL-a-100-2	C-HL-a-100-3	C-LP-a-100-1	C-HL-a-100-3	C-HL-a-100-3	Coastal	C-HL-a-100-3	C-LP-b-400-1	C-HL-a-100-3
8	HL-a-100-2	C-LP-b-400-1	LP-a-100-1	HL-a-100-3	HL-a-100-3	C-LP-b-1000-1	HL-a-100-3	C-LP-a-100-3	C-LP-a-100-3
9	C-LP-a-100-1	C-HL-b-400-3	C-HL-a-100-2	C-HL-a-100-2	C-HL-a-100-2	C-LP-a-100-3	C-LP-a-100-3	C-LP-a-100-2	HL-a-100-3
10	C-HL-b-400-2	HL-a-100-3	HL-a-100-2	HL-a-100-2	HL-a-100-2	C-LP-a-100-2	C-HL-a-100-2	C-HL-a-100-3	C-LP-a-100-2
11	LP-a-100-1	C-HL-b-400-2	C-HL-b-400-3	C-HL-b-400-3	C-HL-b-400-3	LP-b-400-1	C-LP-a-100-2	LP-a-100-3	C-LP-b-400-1
12	HL-b-400-2	C-LP-a-100-3	C-HL-b-400-2	C-LP-b-400-1	C-HL-b-400-2	C-HL-b-400-3	HL-a-100-2	LP-a-100-2	C-HL-a-100-2
13	C-HL-b-400-3	C-HL-a-100-2	HL-b-400-3	C-LP-a-100-3	C-LP-a-100-3	LP-a-100-3	C-LP-b-400-1	C-LP-b-1000-1	HL-a-100-2
14	C-LP-a-100-2	C-LP-a-100-2	C-LP-a-100-3	C-LP-a-100-2	C-LP-a-100-2	LP-a-100-2	LP-a-100-3	LP-b-400-1	LP-a-100-3
15	C-LP-a-100-3	C-LP-b-1000-1	HL-b-400-2	C-HL-b-400-2	C-LP-b-400-1	C-HL-b-400-2	LP-a-100-2	HL-a-100-3	LP-a-100-2
16	HL-b-400-3	HL-b-400-3	C-LP-a-100-2	HL-b-400-3	HL-b-400-3	C-HL-a-100-3	LP-b-400-1	C-HL-a-100-2	C-HL-b-400-3
17	LP-a-100-2	HL-b-400-2	LP-a-100-3	LP-a-100-3	HL-b-400-2	HL-b-400-3	C-HL-b-400-3	C-HL-b-400-3	C-HL-b-400-2
18	LP-a-100-3	LP-b-400-1	C-LP-b-400-1	LP-a-100-2	LP-a-100-3	C-LP-b-400-3	C-LP-b-1000-1	HL-a-100-2	LP-b-400-1
19	C-LP-b-400-1	HL-a-100-2	LP-a-100-2	HL-b-400-2	LP-a-100-2	HL-b-400-2	C-HL-b-400-2	C-HL-b-400-2	C-LP-b-1000-1
20	LP-b-400-1	LP-a-100-3	LP-b-400-1	LP-b-400-1	LP-b-400-1	LP-b-1000-1	HL-b-400-3	HL-b-400-3	HL-b-400-2
21	C-LP-b-1000-1	LP-a-100-2	C-LP-b-1000-1	C-LP-b-1000-1	C-LP-b-1000-1	HL-a-100-3	HL-b-400-2	LP-b-1000-1	HL-b-400-3
22	C-LP-b-400-3	LP-b-1000-1	LP-b-1000-1	LP-b-1000-1	LP-b-1000-1	C-HL-a-100-2	LP-b-1000-1	HL-b-400-2	LP-b-1000-1
23	LP-b-1000-1	C-LP-b-400-3	C-LP-b-400-3	C-LP-b-400-3	C-LP-b-400-3	HL-a-100-2	C-LP-b-400-3	C-LP-b-400-3	C-LP-b-400-3
24	C-LP-b-1000-2	LP-b-400-3	LP-b-400-3	LP-b-400-3	LP-b-400-3	LP-b-400-3	LP-b-400-3	LP-b-400-3	LP-b-400-3
25	LP-b-400-3	C-LP-b-1000-2	C-LP-b-1000-2	C-LP-b-1000-2	C-LP-b-1000-2	C-LP-b-1000-2	C-LP-b-1000-2	C-LP-b-1000-2	C-LP-b-1000-2
26	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2	LP-b-1000-2

Table 14-9. Comparison ranking table for Planning Unit 2.

Plan Rank	Stakeholder MCDA Trend Analysis	NVR - 1	NVR - 2	NVR - 3	NVR - 4	NVR - 5	NVR - 6	NVR - 7	NVR - 8
1	C-WBI-100-1	NS-400	C-WBI-100-1	NS-400	C-WBI-100-1	NS-400	C-WBI-100-1	NS-400	C-WBI-100-1
2	C-R-100-2	C-WBI-100-1	WBI-100-1	C-WBI-100-1	NS-400	C-G-100-1	NS-400	C-G-100-1	NS-400
3	WBI-100-1	WBI-100-1	NS-400	WBI-100-1	WBI-100-1	G-100-1	C-G-100-1	C-WBI-100-1	C-G-100-1
4	C-R-100-3	C-G-100-1	C-R-100-2	NS-100	C-R-100-2	C-WBI-100-1	WBI-100-1	G-100-1	WBI-100-1
5	C-R-400-3	NS-100	C-R-100-3	C-R-100-2	C-R-100-3	C-G-100-4	C-R-100-2	WBI-100-1	C-R-100-2
6	R-100-2	NS-1000	R-100-2	NS-1000	NS-100	WBI-100-1	G-100-1	NS-100	NS-100
7	C-R-100-4	G-100-1	R-100-3	C-G-100-1	C-G-100-1	NS-100	C-G-100-4	C-G-100-4	G-100-1
8	R-100-3	C-R-100-2	NS-100	C-R-100-3	NS-1000	NS-1000	C-R-100-3	NS-1000	C-G-100-4
9	NS-400	C-WBI-400-1	C-R-100-4	C-WBI-400-1	R-100-2	C-WBI-400-1	NS-100	C-WBI-400-1	C-R-100-3
10	R-400-3	Coastal	NS-1000	R-100-2	C-WBI-400-1	G-100-4	C-WBI-400-1	C-R-100-2	C-WBI-400-1
11	R-100-4	C-R-100-3	C-WBI-400-1	Coastal	C-R-100-4	Coastal	R-100-2	G-100-4	NS-1000
12	C-WBI-400-1	C-G-100-4	R-100-4	G-100-1	C-R-400-3	C-R-400-3	G-100-4	C-R-100-3	C-R-400-3
13	C-R-400-2	C-R-400-3	C-R-400-3	C-R-100-4	R-100-3	C-R-100-2	C-R-400-3	Coastal	R-100-2
14	C-G-100-1	R-100-2	Coastal	R-100-3	G-100-1	C-R-400-2	R-100-3	C-R-400-3	C-R-100-4
15	NS-100	C-R-400-2	C-G-100-1	C-R-400-3	Coastal	C-R-100-3	C-R-100-4	C-R-400-2	G-100-4
16	NS-1000	C-R-100-4	C-R-400-2	C-R-400-2	C-R-400-2	R-100-2	NS-1000	R-100-2	C-R-400-2
17	C-G-100-4	G-100-4	G-100-1	C-G-100-4	C-G-100-4	C-R-100-4	C-R-400-2	C-R-100-4	R-100-3
18	C-R-400-4	R-100-3	R-400-3	R-100-4	R-100-4	C-R-400-4	Coastal	R-100-3	Coastal
19	G-100-1	C-R-400-4	WBI-400-1	G-100-4	R-400-3	R-100-3	R-100-4	C-R-400-4	R-100-4
20	WBI-400-1	R-100-4	C-G-100-4	C-R-400-4	G-100-4	WBI-400-1	WBI-400-1	R-100-4	R-400-3
21	R-400-2	R-400-3	C-R-400-4	R-400-3	C-R-400-4	R-400-3	R-400-3	WBI-400-1	C-R-400-4
22	G-100-4	WBI-400-1	R-400-2	WBI-400-1	WBI-400-1	C-G-400-4	C-R-400-4	R-400-3	WBI-400-1
23	Coastal	R-400-2	G-100-4	R-400-2	R-400-2	C-R-1000-4	R-400-2	R-400-2	R-400-2
24	R-400-4	C-R-1000-4	R-400-4	C-R-1000-4	C-R-1000-4	R-100-4	R-400-4	C-G-400-4	C-R-1000-4
25	C-R-1000-4	R-400-4	C-R-1000-4	R-400-4	R-400-4	R-400-2	C-G-400-4	C-R-1000-4	C-G-400-4
26	R-1000-4	R-1000-4	R-1000-4	R-1000-4	R-1000-4	C-G-1000-4	C-R-1000-4	R-400-4	R-400-4
27	C-G-400-4	C-G-400-4	C-G-400-4	C-G-400-4	C-G-400-4	R-400-4	G-400-4	C-G-1000-4	G-400-4
28	G-400-4	G-400-4	G-400-4	G-400-4	G-400-4	G-400-4	R-1000-4	G-400-4	C-G-1000-4
29	C-G-1000-4	C-G-1000-4	C-G-1000-4	C-G-1000-4	C-G-1000-4	R-1000-4	C-G-1000-4	R-1000-4	R-1000-4
30	G-1000-4	G-1000-4	G-1000-4	G-1000-4	G-1000-4	G-1000-4	G-1000-4	G-1000-4	G-1000-4

Table 14-10. Comparison ranking table for Planning Unit 3a.

Plan Rank	Stakeholder MCDA Trend Analysis	NVR - 1	NVR - 2	NVR - 3	NVR - 4	NVR - 5	NVR - 6	NVR - 7	NVR - 8
1	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000
2	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400
3	NS-100	NS-100	NS-100	NS-100	NS-100	C-M-100-1	NS-100	NS-100	NS-100
4	C-M-100-2	C-M-100-2	Coastal	C-M-100-2	C-M-100-2	NS-100	C-M-100-2	C-M-100-2	C-M-100-2
5	M-100-2	M-100-2	C-M-100-2	M-100-2	M-100-2	C-M-100-2	Coastal	C-M-100-1	C-M-100-1
6	C-M-100-1	C-M-100-1	M-100-2	Coastal	Coastal	M-100-1	M-100-2	M-100-2	M-100-2
7	M-100-1	M-100-1	C-M-100-1	C-M-100-1	C-M-100-1	M-100-2	C-M-100-1	M-100-1	M-100-1
8	Coastal	C-G-400-2	M-100-1	M-100-1	M-100-1	C-G-400-2	M-100-1	C-G-400-2	C-G-400-2
9	C-G-400-2	C-G-1000-2	C-G-400-2	C-G-400-2	C-G-400-2	C-G-1000-2	C-G-400-2	C-G-1000-2	C-G-1000-2
10	C-G-1000-2	Coastal	G-400-2	G-400-2	C-G-1000-2	G-400-2	G-400-2	G-400-2	G-400-2
11	G-400-2	G-400-2	C-G-1000-2	C-G-1000-2	G-400-2	G-1000-2	C-G-1000-2	G-1000-2	Coastal
12	G-1000-2	G-1000-2	G-1000-2	G-1000-2	G-1000-2	Coastal	G-1000-2	Coastal	G-1000-2

Table 14-11. Comparison ranking table for Planning Unit 3b.

Plan Rank	Stakeholder MCDA Trend Analysis	NVR - 1	NVR - 2	NVR - 3	NVR - 4	NVR - 5	NVR - 6	NVR - 7	NVR - 8
1	C-RL-100-1	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000
2	C-F-100-1	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400
3	F-100-1	NS-100	C-RL-100-1	C-RL-100-1	C-RL-100-1	C-G-100-1	C-RL-100-1	C-G-100-1	C-RL-100-1
4	RL-100-1	C-RL-100-1	NS-100	NS-100	C-F-100-1	G-100-1	C-F-100-1	G-100-1	C-F-100-1
5	C-RL-400-1	C-RL-400-1	RL-100-1	C-F-100-1	C-RL-400-1	NS-100	C-G-100-1	C-RL-100-1	C-G-100-1
6	C-G-100-1	C-F-100-1	C-F-100-1	C-RL-400-1	NS-100	C-F-100-1	G-100-1	C-F-100-1	G-100-1
7	G-100-1	C-G-100-1	C-RL-400-1	RL-100-1	RL-100-1	C-RL-100-1	NS-100	NS-100	C-RL-400-1
8	C-F-400-1	C-F-400-1	F-100-1	F-100-1	F-100-1	C-RL-400-1	F-100-1	C-RL-400-1	F-100-1
9	NS-1000	RL-100-1	Coastal	C-G-100-1	C-G-100-1	C-F-400-1	RL-100-1	F-100-1	NS-100
10	RL-400-1	F-100-1	RL-400-1	C-F-400-1	C-F-400-1	F-100-1	C-RL-400-1	RL-100-1	RL-100-1
11	F-400-1	G-100-1	C-F-400-1	G-100-1	G-100-1	F-400-1	C-F-400-1	C-F-400-1	C-F-400-1
12	NS-400	F-400-1	C-G-100-1	RL-400-1	RL-400-1	RL-100-1	Coastal	F-400-1	F-400-1
13	NS-100	RL-400-1	G-100-1	F-400-1	F-400-1	RL-400-1	RL-400-1	RL-400-1	RL-400-1
14	C-F-1000-1	C-F-1000-1	F-400-1	Coastal	Coastal	C-F-1000-1	F-400-1	C-F-1000-1	C-F-1000-1
15	F-1000-1	F-1000-1	C-F-1000-1	C-F-1000-1	C-F-1000-1	F-1000-1	C-F-1000-1	Coastal	Coastal
16	Coastal	Coastal	F-1000-1	F-1000-1	F-1000-1	Coastal	F-1000-1	F-1000-1	F-1000-1

Table 14-12. Comparison ranking table for Planning Unit 4.

Plan Rank	Stakeholder MCDA Trend Analysis	NVR - 1	NVR - 2	NVR - 3	NVR - 4	NVR - 5	NVR - 6	NVR - 7	NVR - 8
1	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000
2	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400	NS-400
3	C-RL-400-1	C-RL-1000-1	NS-100	C-RL-400-1	C-RL-400-1	C-RL-1000-1	NS-100	C-RL-400-1	C-RL-400-1
4	NS-100	C-RL-400-1	C-RL-400-1	C-RL-1000-1	C-RL-1000-1	C-RL-400-1	C-RL-400-1	C-RL-1000-1	C-RL-1000-1
5	C-RL-100-1	NS-100	C-RL-1000-1	NS-100	NS-100	NS-100	C-RL-1000-1	NS-100	NS-100
6	C-RL-1000-1	C-RL-100-1	C-RL-100-1	C-RL-100-1	C-RL-100-1	C-RL-100-1	C-RL-100-1	C-RL-100-1	C-RL-100-1
7	Coastal	RL-100-1	Coastal	Coastal	Coastal	C-G-1000-3	Coastal	C-G-1000-3	C-G-100-1
8	RL-100-1	RL-1000-1	RL-100-1	RL-100-1	RL-100-1	C-G-100-1	RL-100-1	C-G-100-1	C-G-1000-3
9	RL-400-1	C-G-1000-3	RL-400-1	RL-1000-1	RL-400-1	C-G-400-3	RL-400-1	C-G-400-3	C-G-400-3
10	C-G-100-1	Coastal	RL-1000-1	RL-400-1	RL-1000-1	C-G-100-2	RL-1000-1	C-G-100-2	C-G-100-2
11	RL-1000-1	C-G-100-1	C-G-100-2	C-G-100-1	C-G-100-1	RL-100-1	C-G-100-1	Coastal	Coastal
12	C-G-100-2	RL-400-1	C-G-100-1	C-G-100-2	C-G-100-2	RL-1000-1	C-G-400-3	RL-100-1	RL-100-1
13	C-G-1000-3	C-G-100-2	C-G-400-3	C-G-1000-3	C-G-1000-3	Coastal	C-G-100-2	RL-1000-1	RL-400-1
14	C-G-400-3	C-G-400-3	C-G-1000-3	C-G-400-3	C-G-400-3	RL-400-1	C-G-1000-3	RL-400-1	RL-1000-1
15	G-100-1	G-100-1	G-100-2	G-100-1	G-100-1	G-100-1	G-100-1	G-100-1	G-100-1
16	G-100-2	G-100-2	G-100-1	G-100-2	G-100-2	G-1000-3	G-100-2	G-100-2	G-100-2
17	G-1000-3	G-1000-3	G-1000-3	G-1000-3	G-1000-3	G-100-2	G-1000-3	G-1000-3	G-1000-3
18	G-400-3	G-400-3	G-400-3	G-400-3	G-400-3	G-400-3	G-400-3	G-400-3	G-400-3

Section 15. Final Array of Alternatives and Tradeoff Analysis

The final array includes plans at 100-year, 400-year, and 1000-year hurricane surge risk reduction design levels. A 100-year plan design is based on a flood elevation that statistically has a one percent chance of being equaled or exceeded in any given year. Similarly, a 400-year design has a 0.25 percent chance of being equaled or exceeded in any given year, and a 1000-year design has a 0.1 percent chance of being equaled or exceed in any give year. For the alternatives with a structural component, however, the designation of 100-year, 400-year, or 1000-year as the design level is, in some cases, a misnomer. For example, the Lake Pontchartrain barrier-weir is designated as a 100-year design because the design elevation of the weir was based on the 100-year storm surge at that location; however, the level of risk reduction it provides to developed areas within the system is much greater.

All of the alternative plans considered in the LACPR technical analysis initially included a coastal restoration component, which was common in each planning unit. In Planning Units 3a, 3b, and 4, however, structural, nonstructural and comprehensive plans have been identified independent of this coastal restoration component. The reason for removing the coastal component from risk reduction plans in Planning Units 3a, 3b, and 4 is that the current technical evaluation failed to identify any measured risk reduction attributable to the stand alone coastal restoration component in these planning units. This exclusion does not indicate that coastal restoration would not be needed but that the focus in these areas should be on the ecologic values provided by restoration rather than risk reduction. Additionally, although significant additional hydrodynamic modeling is needed, future plan development phases may identify specific coastal restoration features capable of producing discrete risk reduction benefits in these areas.

The final array of alternative plans is listed by planning unit in **Table 15-1**. Alternatives are not listed in any particular rank or priority order.

Table 15-1. Final array of alternatives (in no particular order).

Planning Unit 1	Planning Unit 2	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
Coastal only	**NS-400**	NS-100	**NS-400**	NS-100
NS-100	WBI-100-1	**NS-400**	**NS-1000**	**NS-400**
NS-400	C-WBI-100-1	**NS-1000**	C-RL-100-1	**NS-1000**
NS-1000	C-R-100-2	**C-M-100-1**	C-F-100-1	C-RL-100-1
LP-a-100-1	**C-G-100-1**	**C-M-100-2**	**C-G-100-1**	**C-RL-400-1**
C-LP-a-100-1				**C-RL-1000-1**
Plans east of Bayou Lafourche include a coastal restoration component.		Plans west of Bayou Lafourche do not include a coastal restoration component.		

Note: Plans **in bold** achieve "Category 5" risk reduction by providing significant surge risk reduction (based on residual damages) for a 400-year frequency storm event or greater; however, not all areas in the planning unit would receive this level of risk reduction.

Description of the Final Array

The following summarizes and briefly describes the final array of alternatives by planning unit. Descriptions of each individual alternative are provided in Attachment 1.

Planning Unit 1 – The final array in Planning Unit 1 contains six alternatives: one coastal only alternative, three nonstructural alternatives (NS-100, NS-400, and NS-1000), one structural alternative (LP-a-100-1) and one comprehensive alternative (C-LP-a-100-1). The six alternatives are described as follows:

Sustain the coastal landscape through restoration including shoreline protection, marsh creation, and diversions either

- Without any additional nonstructural or structural measures (coastal only), or
- With **100-year, 400-year, or 1000-year nonstructural measures** (NS-100, NS-400, or NS-1000) or
- With a **Lake Pontchartrain surge reduction barrier-weir** across the mouth of Lake Pontchartrain and 100-year upper Plaquemines levees either:
  - With **100-year nonstructural measures** added to areas outside of the levee system (C-LP-a-100-1) or
  - Without any nonstructural measures (LP-a-100-1).

Planning Unit 2 – The final array in Planning Unit 2 contains five alternatives: one nonstructural alternative (NS-400), one structural alternative (WBI-100-1) and three comprehensive alternatives (C-WBI-100-1, C-R-100-2, and C-G-100-1). The five alternatives are described as follows:

Sustain the coastal landscape through restoration including shoreline protection, marsh creation, and diversions,

- With **400-year nonstructural measures** (NS-400), or
- With a new **sector gate on Bayou Barataria** either:
  - Without other measures (WBI-100-1) or
  - With **100-year nonstructural measures** added to areas outside of the levee system (C-WBI-100-1) and
    - With additional **100-year ring levees** around Boutte and Lafitte (C-R-100-2) or
    - With a **barrier-weir and levees along the GIWW** to reduce risk to areas within the Barataria Basin (C-G-100-1).

Planning Unit 3a – The final array in Planning Unit 3a contains five alternatives: three nonstructural alternatives (NS-100, NS-400, and NS-1000) and two comprehensive alternatives (C-M-100-1 and C-M-100-2). The five alternatives are described as follows:

- **100-year, 400-year, or 1000-year nonstructural measures** (NS-100, NS-400, or NS-1000), or
- **100-year Morganza to the Gulf levee with 100-year nonstructural measures** added to areas outside of the levee system with
  - An extension tying into high ground west of Morgan City (C-M-100-1) or
  - A tieback to high ground south of Thibodaux and ring levee around Morgan City (C-M-100-2).

Planning Unit 3b – The final array in Planning Unit 3b contains five alternatives: two nonstructural alternatives (NS-400 and NS-1000) and three comprehensive alternatives (C-RL-100-1, C-F-100-1, and C-G-100-1). The five alternatives are described as follows:

- **400-year or 1000-year nonstructural measures** (NS-400 or NS-1000), or
- **100-year ring levees** around Patterson/Berwick, Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville with **100-year nonstructural measures** added to areas outside of the levee system (C-RL-100-1) or
- **100-year continuous levees along the GIWW** west to the boundary of Planning Unit 4 and 100-year ring levees around Patterson/Berwick with **100-year nonstructural measures** added to areas outside of the levee system (C-G-100-1) or
- **100-year continuous levees along the edge of development** north of the GIWW to high ground west of Abbeville and 100-year ring levees around Patterson/Berwick with **100-year nonstructural measures** added to areas outside of the levee system (C-F-100-1).

Planning Unit 4 – The final array in Planning Unit 4 contains six alternatives: three nonstructural alternatives (NS-100, NS-400, and NS-1000) and three comprehensive alternatives (C-RL-100-1, C-RL-400-1, and C-RL-1000-1). The six alternatives are described as follows:

- **100-year, 400-year, or 1000-year nonstructural measures** (NS-100, NS-400, or NS-1000), or
- **100-year, 400-year, or 1000-year ring levees** to the east and west of Lake Charles; within Lake Charles to separate the river from the land; and around Kaplan and Gueydan with **nonstructural measures** added to areas outside of the levee system (C-RL-100-1, C-RL-400-1, and C-RL-1000-1).

Discussion of Tradeoffs in the Final Array

The final array of alternatives being presented contains a full mix of coastal restoration, structural and nonstructural plans as stand alone and combinations. Coastal restoration as a stand alone plan only rated as an optimally performing plan in one planning unit. A significant portion of the plans in the final array—12 or almost half—are nonstructural plans. At least one nonstructural plan is included in each of the five planning units. In addition, counting the included comprehensive plan combinations, 24 of the 27 plans in the final array include a nonstructural component. Only two alternatives in the final array are based on structural measures without nonstructural measures. However, including the comprehensive plan combinations there are a total of 13 plans that are based principally on structural risk reduction measures.

In all planning units, key tradeoffs exist between risk reduction effectiveness, environmental impacts, social impacts, and cost. For example, in order to implement nonstructural measures, tradeoffs must be made between risk reduction effectiveness and social impacts associated with buyouts of structures. Further consideration of actual participation in the implementation of any nonstructural measures is a critical factor in being able to achieve the level of risk reduction benefits projected for nonstructural components or alternatives. To address this issue, a sensitivity analysis assuming various levels of participation was conducted to determine the effect of participation on nonstructural plan effectiveness in reducing risk. This sensitivity analysis has identified thresholds at which the risk reduction performance of these plans diminishes in comparison to other alternatives as described below. At this point in time, acceptability of plans has only been measured through the stakeholder MCDA process, and references to high or low acceptability in the following paragraphs equates to high or low MCDA rankings.

Planning Unit 1

In Planning Unit 1, the final array includes alternatives that span the full range of possible categories for achieving risk reduction and key tradeoffs can be demonstrated between the alternatives. In this planning unit, the relatively low cost of implementation combined with measurable, although not high, effectiveness allowed stand alone coastal restoration to register as a potentially viable alternative. While the coastal restoration only plan provides some risk reduction and is the least cost plan, it is also less effective than the other alternatives.

All three levels of the nonstructural alternative, NS-100, NS-400, and NS-1000, are identified in Planning Unit 1. Effectiveness, as well as efficiency at the lower design levels, coupled with a high level of acceptability drive these alternatives.

The structural options for Planning Unit 1 both include the basic Pontchartrain barrier-weir, both as a structural, LP-a-100-1, and a comprehensive, C- LP-a-100-1, alternative. These options out perform other structural options despite their relatively low acceptability related to potential indirect environmental impacts and potential for regional impacts to the Mississippi coast. The comprehensive alternative without a barrier-weir (C-HL-a-100-3) was not included in the final array but is included in the tradeoff analysis for comparison purposes. Although it was indicated as being more acceptable through the stakeholder MCDA, it provides less risk reduction at a higher cost than the barrier-weir plans.

In comparing the 100-year nonstructural alternative (NS-100) to the structural barrier-weir plans (LP-a-100-1, and C-LP-a-100-1), their costs are roughly equivalent, but the barrier-weir plans are significantly more effective particularly for the surge events greater than 100 years, even providing significant risk reduction up to the 1000-year event. The risk reduction effectiveness of the 100-year nonstructural plan is also very sensitive to levels of participation. Although more effective, the barrier-weir plans have a higher potential for indirect environmental impacts than the nonstructural or coastal alternatives. The barrier-weir plans also have regional impacts extending into Mississippi that must be considered.

The 400-year nonstructural plan (NS-400) can provide risk reduction equivalent to the barrier-weir structural plans. This plan requires greater first cost investment and purchase or modification of more than 200,000 structures. Likewise, the 1000-year nonstructural plan (NS-1000) provides the best overall risk reduction of the final array for Planning Unit 1 but with greater cost and purchase or modification of nearly 300,000 structures. The 400-year and 1000-year nonstructural plans are less sensitive to the level of participation than the 100-year nonstructural plan and maintain their relative positions in terms of risk reduction at 60 percent participation and above.

Planning Unit 2

Of all the planning units, tradeoffs in the Planning Unit 2 final array are the most pronounced with major differences between the structural plans. A short list of structural-based alternatives was included in the final array in this planning unit based on high efficiency and effectiveness. The Sector Gate South addition to the existing West Bank risk reduction system is included both as a structural, WBI-100-1, and comprehensive, C-WBI-100-1, alternative. These alternatives are driven by high acceptability combined with low cost and relative efficiency. The GIWW barrier alternative, C-G-100-1, is included as a comprehensive alternative and is driven by high efficiency and effectiveness. The final array also includes the more acceptable, environmentally preferred alternative, the comprehensive ridge alignment, C-R-100-2. The ridge alternative C-R-100-4 was not included in the final array but is presented in the tradeoff analysis for comparison purposes. This ridge plan costs approximately 20 percent more than the ridge plan in the final array (C-R-100-2) but only further reduces risk by about one percent.

The West Bank Sector Gate plans (C-WBI-100-1 and WBI-100-1) and the ridge plan (C-R-100-2) each provide equivalent risk reduction, although limited to the 100-year frequency. These plans are identified as environmentally preferable and achieve positive indirect impact scores. The GIWW barrier-weir plan (C-G-100-1) is rated as having the worst potential indirect impact score possible; however, the GIWW barrier-weir plan provides exceptional risk reduction with significant benefits for the West Bank extending up to the 2000-year surge event.

In contrast to Planning Unit 1, the final array in Planning Unit 2 only includes the 400-year nonstructural alternative (NS-400). Even though their relative effectiveness was also a strength, nonstructural alternatives demonstrated much lower relative acceptability in this planning unit. Likewise, the coastal restoration only alternative demonstrated measurable effectiveness but was far more costly and was therefore not an optimal choice. The 400-year nonstructural plan (NS-400) can provide risk reduction similar to the GIWW barrier-weir plan, although it is less effective at the 2000-year surge level. The nonstructural plan requires greater first cost investment and purchase or modification of more than 150,000 structures. In Planning Unit 2, the nonstructural plan maintains its relative positions in terms of risk reduction at 40 percent participation and above.

Planning Unit 3a

In Planning Unit 3a, all three levels of the nonstructural alternative, NS-100, NS-400, and NS-1000, are identified. As in Planning Unit 1, acceptability plays a key role in identifying these alternatives. However, in this planning unit efficiency or effectiveness provides the additional factor in advancing the alternative depending on the design scale. There is also a pair of comprehensive structural-based alternatives in this planning unit. Both of these alternatives are based on the currently authorized Morganza to the Gulf of Mexico plan but vary the location of western terminus of the structural measure. Plan C-M-100-1 extends the levee system to Morgan City while plan C-M-100-2 extends northward to the Lafourche ridge just to the west of Houma, Louisiana. Alternative C-M-100-1 is driven by high effectiveness while alternative C-M-100-2 achieves a balance of acceptability, efficiency, and effectiveness.

A comparison of the 100-year alternatives (NS-100, C-M-100-1, and C-M-100-2) reveals distinct tradeoffs. The 100-year alternatives with structural components are more effective than the 100-year nonstructural alternative across all surge events, particularly for the 100-year and 400-year events. The structural plans, however, have the potential for direct and indirect environmental impacts, such as wetlands impacts from levee footprints, disruption of sheetflow, and the potential for induced development. While the 100-year nonstructural plan (NS-100) is less costly than the 100-year structural alternatives, it includes purchase or modification of some 30,000 structures and is very sensitive to levels of participation.

The 400-year and 1000-year nonstructural plans (NS-400 and NS-1000) are less costly than the structural plans in PU3a; however, they start to fall below the structural plans in terms of risk reduction effectiveness at levels of participation less than 90 percent and 80 percent, respectively. In terms of average percent risk reduction, the 400-year nonstructural alternative is similar to one of the comprehensive Morganza to the Gulf plans (C-M-100-2), and the 1000-year nonstructural alternative is similar to the other comprehensive Morganza to the Gulf variation (C-M-100-1). The 1000-year nonstructural plan could provide the best overall reduction of risk particularly for the

1000-year and 2000-year surge events. Neither of the larger nonstructural plans produces negative environmental impacts, but they do require the purchase or modification of approximately 60,000 and 70,000 structures, respectively.

Planning Unit 3b

In Planning Unit 3b, two of the three levels of the nonstructural alternative, NS-400 and NS-1000, are identified. In this planning unit acceptability does not play a role in identifying these alternatives. In fact nonstructural options were generally viewed with low acceptability. Cost was the key factor, along with efficiency and effectiveness, in advancing these alternatives. The final array also includes a range of comprehensive, structural-based alternatives in Planning Unit 3b. These include a regional ring levee system, C-RL-100-1, a continuous barrier along the edge of development, C-F-100-1, and a continuous barrier along the GIWW, C-G-100-1. Alternatives C-RL-100-1 and C-F-100-1 are supported by high acceptability and balanced efficiency and effectiveness. Alternative C-G-100-1 is driven by high effectiveness with limited acceptability.

Each of the structural-based alternatives includes the improvement of the existing Patterson/Berwick levee at the lower extent of the Atchafalaya Basin. The barrier along the edge of development ties back into high ground northwest of Abbeville. The barrier along the GIWW would require the construction of a similar alternative in Planning Unit 4.

A comparison of the comprehensive alternatives (C-G-100-1, C-F-100-1, and C-RL-100-1) reveals that a continuous barrier along the GIWW (C-G-100-1) would provide exceptional overall risk reduction with benefits into the 2000-year surge event. In fact, this levee designed at the 100-year level performs better than the 400-year and 1000-year nonstructural plans presented. As with similar structural plans, this plan also presents the potential for large direct and indirect environmental impacts, as well as relatively high cost. The continuous levee plan further inland from the GIWW (C-F-100-1) and the ring levee plan (C-RL-100-1) are slightly less costly and produce potentially positive indirect impacts, although both result in relatively large direct impacts. However, each of these plans provides a minimal acceptable level of risk reduction with significant benefits extending just up to the 400-year surge event. Additionally, the GIWW alternative (C-G-100-1) requires the implementation of a similar plan in Planning Unit 4 that was not identified as part of the final array. The 400-year ring levee plan (C-RL-400-1) was not included in the final array because although it would provide roughly twice the average percent risk reduction of two of the comprehensive plans (C-F-100-1 or C-RL-100-1), it provides less risk reduction than the comprehensive GIWW plan (C-G-100-1) at a higher cost.

The two nonstructural plans in the final array for this planning unit (NS-400 and NS-1000) are neutral with respect to environmental impacts but would require the purchase or modification of roughly 24,000 or 33,000 structures, respectively. While these plans are less costly than the plans with structural components, the overall risk reduction provided could better than that of the continuous levee (C-F-100-1) and ring levee (C-RL-100-1) plans but falls short of that provided by the GIWW plan (C-G-100-1). These nonstructural plans would require greater than 90 percent participation to maintain relative effectiveness.

Planning Unit 4

In Planning Unit 4, the final array consists of two types of plans: nonstructural plans at three design levels (NS-100, NS-400, and NS-1000) and comprehensive ring levee plans at three design levels (C-RL-100-1, C-RL-400-1, and C-RL-1000-1). All alternatives in the final array for this planning unit produce negligible environmental impacts. As in Planning Unit 1 acceptability plays a key role in identifying these alternatives. In this planning unit efficiency or effectiveness, depending on the design scale, provide the additional factors in advancing these alternatives.

The suite of comprehensive alternatives (C-RL-100-1, C-RL-400-1, and C-RL-1000-1) is based on the regional ring levee concept. For these alternatives support is derived from a balance of acceptability, efficiency, and effectiveness that varies depending on the design level. These ring levees focus risk reduction only on the densely developed communities. Because of the large spatial extent of this planning unit the barrier along the GIWW performed poorly in several categories (C-G-100-1) and was not included in the final array. Even though it would provide risk reduction benefits equivalent to the 400-year plans, it comes at nearly double the cost of the most costly alternative in the array for this planning unit and produces significant environment impacts both direct and indirect. Without the inclusion of this alternative in Planning Unit 4 the corresponding alternative in Planning Unit 3b may not be implementable.

The nonstructural plans tend to be slightly less costly than the ring levee plans at each corresponding design level. The level of risk reduction is also roughly equivalent between the two sets of alternatives at each design level; however, the risk reduction effectiveness for the nonstructural plans is dependent on levels of participation. The 100-year nonstructural plan maintains its relative position in terms of residual risk at 40 percent participation and above; the 400-year nonstructural plan requires between 60 and 90 percent participation; and the 1000-year nonstructural plan requires between 70 and 90 percent participation. At the 100-year design level the overall risk reduction for both types of plans is minimal.

For all of the plans, significant risk reduction is generally limited to surge events up to the corresponding design level of the plan. Because the ring levee plans provide a limited area of risk reduction these comprehensive plans include a more significant nonstructural component as well. For the 100-year, 400-year, and 1000-year design levels, the ring levee plans require the purchase or modification of roughly 7,500, 14,000, and 21,000 structures, respectively. For the same design levels the nonstructural plan require purchase or modification of roughly 8,500, 19,000, and 30,000 structures.

