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2017 Coastal Master Plan

Appendix D: Planning Tool Methodology

Report: Version I

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Coastal Protection and Restoration Authority

This document was prepared in support of the 2017 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every five years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

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Executive Summary

Motivation

Coastal Louisiana faces long-term sustainability challenges due to severe coastal land loss and increasing flood risk. For more than four decades, national and state government agencies, state and local organizations, corporations, and citizen's groups have invested significant resources in mostly local-scale ecosystem restoration and levee protection. The continuing land loss – at a rate of about 75 square kilometers annually – and tremendous impacts from the 2005 hurricanes reemphasized that more action was required and that to be effective it would need to be coordinated as part of a comprehensive plan.

Following the devastating 2005 hurricane season, Louisiana released its 2007 Comprehensive Master Plan (CPRA, 2007). The 2012 Coastal Master Plan (CPRA, 2012) built on the 2007 Coastal Master Plan and introduced a new planning framework and Planning Tool to formulate a 50-year, $50 billion investment plan.

For the 2017 Coastal Master Plan, CPRA is updating its 50-year estimates of coastal conditions reflecting the new projects that have begun and improved data and modeling