Tradeoff Tables

Secondary performance information that further defines and illustrates tradeoffs between the final alternatives has been compiled in tabular form. This information can aid decisions on additional action on the final array of alternatives and is presented in **Tables 15-2** through **15-6**. These tables include the following information for each final array plan, no action alternative, and an additional plan for comparison purposes:

- Performance metric data;
- A summary of performance for each evaluation criteria;
- A summary of its performance at each of the major surge frequencies considered;
- Relative requirements for nonstructural components and sensitivity of effectiveness to participation;
- The relative effect of future coastal degradation on cost; potential for induced surge impacts;
- A structural risk and reliability assessment;
- Assessment of consistency with LACPR directives and State Master Plan; and
- Present value life cycle costs and cost share apportionment.

The plan chosen for comparison purposes also ranked highly but was not included in the final array. It was chosen to further illustrate tradeoffs, e.g. between the barrier-weir plans and the high level plans in Planning Unit 1. The evaluation data used in this technical assessment is based on plans achieving and maintaining full performance. The secondary information serves several purposes. First, it provides a complete and concise summary of plan performance across the range of metrics and criteria considered. Secondly, it provides indicators of potential weaknesses that should be considered in pursuing certain plans. Finally, it provides information expanded from these initial items that allow a ready comparison of plan tradeoffs and the associated possible residual risks.

Table 15-2. Tradeoff Analysis for Planning Unit 1.

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			Coastal	NS - 100	NS - 400	NS-1000	LP-a-100-1	C-LP-a-100-1	C-HL-a-100-3
General	Plan Description	No additional improvements for Risk Reduction; Level of Protection for Existing Levees reduced over time due to subsidence and sea level rise, changes in coastal landscape; Future Coastal Landscape reflects degraded condition.	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions (steady state and pulsed).	Sustain coastal landscape through restoration. Implement comprehensive 100-year nonstructural measures, including buyouts and raise-in-place.	Sustain coastal landscape through restoration. Implement comprehensive 400-year nonstructural measures, including buyouts and raise-in-place.	Sustain coastal landscape through restoration. Implement comprehensive 1,000-year nonstructural measures, including buyouts and raise-in-place.	Sustain coastal landscape through restoration and construct barrier-weir (with tidal closure structures at the Chef Menteur and Rigoletes) to reduce risk to the Lake Ponchartrain area. Raise upper Plaquemines levees to 100-year level of risk reduction	Comprehensive alternative including coastal restoration, structural, and nonstructural measures. Same as alternative LP-a-100-1, but adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.	Comprehensive alternative. Sustain coastal landscape through restoration; provides for levees at 100-year design level to Laplace, upper Plaquemines, and Slidell; adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.
Performance Data (Metrics)	Population Impacted (Equiv Annual #)	51,017	45,113	39,672	38,517	33,107	40,916	39,725	39,309
	Residual Damages (Equiv Annual $Millions)	1,401	1,106	732	463	384	904	744	870
	Life-Cycle Costs (Equiv. Annual $Millions)	0	543	873	1,761	2,535	903	1,100	1,514
	Construction Time (Years)	15	15	15	15	15	14	14	12
	Employment Impacts (Equiv. Annual #)	6,339	4,983	3,236	1,760	1,370	3,715	3,102	3,717
	EQ - Indirect Impacts (Unit-less Scale +8 to -8)	0	0	0	0	0	-8	-8	-1
	Direct Wetland Impacts (Acres)	0	0	0	0	0	1,000	1,000	3,600
	Historical Properties Protected (# Properties)	122	126	126	126	126	127	127	126
	Historical Districts Protected (# Districts)	41	43	43	43	43	43	43	43
	Archeological Properties Protected (# Sites)	111	221	221	221	221	265	265	275

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			Coastal	NS - 100	NS - 400	NS-1000	LP-a-100-1	C-LP-a-100-1	C-HL-a-100-3
Evaluation Criteria	**Stakeholder MCDA** (Rank)	20th of 27 alternatives	5th	2nd	3rd	1st	11th	9th	4th
	EA Risk Reduction Cost Efficiency (Rank)	N/A	4th	1st	5th	6th	3rd	2nd	9th
	Equivalent Annual Total System Costs $Millions (Rank)	N/A	1,649 (2nd)	1,606 (1st)	2,224 (5th)	2,919 (16th)	1,807 (3rd)	1,845 (4th)	2,384 (7th)
	Period of Analysis Cost Efficiency (Rank)	N/A	2nd	4th	7th	14th	1st	3rd	16th
	Equivalent Annual Residual Damages (% of No Action)	N/A	79%	52%	33%	27%	65%	53%	62%
	Period of Analysis Residual Damages $Millions (% No Action)	31,806	21,037 (66%)	17,545 (55%)	8,771 (28%)	3,924 (12%)	12,893 (41%)	10,498 (33%)	16,977 (53%)
	Avg % Risk Reduction 100-yr to 2,000-yr Freq. % of No Action	N/A	31%	42%	62%	79%	52%	60%	45%
Frequency Event Remaining Risk ($Millions)	100-year	11,935	5,957	2,191	804	618	4,200	1,703	1,440
	400-year	89,937	54,550	50,601	5,450	2,090	19,737	16,335	49,754
	1,000-year	118,260	78,763	74,874	61,995	5,057	54,345	50,410	70,154
	2,000-year	122,343	119,248	115,364	106,842	89,283	108,114	104,180	114,933
Secondary Evaluation Criteria	**# of Structures Included in Nonstructural Components**	N/A	N/A	Buyouts 10,472 (40%) Raise-in-Place 15,763 (60%)	Buyouts 15,649 (7%) Raise-in-Place 203,732 (93%)	Buyouts 44,296 (15%) Raise-in-Place 242,091 (85%)	N/A	Buyouts 10,724 (68%) Raise-in-Place 5,054 (32%)	Buyouts 10,085 (81%) Raise-in-Place 2,332 (19%)
	Impacts of Level of Participation in Nonstructural Measures on Plan Rank	N/A	N/A	Based on residual damages, drops out of Top 10 ranked plans at 90% NS participation	Based on residual damages, drops from 2nd to 7th in plan ranking at 50% NS participation, & out of Top 10 at 40%	Based on residual damages, drops from 1st to out of Top 10 at 40% NS participation	N/A	Based on residual damages, initial ranking of alternative, based on 100% NS participation, is 10th; this drops to 14th at 40%.	Based on residual damages, initial ranking of alternative, based on 100% NS participation, is 19th; this drops to 22nd at 40%.
	Total System Costs adjusted for Future Degraded Coast (Total costs minus coastal costs, plus additional levee costs (to maintain LOP), plus residual damages)	N/A	N/A	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$1.6 to $1.1 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$2.2 to $1.7 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$2.9 to $2.4 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$1.8 to $1.3 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$1.8 to $1.3 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$2.4 to $1.9 Billion**

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			Coastal	NS - 100	NS - 400	NS-1000	LP-a-100-1	C-LP-a-100-1	C-HL-a-100-3
Secondary Evaluation Criteria (cont'd)	Weir Barrier Impacts on Surge Frequency Elevations Around Lake Ponchartrain	N/A	N/A	N/A	N/A	N/A	At the eastern and western ends of Lake Pontchartrain the 100- year High Level Plan (HLP) stage corresponds to about a 300-yr stage with the weir barrier in place; along the South Shore near Orleans Parish Lakefront the 100-yr HLP stage corresponds to about a 500-yr elevation with the weir barrier in place; and along the North Shore near Mandeville the 100-yr HLP stage is about at the stage for a 1,100-yr frequency stage with the weir barrier in place.		N/A
	System Analysis (Regional Impacts - Mississippi Coast)	N/A	N/A	N/A	N/A	N/A	Annual equivalent risk reduction (without SLR) for Louisiana coast equal $372 Million; potential AE incremental impacts (increase in damages) to the Mississippi coast from construction of the weir barrier are $5 Million. 2075 risk reduction for Louisiana coast for a 400-yr and 1,000-yr frequency event (without SLR) are $46.57 Billion and $61.91 Billion, respectively; potential incremental impacts (increase in damages) to the Mississippi coast are $0.27 Billion for a 500-yr event and $0.28 Billion for a 1,000-yr event.		Annual equivalent risk reduction (without SLR) for Louisiana coast equal $293 Million; incremental AE damages to Mississippi coast are $5 Thousand. 2075 potential incremental damages to the Mississippi Coast for a 500-yr and 1,000-yr frequency event (without SLR) are $3.4 Million and $ 8.2 Million, respectively, while risk reduction to Louisiana coast are $11.9 Billion and $41.4 Billion, respectively for a 400-yr and 1,000-yr event.
Risk and Reliability Comparison	Qualitative Failure Scoring	N/A	N/A	N/A	N/A	N/A	Alignment ranked 3rd best of the 10 structural alignments evaluated in detail.		Alignment ranked 5th of the 10 alignments evaluated in detail.
	Levee Lengths	N/A	N/A	N/A	N/A	N/A	108.9 miles of levee		147.9 miles of levee
	Structures	N/A	N/A	N/A	N/A	N/A	Alignment includes: 45 small structures, including environmental structures, & other small drainage structures, road and railroad gates; 13 large structures, including sector gates, tainter gates, and pumping stations (multiple gate structures are proposed at the mouth of Lake Pontchartrain).		Includes 68 small structures and 17 large structures.
Category 5 Risk Reduction	Provides significant surge risk reduction (based on residual damages) for a 400-yr frequency storm event or greater	N/A	No	No	Yes	Yes	Yes	Yes	No

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			Coastal	NS - 100	NS - 400	NS-1000	LP-a-100-1	C-LP-a-100-1	C-HL-a-100-3
State's Master Plan	**Consistency of Alternative with Louisiana's Comprehensive Master Plan for a Sustainable Coast**	**No**	**Yes** (in part) - Both plans include Mississippi River diversions, marsh restoration using dredged material, & shoreline stabilization in strategic areas.	**Yes** (in part)- The State Master Plan describes nonstructural solutions that offers tools that communities can use now to reduce residual risks. Nonstructural plans identified in final array also include coastal restoration measures to sustain coastal landscape.			**Yes** - Includes building outer barrier (identified as critical action item by State); provides greater than 100-yr protection to areas around Lake Pontchartrain; consistent with states multi-faceted protection plan for Plaquemines Parish. Also, includes coastal restoration measures.	**Yes**- Same as LP-a-100-1, but includes nonstructural components in Planning Unit not protected by structural measures. Also, includes coastal restoration measures to sustain coastal landscape.	**No** - Except this plan also includes coastal restoration measures to sustain coastal landscape.
Implementation (Based on preliminary cost estimates used during plan formulation, evaluation and comparison of alternatives to identify final array of alternatives.)	**Total Present Value Life-Cycle Costs**	**N/A**	**$10.7 Billion** (or average annual cost of approx. $543 Million)	**$17.1 Billion** (or average annual cost of approx. $873 Million)	**$34.5 Billion** (or average annual cost of approx. $1,761 Million)	**$49.7 Billion** (or average annual cost of approx. $2,535 Million)	**$17.7 Billion** (or average annual cost of approx. $903 Million)	**$21.6 Billion** (or average annual cost of approx. $1,100 Million)	**$29.7 Billion** (or average annual cost of approx. $1,514 Million)
	Federal Share of Present Value Life-Cycle Costs	**N/A**	**$7.0 Billion** (or average annual cost of approx. $353 Million)	**$11.1 Billion** (or average annual cost of approx. $567 Million)	**$22.4 Billion** (or average annual cost of approx. $1,145 Million)	**$32.3 Billion** (or average annual cost of approx. $1,648 Million)	**$11.4 Billion** (or average annual cost of approx. $587 Million)	**$14.0 Billion** (or average annual cost of approx. $715 Million)	**$19.1 Billion** (or average annual cost of approx. $984 Million)
	Non-Federal Share of Present Value Life-Cycle Costs	**N/A**	**$3.7 Billion** (or average annual cost of approx. $190 Million)	**$6.0 Billion** (or average annual cost of approx. $306 Million)	**$12.1 Billion** (or average annual cost of approx. $616 Million)	**$17.4 Billion** (or average annual cost of approx. $887 Million)	**$6.3 Billion** (or average annual cost of approx. $316 Million)	**$7.6 Billion** (or average annual cost of approx. $385 Million)	**$10.6 Billion** (or average annual cost of approx. $530 Million)
	Challenges / Issues / Other Information	Provides no additional risk reduction beyond that provided by the authorized 100-yr design for the Metro area to be completed by 2011. Coastal landscape would also continue to degrade.	Coastal measures identified are for risk reduction only and were evaluated based on ability of alternative to sustain acreage of existing coastal landscape. Individual measures were not optimized or incrementally evaluated. A representative coastal landscape was included in all alternatives as a first line of defense.	The level of analysis of nonstructural plans demonstrate that nonstructural measures are viable, efficient, and effective. However, a unifying framework is needed that can advance nonstructural implementation in a systematic and integrated way with a base focused at delivery at the individual community level. A programmatic authority for nonstructural implementation (which currently does not exist) would have to be developed to efficiently meet this need.			Weir barrier has not been optimized at this time to try and minimize potential regional impacts resulting from increases in surge elevation outside of the barrier. Additional system analysis modeling runs and economic evaluations would be needed to do this. Also, although preliminary evaluation of the proposed gated structures at the Chef Menteur and Rigoletes have been designed to not impact movement of the tidal prism, additional efforts would be required to address, minimize and mitigate, if necessary, any potential adverse environmental impacts.		Much of the Lake Pontchartrain area would still be subject to high surge elevations and risk from more intense storms.

Table 15-3. Tradeoff Analysis for Planning Unit 2.

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS-400	WBI -100-1	C-WBI -100-1	C-G-100-1	C-R-100-2	C-R-100-4
General	Plan Description	No additional improvements for Risk Reduction; Level of Protection for Existing Levees reduced over time due to subsidence and sea level rise, changes in coastal landscape; Future Coastal Landscape reflects degraded condition.	Sustain coastal landscape through restoration. Implement comprehensive 400-year nonstructural measures, including buyouts and raise-in-place.	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank.	Comprehensive alternative including coastal restoration, structural and nonstructural measures. Same as alternative WBI-100-1, but adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.	Sustain coastal landscape through restoration. Similar structural features as WBI-100-1 but with additional barrier-weir and levees along the GIWW to reduce risk to all areas within the Barataria Basin. Also provides for ring levees to reduce risk to the Lafitte area; adds complement nonstructural measures to reduce residual risk in areas w/o structural risk reduction measures.	Sustain coastal landscape through restoration; construct new sector gate on Bayou Barataria to reduce risk on the West Bank; extend West Bank and Vicinity levees to Boutte and construct/raise Lafitte ring levees to 100-yr level of risk reduction; adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.	Similar to C-R-100-2, except adds construction/raising of Des Allemands ring levee to 100-year level of risk reduction and constructs new levee up the east side of Bayou Lafourche from Larose to Highway 90 at the 100-year level of risk reduction.
Performance Data (Metrics)	**Population Impacted** (Equiv Annual #)	**31,156**	**16,460**	**20,935**	**20,047**	**19,020**	**19,510**	**18,217**
	Residual Damages (Equiv Annual $Millions)	**2,164**	**332**	**983**	**739**	**633**	**821**	**810**
	Life-Cycle Costs (Equiv Annual $Millions)	**0**	**1,603**	**851**	**1,065**	**1,343**	**1,366**	**1,626**
	Construction Time (Years)	**15**	**15**	**6**	**6**	**11**	**11**	**11**
	Employment Impacts (Equiv Annual #)	**9,054**	**1,873**	**3,883**	**3,055**	**2,558**	**3,367**	**3,307**
	EQ - Indirect Impacts (Unit-less Scale +8 to -8)	**0**	**0**	**+2**	**+2**	**-8**	**+4**	**4**
	Direct Wetland Impacts (Acres)	**0**	**0**	**0** (current estimates range from about 117 to 311 acres)	**0** (current estimates range from about 117 to 311 acres)	**1,000**	**700**	**1,600**
	Historical Properties Protected (# Properties)	**12**	**13**	**14**	**14**	**24**	**14**	**14**
	Historical Districts Protected (# Districts)	**0**	**4**	**6**	**6**	**8**	**6**	**6**
	Archeological Properties Protected (# Sites)	**42**	**154**	**160**	**160**	**396**	**160**	**171**

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS-400	WBI -100-1	C-WBI -100-1	C-G-100-1	C-R-100-2	C-R-100-4
Evaluation Criteria	**Stakeholder MCDA** (Rank)	31st of 31 Alternatives	9th	3rd	1st	14th	2nd	17th
	EA Risk Reduction Cost Efficiency (Rank)	N/A	5th	3rd	4th	6th	8th	14th
	Equiv. Annual Total System Costs $Millions (Rank)	N/A	1,935 (5th)	1,834 (4th)	1,804 (3rd)	1,976 (6th)	2,187 (8th)	2,436 (14th)
	Period of Analysis Cost Efficiency (Rank)	N/A	7th	2nd	5th	4th	11th	17th
	Equivalent Annual Residual Damages (% of No Action)	N/A	15%	45%	34%	29%	38%	37%
	Period of Analysis Residual Damages $Millions (% No Action)	36,797	2,979 (8%)	15,016 (41%)	12,100 (33%)	3,874 (11%)	11,313 (31%)	10,859 (30%)
	Avg % Risk Reduction 100-yr to 2,000-yr Freq. % of No Action	N/A	79%	36%	40%	84%	41%	42%
Frequency Event Remaining Risk ($Millions)	100-year	46,652	517	6,102	3,493	2,148	2,783	2,293
	400-year	51,671	5,548	40,302	38,149	6,471	37,566	36,990
	1,000-year	53,208	13,451	44,147	42,170	11,684	41,457	40,879
	2,000-year	53,965	24,867	45,405	43,451	13,601	42,668	41,942
Secondary Evaluation Criteria	**# of Structures Included in Nonstructural Components**	N/A	Buyouts 23,085 (14%) Raise-in-Place 145,039 (86%)	N/A	Buyouts 5,777 (33%) Raise-in-Place 11,568 (67%)	Buyouts 5,777 (46%) Raise-in-Place 6,694 (54%)	Buyouts 5,777 (42%) Raise-in-Place 8,025 (58%)	Buyouts 5,777 (49%) Raise-in-Place 5,923 (51%)
	Impacts of Level of Participation in Nonstructural Measures on Plan Rank	N/A	Based on residual damages, drops from 2nd to 6th at 30% NS participation and out of Top 10 at 20% participation	N/A	Based on residual damages, initial ranking of alternative, based on 100% NS participation is 13th; this drops to 14th at 80% participation	Based on residual damages, initial ranking of alternative, based on 100% NS participation is 8th; this moves up to 6th at 80% and to 4th at 30%	Based on residual damages, initial ranking of alternative, based on 100% NS participation is 18th; this drops to 21st at 90% and to 23rd at 70%	Based on residual damages, initial ranking of alternative, based on 100% NS participation is 15th; this drops to 16th at 90% and to 19th at 80%
	Total System Costs adjusted for Future Degraded Coast (Total costs minus coastal costs, plus additional levee costs (to maintain LOP), plus residual damages)	N/A	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$1.9 to $1.2 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$1.8 to $1.1 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$1.8 to $1.1 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$2.0 to $1.2 Billion**	**Plan ranking (compared to alternative with sustaining the coastal landscape) remains the same**; Equivalent Annual Total System Costs are reduced from **$2.2 to $1.4 Billion**	**Plan ranking (compared to alterntive with sustaining the coastal landscape) remains essentially the same, dropping from 10th to 11th**; Equivalent Annual Total System Costs are reduced from **$2.3 to $1.5 Billion**

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS-400	WBI -100-1	C-WBI -100-1	C-G-100-1	C-R-100-2	C-R-100-4
Secondary Evaluation Criteria (cont'd)	**Weir Barrier Impacts on Surge Frequency Elevations for Areas Included in the Barataria Basin**	N/A	N/A	N/A	N/A	For areas south of Des Allemands the 100-yr ridge (R) plan stage corresponds to about a 250-yr stage with the weir barrier (G) in place; at the Northern shoreline of Lake Cataouatche (near the West Bank) the 100-yr ridge plan stage plots well beyond the 2,000-yr stage with the weir barrier in place; and at the northeastern shoreline of Lake Salvador, the 50-yr ridge plan stage corresponds to about the 1,500-yr stage with the weir barrier in place and the 100-yr ridge plan stage is well beyond the upper limit of the weir barrier frequency plot (2,000-yr)	N/A	N/A
Risk and Reliability Comparison	**Qualitative Failure Scoring**	N/A	N/A	Alignment ranked best (with the lowest chance of failure) among the 6 structural alignments evaluated in detail		Alignment ranked 4th to 5th among the 6 structural alignments evaluated in detail depending on weighting of eval. criteria	Alignment ranked 2nd among the 6 structural alignments evaluated in detail	Alignment ranked last (with the greatest chance of failure) among the 6 structural alignments evaluated in detail
	Levee Lengths	N/A	N/A	75.4 miles of levee		121.4 miles of levee	94.4 miles of levee	181.6 miles of levee
	Structures	N/A	N/A	Alignment includes: 22 small structures, including environmental structures, & other small drainage structures, road and railroad gates; 18 large structures, including sector gates, tainter gates, and pumping stations		Includes 31 small structures and 24 large structures	Includes 26 small structures and 22 large structures	Includes 43 small structures and 31 large structures
Category 5 Risk Reduction	**Provides significant surge risk reduction (based on residual damages) for a 400-yr frequency storm event or greater**	N/A	Yes	No	No	Yes	No	No
State's Master Plan	**Consistency of Alternative with Louisiana's Comprehensive Master Plan for a Sustainable Coast**	No	**Yes** (in part) - the State Master Plan describes nonstructural solutions that offers tools that communities can use now to reduce residual risks. NS plan also include coastal restoration measures to sustain coastal landscape	**No** - the Sector Gate South proposed is included in the raising of the West Bank and Vicinity of metro New Orleans existing levees to the 1% (100-yr) level of protection through ongoing work by the Corps of Engineers, but plan does not include further raising of these levees or construction of an outer barrier. Plans do not protect central basin communities. Plans also includes coastal restoration measures. C-WBI-100-1 includes nonstructural components for areas outside of areas protected by levees.		**Yes -** plan provides for greater than 1% (100-yr) level of risk reduction for the West Bank through building of an outer barrier (weir barrier). Plan also includes coastal restoration, nonstructural measures, and protection of central basin communities.	**No -** Similar to cmt for C-WBI-100-1; except plan does include extending West Bank levees north to Boutte and constructing Crown Point, Jean Lafitte, and Lafitte ring levees to 100-yr level of risk reduction.	**Yes** (in part) **-** Similar to cmt for C-WBI-100-1; except plan does include extending West Bank levees north to Boutte and provides risk reduction to Laforche Bayou area (between Larose to Hwy 90) and to central basin communities, such as Lafitte.

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS-400	WBI -100-1	C-WBI -100-1	C-G-100-1	C-R-100-2	C-R-100-4
Implementation (Based on preliminary cost estimates used during plan formulation, evaluation and comparison of alternatives to identify final array of alternatives)	**Total Present Value Life-Cycle Costs**	**N/A**	**$31.4 Billion** (or average annual cost of approx. $1,603 Million) *PV LCC of coastal restoration component is* ***$15,657*** $Million	**$16.7 Billion** (or average annual cost of approx. $851 Million)	**$20.9 Billion** (or average annual cost of approx. $1,065 Million)	**$26.3 Billion** (or average annual cost of approx. $1,343 Million)	**$26.8 Billion** (or average annual cost of approx. $1,366 Million)	**$32.7 Billion** (or average annual cost of approx. $1,671 Million)
	Federal Share of Present Value Life-Cycle Costs	**N/A**	**$20.4 Billion** (or average annual cost of approx. $1,042 Million)	**$10.8 Billion** (or average annual cost of approx. $552 Million)	**$13.6 Billion** (or average annual cost of approx. $691 Million)	**$16.9 Billion** (or average annual cost of approx. $866 Million)	**$17.3 Billion** (or average annual cost of approx. $882 Million)	**$21.0 Billion** (or average annual cost of approx. $1,073 Million)
	Non-Federal Share of Present Value Life-Cycle Costs	**N/A**	**$11.0 Billion** (or average annual cost of approx. $561 Million)	**$5.9 Billion** (or average annual cost of approx. $299 Million)	**$7.3 Billion** (or average annual cost of approx. $374 Million)	**$9.4 Billion** (or average annual cost of approx. $477 Million)	**$9.5 Billion** (or average annual cost of approx. $484 Million)	**$11.7 Billion** (or average annual cost of approx. $598 Million)
	Challenges / Issues / Other Information	Provides no additional risk reduction beyond that provided by the authorized 100-yr design for the West Bank to be completed by 2011 and local levees within the basin. Coastal landscape would also continue to degrade.	The level of analysis of nonstructural plans demonstrate that nonstructural measures are viable, efficient, and effective. However, a unifying framework is needed that can advance nonstructural implementation in a systematic and integrated way with a base focused at delivery at the individual community level. A programmatic authority for nonstructural implementation (which currently does not exist) would have to be developed to efficiently meet this need.	Construction of a new sector gate on Bayou Barataria (known as Sector Gate South) to provide additional protection to the West Bank and to reduce the length of hurricane levee exposure to potential overtopping / failure is currently being pursued as part of the authorized 100-year project. LACPR effort and results emphasizes the importance of this structure to further risk reduction in this area. This is the most efficient structural measure evaluated in LACPR.	See comment for WBI-100-1	Weir barrier has not been optimized at this time to try and minimize potential impacts resulting from increases in surge elevation outside of the barrier. Additional hydrodynamic modeling runs and economic evaluations would be needed to do this. Also, additional efforts would be required to address, minimize and mitigate, if necessary, any potential adverse environmental impacts. Potential constructability issues due to poor soil conditions and maintaining appropriate circulation through the proposed levee would need to be addressed in more detail in subsequent efforts.	West Bank of New Orleans will still remain vulnerable to surge from very large storms. Also, much of the Barataria Basin remains exposed to hurricane surge. Plan has not investigated improving drainage through the Highway 90 roadway embankment to improve drainage to the upper basin.	West Bank of New Orleans will still remain vulnerable to surge from very large storms. Plan has not investigated improving drainage through the Highway 90 roadway embankment to improve drainage to the upper basin.

Table 15-4. Tradeoff Analysis for Planning Unit 3a.

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 100	NS - 400	NS-1000	C-M-100-1	C-M-100-2	M-100-2
General	Plan Description	No additional improvements for Risk Reduction; Level of Protection for Existing Levees reduced over time due to subsidence and sea level rise, changes in coastal landscape; Future Coastal Landscape reflects degraded condition.	Implement comprehensive 100-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Implement comprehensive 400-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Implement comprehensive 1,000-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Construct Morganza to the Gulf levee with extension tying into high ground west of Morgan City at 100-year design level; adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures; does not include coastal restoration measures for hurricane surge risk reduction.	Construct Morganza to the Gulf levee with extension tying into high ground south of Thibodaux and ring levee around Morgan City at 100-year design level; adds complementary nonstructural measures in areas without structural risk reduction measures; does not include coastal restoration measures for hurricane surge risk reduction.	Construct Morganza to the Gulf levee with extension tying into high ground south of Thibodaux and ring levee around Morgan City at 100-year design level; does not include coastal restoration measures for hurricane surge risk reduction.
Performance Data (Metrics)	**Population Impacted** (Annual Equiv #)	19,069	17,559	15,858	14,544	9,095	9,925	9,937
	Residual Damages (Annual Equiv $Millions)	1,028	512	365	330	426	483	537
	Life-Cycle Costs (Annual Equiv. $Millions)	0	399	544	597	1,126	1,005	969
	Construction Time (Years)	15	15	15	15	10	10	10
	Employment Impacts (Annual Equiv. #)	5,462	3,078	1,805	1,457	2,332	2,490	2,606
	EQ - Indirect Impacts (Unit-less Scale +8 to -8)	0	0	0	0	-7	-4	-4
	Direct Wetland Impacts (Acres)	0	0	0	0	4,900	4,200	4,200
	Historical Properties Protected (# Properties)	0	3	3	3	13	10	10
	Historical Districts Protected (# Districts)	0	0	0	0	0	0	0
	Archeological Properties Protected (# Sites)	72	111	111	111	157	128	128

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 100	NS - 400	NS-1000	C-M-100-1	C-M-100-2	M-100-2
Evaluation Criteria	**Stakeholder MCDA** (Rank)	11th of 13 alternatives	3rd	2nd	1st	6th	4th	5th
	AE Risk Reduction Cost Efficiency (Rank)	N/A	3rd	2nd	1st	4th	5th	8th
	Average Annual Total System Costs $Millions (Rank)	N/A	911 (2nd)	909 (1st)	927 (3rd)	1,552 (7th)	1,489 (5th)	1,507 (6th)
	Period of Analysis Cost Efficiency (Rank)	N/A	11th	2nd	1st	3rd	7th	9th
	Annual Equivalent Residual Damages (% of No Action)	N/A	50%	36%	32%	41%	47%	52%
	Period of Analysis Residual Damages $Millions (% No Action)	12,571	8,337 (66%)	3,937 (31)%	1,927 (15%)	2,188 (17)%	3,616 (29%)	4,154 (33%)
	Avg % Risk Reduction 100-yr to 2,000-yr Freq. % of No Action	N/A	16%	49%	73%	65%	54%	52%
Frequency Event Remaining Risk	100-year	10,629	5,111	1,271	717	422	1,548	2,082
	400-year	22,650	20,976	8,151	3,068	1,852	5,133	5,312
	1,000-year	26,922	26,215	19,436	8,156	15,182	20,469	20,567
	2,000-year	28,659	28,308	23,655	16,545	20,184	20,694	20,763
Secondary Evaluation Criteria	# of Structures Included in Nonstructural Components	N/A	Buyouts 734 (2%) Raise-in-Place 30,643 (98%)	Buyouts 7,695 (12%) Raise-in-Place 55,804 (88%)	Buyouts 12,747 (18%) Raise-in-Place 56,832 (82%)	Buyouts 738 (30%) Raise-in-Place 1,710 (70%)	Buyouts 738 (27%) Raise-in-Place 1,980 (73%)	N/A
	Impacts of Level of Participation in Nonstructural Measures	N/A	Based on residual damages and 100% participation in NS measures, the alternative is ranked 9th; this ranking drops to 11th of 12 alternatives at 90% participation	Based on residual damages and 100% participation in NS measures, the alternative is ranked 2nd; this drops to 4th at 90% participation, 7th at 80% participation and to 10th of 12 alternatives at 70% participation	Based on residual damages and 100% participation in NS measures, the alternative is ranked 1st; this drops to 4th at 80% participation, and to 9th of 12 alternatives at 70% participation	Based on residual damages and 100% participation in NS measures, the alternative is ranked 4th; this rises to 3rd at 90% participation, 2nd at 80% participation and to 1st with 70% participation.	Based on residual damages and 100% participation in NS measures, the alternative is ranked 7th; this rises to 6th at 80% participation and to 5th at 70% participation; at 40% participation alternative drops back to 7th and remains constant at that level for lesser levels of participation.	N/A

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 100	NS - 400	NS-1000	C-M-100-1	C-M-100-2	M-100-2
Secondary Evaluation Criteria (Cont'd)	Total System Costs adjusted for Future Sustained Coast (Total alternative costs plus coastal landscape costs, plus residual damages)	N/A	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equivalent Annual Total System Costs are increased from **$0.9 to $2.1 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/future degraded coast) remains the same**; Equivalent Annual Total System Costs are increased from **$ 0.9 to $2.1 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/future degraded coast) remains the same**; Equivalent Annual Total System Costs are increased from **$ 0.9 to $2.1 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/future degraded coast) remains the same**; Equivalent Annual Total System Costs are increased from **$ 1.6 to $2.7 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/future degraded coast) remains the same**; Equivalent Annual Total System Costs are increased from **$ 1.5 to $2.7 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/future degraded coast) remains the same**; Equivalent Annual Total System Costs are increased from **$ 1.5 to $2.7 Billion** with no additional reduction in remaining risk
Risk and Reliability Comparison	Qualitative Failure Scoring	N/A	N/A	N/A	N/A	Alignment ranked 2nd among the 3 alternatives evaluated in detail	Alignment ranked best (with the lowest chance of failure) among the 3 structural alignments evaluated in detail	
	Levee Lengths	N/A	N/A	N/A	N/A	112.7 miles of levee	85.2 miles of levee	
	Structures	N/A	N/A	N/A	N/A	Includes 31 small structures and 25 large structures	Alignment includes: 28 small structures, including environmental structures, & other small drainage structures, road and railroad gates; 23 large structures, including sector gates, tainter gates, & pumping stations	
Category 5 Risk Reduction	Provides significant surge risk reduction (based on residual damages) for a 400-yr frequency storm event or greater	N/A	No	Yes	Yes	Yes	Yes	Yes
State's Master Plan	Consistency of Alternative with Louisiana's Comprehensive Master Plan for a Sustainable Coast	No	**Yes** (in part)- The State Master Plan describes nonstructural solutions that offers tools that communities can use now to reduce residual risks.			**Yes** (in part) - provides for construction of current Morganza to the Gulf levee alignment to provide 1% level of protection to communities such as Dulac, Montegut, and Chauvin; plan also extends levee protection west to Morgan City and nonstructural components for areas outside of areas protected by proposed levees.	**Yes** (in part) - provides for construction of current Morganza to the Gulf levee alignment to provide 1% level of risk reduction to communities such as Dulac, Montegut, and Chauvin; plan also provides for ring levee around Morgan City with similar level of risk reduction and nonstructural components for areas outside of areas protected by proposed levees.	**Yes** (in part) - provides for construction of current Morganza to the Gulf levee alignment to provide 1% level of risk reduction to communities such as Dulac, Montegut, and Chauvin; plan also provides for ring levee around Morgan City with similar level of risk reduction.

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">Item</th><th rowspan="2">No Action</th><th colspan="5">Final Array of Alternatives</th><th>For Comparison Purposes Only</th></tr>
<tr><th>NS - 100</th><th>NS - 400</th><th>NS-1000</th><th>C-M-100-1</th><th>C-M-100-2</th><th>M-100-2</th></tr>
<tr><td rowspan="4">Implementation
(Based on preliminary cost estimates used during plan formulation, evaluation and comparison of alternatives to identify final array)</td><td>Total Present Value Life-Cycle Costs</td><td>N/A</td><td>$7.8 Billion
(or average annual cost of approx. $399 Million)</td><td>$10.7 Billion
(or average annual cost of approx. $544 Million)</td><td>$11.7 Billion
(or average annual cost of approx. $597 Million)</td><td>$22.0 Billion
(or average annual cost of approx. $1,126 Million)</td><td>$19.7 Billion
(or average annual cost of approx. $1,005 Million)</td><td>$19.0 Billion
(or average annual cost of approx. $969 Million)</td></tr>
<tr><td>Federal Share of Present Value Life-Cycle Costs</td><td>N/A</td><td>$5.1 Billion
(or average annual cost of approx. $259 Million)</td><td>$7.0 Billion
(or average annual cost of approx. $354 Million)</td><td>$7.6 Billion
(or average annual cost of approx. $388 Million)</td><td>$14.3 Billion
(or average annual cost of approx. $732 Million)</td><td>$12.8 Billion
(or average annual cost of approx. $653 Million)</td><td>$12.4 Billion
(or average annual cost of approx. $630 Million)</td></tr>
<tr><td>Non-Federal Share of Present Value Life-Cycle Costs</td><td>N/A</td><td>$2.7 Billion
(or average annual cost of approx. $140 Million)</td><td>$3.7 Billion
(or average annual cost of approx. $190 Million)</td><td>$4.1 Billion
(or average annual cost of approx. $209 Million)</td><td>$7.7 Billion
(or average annual cost of approx. $394 Million)</td><td>$6.9 Billion
(or average annual cost of approx. $352 Million)</td><td>$6.6 Billion
(or average annual cost of approx. $339 Million)</td></tr>
<tr><td>Challenges / Issues / Other Information</td><td>Provides no additional risk reduction; coastal landscape would also continue to degrade.</td><td colspan="3">The level of analysis of nonstructural plans demonstrate that nonstructural measures are viable, efficient, and effective. However, a unifying framework is needed that can advance nonstructural implementation in a systematic and integrated way with a base focused at delivery at the individual community level. A programmatic authority for nonstructural implementation (which currently does not exist) would have to be developed to efficiently meet this need.</td><td>Project's alignment follows dredged material disposal banks and canals in order to minimize effects on wetlands; environmental structures are incorporated into the alignment to restore connections to impounded wetlands to the estuary; if land use practices are not changed to require buffer zones near the levee and prohibit development in wetlands, the levee could encourage new development in low-lying areas; it also has been determined that an interior levee system to provide additional risk reduction to the Houma/Thibodaux area is not warranted. Plan does not include coastal restoration measures for hurricane surge risk reduction.</td><td>Challenges / issues similar to C-M-100-1; proposed levee alignment is consistent with authorized alignment for Morganza to the Gulf project with some minor adjustments/design changes to be further examined in post authorization studies; some construction issues exist with ring levee around Morgan City. Plan is not overly sensitive to level of participation in proposed nonstructural components. Plan does not include coastal restoration measures for hurricane surge risk reduction.</td><td>Challenges / issues similar to C-M-100-1; proposed levee alignment is consistent with authorized alignment for Morganza to the Gulf project with some minor adjustments/design changes to be further examined in post authorization studies; some construction issues exist with ring levee around Morgan City. Plan does not include coastal restoration measures for hurricane surge risk reduction.</td></tr>
</table>

Table 15-5. Tradeoff Analysis for Planning Unit 3b.

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 400	NS - 1000	C-G-100-1	C-F-100-1	C-RL-100-1	C-RL-400-1
General	Plan Description	No additional improvements for Risk Reduction; Level of Protection for Existing Levees reduced over time due to subsidence and sea level rise, changes in coastal landscape; Future Coastal Landscape reflects degraded condition.	Implement comprehensive 400-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Implement comprehensive 1,000-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the GIWW west to the boundary of Plng Unit 4 at the 100-year design level. Adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures; does not include coastal restoration measures for hurricane surge risk reduction.	Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 100-year design level. Adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures; does not include coastal restoration measures for hurricane surge risk reduction.	Raise ring levee around Patterson/Berwick to 100-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 100-year design level. Adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures; does not include coastal restoration measures for hurricane surge risk reduction.	Raise ring levee around Patterson/Berwick to 400-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 400-year design level. Adds complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures; does not include coastal restoration measures for hurricane surge risk reduction.
Performance Data (Metrics)	**Population Impacted** (Annual Equiv #)	7,655	7,117	7,016	3,191	3,839	4,988	4,882
	Residual Damages (Annual Equiv $Millions)	469	183	166	191	229	244	213
	Life-Cycle Costs (Annual Equiv. $Millions)	0	232	290	789	729	635	970
	Construction Time (Years)	15	15	15	10	10	10	12
	Employment Impacts (Annual Equiv. #)	2,248	781	705	928	1,046	1,085	1,037
	EQ - Indirect Impacts (Unit-less Scale +8 to -8)	0	0	0	-8	2	2	2
	Direct Wetland Impacts (Acres)	0	0	0	2,300	2,500	900	1,700
	Historical Properties Protected (# Properties)	6	2	2	18	14	11	15
	Historical Districts Protected (# Districts)	0	0	0	5	1	0	3
	Archeological Properties Protected (# Sites)	14	106	106	264	154	123	123

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 400	NS - 1000	C-G-100-1	C-F-100-1	C-RL-100-1	C-RL-400-1
Evaluation Criteria	**Stakeholder MCDA** (Rank)	17th of 17 Alternatives	12th	9th	6th	2nd	1st	5th
Evaluation Criteria	**AE Risk Reduction Cost Efficiency** (Rank)	N/A	1st	3rd	4th	7th	5th	9th
Evaluation Criteria	**Average Annual Total System Costs** $Millions (Rank)	N/A	415 (2nd)	457 (3rd)	981 (8th)	959 (6th)	880 (4th)	1183 (10th)
Evaluation Criteria	**Period of Analysis Cost Efficiency** (Rank)	N/A	2nd	1st	4th	8th	9th	6th
Evaluation Criteria	**Annual Equivalent Residual Damages** (% of No Action)	N/A	39%	35%	41%	49%	52%	45%
Evaluation Criteria	**Period of Analysis Residual Damages** $Millions (% No Action)	5,449	1,899 (35%)	978 (18%)	574 (11%)	2,114 (39%)	2,497 (46%)	1,173 (22%)
Evaluation Criteria	**Avg % Risk Reduction 100-yr to 2,000-yr Freq.** % of No Action	N/A	41%	67%	79%	35%	33%	62%
Frequency Event Remaining Risk	100-year	4,254	537	433	147	418	1,038	291
Frequency Event Remaining Risk	400-year	8,571	3,643	817	426	5,300	6,486	1,827
Frequency Event Remaining Risk	1,000-year	11,203	9,691	3,928	2,733	10,720	9,360	6,161
Frequency Event Remaining Risk	2,000-year	12,281	11,524	9,274	6,240	11,245	10,261	8,635
Secondary Evaluation Criteria	**# of Structures Included in Nonstructural Components**	N/A	Buyouts 907 (4%)	Buyouts 1,307 (4%)	Buyouts 846 (80%)	Buyouts 846 (55%)	Buyouts 846 (23%)	Buyouts 907 (8%)
			Raise-in-Place 23471 (96%)	Raise-in-Place 31,663 (96%)	Raise-in-Place 210 (20%)	Raise-in-Place 697 (45%)	Raise-in-Place 2,761 (77%)	Raise-in-Place 10,355 (92%)
Secondary Evaluation Criteria	**Impacts of Level of Participation in Nonstructural Measures**	N/A	Based on residual damages and 100% participation in NS measures, the alternative is ranked 2nd of 16 alternatives; this ranking drops to 4th at 90% participation, to 8th at 80% participation, and to 12th at 70% participation.	Based on residual damages and 100% participation in NS measures, the alternative is ranked 1st; this ranking drops to 2nd at 90% participation, to 4th at 80% participation, and to 8th at 70% participation.	Based on residual damages and 100% participation in NS measures, the alternative is ranked 3rd; this rises to 1st at 90% participation and then remains constant in that ranking position for all lesser participation levels.	Based on residual damages and 100% participation in NS measures, the alternative is ranked 8th; this rises to 7th at 80% participation, to 5th at 70% participation.	Based on residual damages and 100% participation in NS measures, the alternative is ranked 9th and then drops to 10th at 90% participation and then remains constant at that level for all lesser participation levels.	Based on residual damages and 100% participation in NS measures, the alternative is ranked 6th; this ranking drops to 7th at 50% participation, to 8th at 40% participation and to 9th at 30% participation.

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 400	NS - 1000	C-G-100-1	C-F-100-1	C-RL-100-1	C-RL-400-1
Secondary Evaluation Criteria (cont'd)	**Total System Costs adjusted for Future Sustained Coast (Total alternative costs plus coastal landscape costs, plus residual damages)**	**N/A**	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs are increased from **$0.4 to $0.7 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs are increased from **$0.5 to $0.7 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs are increased from **$1.0 to $1.2 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs are increased from **$1.0 to $1.2 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs are increased from **$0.9 to $1.1 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs are increased from **$1.2 to $1.4 Billion** with no additional reduction in remaining risk
Risk and Reliability Comparison	**Qualitative Failure Scoring**	**N/A**	**N/A**	**N/A**	Alignment ranked 1st (equally with the C-RL alignment with the lowest chance of failure) among the 3 alternative alignments evaluated in detail.	Alignment ranked last (with the greatest chance of failure) among the 3 alternative alignments evaluated in detail.	Alignment ranked 1st (equally with the C-G alignment with the lowest chance of failure) among the 3 alternative alignments evaluated in detail.	
	Levee Lengths	**N/A**	**N/A**	**N/A**	93.0 miles of levee	114.2 miles of levee	92.8 miles of levee	
	Structures	**N/A**	**N/A**	**N/A**	Includes 18 small structures and 22 large structures	Includes 24 small structures and 22 large structures	Alignment includes: 24 small structures, including environmental structures, & other small drainage structures, road and railroad gates; 21 large structures, including sector gates, tainter gates, and pumping stations	
Category 5 Risk Reduction	**Provides significant surge risk reduction (based on residual damages) for a 400-yr frequency storm event or greater**	**N/A**	**Yes**	**Yes**	**Yes**	**No**	**No**	**Yes** (for areas protected with ring levees)
State's Master Plan	**Consistency of Alternative with Louisiana's Comprehensive Master Plan for a Sustainable Coast**	**No**	**Yes** (in part)- The State Master Plan describes nonstructural solutions that offers tools that communities can use now to reduce residual risks.		**Yes** (in part) - provides risk reduction to areas of highest concentration of assets in Lafayette, New Iberia, Franklin and Abbeville (plan provides for 100-year level of protection to these areas while the state plan calls for greater than 100-year level of protection); plan also provides 100-year risk reduction to areas between New Iberia and Berwick/Patterson as called for in the State Master Plan; plan differs in that proposed levee is provided along the GIWW.	**Yes** (in part) - risk reduction similar to that proposed for C-G-100-1; proposed levee alignment is identical to alignment included in the State Master Plan.	**Yes** (in part) - plan provides for 100-year level of risk reduction to Patterson/Berwick, Franklin, New Iberia, and Abbeville through construction of a regional ring levee system that surrounds/protects these population centers; some critical oil and gas infrastructure would remain unprotected.	**Yes** (in part) - plan provides for 400-year level of risk reduction to Patterson/Berwick, Franklin, New Iberia, and Abbeville through construction of a regional ring levee system that surrounds/protects these population centers; some critical oil and gas infrastructure would remain unprotected. The State plan calls for greater than a 100-year level of risk reduction for the New Iberia and Abbeville area.

Category	Item	No Action	Final Array of Alternatives					For Comparison Purposes Only
			NS - 400	NS - 1000	C-G-100-1	C-F-100-1	C-RL-100-1	C-RL-400-1
Implementation (Based on preliminary cost estimates used during plan formulation, evaluation and comparison of alternatives to identify final array)	**Total Present Value Life-Cycle Costs**	**N/A**	**$4.6 Billion** (or average annual cost of approx. $232 Million)	**$5.7 Billion** (or average annual cost of approx. $290 Million)	**$15.5 Billion** (or average annual cost of approx. $789 Million)	**$14.3 Billion** (or average annual cost of approx. $729 Million)	**$12.4 Billion** (or average annual cost of approx. $635 Million)	**$19.0 Billion** (or average annual cost of approx. $970 Million)
	Federal Share of Present Value Life-Cycle Costs	**N/A**	**$3.0 Billion** (or average annual cost of approx. $151 Million)	**$3.7 Billion** (or average annual cost of approx. $188 Million)	**$10.1 Billion** (or average annual cost of approx. $513 Million)	**$9.3 Billion** (or average annual cost of approx. $474 Million)	**$8.0 Billion** (or average annual cost of approx. $413 Million)	**$12.4 Billion** (or average annual cost of approx. $630 Million)
	Non-Federal Share of Present Value Life-Cycle Costs	**N/A**	**$1.6 Billion** (or average annual cost of approx. $81 Million)	**$2.0 Billion** (or average annual cost of approx. $102 Million)	**$5.4 Billion** (or average annual cost of approx. $276 Million)	**$5.0 Billion** (or average annual cost of approx. $255 Million)	**$4.4 Billion** (or average annual cost of approx. $222 Million)	**$6.6 Billion** (or average annual cost of approx. $340 Million)
	Challenges / Issues / Other Information	Provides no additional risk reduction; coastal landscape would also continue to degrade.	The level of analysis of nonstructural plans demonstrate that nonstructural measures are viable, efficient, and effective. However, a unifying framework is needed that can advance nonstructural implementation in a systematic and integrated way with a base focused at delivery at the community level. A programmatic authority for nonstructural implementation (which currently does not exist) would have to be developed to efficiently meet this need.		Alternative alignment as proposed is not compatible with final array of alternatives identified for PU 4. Alternative requires connecting element in PU 4. There fore, this component has been eliminated from further consideration and is not included in the combination of PU alternatives for developing array of coast wide plans.	Possible disruption to drainage interior drainage areas and environmental impacts from construction access; plan does not include coastal restoration measures for hurricane surge risk reduction.	Less population and commercial/industrial establishments receiving risk reduction than from a continuous levee built closer to the coast; interior drainage concerns and extensive pumping requirements; overtopping of design level could be catastrophic for enclosed areas; plan does not include coastal restoration measures for hurricane surge risk reduction	Same as for Plan C-RL-100-1; however, potential for overtopping is less because of greater level of design provided.

Table 15-6. Tradeoff Analysis for Planning Unit 4.

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			NS - 100	NS - 400	NS - 1000	C-RL-100-1	C-RL-400-1	C-RL-1000-1	C-G-100-2
General	Plan Description	No additional improvements for Risk Reduction; Level of Protection for Existing Levees reduced over time due to subsidence and sea level rise, changes in coastal landscape; Future Coastal Landscape reflects degraded condition.	Implement comprehensive 100-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Implement comprehensive 400-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Implement comprehensive 1,000-year nonstructural measures, including buyouts and raise-in-place. Does not include coastal restoration measures for hurricane surge risk reduction.	Comprehensive ring levee alternatives provide for a 100-year, 400-year and 1,000-year level of risk reduction through either structural or nonstructural measures, as appropriate. Alternatives include: construction of ring levees to the east and west of the Calcasieu River south of Lake Charles and south of the Sulpur/Vinton area; construction of a series of levees within Lake Charles to provide risk reduction to select land areas adjacent to the Calcasieu River; and construction of ring levees around Kaplan and Gueydan. Alternatives add complementary nonstructural measures to areas not protected by structural measures to provide comparable levels of risk reduction to the remainder of the surge impacted area within the Planning Unit. Plans do not include coastal restoration measures for hurricane surge risk reduction.			Provides for const. continuous levee (w/ gates) along the GIWW (from tie-back to high ground near Kaplan west to Lake Charles) plus a ring levee to the west of the Calcasieu River south of Sulpur/Vinton area; const. of a series of levees within Lake Charles to select land areas adjacent to the Calcasieu River; and adds complementary nonstructural measures. Plan does not include coastal restoration measures for hurricane surge risk reduction.
Performance Data (Metrics)	Population Impacted (Annual Equiv #)	4,752	4,106	4,024	3,911	4,221	4,020	3,849	3,325
	Residual Damages (Annual Equiv $Millions)	373	206	169	156	201	173	161	194
	Life-Cycle Costs (Annual Equiv. $Millions)	0	109	176	245	235	262	371	676
	Construction Time (Years)	15	15	15	15	10	12	14	10
	Employment Impacts (Annual Equiv. #)	996	505	369	321	515	396	338	590
	EQ - Indirect Impacts (Unit-less Scale +8 to -8)	0	0	0	0	0	0	0	-5
	Direct Wetland Impacts (Acres)	0	0	0	0	100	100	100	1,800
	Historical Properties Protected (# Properties)	0	2	2	2	1	1	1	0
	Historical Districts Protected (# Districts)	0	0	0	0	0	0	0	0
	Archeological Properties Protected (# Sites)	29	58	58	58	60	60	60	90

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			NS - 100	NS - 400	NS - 1000	C-RL-100-1	C-RL-400-1	C-RL-1000-1	C-G-100-2
Evaluation Criteria	Stakeholder MCDA (Rank)	14th of 19 alternatives	4th	2nd	1st	5th	3rd	6th	12th
	AE Risk Reduction Cost Efficiency (Rank)	N/A	3rd	1st	2nd	6th	4th	5th	10th
	Average Annual Total System Costs $Millions (Rank)	N/A	316 (1st)	345 (2nd)	401 (3rd)	436 (4th - tied with C-RL-400-1)	436 (4th - tied with C-RL-100-1)	532 (8th)	870 (12th)
	Period of Analysis Cost Efficiency (Rank)	N/A	7th	3rd	1st	6th	4th	2nd	10th
	Annual Equivalent Residual Damages (% of No Action)	N/A	55.2%	45.2%	41.9%	53.9%	46.5%	43.2%	52.0%
	Period of Analysis Residual Damages $Millions (% No Action)	3,974	2,506 (63.1%)	1,550 (39.0%)	944 (23.8%)	2,145 (54.0%)	1,592 (40.1%)	871 (21.9%)	1,804 (45.4%)
	Avg % Risk Reduction 100-yr to 2,000-yr Freq. % of No Action	N/A	24.2%	47.4%	68.8%	37.8%	45.0%	73.7%	46.7%
Frequency Event Remaining Risk ($Millions)	100-year	3,034	1,249	504	458	1,012	502	456	713
	400-year	6,592	5,340	2,214	935	4,739	1,585	836	3,488
	1,000-year	10,316	9,206	7,707	3,146	7,608	8,801	2,465	7,412
	2,000-year	12,755	11,720	10,905	8,278	8,928	12,031	6,837	8,298
Secondary Evaluation Criteria	# of Structures Included in Nonstructural Components	N/A	Buyouts 2,248 (26.7%)	Buyouts 2,547 (13.1%)	Buyouts 3,146 (10.5%)	Buyouts 2,248 (30.3%)	Buyouts 2,546 (17.7%)	Buyouts 3,146 (15.0%)	Buyouts 2,248 (40.9%)
			Raise-in-Place 6,160 (73.3%)	Raise-in-Place 16,841 (86.9%)	Raise-in-Place 26,760 (89.5%)	Raise-in-Place 5,173 (69.7%)	Raise-in-Place 11,843 (82.3%)	Raise-in-Place 17,845 (85.0%)	Raise-in-Place 3,244 (59.1%)
	Impacts of Level of Participation in Nonstructural Measures on Plan Rank	N/A	Based on residual damages and 100% participation in NS measures, the alternative is ranked 10th of 18 alternatives and drops to 12th at 30% participation	Based on residual damages and 100% participation in NS measures, the alternative is ranked 4th and drops to 7th at 80% participation and to 10th at 30%	Based on residual damages and 100% participation, alternative is ranked 2nd; ranking drops to 3rd at 80% participation, to 5th at 70%, to 7th at 50%, and to 9th at 30%	Based on residual damages and 100% participation in NS measures, alternative is ranked 9th; ranking drops out of Top 10 at 10% participation	Based on residual damages and 100% participation in NS measures, alternative is ranked 5th; ranking drops to 6th at 10% participation and to 7th at 20%	Based on residual damages and 100% participation in NS measures, alternative is ranked 3rd; ranking drops to 4th at 60% participation and to 5th at 40%	Based on residual damages and 100% participation, initial ranking of alternative is 8th; ranking rises to 7th at 60% participation and 5th at 50% and 4th at 40%.
	Total System Costs adjusted for Future Sustained Coast (Total alternative costs plus coastal landscape costs, plus residual damages)	N/A	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.3 to $0.9 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.3 to $0.9 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.4 to $1.0 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.4 to $1.0 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.4 to $1.0 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.5 to $1.1 Billion** with no additional reduction in remaining risk	**Plan ranking (compared to alternative w/ future degraded coast) remains the same**; Equiv. Annual Total System Costs increases from **$0.9 to $1.4 Billion** with no additional reduction in remaining risk

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			NS - 100	NS - 400	NS - 1000	C-RL-100-1	C-RL-400-1	C-RL-1000-1	C-G-100-2
Risk and Reliability Comparison	Qualitative Failure Scoring	N/A	N/A	N/A	N/A	Alignment ranked best (with the lowest chance of failure) among the 4 structural alignments evaluated in detail.			Alignment ranked 2nd of the 4 alignments evaluated in detail.
	Levee Lengths	N/A	N/A	N/A	N/A	35.8 miles of levee			112.5 miles of levee
	Structures	N/A	N/A	N/A	N/A	Alignment includes: 14 small structures, including environmental structures, & other small drainage structures, road and railroad gates; 11 large structures, including sector gates, tainter gates, and pumping stations.			Includes 26 small structures and 21 large structures, including large sector gate at the Mermentau River.
Category 5 Risk Reduction	Provides significant surge risk reduction (based on residual damages) for a 400-yr frequency storm event or greater	N/A	No	Yes	Yes	No	Yes	Yes	No
State's Master Plan	Consistency of Alternative with Louisiana's Comprehensive Master Plan for a Sustainable Coast	No	**Yes** (in part)- The State Master Plan describes nonstructural solutions that offers tools that communities can use now to reduce residual risks.			**No -** Does not include greater than a 100-year level of protection for the Lake Charles/Sulphur area as recommended in the State Master Plan. For areas between Abbeville and Lake Charles no additional structural risk reduction measures are proposed, except for 100-year ring levees around Gueydan and Kaplan. Alternative adds complementary nonstructural measures at the 100-year level of protection for areas not protected with structural measures.	**Yes** (in part) - Alternatives provide for greater than 100-year level of protection in the Lake Charles/Sulphur area as recommended in the State Master Plan. Raising of highways as proposed in the State Master Plan would be the responsibility of non-Federal interests. For areas between Abbeville and Lake Charles no additional structural risk reduction measures are proposed, except for ring levees around Gueydan and Kaplan. Alternative adds complementary nonstructural measures at the 400-year or 1,000-year level of protection, respectively, for areas not protected with structural measures.		**Yes** (in part) **-** Does not include greater than a 100-year level of protection for the Lake Charles/Sulphur area as recommended in the State Master Plan; provides for 100-year level of protection for areas west of Abbeville to the east side of the Calcasieu River south of Lake Charles from construction of levee along the GIWW; adds complementary non-structural measures at the 100-year level of protection for areas not protected with structural measures

Category	Item	No Action	Final Array of Alternatives						For Comparison Purposes Only
			NS - 100	NS - 400	NS - 1000	C-RL-100-1	C-RL-400-1	C-RL-1000-1	C-G-100-2
Implementation (Based on preliminary cost estimates used during plan formualtion, evaluation and comparison of alternatives to identify final array of alternatives.)	**Total Present Value Life-Cycle Costs**	**N/A**	**$2.1 Billion** (or average annual cost of approx. $109 Million)	**$3.5 Billion** (or average annual cost of approx. $176 Million)	**$4.8 Billion** (or average annual cost of approx. $245 Million)	**$4.6 Billion** (or average annual cost of approx. $235 Million)	**$5.1 Billion** (or average annual cost of approx. $262 Million)	**$7.3 Billion** (or average annual cost of approx. $371 Million)	**$13.2 Billion** (or average annual cost of approx. $676 Million)
	Federal Share of Present Value Life-Cycle Costs	**N/A**	**$1.4 Billion** (or average annual cost of approx. $71 Million)	**$2.3 Billion** (or average annual cost of approx. $114 Million)	**$3.1 Billion** (or average annual cost of approx. $159 Million)	**$3.0 Billion** (or average annual cost of approx. $153 Million)	**$3.3 Billion** (or average annual cost of approx. $170 Million)	**$4.7 Billion** (or average annual cost of approx. $241 Million)	**$8.6 Billion** (or average annual cost of approx. $439 Million)
	Non-Federal Share of Present Value Life-Cycle Costs	**N/A**	**$0.7 Billion** (or average annual cost of approx. $38 Million)	**$1.2 Billion** (or average annual cost of approx. $62 Million)	**$1.7 Billion** (or average annual cost of approx. $86 Million)	**$1.6 Billion** (or average annual cost of approx. $82 Million)	**$1.8 Billion** (or average annual cost of approx. $92 Million)	**$2.6 Billion** (or average annual cost of approx. $130 Million)	**$4.6 Billion** (or average annual cost of approx. $237 Million)
	Challenges / Issues / Other Information	Provides no additional risk reduction; coastal landscape would also continue to degrade.	The level of analysis of nonstructural plans demonstrate that nonstructural measures are viable, efficient, and effective. However, a unifying framework is needed that can advance nonstructural implementation in a systematic and integrated way with a base focused at delivery at the community level. A progamatic authority for nonstructural implementation (which currently does not exist) would have to be developed to efficiently meet this need.			Dispersed (low density) population in Planning Unit limits opportunities for developing feasible alternatives providing high levels of risk reduction to broad geographic areas; proposed alternatives focus risk reduction on concentrated assets in communities located in the northeast and northwest parts of the Planning Unit; large areas of the Planning Unit remain unprotected resulting in less population receiving risk reduction than could be provided with a continuous levee; ring levees provide adequate risk reduction up to the level of protection provided, however, once levees are overtopped by a greater storm event, the resulting damages could be catastrophic; proposed ring levees could provide false sense of security for population protected; ring levees also provide challenges in handling interior drainage and requires extensive pumping; plans do not include coastal restoration measures for hurricane surge risk reduction.			Provides increased risk reduction for larger geographic area than provided for by ring levee alternatives; requires construction of large sector gates across Mermentau River and other locations; high cost alternative; significant environmental impacts, including impacts to natural drainage patterns; plan does not include coastal restoration measures for hurricane surge risk reduction.

Section 16. Example Coastwide Plans and Costs

The plans presented in this section are illustrative of how the final array of alternatives in each planning unit could be added together to create coastwide plans. Even after narrowing down the final array of alternatives to five or six alternatives in each planning unit, there are still several thousand possible combinations of those alternatives that could create a coastwide plan. Rather than create thousands of maps, the LACPR team chose seven different combinations as examples to help decision makers visualize the possible coastwide plans. None of the possible coastwide combinations represents the so called “Great Wall of Louisiana” stretching continuously from the Pearl River to the Sabine River.

Descriptions of Coastwide Plans

Table 16-1 presents the components in each of the seven coastwide plans. **Figure 16-1** presents the coastal restoration components in Planning Units 1 and 2 that are included in each of the seven coastwide plans shown in **Figures 16-2** through **16-8**. As previously discussed in Section 15, alternatives for Planning Units 3a, 3b, and 4 do not include coastal landscape measures for risk reduction. Each of the alternatives included in the final array are included in at least one combination with the exception of C-G-100-1 in Planning Unit 3b, which was not included in any coastwide combination because it is not compatible with any of the final array of alternatives in Planning Unit 4.

Table 16-1. Coastwide plans and components by planning unit.

Plan No.	Description	Planning Unit 1	Planning Unit 2	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
CP-1	Minimum Risk Reduction	Coastal only	WBI-100-1	NS-100	C-RL-100-1	NS-100
CP-2	Comprehensive 100-year Risk Reduction with Ring Levees	NS-100	C-R-100-2	C-M-100-2	C-RL-100-1	C-RL-100-1
CP-3	Nonstructural Only 400-year Risk Reduction	NS-400	NS-400	NS-400	NS-400	NS-400
CP-4	Nonstructural Only Maximum Risk Reduction	NS-1000	NS-400	NS-1000	NS-1000	NS-1000
CP-5	Structural and Nonstructural Various Levels of Risk Reduction	LP-a-100-1	C-R-100-2	C-M-100-2	NS-400	NS-400
CP-6	Comprehensive Maximum Risk Reduction	C-LP-a-100-1	C-G-100-1	C-M-100-1	C-F-100-1	C-RL-1000-1
CP-7	Top Performing Comprehensive Alternatives	C-LP-a-100-1	C-WBI-100-1	C-M-100-2	C-RL-100-1	C-RL-400-1

As previously discussed in Section 15, although some of the alternative numbers indicate a 100-year design, some of these plans actually provide much higher levels of risk reduction. The coastwide combinations are described in more detail below:

- In CP-1, the alternative providing the least amount of risk reduction in each planning unit was selected and combined into a coastwide alternative.
- In CP-2, alternatives providing approximately 100-year risk reduction through both structural and nonstructural measures were selected. The structural measures are mostly ring levees rather than continuous levees. Adding NS-100 to the existing 100-year Lake Pontchartrain and Vicinity project on the East Bank of New Orleans creates a comprehensive plan in Planning Unit 1.
- In CP-3, the NS-400 alternative was selected in each planning unit. The NS-400 plan provides 400-year risk reduction using only nonstructural measures.
- In CP-4, the NS-1000 alternative was selected in each planning unit except Planning Unit 2 where the remaining alternative with the highest level of risk reduction is the NS-400 plan.
- In CP-5, alternatives containing structural and nonstructural measures at various levels of risk reduction were combined.
- In CP-6, the comprehensive alternatives providing the greatest level of risk reduction in each planning unit were combined.
- In CP-7, the comprehensive alternatives that were among the top performers across all the evaluation criteria in each planning unit were combined.

The methods described above for combining planning unit alternatives into coastwide plans may not seem entirely logical; however, the goal was not to present a definite set of strategies but to present each of the alternatives at least once in a coastwide map that could be used for visualization and discussion among stakeholders and decision makers.

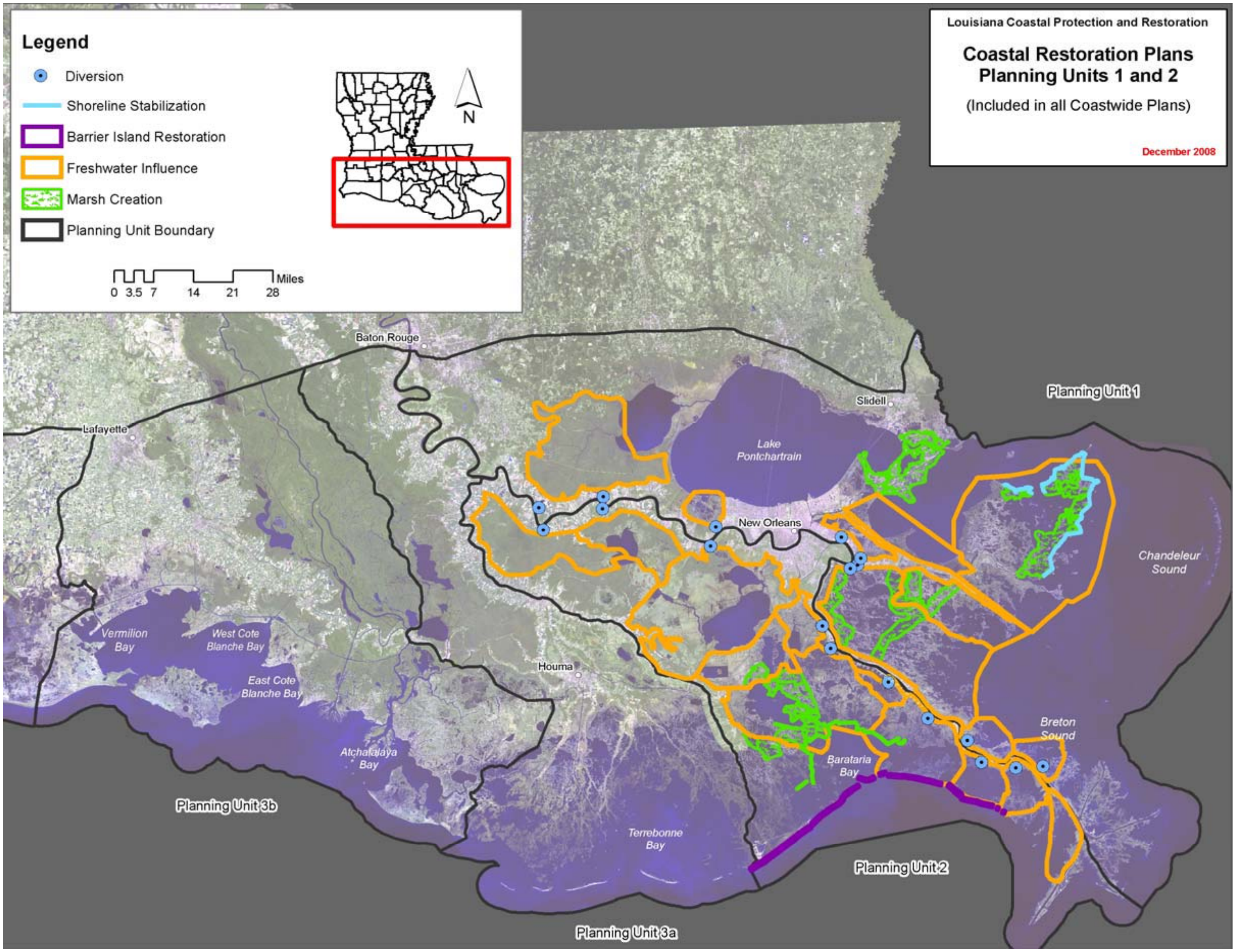


Figure 16-1. Coastal restoration measures in Planning Units 1 and 2.

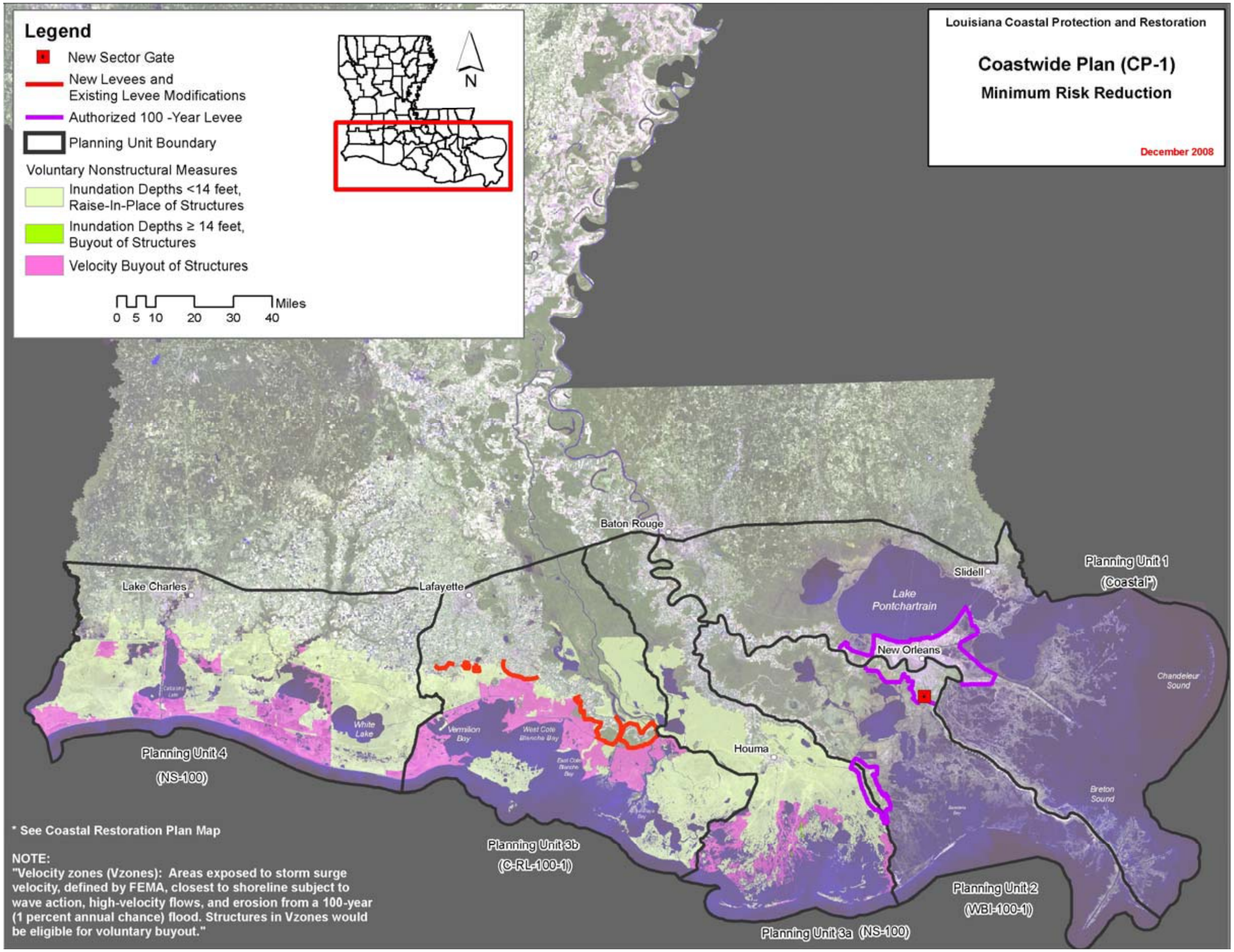


Figure 16-2. Coastwide plan CP-1.

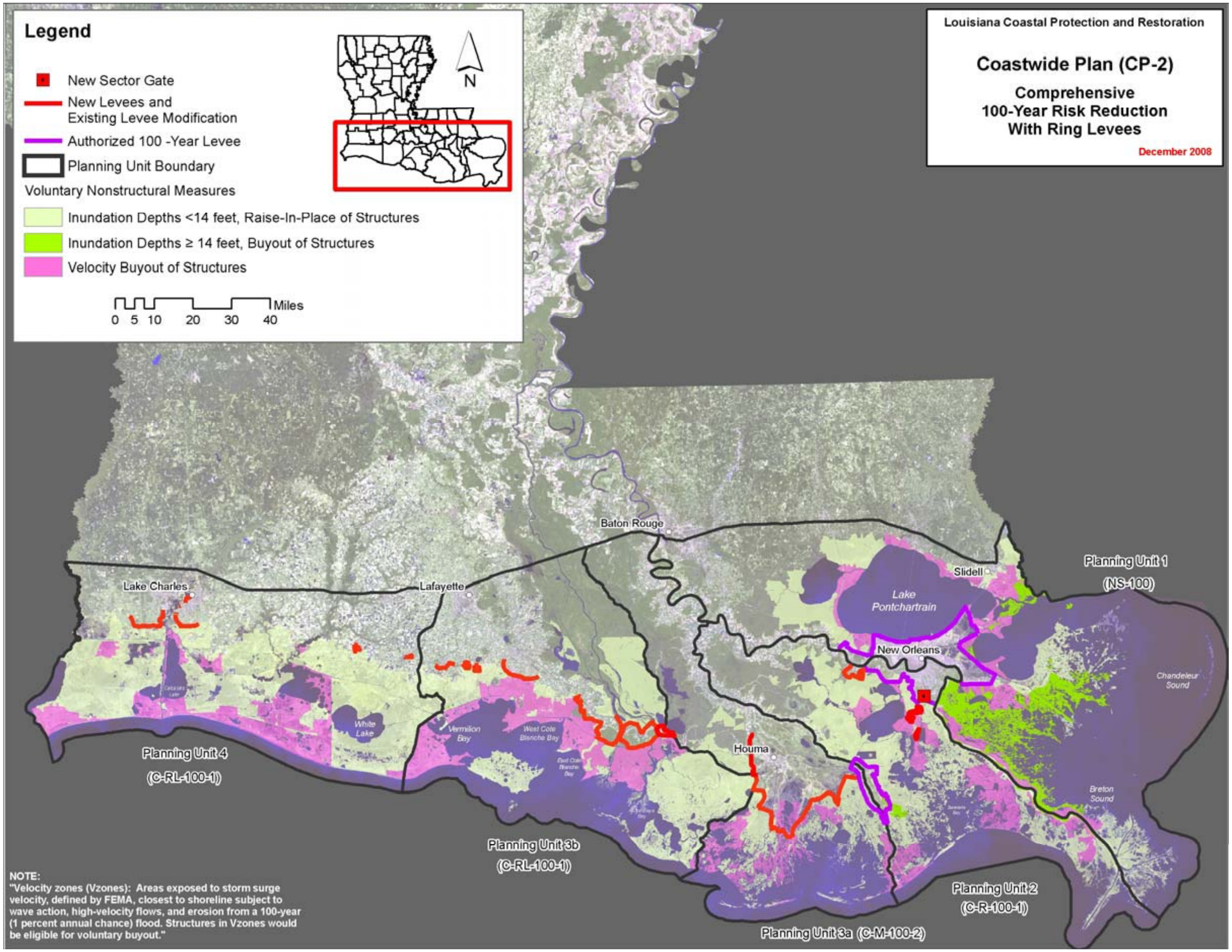


Figure 16-3. Coastwide plan CP-2

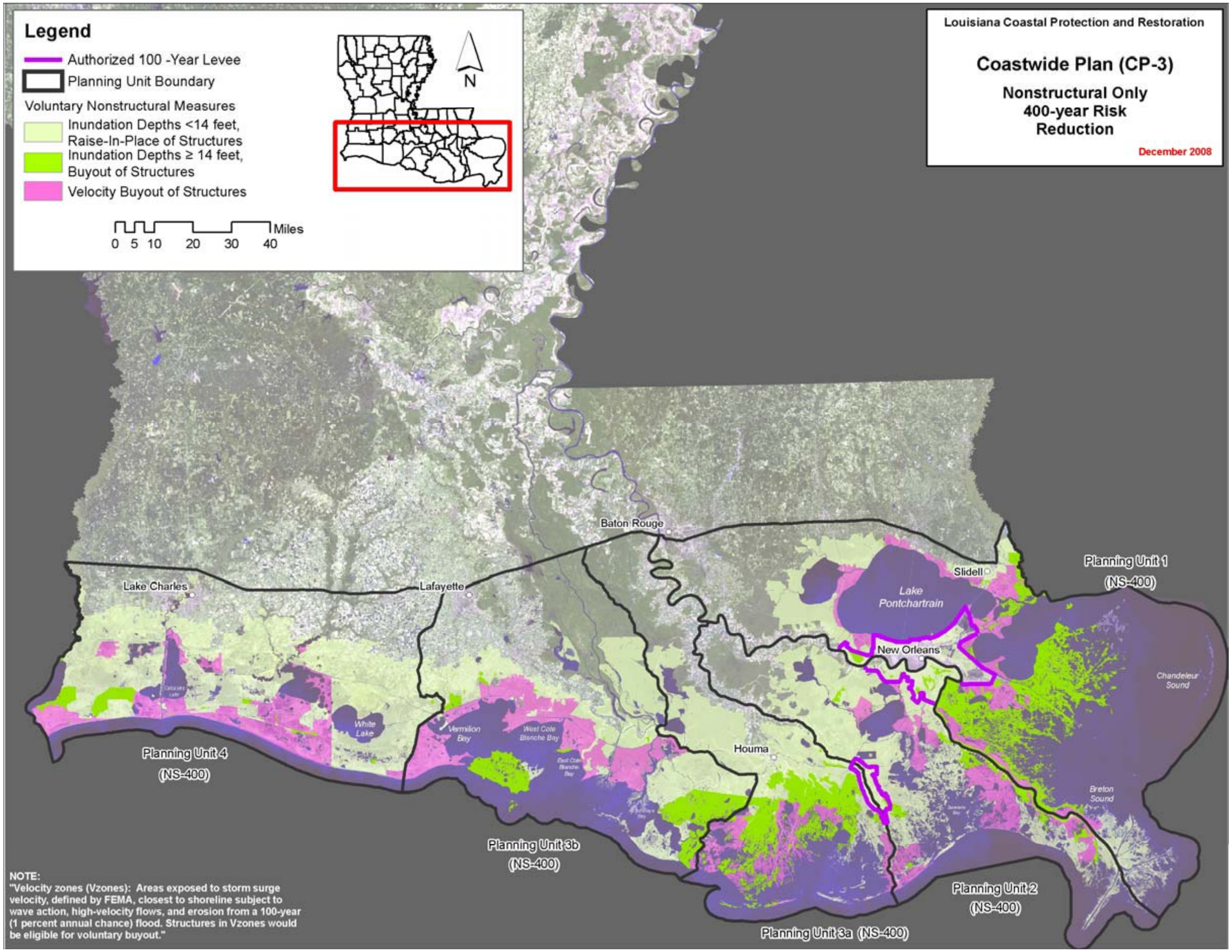


Figure 16-4. Coastwide plan CP-3.

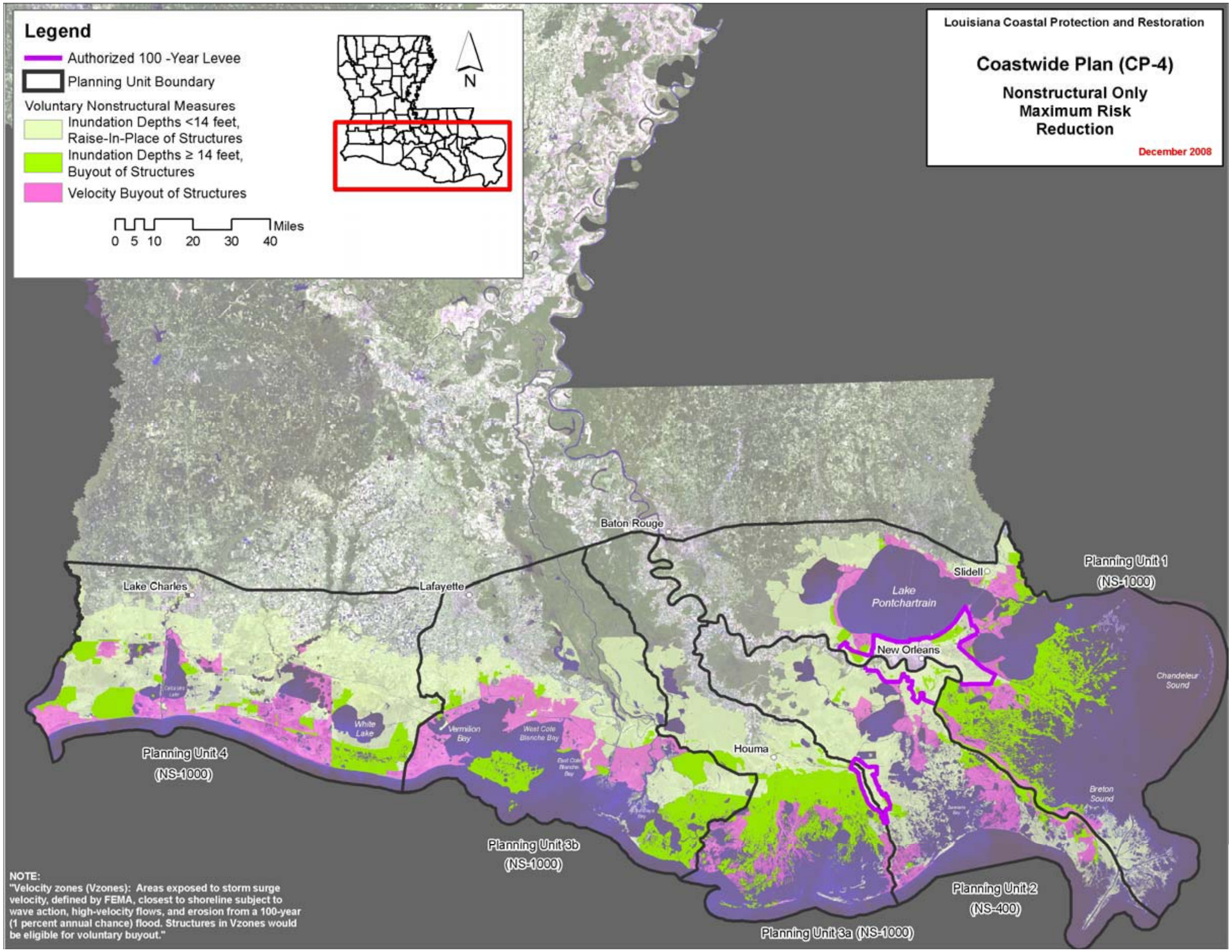


Figure 16-5. Coastwide plan CP-4.

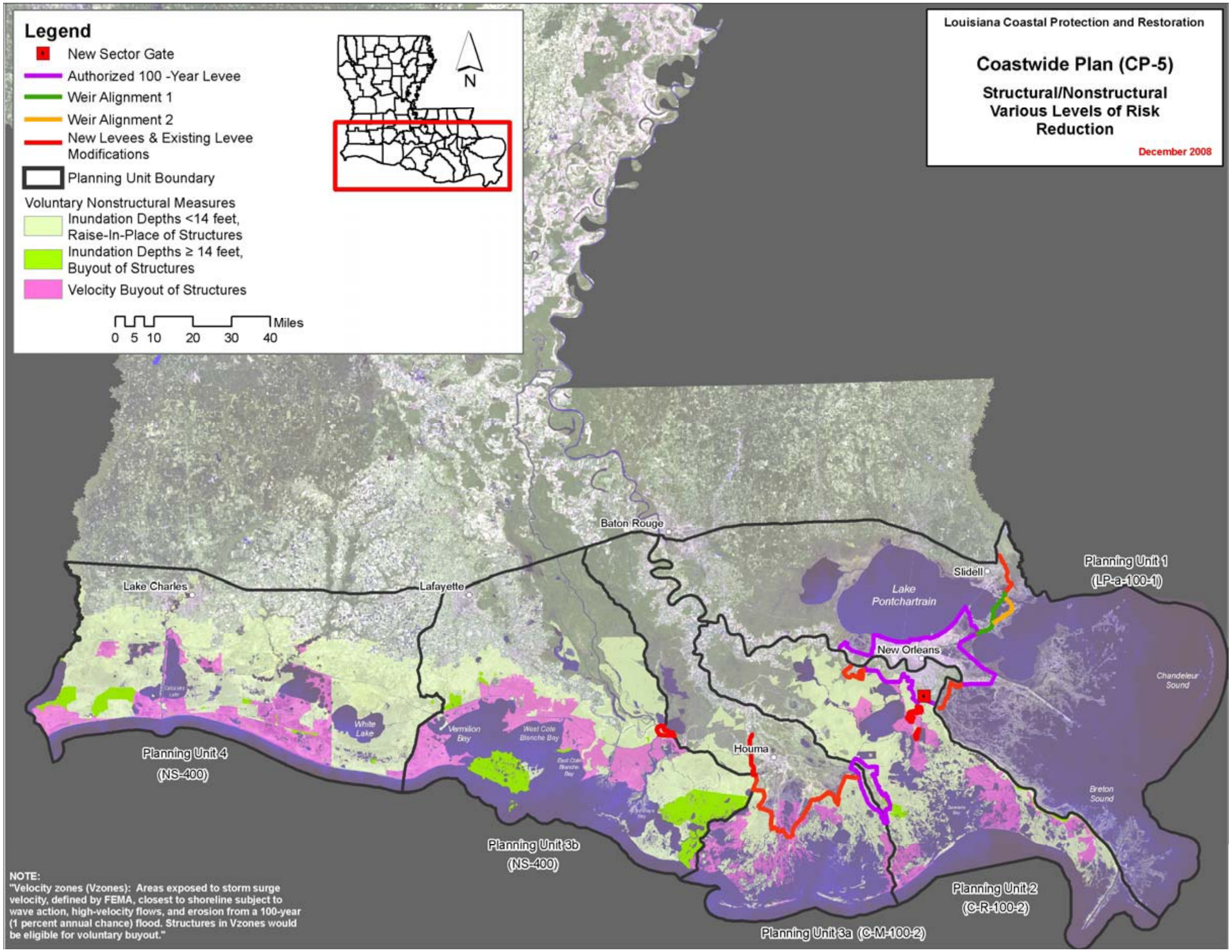


Figure 16-6. Coastwide plan CP-5.

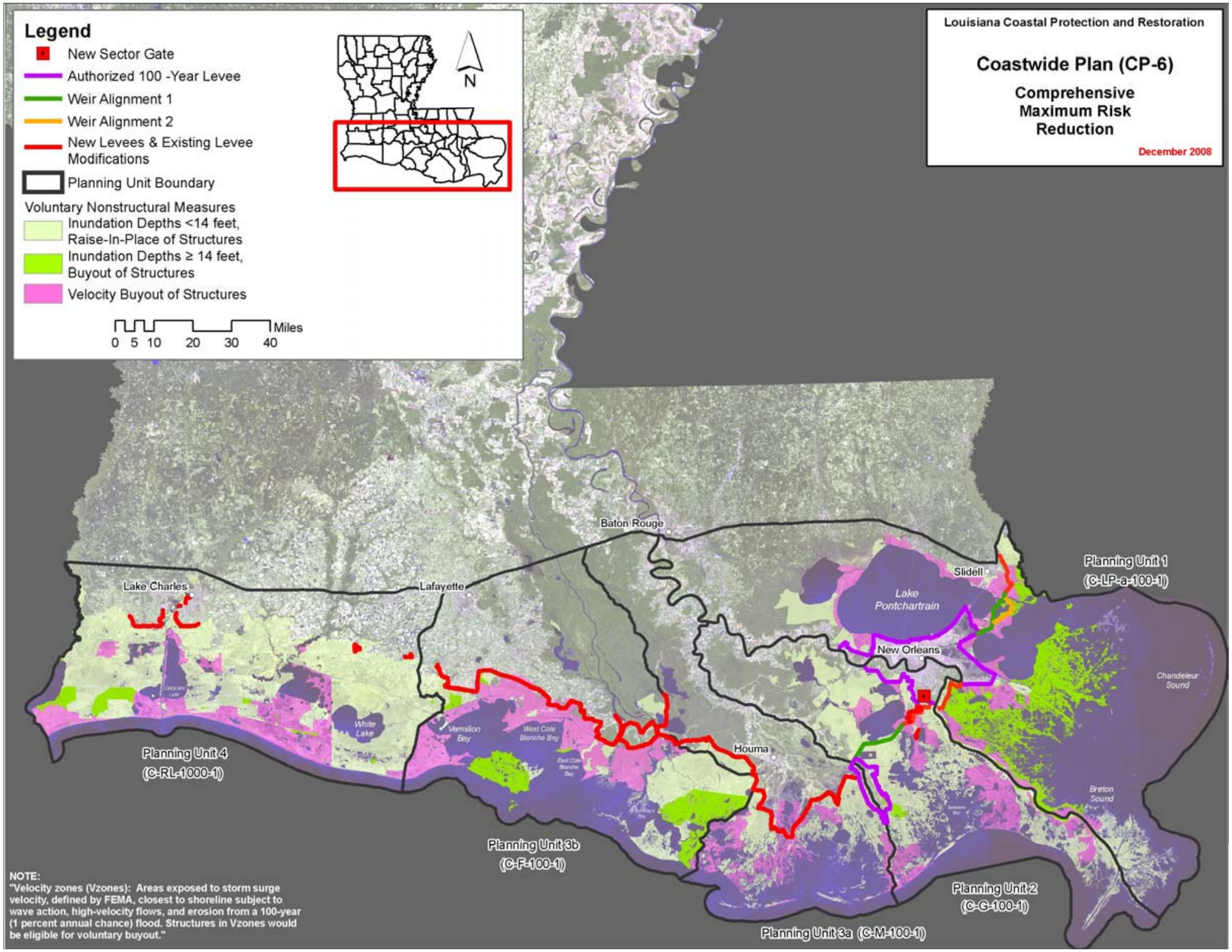


Figure 16-7. Coastwide plan CP-6.

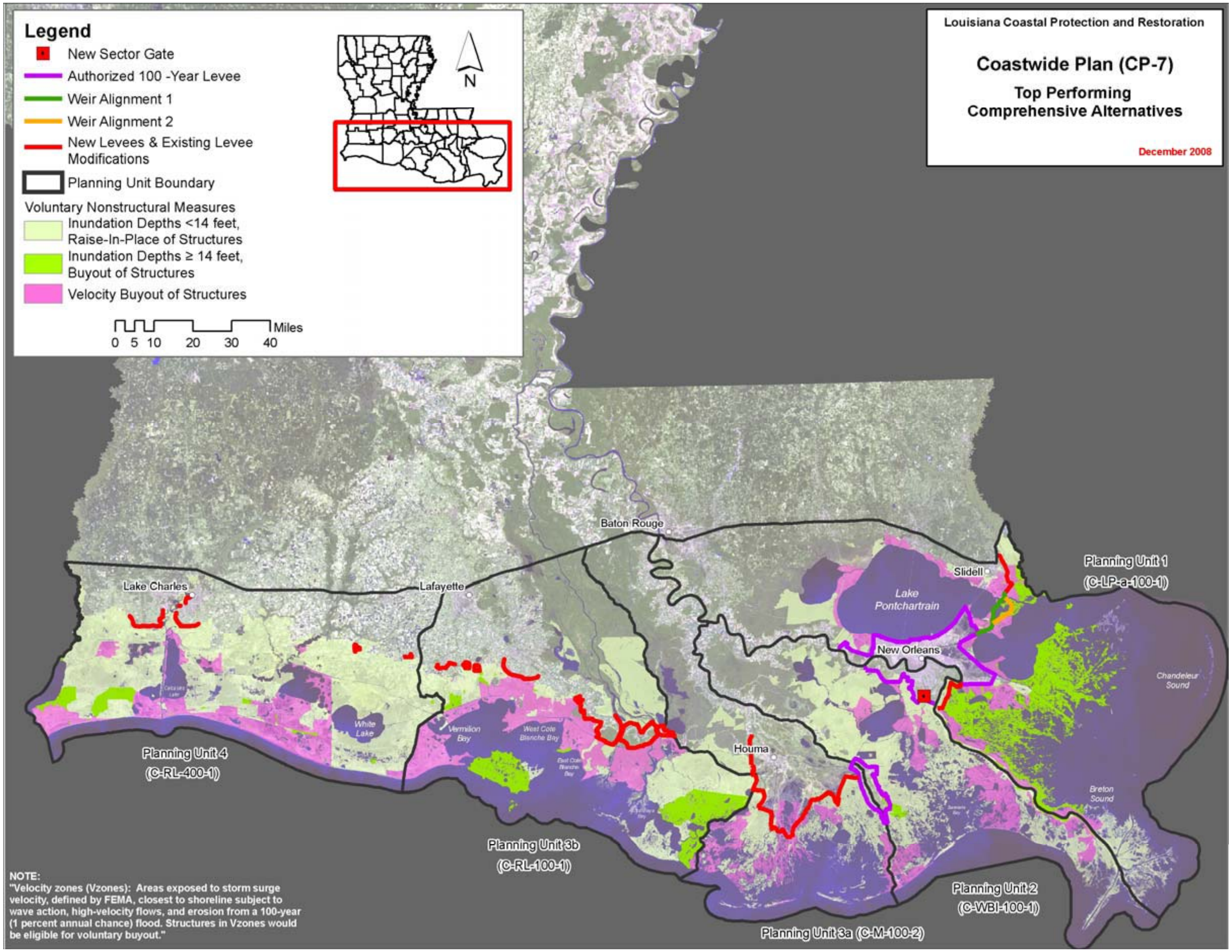


Figure 16-8. Coastwide plan CP-7.

Cost Estimates

The cost estimates developed to populate the cost metrics and used for the evaluation and screening of alternative plans were based on available data, including geologic and LIDAR topography data, rather than specifically collected design data. It is understood by the planning team, and has been noted in the technical review of the LACPR effort, that the lack of detailed geotechnical and survey design data represents a critical uncertainty relative to the final costs of any alternative plan. However, the preliminary cost estimates are conservative for this reason and provided an adequate basis for the assessment of plan efficiency and comparison of relative plan performance.

Through review it has also been determined appropriate to further address the cost estimate uncertainty at this planning stage through the application of cost contingencies. The estimates used for evaluation and comparison of plans employed a standard margin of contingency of 25 percent. Through review of estimates and actual costs for ongoing work related to the post Hurricane Katrina repair and improvement of existing levee systems, more appropriate cost contingency values have been developed.

The final cost estimates for each of the components and for the coastwide plans are shown in **Tables 16-2** and **16-3.** The final cost estimates presented here for the final array are first costs only and employ a 50 percent cost contingency. Because the contingency factor applies to all alternative plans uniformly there is no impact on the comparison of plans presented in this report.

Additionally, a single representative coastal restoration plan in each planning unit was applied to every alternative considered in the analysis. The cost estimates for these representative plans have also been updated to address specific concerns regarding availability of sediment resource for this proposed restoration. The refined costs reflect the identification of highly certain but conservatively costly sources for each restoration measure proposed in those plans. Since these representative plans were included as part of every alternative considered, there is no impact on the comparison of relative plan performance. The refined cost estimates for the coastal components in Planning Units 1 and 2 have been incorporated into the costs for the final array presented here to allow the most reliable representation of the potential present value costs of the final alternatives and their components. The refined coastal restoration cost estimates for all of the planning units are contained in the cost attachment to the *Engineering Appendix.*

A final cost consideration relates to the real time distribution of costs for implementation. All of the plans presented in the final array of alternatives have implementation timeframes that extend over multiple years or decades. The need to disburse funds over these extended timeframes is subject to normal inflation. This value is reflected as a compound index of 2 to 3 percent per year. The result is that actual funding requirements for these plans will inflate over their respective period of implementation. The range of magnitude for inflation of costs for the final alternative is 25 to 75 percent depending on the plan and its projected implementation schedule. It should also be noted that the value of potential damages increases at this same rate of inflation. The effect of inflation specific to each plan in the final array and its various components is presented in the cost attachment to the *Engineering Appendix.*

Table 16-2. Final cost estimates for final array of alternatives.

Planning Unit	Alternative	Total ($Billions)	Non-Federal ($Billions)	Federal ($Billions)
1	**Coastal**	36.2	12.7	23.5
	NS-100	41.7	14.6	27.1
	NS-400	56.1	19.6	36.4
	NS-1000	68.6	24.0	44.6
	LP-a-100-1	44.2	15.5	28.7
	C-LP-a-100-1	47.5	16.6	30.9
2	**NS-400**	22.9	8.0	14.9
	WBI-100-1	10.8	3.8	7.1
	C-WBI-100-1	14.4	5.0	9.4
	C-R-100-2	16.2	5.7	10.5
	C-G-100-1	21.3	7.5	13.9
3a	**NS-100**	6.6	2.3	4.3
	NS-400	9.0	3.1	5.8
	NS-1000	9.8	3.4	6.4
	C-M-100-1	23.0	8.1	15.0
	C-M-100-2	21.0	7.4	13.7
3b	**NS-400**	3.8	1.3	2.5
	NS-1000	4.8	1.7	3.1
	C-RL-100-1	14.1	4.9	9.1
	C-F-100-1	16.3	5.7	10.6
	C-G-100-1	17.2	6.0	11.2
4	**NS-100**	1.8	0.6	1.2
	NS-400	2.9	1.0	1.9
	NS-1000	4.0	1.4	2.6
	C-RL-100-1	4.4	1.5	2.8
	C-RL-400-1	5.2	1.8	3.4
	C-RL-1000-1	7.2	2.5	4.7

Notes: Total First Costs for Scenario 1. Total First Costs include engineering and design, facility relocations, real estate, mitigation, and construction costs. Based on 2007 price levels, 4.875% Discount Rate. Costs include 50% contingencies.

Table 16-3. Final cost estimates for coastwide plans.

Description	Plan No.	Costs by Planning Unit and Plan Component ($Billions)					Total Cost ($Billions)
		PU1	PU2	PU3a	PU3b	PU4	
Minimum Risk Reduction	CP-1	Coastal	WBI-100-1	NS-100	C-RL-100-1	NS-100	
		36.2	10.8	6.6	14.1	1.8	69.5
Comprehensive 100-yr Risk Reduction with Ring Levees	CP-2	NS-100	C-R-100-2	C-M-100-2	C-RL-100-1	C-RL-100-1	
		41.7	16.2	21.0	14.1	4.4	97.3
Nonstructural Only 400-yr Risk Reduction	CP-3	NS-400	NS-400	NS-400	NS-400	NS-400	
		56.1	22.9	9.0	3.8	2.9	94.7
Nonstructural Only Max Risk Reduction	CP-4	NS-1000	NS-400	NS-1000	NS-1000	NS-1000	
		68.6	22.9	9.8	4.8	4.0	110.1
Structural/Nonstructural Various Levels of Risk Reduction	CP-5	LP-a-100-1	C-R-100-2	C-M-100-2	NS-400	NS-400	
		44.2	16.2	21.0	3.8	2.9	88.1
Comprehensive Maximum Risk Reduction	CP-6	C-LP-a-100-1	C-G-100-1	C-M-100-1	C-F-100-1	C-RL-1000-1	
		47.5	21.3	23.0	16.3	7.2	115.4
Top Performing Comprehensive Alternatives	CP-7	C-LP-a-100-1	C-WBI-100-1	C-M-100-2	C-RL-100-1	C-RL-400-1	
		47.5	14.4	21.0	14.1	5.2	102.2

Note: Total First Costs for Scenario 1. Total First Costs include engineering and design, facility relocations, real estate, mitigation, and construction costs. Based on 2007 price levels, 4.875% Discount Rate. Costs include 50% contingencies.

Section 17. Collaboration and Coordination

As previously described, the State of Louisiana established the Coastal Protection and Restoration Authority (CPRA) to develop, implement, and enforce a comprehensive coastal protection and restoration master plan. For the first time in Louisiana's history, a single State authority will integrate coastal restoration and hurricane protection, working in conjunction with other State agencies, political subdivisions, levee districts, and Federal agencies, including the USACE, to speak with one clear voice for the future of Louisiana's coast. Incorporating input from State, parish, local and Federal interests, as well as that of non-governmental organizations, Louisiana's Comprehensive Master Plan for a Sustainable Coast (State Master Plan) portrays the State's desires and needs relative to hurricane risk reduction and coastal restoration. In addition, annual plans provide the State's priorities for implementation.

Some components of the State Master Plan lie within the USACE mission. Additional elements of coastal protection and restoration described in the State Master Plan and annual plans require actions that are outside of the USACE mission. Therefore, many other Federal and State agencies must be involved in the implementation of the State Master Plan to achieve comprehensive hurricane risk reduction and coastal restoration. This section discusses the roles of local, State, and Federal agencies in implementing comprehensive plan(s) for coastal restoration and lays out an approach that could be employed to facilitate collaboration and coordination to move such plan(s) forward.

Louisiana Coastal Protection and Restoration Authority (CPRA)

The CPRA is the single State entity to interface with agencies internal to the State and Federal governments, including the USACE, to implement the State Master Plan. It is a role of the CPRA to collaborate and coordinate with groups and agencies in order to maximize risk reduction, conservation, and coastal restoration efforts. The CPRA will set the State's priorities and be the interface between the State and the appropriate State or Federal agency having the mission capability to fulfill a particular aspect of the State Master Plan. This collaboration and coordination structure for implementation of the State Master Plan is shown in **Figure 17-1**.

The Louisiana's State Master Plan provided a foundation for the LACPR technical report and the LACPR effort has been closely coordinated with the Master Plan. The relationship between the CPRA and the USACE facilitates sharing of the best available scientific and engineering information and working closely with each program's partners and the public. For those components in the State Master Plan compatible with the USACE mission, the CPRA may collaborate with the USACE for implementation. The USACE role in implementation of components of the State Master Plan is discussed in subsequent pages. Continuing cooperation and partnership with the State of Louisiana is, and should be, an integral part of coastal protection and restoration efforts.

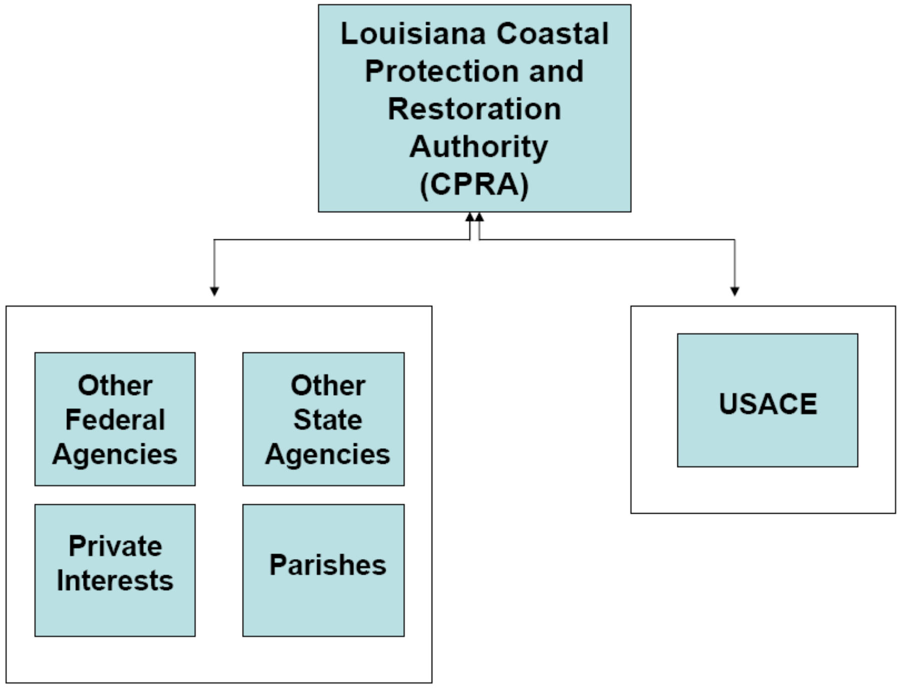


Figure 17-1. Participants in Louisiana's State Master Plan.

USACE Role in State Master Plan Implementation

The USACE does not envision the need for a new, broad authority to implement the alternatives contained in this report or the State Master Plan. To the extent possible, a comprehensive plan for coastal protection and restoration could be implemented through coordinated use of existing authorities. In some cases, the authorities will need to be modified to ensure consistency among similar projects and across the coast. Additionally, since the success of plan development depends on the ability to compare like metrics among individual projects, and some existing authorities' do not afford the ability to conduct investigations to inform those metrics under normal policy (which in many cases uses dollars as the only metric), it therefore may be necessary to modify the authority to allow multi-criteria evaluation similar to LACPR.

Existing Authorities

In general, if authorization exists, the USACE is allowed implementation of a recommended plan with such modifications as the Chief of Engineers may deem advisable in the interest of the purposes specified. Procedures for adoption of proposed project changes differ depending on whether they may be approved by the Chief of Engineers using such delegated discretionary authority or must be submitted to Congress for consideration and legislative modification of the existing authorization. Where proposed changes are significant, they must be documented in a Post Authorization Change Report submitted to USACE Headquarters coupled with supplemental environmental documentation to address any changes in impacts, expansion of the impact area, and consideration of cumulative effects. If it is determined after review that the proposed changes are not within delegated authority but are of sufficient importance to warrant a recommendation for modification of the project authorization, procedures and further reporting requirements for processing such a recommendation to the Congress would be selected as best suits that specific case.

Existing hurricane risk reduction authorities within the New Orleans District were authorized in the mid-1960s with the exception of the West Bank and Vicinity, LA project that was authorized in WRDA 1986. The basis for the possible use of an existing authority seems appropriate whenever there are proposed LACPR features such as levees and/or coastal restoration measures that are common to plan features outlined in the existing project authority or there is a shared goal under the authority and the LACPR plans.

A comprehensive review of all existing authorities will be needed to determine the applicability of each authority to investigating LACPR planning objectives. In view of the age of many of the authorities, it will be necessary to reexamine the objectives of the authorities and evaluate how well the supporting designs accomplish those objectives when analyzed using the latest available engineering technologies and statistical results. Attachment 2 lists all authorized projects and studies in the LACPR planning area that potentially share common features and/or risk reduction goals with the final array of plans.

Potential Nonstructural Program

The gross level analysis of nonstructural plans performed for the LACPR study demonstrated that nonstructural measures are viable, efficient, and effective. Their success in reducing risk and their cost effectiveness make the implementation of nonstructural measures a logical next step toward creating sustainable and resilient communities across the extent of South Louisiana. Nonstructural measures can be implemented incrementally, on a house-by-house basis, or programmatically, across whole neighborhoods or communities. Less time may be required to incrementally implement nonstructural measures as compared with implementation of large-scale structural measures since the benefits of nonstructural measures are realized immediately upon implementation to each structure affected.

Programmatic Implementation - Since nonstructural measures may be a key component to reducing long-term risks and supporting sustainable development, a strategy will need to be developed for programmatic implementation of nonstructural measures. What is needed now is a unifying framework is needed to advance nonstructural implementation in a systematic and integrated way with a base focused on project delivery at the individual community level. Programmatic authority for nonstructural implementation would be needed for this effort.

The nature of nonstructural applications tends to be narrowly and intensely focused on individual community needs. A programmatic authority would support these specialized efforts with a continuous process so that efficiencies in response and delivery can be achieved and many nonstructural projects could be pursued simultaneously.

Precedence for this approach to nonstructural measures implementation, through programmatic authority and procedural guidelines, has been established within the USACE.

Many Federal, State, and local agencies are involved in the Louisiana recovery, the effects of which have not been adequately assessed for their contribution to risk reduction. The State now owns thousands of properties by acquisition through the Road Home Program and the disposition of those properties will affect future flood-risk levels in the region. The nonstructural program must begin with an assessment of these ongoing recovery efforts, specifically the Road Home program, to develop a strategy for integrating risk reduction across other agencies' mission areas. Because of this, programmatic resources should be dedicated to creating a continuous process to establish and maintain close collaboration to clear interagency hurdles; establish rapport among agencies and stakeholders; and develop working relationships, including data sharing, across all levels of government.

Demonstration Projects - The nonstructural evaluation identified potential demonstration projects of specific size and location where nonstructural measures could be implemented in the near-term. The development of demonstration projects would require close coordination with local communities, the State, Federal and local agencies, and supports local desires for risk reduction and economic recovery. Nonstructural demonstration projects are intended to identify the challenges and opportunities that exist for future collaboration among the USACE, other agencies, and local governments in implementing nonstructural measures. Some potential demonstration projects may be located within the City of New Orleans and St. Bernard Parish in Planning Unit 1; in Delcambre in Planning Unit 3b; and in Calcasieu Parish in Planning Unit 4. More details on these demonstration projects can be found in the Nonstructural Plan Component Appendix.

Role of Others in State Master Plan Implementation

In order to fully implement the State Master Plan's vision for sustainable coastal protection and restoration, other Federal, State, and local agencies have to take action. This section describes the roles of other agencies outside the USACE in hazard mitigation planning and identifies authorities that other Federal and State agencies could possibly use to support the State in coastal protection and restoration implementation. In addition, individuals who live in the floodplain are responsible for determining how they will build or retrofit their homes or businesses; how to adequately insure that property; and when and where to evacuate when a hurricane threatens.

Hazard Mitigation Planning

In addition to the structural, nonstructural, and coastal restoration measures already identified in this report, additional practices and strategies for hazard mitigation have been identified and should be implemented fully to achieve maximum benefits for hurricane risk reduction. Four general types of hazard mitigation measures are standard practice for hazard vulnerability reduction. These general measures include (1) providing evacuation and sheltering services, (2) maintaining or enhancing environmental protective features, (3) making structures more hazard resistant, and (4) managing development with nonstructural mitigation measures.

These hazard vulnerability reduction measures, applied through successfully proven principles and practices in coastal communities in the Gulf Coast and Southeast Region of the United States, can help communities better integrate hazard mitigation within the natural and built environment through synergistic environmental restoration, land use planning, structural hardening, and public education. Together, these comprehensive measures can reduce hazards vulnerability and create a more sustainable Louisiana.

More detailed descriptions of these and other hazard vulnerability reduction measures and a table displaying supporting information related to potential benefits and existing authority, institutional capabilities, relative costs, and level of government can be found in the *Hazard Mitigation Planning Appendix*.

Other Federal Authorities

Implementation of the State Master Plan will require action from everyone. In addition to the existing USACE authorities mentioned earlier, other Federal agency missions and authorities have been identified for possible use in State Master Plan and their use may be necessary to fully develop the State's restoration and protection strategy. Attachment 3 lists these authorities and their possible relationship to the State Master Plan. Utilization of these authorities would be subject to execution by the agency as requested by the State.

Implementation Principles

The USACE has established a set of basic principles for implementation of projects and programs, which include management strategies for ensuring plans are implemented in a manner consistent with goals and objectives of coastal protection and restoration efforts. The following four principles guide implementation:

- Ensure Consistency between Programs
- Incorporate Adaptive Management Processes
- Maintain Comprehensive System Focus
- Integrate Ongoing and Future Projects and Programs

Ensuring Consistency between Programs

A need exists for assurance that USACE’s civil works projects and regulatory decisions are integrated and consistent with restoration and hurricane risk reduction efforts in Louisiana. In this context, “consistent” means that the wetland benefits from Federal and State coastal restoration activities would not be undercut or otherwise diminished by adverse wetland impacts associated with civil works projects (such as navigation and hurricane damage risk reduction projects) and development activities within the purview of the USACE’s regulatory program and that ecosystem restoration projects support civil works and hurricane risk reduction activities.

The CWPPRA framers recognized the importance of such consistency and, therefore, included the following provision in the statute:

> *Consistency – (1) In implementing, maintaining, modifying, or rehabilitating navigation, flood control or irrigation projects, other than emergency actions, under other authorities, the Secretary [of the Army], in consultation with the Director [of the U.S. Fish and Wildlife Service] and the Administrator [of the Environmental Protection Agency], shall ensure that such actions are consistent with the purposes of the restoration plan submitted pursuant to this section [Section 3952(d)(1)].*

To promote such consistency, the USACE recommended a series of action items in the Louisiana Coastal Area (LCA) Ecosystem Restoration Study (USACE, 2004). The proposed action items cover navigation, regulated development, hurricane damage risk reduction projects, and other USACE projects.

Additionally, WRDA 2007 includes provisions which could help address the need for consistency between coastal restoration and other civil works projects. For example, Section 7005 calls for the review of Federal water resources projects in coastal Louisiana to determine whether such projects need to be modified to take into account coastal restoration efforts in the LCA plan.

The LACPR effort and Louisiana's Master Plan represent significant progress towards consistency. For the first time, hurricane damage risk reduction measures are being planned in conjunction with coastal restoration measures. However, simply integrating the planning processes for hurricane damage risk reduction and coastal restoration does not guarantee that features such as levees would be consistent with coastal restoration. In some cases, tradeoffs may be made at the expense of either restoration or protection.

Incorporating Adaptive Management Processes

Potential changes in social, political, economic, engineering, and environmental conditions point to the need for an Adaptive Management Framework to guide program and project management. Adaptive management can be used to resolve ecosystem, engineering, policy, socio-economic issues and interactions, and other processes by reducing uncertainties and improving understanding in these areas and their interrelationships. Incorporation of adaptive management will allow the program/projects to move forward even if data is incomplete or if there is uncertainty with scientific understanding. A solid adaptive management strategy may be crucial for ensuring that the program remains true to its basic objectives while also integrating valuable new information and allowing necessary shifts in priorities. Adaptive management activities can be incorporated into several aspects of the USACE 6-step planning process. For example, during plan formulation, stakeholders are engaged, goals and objectives are established, uncertainties are identified and prioritized, conceptual models are created, and hypotheses and performance measures are identified; during design and construction, stakeholder engagement continues and monitoring takes place; and during operations, there is program/project assessment, feedback, implementation and refinement. A more detailed discussion on adaptive management processes can be found in the *Adaptive Management Appendix*.

Incorporation of adaptive management principles across all components of the coastal protection and restoration plans will maximize learning to address key uncertainties and disagreements, facilitate consensus building approaches to improve plan design, and help facilitate learning that will support both current and future decision-making. Principles include but are not limited to 1) the anticipation of possible future uncertainties and contingencies during project/program planning; 2) using a scientific, inquiry-based approach to address the most critical structural, operational, and scientific questions; 3) incorporation of robustness into project/program design; 4) using feedback loops that iteratively feed new information into the decision making process for planning implementation, assessment of project/program components; and emphasizing an open, inclusive and integrative process for design and implementation of projects/programs; 6) emphasis on collaboration and conflict resolution in order to reconcile competing objectives; and 7) acknowledgement of the full arrangement of interests and values by stakeholders.

Additionally, a comprehensive systems approach that employs adaptive management would ensure collaborative engagement among stakeholders for program management, project design, construction, and operation and maintenance while promoting updates to account for changes in future conditions.

Clearly focused and quantitative goals and objectives are essential to adaptive management. They should be logically linked to management actions, action agencies, indicators/metrics, monitoring activities, and ecosystem or risk reduction services. LACPR goals and objectives were identified at the beginning of the planning process. These goals and objectives would be critical elements of the LACPR adaptive management process. They address stakeholder interests, where possible, in order to ensure stakeholder involvement and clearly link the problems to opportunities and solutions.

Additionally, because of the long timeframes over which any comprehensive plan for coastal protection and restoration measures would be implemented, it can be expected that goals and objectives may change over a period of years, resulting in the need to adopt measures that would match the changed conditions. Dramatic changes to the economic base, population centers, and the physical shape of the coast within the life of the comprehensive effort are possible due to rapidly changing conditions or from a single hurricane event; therefore, the USACE and its partners should be prepared to institute significant changes in specific measures and in the overall plan during implementation. New information may also become available over time, e.g., improved estimates of sea level rise. For these reasons, a strategy founded on the principles of adaptive management would be essential to successful execution of a comprehensive plan, both now and in the future.

Recognize and Reduce Uncertainties - In order to successfully implement protection and restoration efforts, technical evaluation must build upon the best available science and engineering knowledge. Although previous research efforts have contributed to a strong understanding of the human and natural processes affecting the Louisiana coastal area ecosystems, scientific, technical, social, and economic uncertainties remain. Developing a strategy to attempt to reduce the risk arising from these uncertainties is necessary.

Numerous types of uncertainties should be addressed to support and improve coastal protection and restoration efforts. Each uncertainty requires a different resolution strategy based on the effects of the uncertainty on the program, degree of uncertainty, cost of addressing the uncertainty, and the importance of reducing the uncertainty. Different strategies for resolving uncertainties may include focused research projects, monitoring existing projects, refinement or re-evaluation of existing data, or demonstration projects. Uncertainties may be related to the science, engineering, modeling, socio-economic impacts, human response, implementation, technical methodology, resource constraints, cost, or effectiveness of restoration and protection measures. Uncertainties may also be related to development and refinement of forecasting tools. An uncertainty is considered critical if its resolution is vital to advancing the planning and implementation of a comprehensive plan in the near term. For example, the uncertainty associated with redevelopment of specific areas in coastal Louisiana may lead to changes in coastal protection and restoration plans as the level of uncertainty is reduced. Another example of uncertainty which could significantly affect the plans would be the impacts from future hurricanes or other natural processes, such as sea level rise. As a result of decreasing uncertainties, it is likely that plans will change over time.

An explicit adaptive management strategy can address these uncertainties to better achieve system objectives. Adaptive management recognizes that knowledge about these future conditions is uncertain. The aim of such a strategy is to find a way to achieve the objective as quickly as possible while avoiding inadvertent mistakes that could lead to unsatisfactory results. Additionally, investigations to further reduce the scientific and technical uncertainties and to enhance the likelihood that restoration and protection projects would successfully meet project goals is necessary during plan implementation.

Specific studies would be needed to provide additional detailed design of any specific components within this technical report. These studies could potentially include additional or revised ecosystem targets, flood impacts, ecological effects, and data collection. Also, new technologies would likely emerge during the implementation process, offering the possibility of improving the plan outputs while reducing costs. The implementation process must allow flexibility to consider and include new technologies as they emerge.

Demonstration Projects as an Adaptive Management Tool - Demonstration projects can be important components of adaptive management as they link back to science and management and provide an opportunity for learning and feedback for improved decision making. Demonstration projects may be used to resolve critical areas of scientific or technical uncertainty or fill in data gaps in order to advance coastal restoration and hurricane risk reduction projects, such as new technologies for building levees, floodwalls, or armoring. Both full-scale restoration opportunities and large-scale studies may depend upon results from demonstration projects to advance planning and analysis of alternatives. In order to be responsive to program needs, demonstration projects should be implemented as soon as possible and have the ability to provide meaningful results in a relatively short timeframe in order to provide information in time to feed the design and planning process to achieve the short-term and long-term project objectives and goals.

Maintaining a Comprehensive System Focus

Developing a comprehensive and integrated system for coastal protection and restoration requires a process, as well as a product. A system can be defined as a group of structures, policies, plans, and practices that interact in an organized fashion to serve a common purpose. A system is created when all the components, taken together, form a functional unit. Building a system requires that components behave or perform in complementary ways, producing cumulative outputs to achieve a stated purpose. All components must enhance the overall performance of the system and are formulated with the system in mind; scaling and timing must complement or increase overall system outputs. Components are defined by their expected interactions and dependencies. The outputs of one component are the inputs of another. The system's success depends on the reliable performance of each of its components.

Systems rarely function in isolation; therefore, evaluation of each protection and restoration project would cover each individual function and appraise its contribution to the comprehensive system performance. An integrated system fits seamlessly into a larger context or framework without detracting from or degrading the larger context.

For example, wetlands creation may protect against more frequent, less severe storms or support the integrity of other storm protection features during more severe events. However, the created wetlands should also contribute ecosystem outputs in order to be of value across purposes. The same is true for navigable flood gates. Gate operation should not impede navigation except during storm events when protection takes priority. When a hurricane and storm damage reduction system functions across multiple purposes, this constitutes a form of horizontal integration. At times, project purposes would compete for priority. Knowing the tradeoffs necessary to meet multiple purposes is necessary for horizontal integration.

Vertical system integration occurs when it complements other activities, plans, or programs within the USACE, other Federal agencies, or State and local agencies and authorities. A comprehensive system would encompass other efforts for protection, restoration, reconstruction, and recovery. Achieving vertical integration requires an understanding of the purposes and perspectives of other agencies and how those agencies interact so that decisions can be made regarding this interrelationship.

Achieving compatibility with other Federal, State, and local agencies' goals might require acknowledgement of tradeoffs or setting of priorities. In order to accomplish multiple goals, a method of risk reduction might be uniformly applied throughout the area, knowing that some areas of high population concentration would be treated similarly to areas that have been decimated by Hurricane Katrina. Alternately, decisions could be made to stage construction so that maximum benefits are obtained first with additional projects to follow that support recovery. Integration of the flood and storm risk reduction system requires that all parties involved understand the strategy for system completion so that projects can be coordinated and expectations managed.

The components of a system may be quite diverse but all must contribute to a common purpose. Providing risk reduction from floods and storms can take many forms and different governing authorities and entities participating at different levels. Federal, State, and local agencies, along with private interests, would need to take responsibility for all actions and construction of physical features designed for the safety of the community.

Interior laterals, canals, and pumps are used for drainage when rainfall occurs and are maintained and operated by local community authorities. Riverbank levees channel Mississippi River floods through the city; floodwalls, levees, flood gates, and closures hold back storm surge. These structures are built commonly by the USACE and are maintained locally by the non-Federal sponsor. The National Flood Insurance Program, as provided by FEMA and enforced by local communities, provides insurance coverage to policyholders in the event of flooding. Local communities and State agencies provide temporary evacuation and shelter from storm or flood events. Local residents take precautions and measures to reduce their susceptibility to floods.

Building and assuring a comprehensive risk reduction system involves using all these components as necessary to address the system's purpose at all levels of government, including local interests. No single entity has authority to implement all these projects and activities. However, before a system can be fully integrated, a means should be devised whereby individual agency and community contributions to the comprehensive system can be evaluated and decisions made with regard to how the components complement the overall plan.

Integrating Ongoing and Future Projects and Programs

The comprehensive nature of the plans proposed by LACPR and the State Master Plan requires understanding the impacts of these proposals to insure consistency across project purposes and stakeholder needs. Numerous existing and proposed Federal projects address flood control, navigation, hurricane and storm damage risk reduction, and coastal restoration. Further, the State of Louisiana, other Federal agencies, and local governments have projects that impact the coastal landscape. All of these projects have various purposes, authorities, sources of funds, and construction schedules. This presents a major challenge to the integration of plans into a cohesive coastal protection and restoration vision.

Communication and Management Strategy

Hard work lies ahead in terms of significantly reducing risk to populated areas in Louisiana and restoring the Louisiana coastal areas. A well-coordinated strategy, based on the USACE's Actions for Change, which recognizes the need for a comprehensive systems approach to coastal protection and restoration, risk-informed decision making, communication of risk to the public, and technical and professional expertise, would facilitate success and ensure that all coastal protection and restoration projects in the State of Louisiana are fully coordinated with each other.

The magnitude of the effort necessary for implementation requires well-informed decision making. In order to be well informed, effective communication regarding the transfer of ideas, collaboration on on-going work and investigations, and leveraging of capabilities of all involved is necessary. Many related features must be integrated with each other, as well as with the components of numerous ongoing Federal, State, and local efforts. The need for an intense, innovative, transparent decision-making process is essential to achieve the goals and objectives within a reasonable timeframe. While agency decisions are made in collaboration with the sponsor (State of Louisiana), that decision maker is, as is the case of the USACE, the government, who is best served by having all the necessary information at hand at the time of the decision. For that reason, an implementation strategy requires a structure and staff that affords ready transfer of information to the decision maker in a format that allows for the decision. In addition, implementation of each component or group of components within a project would need to be linked to the overall system plan in order to meet the goals on schedule.

Current Communication Channels

Traditionally, the Federal process for review and approval of civil works projects by the USACE has involved a number of Federal agencies, a chain of command, and a significant coordination between the Executive and Legislative Branches at a number of levels. Likewise, there are processes for review and approval of projects within Louisiana State Government. Additionally, local government entities and special interest groups have great stakes in coastal restoration and hurricane risk reduction and would argue to have their interests acknowledged and addressed.

Between these groups exists a number of communication channels (**Figure 17-2**). These traditional interactions, coupled with the complexity and expected duration of coastal restoration and protection in Louisiana, add to the challenge of successful communications to support decision making. Considering the changing coast and other dynamic factors, a strong need to institute a new process has become evident.

A number of primary and secondary communication channels exist within the traditional project implementation process. Working within this framework would become increasingly challenging as multiple coastal protection and restoration projects are implemented over multiple years.

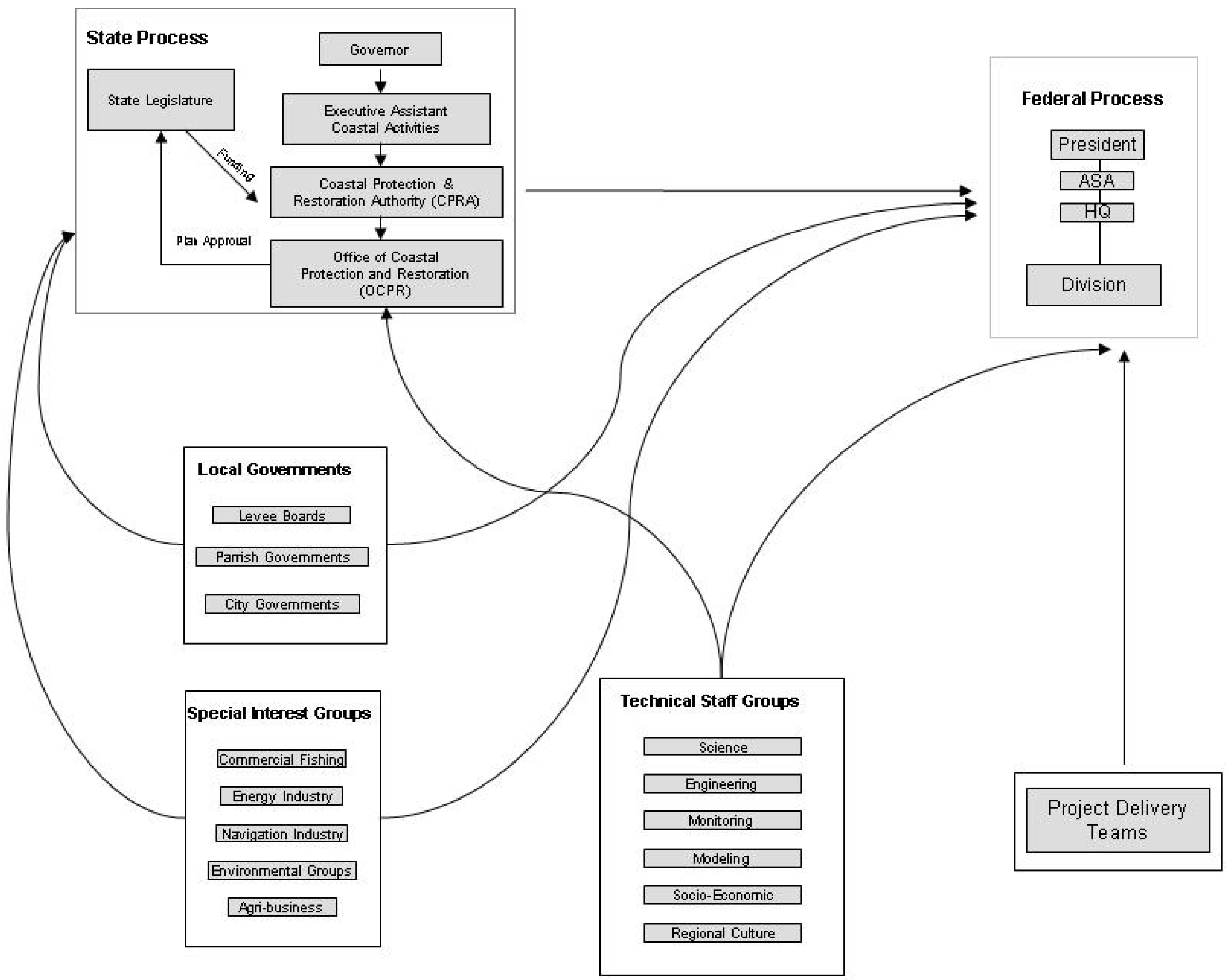


Figure 17-2. Typical communication channels between groups.

New Communication and Collaboration Framework

Although not meant to replace any group's existing authorities or relieve any group's responsibilities, some of the traditional communication channels would be greatly improved by virtue of better communication between participants in implementation through a new program management structure that is more effective in implementing coastal protection and restoration projects (**Figure 17-3**). A memorandum of agreement between the State and Federal Governments may be needed to adopt this new process. This approach would advantageously formalize involvement from local governments, stakeholders, technical staff groups, and the project delivery teams.

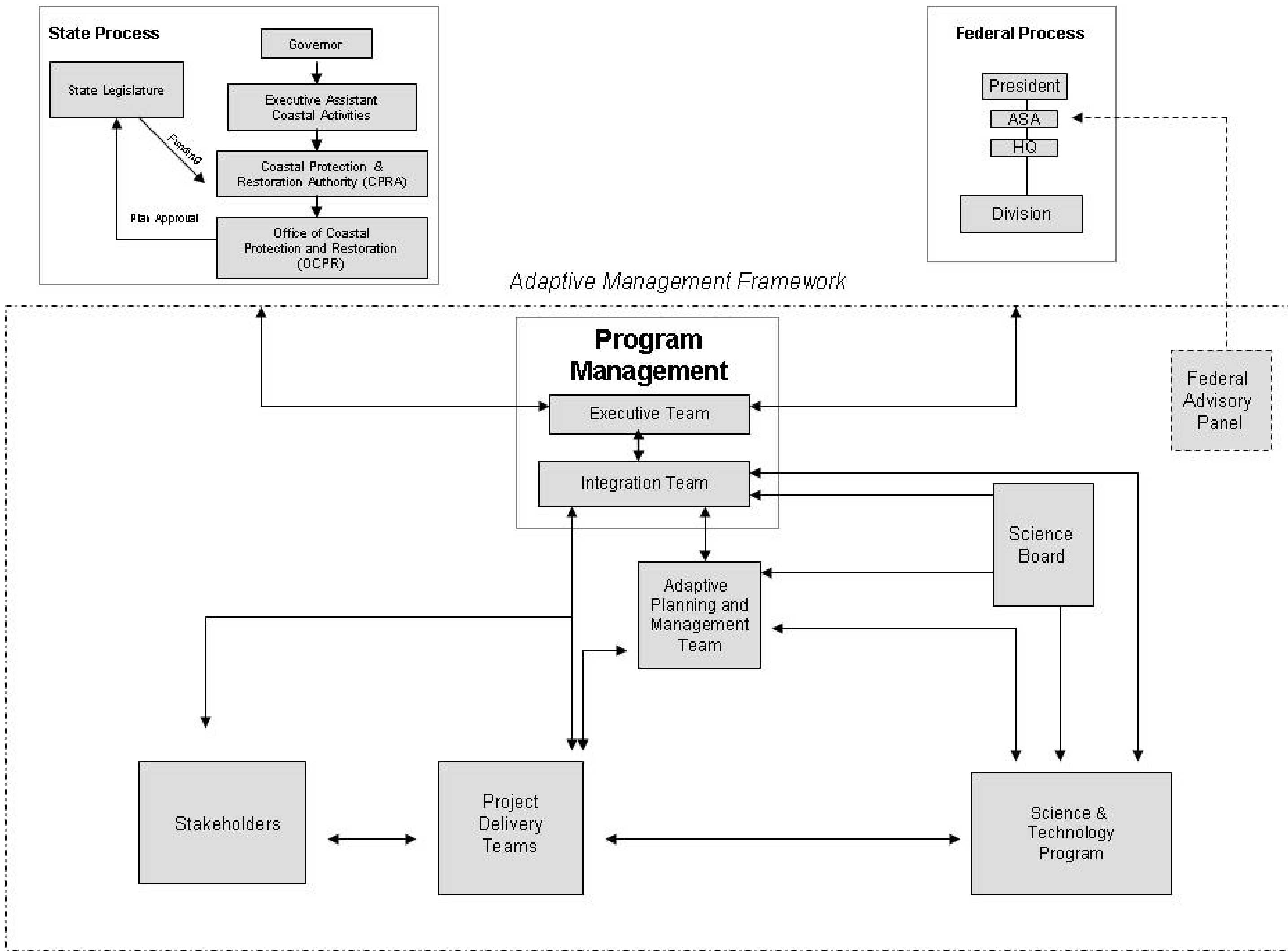


Figure 17-3. New communication and collaboration framework.

Good decision making and guidance are best served with the most up-to-date information at the time of the decision. Included in the proposed communication structure is the concept of adaptive management. At the program level, the key to successful implementation is a framework for adaptive management (**Figure 17-3**). This framework promotes effective communication between stakeholders, project teams, the Science and Technology program, the Adaptive Planning and Management Team, Federal and State Governments, and Program Management. At this level, adaptive management is achieved by the incorporation of new information and technology into new and existing projects as it becomes available and by the assimilation of lessons learned as new projects are developed. In addition to the State and USACE teams and other Federal and State agencies, the Executive Team may seek input from other resources.

Adaptive Management Framework

Adaptive Management incorporates an active collaborative process for the purpose of creating informed and contributing stakeholders, and for bridging gaps in communication and understanding amongst stakeholders, the scientific community, and Program Management who is responsible for implementation of LACPR. Integration of adaptive management processes and principles into the implementation a restoration and storm risk reduction program can be beneficial to decision makers, project teams, scientists/technical experts, and stakeholders in the following ways:

1. Improved probability of project/program success- Adaptive management reduces the uncertainties associated with project implementation and improves the probability of project success by addressing the risks posed by these uncertainties. With improved knowledge, decision-makers are able to take appropriate management actions to increase success.
2. A precautionary approach to act in the face of uncertainty – Adaptive management allows program/project managers to proceed with precautionary measures in the face of many uncertainties, understanding that as more information is obtained concerning ecosystem functionality and project performance, more specificity can be incorporated into engineering design and development of operational scenarios. Adaptive management provides flexibility that allows managers to respond to changing environmental conditions and improved decision-making.
3. Long-term collaboration between implementing agencies and stakeholders- Adaptive management brings together agency staff, decision-makers, and stakeholders, and encourages collaboration through the development and strengthening of institutional ties (Ringold et al., 1996).
4. Forum for dialogue between scientists and managers- Adaptive management provides an opportunity for scientists to provide restoration managers and decision-makers with interpretation of monitoring results and assessments so that new knowledge can be incorporated into the decision-making process.
5. Encouragement of robust alternatives with performance-based versatility- The concept of robustness is important to implement an adaptive management

strategy and can be defined as developing a design which can operate effectively given the variability and uncertainty of future events. The use of robust alternatives addresses the dilemma of making rational decisions today when current conditions are unknown and future conditions are uncertain. Incorporating this flexibility into one or more project or program plan alternatives would help managers evaluate alternatives that reduce the risk of not meeting restoration goals and objectives compared to non-adaptive management alternatives that include higher risk. A robust management action would produce acceptable outcomes over many different combinations of system behavior and future conditions (Peters and Marmorek, 2001).

These benefits are the reasons why adaptive management is an advantageous approach for ecosystem and storm risk reduction projects/programs that are faced with large uncertainties concerning their chance of success. Adaptive management may not need to be applied to all components of LACPR, but in cases where uncertainties are prohibiting progress, adaptive management may be the best way to implement the program/project.

Executive Team and Integration Team - A key element of the suggested communication and collaboration framework is centered on an Executive Team. The proposed Executive Team would be comprised of two representatives from the State and two from the USACE, one being the USACE Mississippi Valley Division Commander who would also be the Program Manager. The Executive Team would be responsible for the program's routine guidance and direction on day-to-day management, through delegated authority at the programmatic level. Issues that fall outside of the prosecution of authorized implementation would be vetted upward through State and Federal Governments to the appropriate decision making authorities. The two governments would define the Team's specific duties, which are expected to include prioritizing and scheduling work, planning and executing the budget, reviewing projects for consistency, directing and assigning resources, directing project reviews, and recommending projects for approval to higher authority.

The Executive Team would coordinate all appropriate input to formulate and transmit formal recommendations for project implementations and other recommended actions to their respective governments in an effective and efficient manner that would improve the overall implementation process. They would be responsible for monitoring and insuring effective implementation of a comprehensive systems approach, and reviewing project and planning activities for consistency.

In addition to traditional program management, the Executive Team may direct the application of a multi-criteria decision support tool to ensure the inclusion of stakeholder, technical, and political views in the weighting of alternative plan evaluations. This tool would aid the collaborative-adaptive management process and risk informed decision making process for long-term implementation.

As stated previously, the Executive Team's guidance and direction is only as good as the information provided to them. In order to facilitate the flow of information in an appropriate format, the Executive Team would be supported by the Integration Team, which would be staffed by mid-level State and agency personnel and supported by other staff and contract resources as necessary. In the proposed strategy, the Integration Team is the "working unit" of this new management structure, consolidating and funneling information from the Project Delivery Teams, Local Governments, Federal Agencies, Special Interest Groups, Technical Staff Groups, the Adaptive Planning and Management (AP&M) Program and the Science and Technology (S&T) Program to the Executive Team. In addition, the Integration Team would use results from a multi-criteria decision support tool to make recommendations to the Executive Team.

The Integration Team would act on and take direction from the Executive Team. They would be the center coordination point for communication, issue management, technical staff interactions, program/project management, stakeholder interactions, and other critical implementation activities required by the Executive Team and the program management process. The Integration Team would identify, organize, and process all issues and other aspects of day-to-day implementation. They would manage the Executive Team's routine agenda and prepare "decision packets" for the Executive Team that includes alternative and recommended courses of action.

By applying adaptive management, the Executive Team would aggressively resolve engineering, scientific, policy, and other issues (reduce uncertainties/answer unanswered questions) that prevent progress toward implementation, then direct the Integration Team to identify, collect, and manage the flow of issues and their resolution. Additionally, the Integration Team would identify issues and pertinent information collected from the stakeholders, agency staff, and academia and would maintain an inventory of issues and their status of resolution.

The Executive Team would meet on a regular basis to process issues, take actions, give direction to the Integration Team, and prepare recommendations for consideration and approval by the two government entities. For many issues, a management or "executive" decision by the Executive Team would bring resolution without further action. When the Executive Team requires more information for decision-making, or to send an issue or recommendation upward in the Executive Team's State and Federal authority chains, the Executive Team, through the Integration Team, would direct the appropriate team to investigate the issue further and return it to the Executive Team via the Integration Team later for final resolution. This further investigation would often involve scientific, engineering, monitoring and assessment, research, or other investigations. The Executive Team would direct resources to execute these directives. As the Integration Team resolves issues, they would be responsible for posting the resolutions in an issue-inventory database to ensure that all concerned parties know which issues are resolved and thereby eliminate the recycling of previously resolved issues.

Federal Advisory Panel – An advisory panel may sometimes be appointed by the Secretary of the Army or other Administrative direction to provide independent guidance for the implementation of coastal protection and restoration projects. A panel typically consists of representatives of the following: the State Governor; the Department of Agriculture; the Department of Transportation, the United States Geological Survey; the United States Fish and Wildlife Service; the Environmental Protection Agency; the Federal Emergency Management Agency; landowners; conservation and environmental advocacy groups; and agriculture and industry advocacy groups. The Secretary of the Army or his representative would be the chairperson of an advisory panel for USACE-led projects and programs. Advisory panels will be required to adhere to the requirements established by the Federal Advisory Committee Act.

The role of an advisory panel is to help seek innovative solutions to complex problems and to provide guidance for the implementation. An advisory panel promotes communication and collaboration between agencies at all agency levels and stakeholders. In addition, it helps to focus priorities and achieve objectives common across agencies. Since coastal restoration and protection in Louisiana is a major effort, it is expected that advisory panels may be used. The management structure (**Figure 17-3**) reflects that possibility. Advisory panels would report to the Chair. Those recommendations, issues, or concerns presented to the Chair that are deemed actionable by the Assistant Secretary of the Army (Civil Works) would be directed downward through the USACE chain to the delegated program manager, assumed to be the Commander of the USACE Mississippi Valley Division.

Adaptive Planning and Management Team (AP&M) - Considering implementation of coastal restoration and protection will take many decades and thereby be subject to changing populations, investments, coastal dynamics, and priorities, it is advisable that adaptive planning be included. The AP&M Team could provide essential support in meeting goals and objectives through the application of a system-wide perspective to planning and implementation. The team should consist of a multi-agency staff from the appropriate disciplines, including engineering, planning, science, economics, sociology, modeling, and resource management. The AP&M Team should work closely with the Project Delivery Teams, S&T office, as well as the Integration Team in order to fully implement the proposed implementation strategy.

An AP&M Team would be primarily responsible for developing recommendations, refinements, and improvements throughout implementation. This team would make sure the right questions are being addressed in a structured format and that the process for answering them and disseminating the information is collaborative and transparent. In addition, an AP&M Team could provide guidance and support for project level adaptive management and would verify integration of the AP&M Team with appropriate planning activities at the USACE and with the State of Louisiana.

In addition, an AP&M Team could provide a structure to ensure that decisions are implemented based upon best available science, technology, and socio-economic data, and that a process is in place to acquire and incorporate new or better information as it becomes available. The AP&M team would work with project teams to set up adaptive management plans, make recommendations for improving project plans, and adjust implemented actions based on new or improved information, to increase the probability of achieving goals and objectives. Such a process requires the development of key adaptive management components, such as sound baseline data and monitoring, models, data management, and continued research. An AP&M Team could work closely with project teams to define these needs and with the S&T Program to develop the necessary tools or tasks.

Science and Technology Program (S&T) - Although the body of data and knowledge for coastal Louisiana has advanced sufficiently, to provide a sound basis for implementation of restoration and hurricane risk reduction projects, certain aspects require increased analyses, monitoring, modeling, and research and experimentation to decrease uncertainties, especially in the area of predicting ecosystem and socio-economic response to the restoration and hurricane risk reduction projects.

An S&T Program was established under LCA by the USACE and the non-Federal sponsor to effectively address coastal ecosystem restoration needs, and to provide a strategy and process to facilitate integration of science and technology into the decision making process (USACE, 2004). This S&T program can be utilized to ensure that the best available science and technology are integrated into planning, design, construction, and operation of coastal protection and restoration projects.

To be most effective, the LCA S&T Program would be modified to not only provide the necessary environmental and engineering science, but also include social and economic science and analyses, to completely and effectively address both coastal restoration and hurricane risk reduction needs. The program would provide analytical tools and recommend to the Project Teams the appropriate modeling, monitoring, research, and/or experimentation to ensure that current issues of uncertainty can be addressed. In addition, they would be responsible for implementation of a regional monitoring and assessment plan, including the collection of baseline and project performance data. The S&T Program would conduct data mining, identifying data gaps, and collect new data where needed as directed by the Project Delivery, AP&M, and Integration Teams. They would also be responsible for setting up a system-wide database to house and manage all scientific data for coastal Louisiana and include a systematic approach for coordination with other ongoing and planned related research and monitoring activities and to make sure sufficient information is obtained to address critical questions. In order to achieve these tasks, additional appropriations, and possibly an additional authorization, would be required.

The S&T Program would execute programs under broad tasks directed by a Program Manager in collaboration with the Executive Team to include Decision Support, Assessment, Modeling and Evaluation, and Data Management. In addition, the S&T Program would assist in the implementation of demonstration projects designed to resolve critical areas of scientific or technical uncertainty and to advance coastal restoration plans by improving the planning, design and implementation of full-scale restoration and hurricane risk reduction projects. In general, the S&T Office coordinates, administers, and reports on science activities conducted as part of coastal restoration planning and implementation efforts in order to provide the Integration and Executive Teams, and project managers and other execution teams the best available science and technology support to plan, construct, and operate sound coastal restoration and hurricane risk reduction projects.

It may also be necessary to broaden the mission of the LCA S&T Office. Currently the LCA S&T Office is tasked with the evaluation of ecosystem uncertainties. In order to participate fully in broader risk reduction efforts, other missions, such as uncertainties associated with nonstructural and structural projects, may need to be added. Modification to the authority granted under WRDA 2007 may be appropriate to meet these needs.

Science Board - In order to provide national perspective of general scientific processes and structure of an Adaptive Planning and Management (AP&M) Program and the Science and Technology (S&T) Program, a Science Board is essential to ensure the application of world-class science and adaptive management principles. A Science Board was established under LCA for a similar purpose, and as discussed for the LCA S&T Office it, with appropriate modifications to legislation, may be utilized for risk reduction projects.

The LCA Science Board consist of a multidisciplinary group of National Academy of Science-level academics (convened on a contract basis), in addition to a representative of the USACE (Federal lead agency), a representative of the State of Louisiana (Non-Federal lead), and a representative of appropriate additional Federal agencies. Each member of the Science Board would have appropriate scientific credentials in an appropriate field of science or engineering and have experience in the science and technology issues surrounding coastal protection and restoration. As a result, membership of the existing LCA Science Board may need to be broadened to include the appropriate membership. The role of the Science Board would be to periodically review the AP&M Program as it relates to adaptive management practices and principles, and S&T Program as it relates to use of science and technology. The Science Board would prepare reports providing recommendations and advice to Program Manager and the S&T and AP&M Programs. The purpose of these reviews and reports is to provide an independent assessment of the programs. The S&T and AP&M programs would maintain regular communication with the Science Board between formal review sessions.

The Science Board would review and recommend ways to improve the processes for integrating the S&T Program and AP&M Program activities with the coastal protection and restoration program. The Science Board would report to the Program Manager and the S&T and AP&M Programs regarding the effectiveness of the programs and provide recommendations for improvement of the process. Additionally, the Science Board would provide reviews of how effectively the Program is incorporating the output of the Programs and the recommendations of the Science Board into the overall coastal protection and restoration program, and recommendations for improvement of the process.

As a group, the Science Board would maintain an understanding of the coastal protection and restoration program's goals, objectives, and actions and the state of the applicable science. The Science Board would help identify gaps in scientific information and tools used to incorporate science and adaptive management into the coastal restoration program, and recommend tools, processes, and methodologies from a review of current research to reduce uncertainties and improve ongoing coastal restoration efforts. In addition, the Science Board would recommend, if needed, new initiatives, innovative restoration tools, and methodologies for dealing with other challenging research and development issues. The Science Board would work closely with the S&T Program and Integration Team to review recommended changes that are needed in the applied science strategies of the restoration program.

The USACE Mississippi Valley Division Commander would share with the Executive Team the findings of the Science Board for consideration in directing teams. This information may also help guide the actions of other participants in the implementation of the State Master Plan by virtue of the collaboration and communication structure.

Stakeholder Involvement - Stakeholder engagement and the use of a collaborative approach to problem solving are critical components to ensure the success of coastal protection and restoration projects. Because of the size and complexity of risk reduction projects, it is important that stakeholders are not just involved, but actively engaged in problem-solving at the program and project levels. Engaging stakeholders in project planning, design, implementation, and evaluation has many benefits including: (1) building better understanding among stakeholders; (2) promoting relationships and trust as well as establishing lines of communication; (3) providing an opportunity for cooperative learning (i.e., issues that may be confusing, unclear, or unknown at the initiation of the project); (4) providing a mechanism to identify and address key issues and concerns; (5) creating networks for “honest dissemination” of new understanding as the project/program unfolds; (6) enabling development of creative solutions that address the unique mix of stakeholder interests; and (7) increasing the likelihood of program/project success (USACE, 2007). The LACPR team recognizes that all organizations, entities, and individuals have interests and is committed to addressing these interests proactively within the context of the project/program in order to reduce the likelihood of delay and help remove any obstacles.

Federal Agency Participation - There are multiple levels of participating agencies in Louisiana coastal protection and restoration. The Federal Principals Group, Regional Work Group, and Habitat Evaluation Team were established to facilitate communication and the input of agency guidance into this technical report. The Federal Principals Group has oversight of the Regional Work Group, and the Regional Work Group has oversight of agency members on the Habitat Evaluation Team. These groups are advisory in nature and they would not have management responsibility for projects, but would participate in technical assessments, planning, and would provide inputs into decision making. The participation of the Federal agencies in these capacities does not in any way limit the prerogatives of the participating agencies in exercising their statutory authorities and responsibilities. In addition, it is envisioned that Federal agencies will be represented on the AP&M Program and individual Project Delivery Teams.

Project Delivery Teams - To plan and implement its large number of individual projects, the USACE utilizes multiple Project Delivery Teams, which are interdisciplinary teams of staff professionals from the USACE and sponsoring and cooperating agencies, each led by a USACE Project Manager. Each individual project would have a Project Delivery Team that includes the disciplines and represents the functions of planning, engineering, construction, operations, and real estate that would provide the needed expertise for that specific project. The team conducts planning studies, perform project designs, and oversee the building of projects by construction contractors. Numerous technical groups are available for support on program and project planning, and for engineering design. The basis for recommendation for action is derived from reports of the Project Delivery Team through the Program Manager. These reports, coupled with information obtained through the implementation of the communication process described above, afford the Program Manager to make fully informed decisions and recommendations through the USACE chain.

Section 18. Other Plans and Studies Related to LACPR

The following section provides a brief description of some other plans and studies that have relevance to coastal protection and restoration in southern Louisiana. The first effort described is the Dutch Perspective report prepared by several Dutch organizations at the request of the LACPR team. Following the description of the Dutch Perspective are summaries of plans provided by two different stakeholder groups—the Multiple Lines of Defense Strategy report prepared by a group of non-governmental scientists and an Inner Levee Plan for the East Bank of New Orleans proposed by an advocacy group that represents a number of New Orleans businesses and civic organizations. Finally, several ongoing and future studies being conducted by the USACE related to coastal protection and restoration are described—an ecosystem restoration plan for the Mississippi River Gulf Outlet area; development of a regional sediment management budget for coastal Louisiana; and maximizing river resources using large-scale diversions.

The Dutch Perspective

Following Hurricane Katrina, the Dutch Rijkswaterstaat, part of the Dutch Ministry of Transportation and Water Management, offered its engineering expertise to the USACE. Although the challenges faced in the Netherlands are not identical to those faced in South Louisiana, their thousand years of experience in protecting their land from inundation can provide valuable lessons in planning and designing an improved hurricane risk reduction system for South Louisiana. Under a Memorandum of Agreement between the Dutch Rijkswaterstaat and the USACE, a number of technical exchange workshops and technical report reviews have been held to assist in the LACPR effort.

As part of the LACPR effort, the Dutch Rijkswaterstaat and Netherlands Water Partnership, a Dutch consortium of government agencies, researchers, and consultants, produced a report titled *A Dutch Perspective on Coastal Louisiana: Flood Risk Reduction and Landscape Stabilization* (Dijkman et. al., 2007). The purpose of the *Dutch Perspective* report was to obtain an independent view of risk reduction and restoration issues for the Louisiana coastal area from the Dutch based on their experience in dealing with similar issues in The Netherlands. Their report was prepared in parallel with the LACPR Technical Report and was not intended to provide information directly into the technical analysis at this stage; however, after reviewing the Dutch report, the team has concluded that the strategies, alternatives, and issues in the *Dutch Perspective* report are not that different than those in the LACPR Technical Report. This consistency provides assurance that LACPR plan formulation is sound and has considered appropriate measures to address hurricane surge risk reduction in the New Orleans metropolitan area. The Dutch report will be a continuing reference document for the USACE. The continuing cooperation and exchange with the Dutch is, and should continue to be, an integral part of coastal protection and restoration planning.

Dutch Perspective Alternatives and Preferred Strategy

The Dutch report only addresses Planning Units 1 and 2. In Planning Unit 1, the Dutch team looked at similar alternatives to LACPR, i.e. barrier-weir (“closed coast”) vs. high level (“open coast”). Although the Dutch report presents a preferred strategy, the Dutch team did not come to a firm conclusion as to which plan would be recommended because of the limitations of their hydraulic and benefits analysis. In Planning Unit 2, the Dutch team again looked at an open vs. closed coast which corresponds to the LACPR ridge vs. barrier-weir strategies. The Dutch recommended the open coast strategy which corresponds to the LACPR ridge plan.

The Dutch team’s preferred strategy, ‘Protected City and Closed Soft Coast,’ (**Figure 18-1**) combines various elements of five different strategies that the Dutch team considered. This strategy is modeled after the flood risk reduction approach implemented in the Netherlands after the 1953 flood disaster; however, the Dutch have learned that ‘shortening’ the coast using hardened structures such as barriers which disrupt the natural hydrology can have major adverse environmental impacts. Based on these lessons learned, the ‘closed soft coast’ concept implies a maximum shortening of the coast for active flood reduction while creating a sustainable ecosystem and landscape that supports coastal protection.

Different strategies were chosen for the Pontchartrain and Barataria basins. The Pontchartrain Basin would have gated structures in the Rigolets and Chef Menteur passes, which would be closed under the threat of a major storm surge. The Barataria Basin would remain an open estuary with wetland stabilization being the primary measure for hurricane surge reduction. Improving the culvert system under US 90 and other barriers in this estuary are proposed to allow more natural water flows in the estuary.

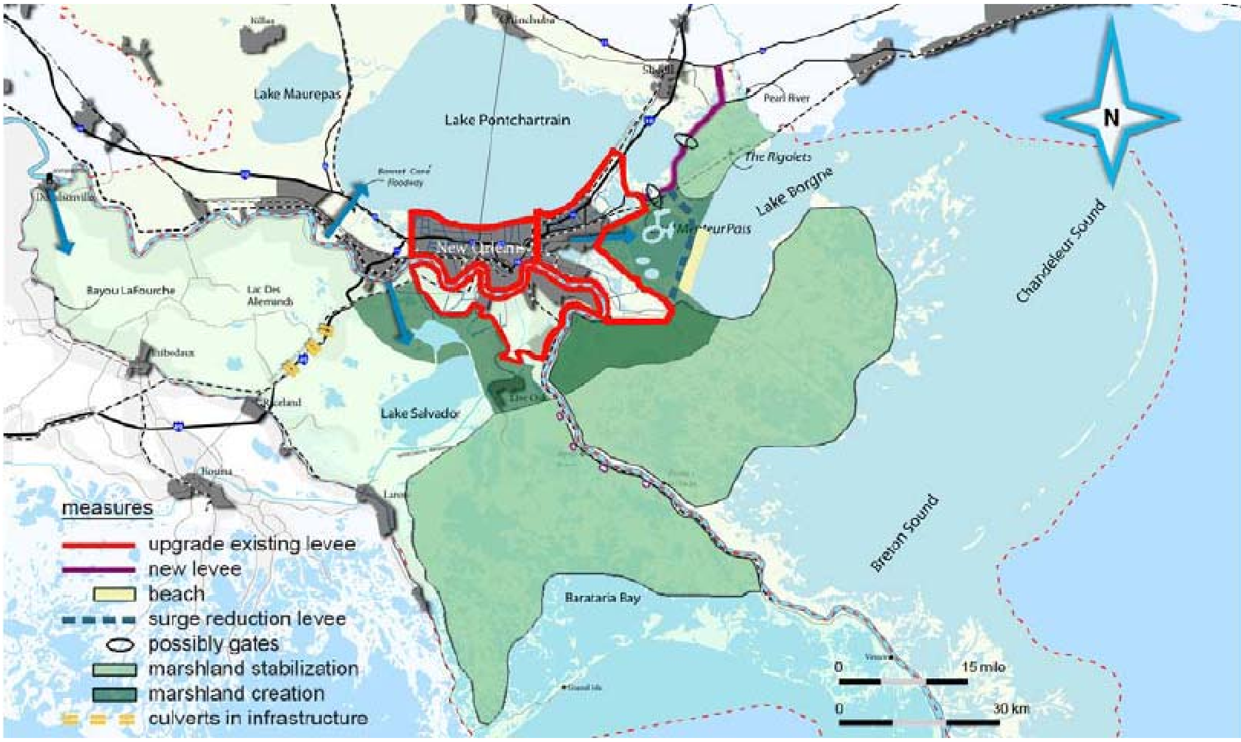


Figure 18-1. Dutch Perspective strategy "protected city and closed soft coast"

The following measures are included in the Dutch preferred strategy:

- **Levees around the metropolitan area of New Orleans** would consist of three levee rings including storm surge barriers in the various navigation and drainage canals. Ring 1 would surround the central part of the City with a 5000-year or higher risk reduction levee. Rings 2 and 3 would surround the eastern and southern parts of the City, with a 1000-year or higher risk reduction levee.

- **Salt marsh stabilization** includes restoring 750 square miles in the Pontchartrain basin and 600 square miles of marsh restoration in the Barataria Basin. As these measures are planned to take as long as 50 years, no immediate effect on surge or wave reduction was considered when determining levee heights around New Orleans. Once in place, however, the marsh system could help reduce future costs of levee and barrier upgrades.

- **Freshwater marsh (cypress swamp) revitalization and creation** are proposed in a wide zone (between 1 and 6 miles wide) immediately around the levee rings in the New Orleans area totaling about 140 square miles. This measure could afford some surge reduction and, in particular, reduction in wave loads on the levees.

- **Converting part of Lake Borgne into a freshwater marshland** could reduce surge on the eastern part of the City. This measure would require separating Lake Borgne from the Gulf by a ridge levee, partly filling in the lake and providing freshwater sufficient to establish a fresh water swamp in the lake.

Dutch Perspective Recommendations on Pilot Projects and Priority Studies

The Dutch team's preferred strategy is a mix of measures that are based on proven technology but also on innovative concepts. Even proven technology, suited for the typical Dutch environment and engineering technology, will need validation when applied to the environment and characteristics of the Louisiana coast. Proven technology can also be improved upon, which is especially relevant when costly large-scale applications are anticipated as in the case of LACPR. The success of any strategy in achieving sufficient marsh creation and long-term, large-scale landscape stabilization depends on the successful implementation of innovative cost-effective solutions. Therefore, the Dutch team suggested that several pilot projects and priority studies be implemented as a means to validate engineering solutions, reduce uncertainties, and fill in knowledge gaps. The following pilot projects and/or priority studies recommended by the Dutch are examples of the types of projects that could be investigated by a science and technology program as described in the *Adaptive Management Appendix*:

Levee construction and stability pilot projects

- **Overtopping erosion tests on existing levees.** The Dutch team suggests performing field tests on existing levees in order to get a good understanding of the actual strength of the levees and to provide ideas on ways to further improve the strength. Recently, a new device, the *wave overtopping simulator*, was designed and constructed in the Netherlands and field tests were performed on an existing levee.
- **Ridge-levee concept.** A new type of gradual slope, ridge-like levee covered with vegetation has been proposed by the Dutch team for reducing storm surges. In order to explore the uncertainties associated with construction methods; management and maintenance requirements; soil characteristics; long-term stability; and the development of vegetation, a pilot study is needed in which a section (for example, a mile in length) is actually constructed.

Marsh stabilization pilot projects

- **Canal infilling.** The Dutch team proposes a pilot project to develop efficient techniques to fill or plug man-made canals in the wetlands. The number of canals involved, and the scale of the area, suggests a thorough rethinking of the existing techniques for plugging or filling canals.
- **Increasing the effect of freshwater discharge.** This pilot project aims at optimizing marsh growth and increasing the mixing zone with saline waters. Areas would be semi-enclosed by low ridge-levees to enhance the flooding effect and residence time of the diverted freshwater.
- **Lake segmentation and land formation.** In this pilot project, artificial low ridge-levees, islands, and suitably placed oyster reefs would be utilized to divide lakes into segments. This segmentation would reduce energy levels but maintain the required flow.

Marsh creation pilot projects

- **Accelerated natural freshwater marsh creation.** This pilot would aim to find the optimal mix of water discharge, sediment availability, and flooding cycle to attain fastest accretion rates. The size of a suitable pilot area is estimated at between 20 to 200 acres.
- **Natural salt or brackish water marsh development.** This pilot project is similar to the previous pilot project but would have a salt or brackish environmental instead of a freshwater system. For this pilot, daily water level variations should be allowed according to local tides.
- **Accelerated saltwater marsh development.** A pilot is proposed to study the applicability of the traditional Dutch method of salt marsh creation, which has been applied in that country for hundreds of years, to the Louisiana coastal area. The experiment could start with the creation of five to ten parallel low-crested wooden structures to start salt marsh formation along a one-mile stretch of coastline.

Priority studies

- **Risk assessment.** The risk assessment carried out in the Dutch perspective report resulted in a tentative and first order economic optimization of the flood risk reduction level for New Orleans. The Dutch team recommends improving this analysis through a joint effort by U.S. and Dutch specialists.
- **Effects of vegetation on surges and waves.** The effect of vegetation on water levels and waves remains difficult to estimate. This effect, however, has a direct impact on the hydraulic design parameters for infrastructure, and hence the costs and reliability of that infrastructure. Therefore, the Dutch team highly recommends that priority studies be undertaken to address the effect of different types of wetlands on surge, wave, and wind reduction.

The Lake Borgne area was selected by the Dutch team as a primary site for execution of the pilot studies because of its sensitivity to storm surge and its short distance to the City of New Orleans.

Multiple Lines of Defense Strategy Assessment

The multiple lines of defense strategy is based on reducing risk from hurricane surge using both engineered features, such as levees, and by the natural coastal wetland buffer along the Louisiana coast. The Multiple Lines of Defense Assessment Team, a group of non-governmental coastal scientists and engineers dedicated to the continued development and application of the Multiple Lines of Defense Strategy, has released a draft report titled *Comprehensive Recommendations Supporting the Use of the Multiple Lines of Defense Strategy to Sustain Coastal Louisiana*. The Multiple Lines of Defense report is available online at *www.mlods.org*.

Inner Levee or Compartment Plan

The Flood Protection Alliance (formerly of the Bring New Orleans Back committee) has proposed an inner levee or compartment plan for the East Bank of Greater New Orleans. The proposed containment system would inhibit flood waters from flowing unencumbered across portions of the city. The plan includes connecting natural ridges, drainage canal levees and elevated railway right of ways; gating sewer pipes; repairing roadways at parish lines; constructing a moveable gate at Bayou St. John; and retrofitting underpasses. An analogy used by the Flood Protection Alliance is that the inner levee plan would change New Orleans from a "bowl" to a "muffin pan."

In the Netherlands, similar compartment plans are also being investigated. The Dutch firm Royal Haskoning, Inc. has performed an independent study of the effectiveness of the New Orleans compartment plan for flood risk reduction. Their preliminary cost-benefit analysis for an event similar to Hurricane Katrina reveals that the compartment plan has potential economic benefits.

Mississippi River Gulf Outlet Ecosystem Restoration Plan

In response to a Congressional directive, the USACE began a study in 2006 to de-authorize deep-draft navigation on the portion of the Mississippi River Gulf Outlet (MRGO) between the Gulf Intracoastal Waterway and the Gulf of Mexico. In January 2008, the Chief of Engineers finalized a report recommending construction of a rock closure structure near Bayou La Loutre in Hopedale, Louisiana. In June 2008, the Assistant Secretary of the Army for Civil Works transmitted the Report of the Chief of Engineers to Congress officially closing the channel and ending 45 years of shipping on the MRGO. Congress had earlier approved the de-authorization report and authorized closure of the channel through the Water Resources Development Act of 2007.

As a supplement to the MRGO closure plan, the USACE is embarking on a feasibility study which will result in a comprehensive Ecosystem Restoration Plan to address areas affected by the MRGO channel. In collaboration with a multi-disciplinary, multi-agency team, the USACE will identify potential plan features, which may include marsh creation, shoreline protection, barrier island rebuilding, and freshwater diversions from the Mississippi River. The plan is being developed under the authority provided in the Water Resources Development Act of 2007.

As the ecosystem restoration plan is developed and finalized, the USACE will include the public and stakeholders in the decision-making process. The draft report is expected to be released to the public in May 2010. Additional information on the MRGO Ecosystem Restoration Plan Feasibility Study can be found at *http://mrgo.usace.army.mil/*.

Development of a Regional Sediment Budget for Coastal Louisiana

A regional sediment budget is needed to best manage planned and future projects along the Louisiana coast. The USACE Engineering Research Development Center is assisting the New Orleans District in developing a regional sediment budget for the coastal and riverine regional system in southern Louisiana. Specifically, the rate and direction of net and gross transport of sediment (separated into sand and finer fractions, as possible) throughout the coastal zone and within the riverine systems will be defined and used to develop an Existing Condition Regional Sediment Budget. Existing GIS databases (from the USACE New Orleans District, Louisiana Department of Natural Resources, U.S. Geologic Survey, and Louisiana universities) will be adapted to complete these analyses. A USACE technical report documenting the study will be published.

Conceptual Sediment Budget

The USACE has already completed a conceptual sediment budget by rapidly assessing and coalescing existing literature, studies, models, and dredging activities. This effort identified regions without information, areas with conflicting evidence, confidence with estimates, and additional data needs so that future data collection and studies can be focused. This conceptual sediment budget will be utilized to develop the existing budget and extend it to possible future conditions as described below.

Working Sediment Budget

The working sediment budget will build on the conceptual budget and refine estimates for those locations with conflicting information, no existing estimates or large uncertainty, based on more extensive data analysis. Historical bathymetry, shoreline position, and engineering activities (e.g., beach nourishment, dredging and placement) will be analyzed in detail. Analyses for the Mississippi and Atchafalaya Rivers will access ongoing work as well as river stage data, channel geometry, and the review of existing dredging records. This phase of the study will take a broad regional perspective, and provide baseline conditions of the lower Mississippi River from Old River to Head of Passes. Extending the assessment to Old River will allow for the analysis of the Old River Control Complex (a flow-sediment diversion) that has been in operation since the 1960s. From these analyses, estimates for net and gross sand and fine sediment transport rates will be developed. Areas needing further analysis to define sediment transport pathways and magnitudes will be identified.

Evaluation and Conceptual Modeling of Future Engineering Activities

The regional sediment budget will be further developed to determine how engineering activities modify the existing sediment transport pathways, magnitudes, flow speed and direction, wave height and direction, and storm impact (surge, duration, etc.). Example analyses include: (a) How close can sediment be mined from the nearshore and not adversely impact the barrier islands or inlet systems? (b) How deep, wide, long can sediment be borrowed from the bay and estuary system without creating a "sink" for mainland or barrier island sediment or increasing waves in the bay? (c) Can flood/ebb shoals be mined without adversely impacting inlets/adjacent barrier islands? (d) Can river diversions be used successfully to increase the sediment source to the regional system? These types of analyses are intended to provide screening-level guidance so that the USACE can evaluate how various engineering activities will modify the regional sediment budget.

Maximizing River Resources using Large-Scale Diversions

A primary cause of the significant land loss in coastal Louisiana over the last 80 years is the reduction of riverine sediment delivery to coastal wetlands and the restriction of delta building processes. The construction of levees along the Mississippi and Atchafalaya Rivers has offered effective navigation and flood control benefits but has dramatically altered the natural hydrology and sediment transport that built the coast producing massive sediment deficits and wetland loss and reduced natural storm surge buffering capacity. Sediments traveling down the Mississippi River that could be used to build land in critical areas are lost from the system once the River reaches the Gulf of Mexico at the Bird's Foot delta (represented by the blue shading in **Figure 18-2**).

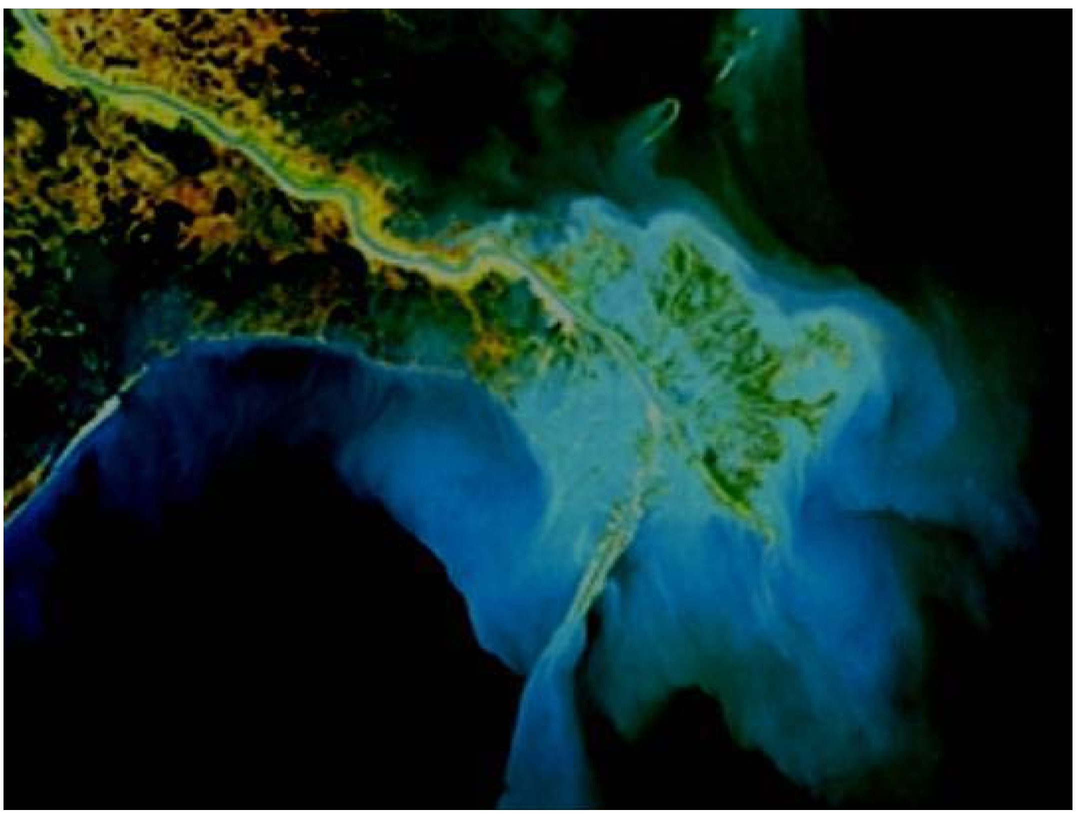


Figure 18-2. Sediment losses off the Bird's Foot Delta

WRDA 2007 Section 7002, which directs a comprehensive plan for *"protecting, preserving, and restoring the coastal Louisiana ecosystem,"* also directs the USACE to consider integration of *"an investigation and study of the maximum use of the water and sediment of the Mississippi and Atchafalaya Rivers for coastal restoration purposes* *consistent with flood control and navigation"* into the framework for a long-term program. An effective restoration program that addresses the deterioration of estuaries must explore strategies for replicating natural riverine processes that can both build new and maintain existing coastal wetlands. Many recent coastal restoration plans (e.g., the 1998 Coast 2050 report and the LCA Study) document the importance of major realignment of the lower Mississippi River as essential to addressing coastal sedimentation issues and comprehensive restoration. Maximizing the use of sediment from the Mississippi and Atchafalaya Rivers to sustain both the present wetlands and delta building processes is essential.

The LCA Chief's Report assumed large-scale "restoration concepts" involving the Mississippi and Atchafalaya Rivers could proceed on a measured pace, with primary focus on projects specified by Congress as critical in the near-term. However, after Hurricanes Katrina and Rita and faced with subsidence and accelerated sea level rise, restoration strategies are considered an urgent and integral element of coastal protection and restoration.

This LACPR technical report describes alternatives with freshwater diversion features as a means to maintain the current coastal landscape and ecosystem functions. Most of those diversions could be classified as large diversions with high flow design capacities greater than 15,000 cfs with the largest diversion being over 175,000 cfs. It should be noted that the LACPR team has not determined the cumulative impacts that multiple diversions may cause on the system. Nor has the team quantified the impacts on navigation or flood control on the Mississippi River. In addition, technical issues for freshwater diversions persist, particularly for the larger scale diversions. These issues include how well the measures may actually perform, how they should be operated, and the tradeoffs that will be required such as over-freshening of marsh areas and displacement of associated fisheries and wildlife. These proposed measures would be expected to evolve over time and be further studied as the USACE looks to improve its understanding of large-scale diversions.

Section 19. Summary of Findings

This section discusses key findings from the LACPR effort which have significance to current and future analyses and risk based decisions. Findings are related to tradeoffs within a multiple lines of defense strategy; risk informed decision making; the stakeholder MCDA process; long-term sustainability of the coast; and other key findings.

Findings on the Multiple Lines of Defense Strategy

A multiple lines of defense strategy has advantages over single strategy approaches. No single measure or approach for achieving risk reduction will be sufficient for achieving the multiple risk reduction objectives established for coastal Louisiana. Each individual measure has weaknesses and tradeoffs. Therefore, an integrated comprehensive system comprising coastal restoration features, nonstructural measures, and structural components is the most promising approach for reducing storm surge risk in South Louisiana.

- **The only way to provide adequate personal safety from hurricanes is through evacuation before the storm.** Hurricane risks can never be eliminated or entirely prevented. Therefore, individuals have a personal responsibility to evacuate as directed by local officials or sooner.

- **Individual and community decisions have a primary role in determining future risks to both life and property.** Recognizing hurricane threats and risks inherent to life in South Louisiana, individuals and communities must decide where and how to build or rebuild; how to adequately insure that property; and when to evacuate. State and local governments have a critical role to play in implementing certain nonstructural measures such as evacuation planning, land use planning, zoning, and permitting. As emphasized in the State Master Plan, all residents of coastal Louisiana should buy flood insurance; homeowners can elevate or retrofit their homes using available hazard mitigation funds; and citizens must comply with the provisions of the 2007 Louisiana State Uniform Construction Code, which is designed to ensure that new construction can better withstand hurricane force winds.

- **Some features in the coastal landscape are critical contributors to the long-term sustainability of a comprehensive risk reduction system for coastal communities.** The coastal landscape, and the restoration and maintenance of that landscape, are important considerations in a comprehensive system for risk reduction. Continuing erosion of coastal wetlands reduces the natural buffer separating coastal communities from the Gulf of Mexico. As coastal wetlands disappear, these communities will face a choice of building higher and stronger structural defenses; relocating to areas with lower risks; or continuing to live in areas under ever-increasing risk. Robust hydro-modeling enabled the analysis of the performance and contribution of the coastal landscape in limiting storm surges. While the effect of the coastal landscape on surge is not a substitute for structural and nonstructural risk reduction measures, coastal features can significantly increase the reliability and sustainability of comprehensive risk reduction systems as well as existing development. Critical features within the coastal landscape (e.g. wetlands, land bridges, highways, etc.) that have a measureable influence on surges have been identified across the entire Louisiana coast.

- **Structural measures provide the greatest level of risk reduction when removed from the immediate proximity of development**. All structural measures are capable of providing significant risk reduction with increasing design levels. However, the technical evaluation has indicated that levee alignments that allow some distance between the levee and the development footprint produce greater, and often significant residual protection above the indicated design level. The evaluation results show that 100-year level structural alignments that meet this parameter may provide significant risk reduction for the 400-year to 1000-year surge events. Structural alignments which are adjacent to developed areas (e.g. ring levees) are susceptible to higher consequences once the design level surge is exceeded. This effect is correlated to the relative capacity for storing flood water once surge exceeds the design associated with each plan.

- **Structural measures are not always the best solution.** In densely populated areas like greater New Orleans, structural features, such as new levees and floodwalls, may be a needed component of an overall risk reduction strategy. Such measures, however, may not be the best choice for risk reduction in areas of more dispersed population where investment in building long levees may be disproportionately higher than the infrastructure values behind them. Building and maintaining structural features is a large, long-term investment, and structural features have significant drawbacks such as environmental impacts, intensive resource requirements, the potential for being exceeded or possible failure, inducing development, or other unintended consequences.

- **Nonstructural measures are a key component for risk reduction.** Hurricane risks can never be eliminated or entirely prevented; however, the relocation or removal of assets from a flood affected zone, or elevation of assets above the flood affected zone, can significantly and reliably reduce risks. Buyouts and relocations provide the most definitive risk reduction. Other nonstructural measures, such as floodproofing and raising-in-place, reduce risk but do not eliminate it. Nonstructural measures should be a key component of any comprehensive plan to reduce storm surge risk; however, as described below, relocation of all residents out of the floodplain is not a viable option.

- **Relocation of all residents out of the coastal floodplain is not a viable option.** People have lived in South Louisiana for over 12,000 years. Coastal Louisiana will continue to be a population and employment center because many industries are specifically linked to resources that are located in coastal Louisiana. Examples include port facilities, oil and gas reserves, navigation fabrication facilities, and commercial fisheries that are directly linked to the Gulf of Mexico, the Mississippi River, and other geographic features of coastal Louisiana. Many employment opportunities will continue to exist in these and other economic sectors. These opportunities, the associated populations, and resulting public and private investments are unlikely to be relocated from coastal Louisiana.

- **The effectiveness of buyout and raise-in-place nonstructural plans depends on the level of participation.** In comparison to structural and coastal restoration measures, successful implementation of nonstructural measures requires a higher degree of direct participation by individuals and other government agencies besides the USACE. Decision makers must consider the risk reduction effectiveness for differing levels of participation based on acceptability of local interests of such actions, which needs to be better defined through continued coordination/interaction with the public, stakeholders and the State. For LACPR, nonstructural plans or plan components have been evaluated based on the total number of affected structures for each design surge level; however, their actual effectiveness is highly influenced by the ultimate level of individual participation. In some areas and for some specific plans extremely high levels of participation (80 to 90 percent) are necessary in order for the projected risk reduction values to be realized. In other areas, participation rates can be as low as 40 to 60 percent without impacting the formulation and ranking of alternatives. Lack of participation could result in unacceptable levels of residual risk. Therefore, incentives may be needed to improve participation in buyouts and raise-in-place measures in order to make these types of plans successful.

Findings on Risk-Informed Decision Making

- **Tradeoffs are critical to risk informed decision making.** While the MCDA tool can provide a clearer appreciation of the performance values across a range of key performance attributes, certain critical performance criteria should always be considered independently and compared to allow full understanding of risks and tradeoffs. Fiscal decision makers must always consider efficiency, effectiveness, and ultimately costs. Consideration should also be given to environmental tradeoffs, if not independently through the MCDA methodology.

- **Consideration of risk reduction for extreme events or a range of events requires use of non-traditional evaluations of efficiency and effectiveness.** The traditional presentation of annualized costs and benefits understates the potential impact of large storm surge events by expressing probabilities over a short, one year, timeframe. Considering the probability of these larger events occurring over a longer period (perhaps the period of analysis, i.e. 65 years) more effectively communicates risk. The individual event probabilities and relative damage risks would change by an order of magnitude or greater when considering such a timeframe. Some consideration should be given to whether the period of analysis or a longer "period of performance" might be appropriate. The comparison of plan preferences based on both annualized values and period of analysis values may be useful in alternative screening.

- **The determination of acceptable levels of risk is part of the ultimate goal of a risk-informed decision framework.** This report provides a range of risk reduction levels from no additional risk reduction to 1000-year risk reduction but does not dictate what the ultimate risk reduction level should be. The USACE has traditionally made the decision of the level of risk reduction based on investment decisions and the decision criteria has been the benefit-cost ratio based on annualized benefits and annualized costs which often eliminates consideration of greater than 100-year risk reduction. The determination of acceptable risk is contingent on the stakeholders' understanding of the range of risk and available options for addressing that risk. Future efforts should pay attention to the concept of acceptable risk as an aid to risk management decisions through increased and improved communication of the relative potential risk either with or absent any alternative actions.

Findings on Stakeholder MCDA Process

- **MCDA provides value in interfacing with outside interests and understanding performance preferences.** The MCDA tool provides an excellent means of interfacing with stakeholder and interested parties and identifying and quantifying their values regarding areas of plan performance. The tool also provides a working platform to allow these parties to explore their value beliefs and develop their understanding of how those values translate to plan preferences and their attendant risks. The collection of stakeholder input, assessment of their values and preferences, and the communication of those relationships provides insight to the planning team and decision makers regarding potential tradeoffs between alternatives and their acceptability.

- **The development of evaluation data for the metrics selected in an MCDA is critical.** The application of MCDA should begin at the onset of study scoping and support the development of plan formulation and the plan evaluation. Although the MCDA performed in the LACPR technical analysis has provided great insight with regard to stakeholder values and where performance tradeoffs exist further refinement of metric evaluations would enhance overall confidence in the final output. Several of the selected metrics in the LACPR analysis were limited in their evaluation due to the complex nature of the needed analysis relative to the large number of alternatives and time available. More detailed methodologies have been investigated for the evaluation of both regional economic outputs and cultural and sociological impacts. These investigations are presented in the appendices of this report to support the development of future planning efforts. The indirect environmental impact metric has also been identified for future refinement. Indirect impacts have been assigned to the alternative plans qualitatively using expert judgment and applying a scale of -8 to +8. This particular metric value provides a representation of significant potential ecologic impacts that is one of the most significant areas of tradeoff between alternative plans. The current qualitative scale is deceptive in its representation of these impacts relative to other significant, and quantitatively gauged performance factors such as expected damage, cost, and population impacted. Future refinement of the LACPR effort should include steps to adequately analyze and quantify potential indirect impacts.

- **MCDA has limitations as a plan selection methodology.** Although all information gathered directly from stakeholders may provide valuable insight, without adequate iterations of engagement and information feedback with stakeholders full confidence can not be developed in the plan preference information produced using MCDA. Most importantly, even with adequate development and stakeholder engagement, the MCDA tool does not represent a stand alone plan selection process.

Findings on Long-Term Sustainability of the Coast

- **Diversion of Mississippi River freshwater, nutrients, and sediment is essential for the restoration of natural deltaic processes that sustain coastal wetlands.** Therefore, projects to divert freshwater and sediments from the Mississippi River into adjacent estuaries are integral components of coastal protection and restoration plans. Currently, over 20 diversions are either being studied or constructed along the Mississippi River. These projects and studies, all developed through various authorizations, require strategic coordination with other Mississippi River management efforts to ensure success in construction and operation. The USACE is working to implement a near-term plan for diversions as well as a comprehensive plan that will include significant scientific developments to better understand the hydrodynamics of the system and the potential long-term configuration of the river delta system.

- **Adequate sediment resources are available to implement proposed coastal restoration plans but acquiring those resources involves tradeoffs.** The study team was able to conservatively identify sediment sources and timeframes for the construction of the coastal landscape features included in the extensive restoration plans considered for the final alternative array. This analysis indicated that in addition to riverine sediments from proposed diversions along the Mississippi River and tributaries, significant sediment would need to be acquired either from offshore sources or from interior bay and lake bottoms. As with any of the alternative actions being considered there are tradeoffs associated with either of these options. Offshore sources represent a more costly option and these sediments potentially introduce a highly saline component into a less saline or fresh environment producing an adverse response and adjustment period prior to system improvement. Removal of sediment from interior water bottoms can significantly alter the hydrodynamics of the estuary and have potentially far reaching impacts. A sensitivity analysis was also performed to determine the impact that failure to undertake coastal restoration would have on alternative plans. In some areas of the coast, failing to prevent continued wetland loss would result in increased implementation costs for other risk reduction features. However, with additional investment, the intended level of performance for any alternative could be maintained, and the relative rank performance of the alternatives without coastal components would be the same.

Other Findings

- **The size and magnitude of storm threats are generally greater in the area of the central Gulf Coast near the Mississippi River.** Statistical analysis of historic storm data indicates the potential for occurrence of larger, more intense storms (Category 2 or greater) increases toward the center of the Gulf Coast near the Mississippi River. The area of the Gulf Coast from roughly Panama City, Florida to New Iberia, Louisiana is approximately 1.5 times more likely to experience a Category 2 or greater storm than the remainder of the Gulf Coast. The area from roughly Mobile, Alabama to Grand Isle, Louisiana is twice as likely to experience storms of that magnitude.

- **Rule of thumb approaches for estimating the contribution of wetlands to risk reduction are unreliable.** Prior to the storm surge modeling performed for LACPR, a common rule of thumb ("x miles of wetlands reduce surge heights by y feet") was used to predict the storm surge reduction potential of wetlands; however, the results of the LACPR model have shown that a general rule of thumb is not appropriate for making risk-informed decisions. Additional detailed modeling of alternative coastal features and landscapes will be needed in subsequent steps to better determine their role in risk reduction. Protecting and restoring coastal wetlands in some areas of the coast provides greater risk reduction potential and in others greater ecologic benefit. The identification of existing critical landscape features across the coast clearly indicates that the potential for additional risk reduction through strategic application of coastal restoration features is possible. Restoration also remains a critical need in all areas of the coast and significant ecosystem benefits are attainable. In areas where risk reduction is not apparent, coastal restoration focus can be on ecologic performance goals.

- **Regional tradeoffs across state boundaries must be considered.** A regional analysis conducted for Louisiana and Mississippi identified potential impacts and tradeoffs for each state. For example, the Pontchartrain barrier-weir plan (LP-a-100-1 and C-LP-a-100-1), which is included in the final array for Planning Unit 1, has a potential to raise water levels in Mississippi resulting in economic, environmental, and cultural impacts. The estimated additional annual impact of $5 million would represent an approximately 6 percent increase in potential damages over the Mississippi base condition. Conversely, these potential impacts to Mississippi correspond to a little over one percent of the expected annual damage reduction in Louisiana (approximately $375 million annual benefits). The significance of those relative impacts should be weighed against the benefits achieved on a regional scale. Further analysis would be required if the Pontchartrain barrier-weir plan were to proceed into engineering and design. The Pontchartrain barrier-weir plan could potentially be optimized to minimize adverse impacts with any remaining impacts mitigated.

- **Uncertainties are amplified in planning large-scale coastal restoration and hurricane risk reduction systems.** The team has attempted to capture some of the uncertainties associated with relative sea level rise and land use/population growth through the use of scenarios. While there are certainly many additional uncertainties associated with the different types of risk reduction approaches, the level of design across all measures and alternatives at this time is such that clear distinctions between types of approaches and alternatives would be difficult. To a large extent uncertainty with water levels has been addressed as part of the development of the storm surge and hydrodynamic data and extrapolated to the performance metrics; however, there are always additional uncertainties that cannot be quantified. Adaptive management can be used to resolve ecosystem, engineering, policy, socio-economic issues and interactions, and other processes by reducing some of the uncertainties over time.

- **Changes in social, political, economic, engineering, and environmental conditions over the next decades will require an adaptive management framework to guide program and project management.** Adaptive management incorporates new information and technology into new and existing projects as it becomes available and assimilates lessons learned as new projects are developed. An adaptive management framework will be centered on the understanding of overarching protection and restoration system goals as well as the actions and capabilities of all parties involved in plan development. This communication and shared responsibility will leverage all currently existing missions and authorities. Since adaptive management requires continuing evaluation and introduction of the latest science, investment in science and technology is needed.

Section 20. Conclusions and Recommendations

As revealed by the hurricanes of 2005, South Louisiana is highly vulnerable to catastrophic flooding from large hurricanes. In response to those devastating events, Congress directed the USACE to conduct a comprehensive “Category 5” hurricane risk reduction analysis and design in close coordination with the State of Louisiana. In collaboration with the State and many others, the USACE developed and analyzed a full range of alternatives, which are based on a number of structural, nonstructural, and coastal restoration measures, to reduce storm surge risk in South Louisiana.

The technical analysis in this report has provided a clearer picture of the probability of large, storm related surge events that will significantly impact the population, property, and national and regional economy. The LACPR effort quantified that probability by using supercomputers to simulate a spectrum of hurricanes that could strike the Louisiana coast. Scientists have concluded that the two primary parameters for estimation of maximum storm surges along the coast are storm intensity (related to the Saffir-Simpson scale) and storm size (not related to the Saffir-Simpson). As a representation of “Category 5” risk reduction, this technical report presents alternatives at the 100-year, 400-year, and 1000-year design levels. The 400-year flood event is an approximation of Hurricane Katrina.

The manner of attaining risk reduction, as well as the level attainable, is influenced by the range of considerations and tradeoffs presented in this technical report. Historically, the most significant consideration has been the relative potential return on investment, or benefit versus cost, provided by any alternative action taken to reduce risk. Hurricanes Katrina and Rita clearly highlighted that this type of investment decision does not necessarily result in a full understanding of the level of risk exposure. The information presented in this technical report has been developed and presented to enable consideration of decisions without the emphasis on economic outputs but with regard to the cost and tolerance for potential residual or remaining risks. Although property damages can be reduced through various risk reduction measures, evacuation is the only effective means to substantially reduce loss of life related to hurricane events.

A stakeholder-engaged, risk-informed approach is highly desirable in considering options for the reduction of storm damage risks. The broad and inclusive consideration of potential risks, costs, and tradeoffs in other performance attributes is significant to the ultimate decision. Therefore, a Risk-Informed Decision Framework serves as the overarching approach for evaluating, comparing, and identifying the final array of alternative plans. This framework serves two functions: first, to inform affected stakeholders and decision makers of the magnitude of risks related to hurricane storm surge in South Louisiana, and second, to enable stakeholders and decision makers to clearly understand the tradeoffs that would be required to reduce those risks.

An important input into the LACPR Risk-Informed Decision Framework was the use of a Multi Criteria Decision Analysis (MCDA) tool, which facilitated the incorporation of stakeholder values into the decision-making process. The process of developing the stakeholder-based MCDA tool will continue to provide valuable understanding of broader stakeholder interests and values for plan performance; however, it will require additional feedback to and engagement with stakeholders to fully develop reliable plan preference information and be effective in communicating risks.

A broad range of viable options is available for the reduction of risk from large or "Category 5" surge events. The comparison of alternatives through the Risk-Informed Decision Framework resulted in a final array consisting of five or six plans in each of the five planning units. Over half of those plans would achieve some degree of "Category 5" risk reduction by providing significant surge impact reduction for a 400-year frequency storm event or greater; however, in some cases, the level of risk reduction varies throughout the planning unit. The final array consists primarily of nonstructural and comprehensive (structural and nonstructural) alternatives. The balance of the final array consists of two structural alternatives and a single stand alone coastal restoration alternative.

The restoration and maintenance of the coastal landscape are important considerations in a comprehensive system for risk reduction. The extensive effort represented by simply maintaining the Louisiana coast in its current state raises questions regarding long-term sustainability of this landscape. Robust hydromodeling enabled the analysis of the performance and contribution of the coastal landscape in limiting storm surges. Critical features within the coastal landscape (e.g. wetlands, land bridges, highways, etc.) that have a measureable influence on surges have been identified across the entire Louisiana coast. This indicates that restoration and maintenance of specific coastal landscape features, as opposed to the coastal landscape as a whole, could significantly increase the reliability and sustainability of comprehensive risk reduction systems as well as existing development. Additional detailed modeling and evaluation is needed to further define the most efficient and sustainable actions to enhance risk reduction.

Nonstructural measures, such as raising structures in place, appear to be viable, efficient, and effective. Cost effectiveness and potential to reduce risk make the implementation of nonstructural measures, along with structural and costal restoration measures, a logical next step toward creating sustainable and resilient communities across the extent of South Louisiana. However, since a simplifying assumption of 100 percent participation was used for the LACPR analysis, further evaluation and collaboration with stakeholders will be needed to develop realistic, implementable plans.

Plans in the final array have the potential to reduce damages by approximately 15 to 85 percent on average across the range of storm events. The theoretical coastwide property damages (based on no further action to reduce risk) range from $77 billion for a 100-year event to $219 billion for a 1000-year event. The total first costs of the final array plans range from approximately $2 billion for a 100-year nonstructural plan in Planning Unit 4 to $69 billion for a 1000-year nonstructural plan in Planning Unit 1. Total first costs for potential coastwide plans (consisting of an alternative from each planning unit) range from approximately $59 billion for the combination of least costly alternatives in each planning unit to approximately $139 billion for the combination of most costly alternatives in each planning unit.

Even for the best performing plans presented in the final array, substantial residual risk remains for the most extreme surge events. In evaluating the performance of alternatives across a wide range of surge events an assumption of continuous resilience has been employed. In other words features designed based on a more frequent event are exceeded but would not fail for less frequent, larger events. This assumption was used to evaluate initial alternatives and would need to be further evaluated in future analyses. All structural measures are capable of providing significant risk reduction, particularly with increasing design levels. However, evaluation results have indicated that some 100-year level structural alignments could potentially provide significant risk reduction for the 400-year to 1000-year surge events if those features remains intact for these higher level events. The technical evaluation has indicated that levee alignments that allow some distance between the levee and the development footprint produce greater, and often significant residual protection above the indicated design level. However, the assumption of continuous resilience, the design requirements to support such an assumption, and the specific potential for system failure, should be investigated in detail at the planning unit scale.

Large uncertainties surround any large-scale, long-term plans for coastal protection and restoration in South Louisiana. Although this technical report considers some of these uncertainties by varying relative sea level rise rates, economic growth, and population trends across future scenarios, critical issues surrounded by large uncertainties, such as climate change, future hurricane patterns, land loss, sediment sources, and funding remain. The documentation of risk and uncertainty allows stakeholders and decision makers to appreciate the tradeoffs inherent in decisions for action. The extensive technical evaluation and diverse comparison of plan performance presented in this technical report provides a basis for making risk-informed decisions.

Implementation Options

The final array of alternative plans and implementation options presented in this technical report provide a basis for continued development of an approach for addressing the comprehensive reduction of risks associated with large storm surge events. The range of performance and tradeoffs represented in these alternatives also present initial choices that both stakeholders and decision makers will need to make. Resolving tradeoffs begins at the stakeholder and local sponsor level.

While the LACPR technical report strives to be consistent with the Louisiana master plan for comprehensive protection and restoration, the State's plan was completed without the benefit of complete performance evaluation of the plans and their tradeoffs. Since the tradeoffs have not been vetted through the stakeholders and our State partners, it is premature to definitively determine which plans or components are more desirable for either continued development or implementation.

Each major type of measure, such as nonstructural, or any combination of measures can provide some level of risk reduction. Implementation time and resultant effect are also tradeoff considerations. The State of Louisiana working with the public, stakeholders, and agencies should consider options for implementation as well as the final array of alternatives. The following implementation options should be considered in each planning unit:

1. Execute through a comprehensive basin plan
2. Focus on structural features
3. Focus on coastal features
4. Focus on nonstructural actions
5. Develop hazard mitigation efforts

These options reflect the tradeoffs regarding an implementation approach. Option 1 is a comprehensive effort that would investigate alternatives that leverage all possible combinations of measures (nonstructural, structural, coastal, and hazard mitigation) for the entire basin. Other options could focus on individual measures or combinations of measures. Each option would require utilization of different authorities.

The USACE in partnership with the State of Louisiana is prepared to continue refinement of the plans and decision process. Steps have been taken during this technical effort to provide the foundation for refining both evaluations and the continued dialog between the Federal and State partners and stakeholders.

Authorities for Implementation

Numerous project and study authorities exist throughout the coastal area as identified in the following subsections as well as Attachment 2. In instances where risk reduction features and existing authorities coincide, further analyses through the process of Post Authorization Change reports may be possible. The decision of whether a new legislative authorization is needed, however, depends on a case-by-case examination of the original authority and the proposed change, as well as approval by the appropriate decision maker. In some areas of coastal Louisiana, continued development of a comprehensive risk reduction system by the USACE, if desired, will require new authority. In addition, policy waivers may be needed in cases where current policy procedures requiring a traditional economic analysis would make it difficult to economically justify the levels of risk reduction presented in this report. Ultimately, the scale and duration associated with effective implementation and maintenance of a comprehensive system for risk reduction will require an adaptive management approach.

The Louisiana Coastal Area (LCA) ecosystem restoration authority contained in the Water Resource Development Act (WRDA) of 2007 provides for the initiation of coastal restoration efforts. WRDA 2007 also provides study authority for a Comprehensive Plan to be consistent with both the LACPR effort and the protection and restoration master plan mandated by State statute. These authorities provide opportunities for the continuing development of coastal restoration measures, as well as refining the analysis and improving the understanding of strategic coastal landscape contributions to risk reduction.

Nonstructural measures are also clearly important based on the analysis in the technical report. A programmatic framework for the potential implementation of nonstructural measures, however, overlaps the missions of several Federal and state agencies and would benefit from further development of coordinated guidelines.

Planning Unit 1

Coastal features are an important consideration for risk reduction in Planning Unit 1. The key coastal restoration authorities are the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA program) and Title VII of WRDA 2007 (Louisiana Coastal Area). If the decision is made to pursue a structural and/or nonstructural approach, the following project and study authorities may be available to investigate and potentially implement elements of the final array:

- Lake Pontchartrain and Vicinity (project)
- New Orleans to Venice (project)
- Pearl River Basin, St. Tammany Parish (project)
- Southeast Louisiana Urban Flood Control (projects and studies)
- West Shore Lake Pontchartrain (study)

Planning Unit 2

Similar to Planning Unit 1, coastal features are an important consideration for risk reduction in Planning Unit 2. The same coastal restoration authorities apply, i.e. the CWPPRA program and Title VII of WRDA 2007 (Louisiana Coastal Area). The ongoing Donaldsonville to the Gulf Feasibility Study is investigating structural, nonstructural, and environmental mitigation measures as part of a comprehensive basin-wide study. In addition to the Donaldsonville to the Gulf study, the following project authorities could potentially be expanded to incorporate additional or modified structural or nonstructural measures:

- West Bank and Vicinity
- New Orleans to Venice
- Larose to Golden Meadow
- Grand Isle and Vicinity

Planning Unit 3a

In Planning Unit 3a the contribution of coastal features to risk reduction and reliability needs additional refinement to investigate the merits of strategic placement of coastal measures. This refinement can be accomplished through the Section 7002 Comprehensive Plan authority in WRDA 2007.

In this planning unit, decisions must be made regarding stand alone nonstructural versus structural/nonstructural approaches. Both of the comprehensive plans in the final array are variations of the Morganza to the Gulf of Mexico project authorized in WRDA 2007. The USACE is currently pursuing a Post Authorization Change under the Morganza to the Gulf authority. This study will evaluate both structural and nonstructural measures for the Morganza project area.

In addition to the Morganza to the Gulf authority, the following project and study authorities may be available to investigate and potentially implement structural and nonstructural elements of the final array:

- Larose to Golden Meadow (project)
- Morgan City and Vicinity (project)
- Atchafalaya Basin (project)
- Lower Atchafalaya Basin (study)

Planning Unit 3b

In Planning Unit 3b the contribution of coastal features to risk reduction and reliability needs additional refinement to investigate the merits of strategic placement of coastal measures. This refinement can be accomplished through the Section 7002 Comprehensive Plan authority in WRDA 2007.

In this planning unit, decisions must be made regarding stand alone nonstructural versus structural/nonstructural approaches. In Planning Unit 3b the final array contains a suite of three comprehensive plans that have no common structural features; therefore, decisions must also be made regarding the extent of the structural alignment, e.g. continuous levees versus ring levees.

A portion of Planning Unit 3b, from approximately Abbeville westward, is included in the Southwest Coastal Louisiana Feasibility Study authority; however, there is a lack of authority for study or implementation in most of this planning unit. Therefore, new authority would be needed to complete additional investigation or implementation of the LACPR structural and/or nonstructural risk reduction plans in Planning Unit 3b.

Planning Unit 4

In Planning Unit 4 the contribution of coastal features to risk reduction and reliability needs additional refinement to investigate the merits of strategic placement of coastal measures. This refinement can be accomplished through the Section 7002 Comprehensive Plan authority in WRDA 2007 and/or the Southwest Coastal Louisiana Feasibility Study.

Nonstructural measures play a dominant role in all of the plans including the comprehensive ring levee plans. The limited extent of the ring levees results in the nonstructural component of the comprehensive plans being comparable to the corresponding stand alone nonstructural plan. The Southwest Coastal Louisiana Feasibility Study authority provides the ability to further study these alternatives in addition to others, such as a 12-foot barrier along the GIWW.

Path Forward

The information contained within the Louisiana Coastal Protection and Restoration (LACPR) Final Technical Report dated June 2009 has been reviewed by technical experts both within the U.S. Army Corps of Engineers (USACE) and independent to the USACE. In addition to their review of the February 2008 version of the technical report, an independent external peer review panel from the National Academy of Sciences is conducting a second review based on the March 2009 version of the technical report. Prior to submission of the LACPR Final Technical Report to Congress, the report will also undergo review by National policy reviewers, other Federal agencies, the State of Louisiana, non-governmental organizations, and the public. Comments and responses will be documented in a separate report that will be posted to the LACPR website, www.lacpr.usace.army.mil, and provided to Congress as a supplement to the technical report. The Chief of Engineers will also issue a formal response to the National Academy of Sciences after the review panel has issued its final report on LACPR.

Using the information in this technical report, the USACE will continue to coordinate with the State of Louisiana and further develop options and priorities in each planning unit. The USACE and the State will then jointly coordinate those options and priorities with other Federal agencies, local entities, non-governmental organizations, and the public. The USACE will implement potential recommended projects in accordance with current policy and in the most expeditious manner available by maximizing the use of available construction and study authorities (i.e., modifications of on-going projects/studies, post-authorization change reports, or new authorizations).

The findings and conclusions contained herein reflect the information available at this time. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the findings and conclusions may be modified before they are transmitted to Congress as technical information. However, prior to transmittal to Congress, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

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Alvin B. Lee
Colonel, U.S. Army
District Engineer – New Orleans

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List of Acronyms

ADCIRC	ADvanced CIRCulation (wind and wave modeling system)
AP&M	Adaptive Planning and Management (team)
CLEAR	Coastal Louisiana Ecosystem Assessment and Restoration (model)
CP	Coastwide Plan
CPRA	Coastal Protection and Restoration Authority (State of Louisiana)
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
GOHSEP	Governor's Office of Homeland Security and Emergency Preparedness
HSDRRS	Hurricane and Storm Damage Risk Reduction System
IPAWS	Integrated Public Alert and Warning System
IPET	Interagency Performance Evaluation Task force
JPM-OS	Joint Probability Method-Optimum Sampling
LACPR	Louisiana Coastal Protection and Restoration
LCA	Louisiana Coastal Area (*Ecosystem Restoration Study*, 2004)
MCDA	Multi-Criteria Decision Analysis
MRGO	Mississippi River-Gulf Outlet
MsCIP	Mississippi Coastal Improvements Program
NAVD 88	North American Vertical Datum 1988
NED	National Economic Development
NER	National Ecosystem Restoration
PU	Planning Unit
RIDF	Risk-Informed Decision Framework
S&T	Science and Technology (program)
STWAVE	STeady State spectral WAVE (model)
USACE	U.S. Army Corps of Engineers
WAM	WAve prediction Model
WRDA	Water Resources Development Act

Glossary

100-year Design: A hurricane risk reduction design (e.g. a levee design) based on a flood elevation that statistically has a 1% chance of being equaled or exceeded in any given year. Similarly, a 50-year design is based on a flood elevation that has a 2% chance of being equaled or exceed in any given year (divide 1 by the return period and multiply by 100 to get the percent chance).

Adaptive Management: A "learning by doing" management approach which promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (National Academy of Sciences 2004).

ADCIRC: The ADvanced CIRCulation hydrodynamic model simulates water levels and is used to calculate the design still water level in storm events.

Alternative: For LACPR, an alternative incorporates one or more structural, nonstructural, and/or coastal restoration measures for risk reduction. Alternatives emerge from the plan formulation process.

Appropriation: The provision of funds, through an annual appropriations act or a permanent law, for federal agencies to make payments out of the Treasury for specified purposes. The formal federal spending process consists of two sequential steps: congressional authorization and then appropriation. Typically set forth in the annual Energy and Water Development Appropriations Acts (Woolley, 2008).

Authorization: A statutory provision that obligates funding for a program or agency. An authorization may be effective for one year, a fixed number of years, or an indefinite period. An authorization may be for a definite amount of money or for "such sums as may be necessary." The formal federal spending process consists of two sequential steps: congressional authorization and then appropriation. Authorizations are established by Congress in Public Law (Woolley, 2008).

Barrier Islands: A linear landform created by the interaction between water and sediments within or extending into a body of water. The barrier islands along the Louisiana coast are a result of sediments deposited by the Mississippi River during its wandering over the past several thousand years. Examples of this phenomenon are the Isles Dernieres chain west of Terrebonne Bay and the Breton Island chain east of St. Bernard Parish.

Barrier-Weir: A structural measure similar to a continuous levee that can withstand overtopping. In LACPR alternatives, barrier-weirs serve as an outer line of defense in a multiple lines of defense strategy. Barrier-weirs are designed to reduce storm surge, blocking the surge for lower surge heights but eventually allowing reduced overtopping at higher surge heights.

Base Condition: The base condition is the no action condition assuming none of the LACPR alternatives are implemented. The base condition includes outputs of the hydromodeling analysis, which statistically predict the hurricane threat; an inventory of economic and environmental assets; and descriptions of existing projects designed to reduce risk to those assets.

Base Year: In cases where alternatives have different implementation periods, a common year, or base year, is established. Costs and benefits are compounded or discounted to that base year. For LACPR, the base year is 2025 since it generally represents the end of the implementation period, or initial construction period, for most alternatives considered.

Breach: A rupture, break, or gap in a levee system whose cause has not been determined. See also **Failure Breach** and **Overtopping Breach**.

Category 5 Hurricane: A storm on the Saffir-Simpson Hurricane Scale having winds greater than 155 mph (135 kt or 249 km/hr). Storm surges are generally greater than 18 feet above normal. Only three verified Category 5 Hurricanes have made landfall in the United States since recordkeeping began: The Labor Day Hurricane of 1935 (Florida Keys), Hurricane Camille in 1969 (Mississippi and Louisiana), and Hurricane Andrew in August 1992 (Florida and Louisiana).

Chief's Report: A final recommendation on a civil works project signed by the Chief of Engineers. Congress uses a favorable Chief's report as the basis for authorizing projects (Woolley, 2008).

Chenier: A geologic formation found within the Prairie Marshes of coastal Vermilion and Cameron Parishes of southwest Louisiana that consists of ancient beach lines that, in most cases, parallel the Gulf of Mexico. These intermittent shell ridges are called "cheniers" because of the live oaks that grow on them; the term cheniere is a French term for oak. The ridges developed from sediment that escaped the delta over the past 3,000 years and was transported and deposited along the coast of western Louisiana and periodically eroded as the river shifted courses.

CLEAR Model: The CLEAR model (which stands for "Coastal Louisiana Ecosystem Assessment and Restoration") is a modeling system developed by the Department of Natural Resources' Coastal Restoration Division in collaboration with the Center for Ecology and Environmental Technology at Louisiana State University to link scientific understanding of the following four major features of the Mississippi River Delta: (1) physical process (river and coastal ocean); (2) geomorphic features; (3) ecological succession (or state change); (4) water quality conditions. For LACPR, the CLEAR model was used to predict coastal wetland land loss by the year 2060.

Comprehensive: In general, comprehensive means "large in scope or content." The term comprehensive has been used for LACPR in the following three ways:

> **(1) Comprehensive Alternatives** are plans that contain at least two of the three types of **risk reduction measures**—nonstructural, structural, and coastal restoration—presenting a **multiple lines of defense strategy** and providing comparable levels of risk reduction to all economic assets in the surge impacted areas.
>
> **(2) "*Comprehensive Category 5 Protection*" -** This terminology was used in the Congressional authority.
>
> **(3) "*Comprehensive Hurricane Protection Analysis and Design*" -** This terminology was used in the Congressional authority. The LACPR effort addresses this requirement by presenting a full range of structural, nonstructural, and coastal restoration hurricane risk reduction measures across South Louisiana.

Construction Costs: Construction costs include the cost of materials and construction of physical structures as well as construction management costs. Construction costs also include costs associated with maintaining the risk reduction levels of structural measures into the future associated with relative sea level rise and/or degradation of the coast, i.e. future levee lifts. See also **First Costs** and **Life Cycle Costs**.

Critical Landscape Features: Features of the coastal landscape that tend to have significant effects on surge. The features identified through modeling range from critical wetland segments to natural ridges to manmade embankments.

Depth-Damage Relationships: Depth-damage relationships are used to indicate the percentage of the structural and content value that was damaged at each depth of flooding for residential and non-residential properties. Damage percentages were determined for each one-half foot increment from one foot below first-floor elevation to two feet above first floor, and for each 1-foot increment from 2 feet to 15 feet above first-floor elevation.

Diversion: A turning aside or alteration of the course or flow of water. In coastal restoration, this action usually consists of channeling water through a canal, pipe, or conduit to introduce water and water-borne resources into a receiving area. “Steady state” diversions are diversions that are operated on a relatively consistent basis. “Pulsed” diversions are diversions that are operated with periodic unrestricted flows (once every four or five years), followed by four or five consecutive low-discharge years.

Failure Breach: A breach in a levee system for which a cause of failure is both known and occurred without overtopping. Usually requires an investigation to determine cause.

First Costs: First costs include engineering and design, facility relocations, real estate, mitigation, and construction costs. See also **Construction Costs** and **Life Cycle Costs**.

Frequency-Damage Relationships: The potential flood damage associated with each of the five frequency storm events (10-, 100-, 400, 1000, and 2000-year events) for each of project alternatives. The frequency-damage relationships were calculated for three levels of confidence (10 percent, 50 percent, and 90 percent) to account for hydrologic uncertainty.

Joint Probability Method: A statistical tool involving an assumption of independence of storm parameters so that the combined probability of a particular hurricane is the product of the probabilities of each of the governing parameters. These parameters include forward speed, storm radius, central pressure depression, and storm position; a dependence on track angle is assumed and accounted for by separation of the storm into directional families.

Levee: An earth embankment, floodwall, or structure whose purpose is flood damage reduction or water conveyance. A continuous levee is generally long and linear; in contrast, a ring levee partially or completely encircles or "rings" a small area.

Life Cycle Costs: Life cycle costs are the total cost of implementing an alternative plan, which includes first costs plus operation and maintenance, repair, replacement and rehabilitation costs. See also **Construction Costs** and **First Costs.**

Measure: A component of alternative plans for risk reduction. Categories of risk reduction measures include structural, nonstructural and coastal restoration. See also **Risk Reduction Measure.**

Metric: A parameter for measuring the performance of objectives.

Mississippi River and Tributaries Project Design Flood: The Mississippi River and Tributaries Project Design Flood is a worst-case scenario derived for each location within the Mississippi River Basin, calculating water volumes for the purposes of designing risk-reduction measures.

Multi-Criteria Decision Analysis: Multi-criteria decision analysis is a discipline aimed at supporting decision-makers who are faced with making numerous and conflicting evaluations, highlighting these conflicts and deriving a way to come to a compromise in a transparent process.

Multiple Lines of Defense: The Multiple Lines of Defense concept (Lopez 2006) integrates the following natural and engineered risk reduction elements in coastal Louisiana: (1) the Gulf of Mexico shelf, (2) barrier islands, (3) bays or sounds, (4) marsh landbridges, (5) ridges, (6) highways, (7) flood gates, (8) levees, (9) pump stations, (10) elevated buildings, and (11) evacuation routes.

No Action Alternative: The USACE is required to consider the option of “no action” as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). With the no action plan, which is synonymous with the without project condition, it is assumed that no project would be implemented by the Federal Government or by local interests to achieve the planning objectives. The no action plan forms the basis, which all other alternative plans are measured against.

Overtopping: Water levels that exceed the crest elevation of a levee and flow into protected areas.

Overtopping Breach: A breach whose cause is known to be a result of overtopping (system exceeded).

Period of Analysis: The time horizon for which project benefits, deferred construction costs, and operation, maintenance, repair, rehabilitation, and replacement costs are analyzed. For LACPR, the period of analysis is from the base year 2025 to 2075. See also **Base Year**.

Plan or Alternative Plan: In general, a plan is any detailed scheme, program, or method worked out beforehand to accomplish an objective. For LACPR, an alternative plan incorporates one or more structural, nonstructural, and/or coastal restoration measures for risk reduction. Alternative plans emerge from the plan formulation process.

Post Authorization Change (PAC): Modification to an authorized project, at the discretion of the Chief of Engineers, for engineering or construction reasons to serve the project purposes authorized by Congress (Woolley, 2008).

Relative Sea Level Rise: In coastal Louisiana, relative sea level rise is often segmented into a global increase in water mass (global **sea level rise**), a rise in local water level due to density changes in the water, and a drop in local land elevation (**subsidence**).

Residual Risk: The flood risk that remains after a hurricane surge risk reduction project has been implemented.

Return Period or Interval: Average period of time between occurrences of a given hurricane or tropical storm event or occurrences of a given storm surge, e.g. the 100-year storm surge event.

Ridges: Geographical features along the Louisiana coast where wind and wave action has built linear barriers of sand and soil parallel to the coastline. These features are found most often in the **Chenier** Plains of Southwest Louisiana.

Risk: The probability for an adverse outcome. Risk = (Frequency of an event) x (Probability of occurrence) x (Consequences).

Risk-Informed Decision Framework: A new decision framework that augments the six-step USACE planning process by incorporating specific techniques and methods from risk analysis and multi-criteria decision analysis. The approaches incorporated within the risk informed decision framework enhance communication and collaboration among decision-makers and stakeholders by providing structure and mechanisms for capturing information about attitudes and values of decision-makers and stakeholders that are essential to defining objectives, metrics, and weights for metrics that reflect priorities.

Risk Reduction Measure: A component of alternatives for risk reduction. Categories of risk reduction measures include structural, nonstructural and coastal restoration. See also **Measure.**

Saffir-Simpson Hurricane Scale: The Saffir-Simpson Hurricane Scale is a 1-5 rating based on a hurricane's intensity at a given point in time. This scale is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline in the landfall region.

Sea Level Rise: Sea level rise is an increase in sea level. Multiple complex factors may influence this change.

Stage-Damage Relationships: A water elevation NAVD88 (2004.65 epoch) was calculated for each census block. Flood damages were calculated at 1-foot increments from the beginning damage elevation to an elevation where damages for all the structural categories have reached a maximum amount of damage.

Stage-Frequency Data: Stage-frequency data were derived from the hydromodeling results for each planning subunit under existing and future without project and with project conditions. Stages were provided for five frequency storms (10-, 100-, 400-, 1000-, and 2000-year events). The stage-frequency data were combined with the **stage-damage relationships** to develop **frequency-damage relationships** for each planning subunit. The frequency-damage relationships are then used to derive the expected annual damages.

Standard Project Hurricane: A hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region, excluding extremely rare combinations. It is further assumed that the standard project hurricane would approach a given project site from such direction, and at such rate of movement, to produce the highest hurricane surge hydrograph, considering pertinent hydraulic characteristics of the area. Based on this concept and on extensive meteorological studies and probability analyses, a tabulation of “Standard Project Hurricane Index Characteristics” was mutually agreed upon by representatives of the U.S. Weather Service and the USACE (NOAA 1979).

Still Water Level: The elevation of the water surface without waves. See **Water Level**.

Subsidence: Subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea level.

Sustain: To support and provide with nourishment to keep in existence; maintain.

Sustainability: The ability of a coastal landscape feature to maintain its general location, spatial configuration, and habitat functions over time. **Maximum sustainability** is the maximum amount of measurable sustainable wetland habitat, within a given area, based on a set of proposed restoration alternatives for that same area.

Systematic: Of or pertaining to a system, e.g. a hurricane risk reduction system; methodical in procedure or plan, e.g. systematic approach; formed with regular connection and adaptation or subordination of parts to each other, and to the design of the whole (based on Merriam-Webster and Webster’s Revised Unabridged Dictionary).

Uncertainty: Lack of confidence in a risk prediction.

Velocity Zones or V zones: Areas designated by FEMA closest to the shoreline subject to wave action, high-velocity flows, and erosion from a 100-year event.

Water Level: The height of the water surface measured above a datum.

With Project Conditions: The with project conditions are the projected changes in future conditions as the result of implementing one or more LACPR alternatives.

Without Project Conditions: The without project conditions are the projected changes in future conditions resulting from no action, or not implementing any of the LACPR alternatives.

Attachment 1 - Alternative Descriptions and Codes

This attachment describes the 111 alternatives that were evaluated and then narrowed down into a final array of 27 alternatives. The only modification that was made to the final set of alternatives is that the coastal restoration components were removed from the plans in Planning Units 3a, 3b, and 4 since they were not found to contribute to risk reduction. Maps showing each individual alternative can be found in the *Evaluation Results Appendix*.

Primary Code	Primary Code Description	Planning Unit	Variation Code	Variation Code Description
R#	Coastal restoration alternative	**All Planning Units**	-100-	100-year design level
NS-	Nonstructural alternative		-400-	400-year design level
C-	Comprehensive alternative		-1000-	1000-year design level
LP-	Lake Pontchartrain Surge Reduction Plan (includes barrier-weir with surge gates across The Rigolets and Chef Menteur Pass)	**Planning Unit 1** (e.g. PU1-LP-a-100-1)	-a-	Golden Triangle alignment at the confluence of the GIWW and MRGO.
			-b-	Alignment at the edge of the Golden Triangle and Lake Bornge
HL-	High Level Plan (raise existing levees)		-1	Primary alignment-All PU1 primary alternatives include the Lake Pontchartrain and Vicinity levees and upper Plaquemines levees. The primary alignments for 'LP' also include a barrier-weir across the passes of Lake Pontchartrain with a tieback to high ground east of Slidell.
			-2	Primary alignment (-1) plus Northshore and Westshore levees.
			-3	Primary alignment (-1) plus Slidell and Westshore levees.
WBI-	West Bank Interior Plan.	**Planning Unit 2** (e.g. PU2-WBI-100-1)	-1	Primary alignment -All PU2 primary alignments include West Bank and Vicinity levees with new sector gate and Larose to Golden Meadow levees. Primary alignments for 'R' and 'G' also include Lafitte ring levees.
R-	Ridge Alignment Plan (parallel to ridges along the West Bank of the Mississippi River and Bayou Lafourche.		-2	Primary alignment (-1) plus Boutte levee.
G-	GIWW Alignment Plan		-3	Primary alignment (-1) plus Boutte and Des Allemands levee.
			-4	Primary alignment (-1) plus Boutte, Des Allemands, and Bayou Lafourche levees.
M-	Morganza levee alignment	**Planning Unit 3a** (e.g. PU3a-M-100-2)	-1	Morganza alignment with tieback to high ground west of Morgan City
G-	GIWW Alignment Plan with Morganza Levee at 100-year design		-2	Morganza alignment with tieback to high ground south of Thibodaux and ring levee around Morgan City
G-	GIWW levee alignment	**Planning Unit 3b** (e.g. PU3b-G-100-1)	-1	Primary alignment (no variations to primary alignments in PU3b)
F-	Franklin to Abbeville alignment (inland of the GIWW)			
RL-	Ring levee alignment			
G-	GIWW levee alignment	**Planning Unit 4** (e.g. PU4-RL-400-1)	-1	For the 'G' alignments, the primary alignment follows the GIWW across the planning unit boundaries.
RL-	Ring levee alignment		-2	GIWW alignment with tieback to high ground near Kaplan.
			-3	GIWW alignment with the levee set at a height of 12 feet.

Planning Unit 1 Alternative Descriptions

Note: All nonstructural, structural, and comprehensive alternatives in Planning Unit 1 include a coastal restoration component (see description of R2 below).

Alternative	Alternative Description
0	No action (without project) alternative.
R1, R2, and R3	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions. R1 proposes steady state diversions while R2 proposes pulsed diversions. R3 is as proposed in the State Master Plan.
NS-100	Implement comprehensive 100-year nonstructural measures.
NS-400	Implement comprehensive 400-year nonstructural measures.
NS-1000	Implement comprehensive 1000-year nonstructural measures.
LP-a-100-1	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Plaquemines levees to 100-year level of risk reduction.
LP-a-100-2	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Plaquemines levees and construct new levees around Laplace and across the Northshore to the 100-year level of risk reduction.
LP-a-100-3	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Plaquemines levees and construct new levees around Laplace and Slidell to the 100-year level of risk reduction.
LP-b-400-1	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise Lake Pontchartrain and Vicinity and upper Plaquemines levees to 400-year level of risk reduction.
LP-b-400-3	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise Lake Pontchartrain and Vicinity and upper Plaquemines levees and construct new levees around Laplace and Slidell to the 400-year level of risk reduction.
LP-b-1000-1	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise Lake Pontchartrain and Vicinity and upper Plaquemines levees to 1000-year level of risk reduction.
LP-b-1000-2	Construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise Lake Pontchartrain and Vicinity and upper Plaquemines levees and construct new levees around Laplace and across the Northshore to the 1000-year level of risk reduction.
HL-a-100-3	Construct high level plan providing 100-year design level of risk reduction to Laplace, upper Plaquemines, and Slidell.
HL-a-100-2	Construct high level plan providing 100-year design level of risk reduction to Northshore of Lake Pontchartrain, upper Plaquemines, and Laplace.
HL-b-400-2	Construct high level plan providing 400-year design level of risk reduction to the Northshore and Southshore of Lake Pontchartrain, upper Plaquemines, Laplace and Slidell.
HL-b-400-3	Construct high level plan providing 400-year design level of risk reduction to Southshore of Lake Pontchartrain, upper Plaquemines, Laplace and Slidell.
C-(Structural code)	Comprehensive alternatives are noted by a “C-“ in front of the structural alternative code. Structural alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.

Planning Unit 2 Alternative Descriptions
Note: All nonstructural, structural, and comprehensive alternatives in Planning Unit 2 include a coastal restoration component (see description of R2 below).

Alternative	Alternative Description
0	No action (without project) alternative.
R1, R2, and R3	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions. R1 proposes steady state diversions while R2 proposes pulsed diversions. R3 is as proposed in the State Master Plan.
NS-100	Implement comprehensive 100-year nonstructural measures.
NS-400	Implement comprehensive 400-year nonstructural measures.
NS-1000	Implement comprehensive 1000-year nonstructural measures.
WBI-100-1	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank.
WBI-400-1	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Raise West Bank and Vicinity and Larose to Golden Meadow levees to 400-year level of risk reduction.
R-100-2	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and construct/raise Lafitte ring levees to 100-year level of risk reduction.
R-400-2	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and raise those levees as well as Larose to Golden Meadow levees to 400-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
R-100-3	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and construct/raise Lafitte and Des Allemands ring levees to 100-year level of risk reduction.
R-400-3	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and raise those levees as well as Des Allemands and Larose to Golden Meadow levees to 400-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
R-100-4	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Construct/raise Lafitte and Des Allemands ring levees to 100-year level of risk reduction and build new levees around Boutte and up the east side of Bayou Lafourche from Larose to Highway 90 at the 100-year level of risk reduction.
R-400-4	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte; extend levees from Larose up Bayou Lafourche to Highway 90; and raise Des Allemands ring levees to 400-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
R-1000-4	Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte; extend levees from Larose up Bayou Lafourche to Highway 90; and raise Des Allemands ring levees to 1000-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
G-100-1	Similar structural features as PU2-WBI-100-1 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
G-100-4	Similar structural features as PU2-R-100-4 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
G-400-4	Similar structural features as PU2-R-400-4 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.

Alternative	Alternative Description
G-1000-4	Similar structural features as PU2-R-1000-4 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
C-(structural code)	Comprehensive alternatives are noted by a “C-“ in front of the structural alternative code. Structural alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.

Planning Unit 3a Alternative Descriptions

Note: All nonstructural, structural, and comprehensive alternatives in Planning Unit 3a included a coastal restoration component (see description of R1 below) for evaluation; however, the coastal component in this planning unit was not found to contribute to risk reduction so it was removed from the plans in the final array.

Alternative	Alternative Description
0	No action (without project) alternative.
R1	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions from the Mississippi River.
NS-100	Implement comprehensive 100-year nonstructural measures.
NS-400	Implement comprehensive 400-year nonstructural measures.
NS-1000	Implement comprehensive 1000-year nonstructural measures.
M-100-1	Construct Morganza to the Gulf* levee with extension tying into high ground west of Morgan City at 100-year design level.
M-100-2	Construct Morganza to the Gulf* levee with tieback to high ground south of Thibodaux and ring levee around Morgan City at 100-year design level.
G-400-2	Construct Morganza to the Gulf* levee at the 100-year design level with a second levee along the GIWW with tieback to high ground south of Thibodaux and ring levee around Morgan City providing a 400-year level of risk reduction for Houma and Morgan City.
G-1000-2	Construct Morganza to the Gulf* levee at the 100-year design level and a second levee along the GIWW with tieback to high ground south of Thibodaux and ring levee around Morgan City providing a 1000-year level of risk reduction for Houma and Morgan City.
C-(structural code)	Comprehensive alternatives are noted by a “C-“ in front of the structural alternative code. Structural alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.

*Although the Water Resource Development Act 2007 recently authorized the Morganza to the Gulf project, it is not included in the without project conditions since it was not authorized at the time the analysis was conducted.

Planning Unit 3b Alternative Descriptions

Note: All nonstructural, structural, and comprehensive alternatives in Planning Unit 3b included a coastal restoration component (see description of R1 below) for evaluation; however, the coastal component in this planning unit was not found to contribute to risk reduction so it was removed from the plans in the final array.

Alternative	Alternative Description
0	No action (without project) alternative.
R1	Sustain coastal landscape through restoration including shoreline protection, marsh creation, etc.
NS-100	Implement comprehensive 100-year, 400-year or 1000-year nonstructural measures.
NS-400	Implement comprehensive 400-year nonstructural measures.
NS-1000	Implement comprehensive 1000-year nonstructural measures.
G-100-1	Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the GIWW west to the boundary of Planning Unit 4 at the 100-year design level.
F-100-1	Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 100-year design level.
F-400-1	Raise ring levee around Patterson/Berwick to 400-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 400-year design level.
F-1000-1	Raise ring levee around Patterson/Berwick to 1000-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 1000-year design level.
RL-100-1	Raise ring levee around Patterson/Berwick to 100-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 100-year design level.
RL-400-1	Raise ring levee around Patterson/Berwick to 400-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 400-year design level.
C-(structural code)	Comprehensive alternatives are noted by a “C-“ in front of the structural alternative code. Structural alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.

Planning Unit 4 Alternative Descriptions

Note: All nonstructural, structural, and comprehensive alternatives in Planning Unit 4 included a coastal restoration component (see description of R1 below) for evaluation; however, the coastal component in this planning unit was not found to contribute to risk reduction so it was removed from the plans in the final array.

Alternative	Alternative Description
0	No action (without project) alternative.
R1	Sustain coastal landscape through restoration including shoreline protection, marsh creation, etc.
NS-100	Implement comprehensive 100-year nonstructural measures.
NS-400	Implement comprehensive 400-year nonstructural measures.
NS-1000	Implement comprehensive 1000-year nonstructural measures.
G-100-1	Construct a continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land at the 100-year design level. Alignment joins with similar alignment in Planning Unit 3b.
G-100-2	Construct a continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land at the 100-year design level. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.
G-400-3	Construct a continuous 12-foot levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land. Includes small ring levees around parts of Lake Charles, Gueydan, and Kaplan to provide 400-year level of risk reduction. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.
G-1000-3	Construct a 12-foot continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land. Includes small ring levees around parts of Lake Charles, Gueydan, and Kaplan to provide 1000-year level of risk reduction. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.
RL-100-1	Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to the 100-year design level.
RL-400-1	Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to the 400-year design level.
RL-1000-1	Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to 1000-year design level.
C-(structural code)	Comprehensive alternatives are noted by a “C-“ in front of the structural alternative code. Structural alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures.

Attachment 2 – Authorized USACE Projects and Studies

Authorized Projects

Project	Purpose	Authorizing Document	Constraints	Applicability to LACPR Final Array
Planning Unit 1				
Pearl River Basin, St. Tammany Parish, LA	200-year River and Hurricane Flood Protection	FY85 Supplemental Appropriation Act and WRDA 1986. Vicksburg District Report	4.98-mile levee system headwater flood protection from Pearl River above I-10. 11.45-mile levee system headwater and hurricane below I-10.	LP-a-100-1 & C-LP-a-100-1 Structural Parts only
Lake Pontchartrain & Vicinity (LP&V)	Standard Project Hurricane (circa 1969) Risk Reduction	HD 231 89th Chief's Report	Does not address non-structural. Some limitations as to extent of coverage for PU 1. No coastal restoration.	LP-a-100-1 & C-LP-a-100-1 Structural Parts only
Mississippi River Delta at or below new Orleans (New Orleans to Venice)	100-yr (circa 1970) Risk Reduction	HD 550 87th Chief's Report	There will be issues as a result of flood inducements created by other plans.	Upper Plaquemine east bank as part of LP-a-100-1 & C-LP-a-100-1
Flood Control, Mississippi River & Tributaries Mississippi River Levees	Mississippi River & Tributaries Project Design Flood Protection	Flood Control Act 1927 and many subsequent authorizations	Historically used flood control for Mississippi River headwater runoff flood control	Contains authority for Caernarvon and Bonnet Carre diversions.
4th Supplemental Risk Reduction Projects	Reduce storm damage through measures to reverse wetland losses	P.L. 109-234, Title II, Chapter 3	Limited to areas affected by navigation, oil/gas, and other channels and through mod of the Caernarvon Diversion structure or its operations.	Coastal restoration component of final array.
Louisiana Coastal Area (LCA)	Coastal Restoration	WRDA 2007, Title VII, Section 7001 – 7011	Ecosystem restoration only.	Coastal restoration component of final array.
Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA)	Coastal Restoration	P.L. 101-646 enacted November 29, 1990)	Wetlands only coastal restoration	Coastal restoration component of final array.
Southeast Louisiana Urban Flood	Interior drainage 10-yr flood essentially within	FY96 Energy and Water Development	Limited to Orleans, Jefferson and St. Tammany parishes.	Nonstructural plans (reduce interior flooding

Project	Purpose	Authorizing Document	Constraints	Applicability to LACPR Final Array
Control (SELA)	banks	Appropriations Act (PL 104-46, Nov 13, 1995 Reconnaissance Reports; WRDA 1996	USACE Headquarters policy guidance has closed new work in Jefferson and Orleans parishes.	by increasing pump capacity or raising/removing structures from floodplain.)
Planning Unit 2				
West Bank & Vicinity	Standard Project Hurricane (circa 1979) Hurricane Risk Reduction	WRDA 1986 Draft EIS, Chief's Report	None known	NS-400, WBI-100-1, C-WBI-100-1 & C-G-100-1
Grand Isle & Vicinity	50-yr wave damage risk reduction, beach erosion control. Frequency analysis (circa 1969)	HD 132 84th Chief's Report	Project limited to the Island of Grand Isle, LA	Possible consideration for barrier Island and shore line restoration for Coastal features.
Larose to Golden Meadow	100-year (circa 1972) Hurricane Risk Reduction	HD 184 89th Chief's Report	There will be issues as a result of flood inducements created by other plans	Larose to Golden Meadow east levee will require modification for C-G-100-1 PU-2.
Mississippi River Delta at or below new Orleans (New Orleans to Venice)	100-yr (circa 1970) Risk Reduction	HD 550 87th Chief's Report	There will be issues as a result of flood inducements created by other plans.	Plaquemine west bank back levees will need to be raised for C-G-100-1
Flood Control, Mississippi River & Tributaries Mississippi River Levees	Mississippi River & Tributaries Project Design Flood Protection	Flood Control Act 1927 and many subsequent authorizations	Historically used flood control for Mississippi River headwater runoff flood control	Contains authority for Davis Pond diversion.
Louisiana Coastal Area (LCA)	Coastal Restoration	WRDA 2007, Title VII, Section7001 – 7011	Ecosystem restoration only.	Coastal restoration component of final array.

Project	Purpose	Authorizing Document	Constraints	Applicability to LACPR Final Array
Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA)	Coastal Restoration	P.L. 101-646 enacted November 29, 1990)	Wetlands only coastal restoration	Coastal restoration component of final array.
Planning Unit 3a				
Morganza to the Gulf of Mexico	100-year hurricane risk reduction currently being reevaluated using latest JPM-OS frequency analysis	WRDA 2007 Chief's Report	Project currently being revaluated. Issues over design criteria and projected increases in project costs.	C-M-100-1 and C-M-100-2
Larose to Golden Meadow	100-year (circa 1972) Hurricane Risk Reduction	HD 184 89th Chief's Report	There will be issues as a result Morganza to the Gulf flooding inducements	Larose to Golden Meadow west levee is a part of C-M-100-1 and C-M-100-2.
Flood Control, Mississippi River & Tributaries, Atchafalaya Basin, Louisiana	Mississippi River & Tributaries Project Design Flood Protection	Flood Control Act 1927 and numerous subsequent authorizations	Possible tie-in to plans to prevent backwater flooding east of Morgan City	C-M-100-1 & C-M-100-2
Morgan City & Vicinity Franklin & Vicinity Area	Standard Project Hurricane (circa 1966) Risk Reduction.	P.L. 89-298 Chief's Report	No local sponsor for Morgan City & Franklin & Vicinity no authority for nonstructural	Possible application for C-RL-100-1, C-F-100-1 plans
Planning Unit 3b and 4 (no existing project authorities—see study authorities in the following table.)				

Authorized Studies

Study Name	Purpose	Authority	Constraints	Applicability to LACPR Final Array
Planning Unit 1				
West Shore Lake Pontchartrain Study	Hurricane Protection	House Resolution (1971) Senate Resolution (1974)	Ring levee plan did not make the final array of plans in Planning Unit 1	NS-100, NS-400, NS-1000
MRGO Ecosystem Restoration Plan Feasibility Study	Coastal Restoration	WRDA 2007 Section 7013	Ecosystem restoration only.	Coastal restoration component of final array.
Planning Unit 2				
Donaldsonville to the Gulf	Flood control, navigation, wetland conservation and restoration, wildlife habitat, commercial and recreational fishing, prevent salt water intrusion and promote fresh water and sediment diversion, and other purposes	House Resolution (1998)	None known; under study	NS-400, WBI-100-1 (coastal component only), C-WBI-100-1 & C-G-100-1
Planning Unit 3a				
Lower Atchafalaya Basin Reevaluation Study	Flood Protection, Navigation and Environmental Management	P.L. 103-126 Senate Report (1994)	Possible tie-in to plans to prevent backwater flooding east of Morgan City. Has authority for nonstructural measures in Morganza Basin	NS-100, NS-400, NS- 1000, C-M-100-1, C-M-100-2
Planning Unit 3b and 4				
Southwest Coastal Louisiana Feasibility Study	Hurricane protection and storm damage reduction and related purposes	House Resolution (2005)	None known; under study	NS-100, NS-400, NS-1000, C-RL-100-1, C-RL-400-1, C-RL-1000-1
Coastwide				
Louisiana Coastal Area Comprehensive Plan	Protect, preserve, and restore the coastal Louisiana ecosystem	WRDA 2007 Section 7002	Must be integrated with hurricane risk reduction.	Coastal restoration components.

Attachment 3 – Federal Agency Relationship to State Master Plan/LACPR

Agency Name		Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Department of Homeland Security	**Federal Emergency Management Agency (FEMA)**	The primary mission of the Federal Emergency Management Agency is to reduce the loss of life and property and protect the nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation.	Robert T. Stafford Disaster Relief and Emergency Assistance Act, PL 100-707, signed into law November 23, 1988; amended the Disaster Relief Act of 1974, Public Law 93-288.	FEMA's program provides funds to States, Territories, Federally recognized Indian Tribes, and communities for hazard mitigation planning and for the implementation of mitigation projects prior to a disaster event. The program provides a significant opportunity to raise risk awareness and reduce the nation's disaster losses through pre-disaster mitigation planning and the implementation of feasible, effective, and cost-effective mitigation measures. The program provides funding to reduce loss of life, as well as damage and destruction to property from natural hazards.	National	Appropriations - $32.2B Fiscal Year 2009 President's Budget	Grants, Cost Share, Emergency Funds Governor must request funds for designated disaster areas to permit allocation of funds	Indefinite	Provides funding to USACE to assist in disaster efforts. Participates with USACE and other Federal and State agencies in emergency planning.	-FEMA provides a broad emergency management capabilities including: planning, mitigation, warning, operations, rehabilitation, and recovery. Uses other Federal agencies, relief organizations, State, and local communities to support disaster efforts. Activities include: debris removal, contribute to repair or replacement of State or local government facilities, temporary housing assistance, loans, and training.
	FEMA Federal Insurance and Mitigation Administration (FIMA)	Flood insurance is designed to provide an alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods. Flood damage is reduced by nearly $1 billion a year through communities implementing sound floodplain management requirements and property owners purchasing of flood insurance. Additionally, buildings constructed in compliance with NFIP building standards suffer approximately 80 percent less damage annually than those not built in compliance.	National Flood Insurance Act of 1968 ANF Flood Disaster Protection Act of 1973	The NFIP is a Federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages.	National	Appropriations - $156.6M Fiscal Year 2009 President's Budget	Grants, Cost Share	Indefinite	Participates with USACE in developing flood insurance maps and flood project certification.	-FEMA provides: identification and mapping of flood-prone areas; flood mitigation assistance; define 100-year standard and certification, direction for State flood plain management programs; defines flood plain management regulations; technical assistance to communities, developers, and technical staff; train local and State officials on building criteria; define insurance rates; and promote flood insurance program.
	US Coast Guard	The United States Coast Guard (USCG) is a military branch of the United States involved in maritime law, mariner assistance, and search and rescue, among other duties of coast guards elsewhere. Stated mission is to protect the public, the environment, and the United States economic and security interests in any maritime region in which those interests may be at risk, including international waters and America's coasts, ports, and inland waterways.	Congressional Act created the Coast Guard in 1915	USCG has a broad role in homeland security, law enforcement, search and rescue, marine environmental pollution response, and the maintenance of river, intra-coastal and offshore aids to navigation.	National	Appropriations - $7.8B Fiscal Year 2009 President's Budget	Projects, Programs, Grants, Cost Share	Indefinite	Coordinates navigation projects with USACE, including navigation safety, such as debris removal.	-Promotes national policy to: preserve, protect, develop, and where possible, to restore or enhance, the resources of the nation's coastal zone. -Minimize disruptions to the movement of goods and people, -Maintain waterway restoration capabilities -Partner with Federal, State and local partners to respond to any major disaster.

Agency Name		Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Department of Interior	United States Fish and Wildlife Service (USFWS)	Assist in the development and application of an environmental stewardship ethic for our society, based on ecological principles, scientific knowledge of fish and wildlife, and a sense of moral responsibility. Guide the conservation, development, and management of the nation's fish and wildlife resources. Administer a national program to provide the public opportunities to understand, appreciate, and wisely use fish and wildlife resources.	Fish and Wildlife Act of 1956 (16 U.S.C. 742a-742j	A 1940 reorganization plan (54 Stat. 1232) in the Department of the Interior consolidated the Bureau of Fisheries and the Bureau of Biological Survey into one agency to be known as the Fish and Wildlife Service. The Bureau of Sport Fisheries and Wildlife was created as a part of the U.S. Fish and Wildlife Service in the Department of the Interior on November 6, 1956, by the Fish and Wildlife Act of 1956 (70 Stat. 1119).	National	Appropriations - $2.2B Fiscal Year 2009 President's Budget	Grants, Cost Share	Indefinite	Under the Fish and Wildlife Coordination Act participation with USACE in development of proposed projects. USACE funds the coordination. Review USACE documents and assists in monitoring USACE work. Member of CWPPRA Task Force.	-Provide fish and wildlife consultation, wildlife refuge management, fish hatchery management, NEPA review, critical habitat improvement encouragement, funds grants for endangered species, evaluates contaminate exposure, for coastal resources seeks partnerships for habitat restoration & protection projects, administers provisions of the Coastal Barrier Resources Act, law enforcement for wildlife crimes, conservation training, management of Federal Aid in Wildlife & Sport Fishery Restoration Program, grant funds to States for coastal wetland projects, and Invasive Species Program.
	United States Geological Survey (USGS)	The USGS serves the nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.	Act of March 3, 1879 (43 U.S.C. 31(a))	Classification of the public lands, and examination of the geological structure, mineral resources, and products of the national domain	National	Appropriations - $968.5M Fiscal Year 2009 President's Budget	Grants, Cost Share	Indefinite	Provide technical assistance to USACE, including coastal land lost mapping, surveys, ecosystem monitoring and gauging of waterways.	-Respond to critical regional needs associated with coastal areas such as: nutrient enrichment, oxygen depletion contamination, fish kills; shoreline erosion, sea level rise, groundwater, sand and gravel, energy resources; living marine resources, habitat loss, biodiversity loss, waste water, and non-indigenous species. -Provide the scientific information, data, knowledge, and tools required to define management practices -Conduct sediment transport, water quality, hydraulic, fish & wildlife, and other technical studies in partnership with Federal, State, and local agencies.
	Minerals Management Service (MMS)	MMS's mission is to manage the ocean energy and mineral resources on the Outer Continental Shelf and Federal and Indian mineral revenues to enhance public and trust benefits, promote responsible use, and realize fair value.	Public Law 97-451—Jan. 12,1983	The Federal agency that manages the nation's natural gas, oil and other mineral resources on the outer continental shelf (OCS). OCS Lands Act requires Sec. DOI to prepare and maintain an oil and gas leasing program, which includes Gulf of Mexico.	States with offshore oil and gas production	Appropriations - $307.1M Fiscal Year 2009 President's Budget	Grants, Projects	Indefinite	Coordination with Corps dredging related to OCS regarding coastal restoration.	-Awards grant to the Louisiana Department of Natural Resources through the Coastal Impact Assistance Program (CIAP) to create beach, dune, and marsh habitats on the East Grand Terre Island using dredged material. -Awards grants to the Louisiana Department of Natural Resources through the Coastal Impact Assistance Program (CIAP) to study different types of shoreline protection at the existing Rockefeller Refuge area along the Louisiana Gulf of Mexico shoreline. -Committed through the CIAP to helping States in their coastal restoration efforts.

Agency Name		Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Department of Commerce	National Oceanic and Atmospheric Administration (NOAA)	To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs.	National Oceanic and Atmospheric Administration Commissioned Officer Corps Act of 2002 (Public Law 107–372; 33 U.S.C. 3023	An informed society that uses a comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions	National	Appropriations - $4B Fiscal Year 2009 President's Budget	Grants	Indefinite	Member of the Mississippi River Commission Member of CWPPRA Task Force.	-Address four major issues pertinent to State, regional, and national needs: seafood harvesting and production, water resources, wetland restoration and sustainable coastal communities. -Devoted to restoring the nation's coastal, marine, and migratory fish habitats. -Funds and implements quality restoration projects to ensure healthy and sustainable fishery resources.
	NOAA National Ocean Service (NOS)	To provide science-based solutions through collaborative partnerships to address evolving economic, environmental, and social pressures on our oceans and coasts.	Marine Protection, Research, and Sanctuaries Act of 1972, Title II, Section 201 and 202, Public Law 92-532; National Ocean Pollution Planning Act of 1978, Section 6, Public Law 95-273; and Exec. Order 13158.	NOS facilities, data-processing systems, computing and communication systems, financial and administrative offices, and management approach provide support to many NOAA programs. To achieve the vision outlined in the NOS Strategic Plan and through NOAA program activities, NOS coordinates activities across six thematic areas—observations, modeling, coastal communities, technology, partnerships, and expert workforce. NOS also conducts outreach activities to inform the public.	National	Appropriations - $488.2M Fiscal Year 2009 President's Budget	Grants, Cost Share, Cooperative Agreement	Indefinite	Stakeholder in USACE studies and projects.	-Responsible for creating and maintaining the 1000 nautical charts of the U.S. Exclusive Economic Zone that portray marine environment showing the nature and form of the coast, the general configuration of the sea bottom including water depths, locations of dangers to navigation, locations and characteristics of man-made aids to navigation.

Agency Name		Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Department of Commerce	NOAA National Marine Fisheries (NMFS)	Stewardship of living marine resources through science-based conservation and management and the promotion of healthy ecosystems.	Public Law 104–297—Oct. 11, 1996	Responsible for the stewardship of the nation's living marine resources and their habitat. NOAA's National Marine Fisheries Service is responsible for the management, conservation and protection of living marine resources within the United States' Exclusive Economic Zone (water three to 200 mile offshore).	National	Appropriations - $782.3M Fiscal Year 2009 President's Budget	Grants, Cost Share	Indefinite	Provides for USACE projects consultation of threatened and endangered species and Essential Fish Habitat.	-Responsible for the management, conservation and protection of living marine resources within the United States' Exclusive Economic Zone -Ensures compliance with fisheries regulations, restores and protects habitat and works to reduce wasteful fishing practices, and promote sustainable fisheries. -Works with private and public partners in Louisiana to create salt marsh habitat, remove invasive species, implement hydrologic restoration, create oyster reefs, and remove marine debris. -Collaborates with other agencies, industry, and citizens to protect and restore coastal and marine resources impacted by oil spills, releases of hazardous substances, and vessel groundings.
	NOAA National Weather Service	The National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy.	Public Law 102–567, title VII, Oct. 29, 1992, 106 Stat. 4303	NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community.	National	Appropriations - $930.7 M Fiscal Year 2009 President's Budget	Grants	Indefinite	Provides statistical hydrologic information and criteria for analysis of USACE projects. Provides forecast weather dates for operation of water resource projects.	-Conduct research to advance the understanding and prediction of hurricanes and other tropical weather. -Participates in disaster response. -Provides standards for performing predictive forecasts of weather for project assessment.

Agency Name	Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Department of Energy (DOE)	Advancing the national, economic, and energy security of the United States; promoting scientific and technological innovation in support of that mission; and ensuring the environmental cleanup of the national nuclear weapons complexes.	Department of Energy Organization Act, Public Law 95–91, Title I, Section 102, and Title III, Section 301, (19 Stat. 565), 42 U.S.C. 7101	**Energy Security:** Promoting America's energy security through reliable, clean, and affordable energy **Nuclear Security:** Ensuring America's nuclear security **Scientific Discovery and Innovation:** Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology **Environmental Responsibility:** Protecting the environment by providing a responsible resolution to the environmental legacy of nuclear weapons production **Management Excellence:** Enabling the mission through sound management	National	Appropriations - $25B Fiscal Year 2009 President's Budget	Grants	Indefinite	USACE provides reimbursable support to DOE in managing environmental clean up and support infrastructure.	-Coordinates between Federal, State and local leaders, deployment of trained staff and improvements to modeling tools. -Monitor energy system damage and repair work and identify the supporting resources needed for restoration. -Deploy DOE technical response teams to affected areas to assist in response and restoration efforts. -Provides 40% of total Federal Government R&D. -Manage and regulates multiple source of energy oil, gas, hydro, nuclear, etc. -Provides for nuclear cleanup.

Agency Name	Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Department of Transportation (DOT)	Serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future.	The Department of Transportation Act (DOT Act) of 1966 Public Law 89-670	**Safety**: Enhance public health and safety by working toward the elimination of transportation-related deaths and injuries. **Reduced Congestion**: Reduce congestion and other impediments to using the nation's transportation system. **Global Connectivity**: Facilitate an international transportation system that promotes economic growth and development. **Environmental Stewardship**: Promote transportation solutions that enhance communities and protect the natural and built environment. **Security, Preparedness and Response**: Balance transportation security requirements with the safety, mobility and economic needs of the nation and be prepared to respond to emergencies that affect the viability of the transportation sector.	National	Appropriations - $40.1 B Fiscal Year 2009 President's Budget	Grants, Cost Share	Indefinite	USACE coordinates highway and bridge relocations with DDT.	-Researches transportation strategies and technologies to reduce greenhouse gases, identifies facilities that may be at risk from possible effects of climate change and climate anomalies, and develops an array of tools to assess the transportation system's ability to adapt to variances in global climate. -Studies how long-term shoreline changes can be quantified and used to estimate future shoreline positions, ways to evaluate the vulnerability of coastal highways, the general options available for roadway relocation, and alternative shoreline stabilization techniques available for protecting a highway in place.
Department of Agriculture (USDA) National Resource Conservation Service (NRCS)	NRCS programs help reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damages caused by floods and other natural disasters. Public benefits include enhanced natural resources that help sustain agriculture productivity and environmental quality while supporting continued economic development, recreation and scenic beauty.	Soil Conservation and Domestic Allocation Act of 1935	The NRCS programs include: • Conservation Technical Assistance • Environmental Improvement • Stewardship • Water Resource • Community Assistance • Technical Processes Tool and other Technical Resources • Resource Inventory Assessment • Compliance, Appeals, Mediation, Relief.	National	Appropriations - $2.5B Fiscal Year 2009 President's Budget.	Grants, Cost Share	Indefinite	NRCS cooperated with USACE on watershed management projects. Member of CWPPRA Task Force.	-Provides plant material to develop coastal shoreline and dune stabilization, biomass production, carbon sequestration, erosion reduction, wetland restoration, water quality improvement, streambank and riparian area protection, and other special conservation treatment needs.

Agency Name		Agency Mission	Authority	Purpose of Authority	Geographic Scope	Funding Source/Levels	Method of Allocation	Duration of Funding	Relation to USACE Programs/ Mission	Relation to State Master Plan/LACPR
Environmental Protection Agency (EPA)	General	Protect human health and to safeguard the natural environment—air, water, and land—upon which life depends	December 2, 1970 EPA was established by White House and Congress	• Develop and enforce Regulatory • Give Grants • Study Environmental Issues • Sponsor Partnerships • Train about the Environment • Publish Information	National	Appropriations - $7.1B Fiscal Year 2009 President's Budget. Supports Lake Pontchartrain Basin Restoration Program ($978K)	Grants	Indefinite	EPA coordinates environmental regulatory requirements with USACE for proposed and existing projects. Member of CWPPRA Task Force.	- Performs the following: NEPA review, Clean Water Act review, compensatory mitigation planning, policy & program consistency, watershed collaboration, restoration planning, water quality management, hypoxia management, environmental justice, environmental enforcement & compliance, air quality management, and provides for grants for research, support of State programs, and education.
	Gulf of Mexico Program	Non-regulatory inclusive partnership to provide a broad support geographic focus on major environmental issues in the gulf.	Formed by EPA in 1988	Supports a collaborative multi-organizational Gulf States led partnership. The program is designed to assist stakeholders, develop regional ecosystem-based framework for restoring and protecting the Gulf.	Gulf of Mexico Region	Appropriations - $4.7M Fiscal Year 2009 President's Budget.	Grants, Cost Share	Indefinite	USACE participates as one of the 13 Federal agencies in management of the program. New Orleans District serves as POC for the 5 Gulf of Mexico USACE districts.	-Primarily this program provides a forum of collaboration among Gulf of Mexico region Federal, State, and local agencies. The issues covered involve improvement of water quality, restoration of coastal ecosystems, hypoxia, research & other grants, and resolution of coastal environmental issues.
	Barataria-Terrebonne National Estuary	The mission of the BTNEP is the preservation and restoration of the Barataria-Terrebonne estuarine system (1 of 28 National Estuary Programs)	Established by Congress through section 320 of the Clean Water Act in 1987 and administrated by the Environmental Protection Agency	Prevent activities that: threaten an estuary's public water supply, are harmful to shellfish, fish and wildlife populations negatively impact recreational opportunities for estuary residents	Louisiana's Barataria and Terrebonne Basins	Appropriations - $20,000 for 2008. Grants	Grants	Indefinite	Coordinates with USACE coastal activities.	-Rebuild eroded wetlands in the area through the diversion of fresh water, sediment, and nutrients. -Sustain and restore wetlands that support viable fish and wildlife resources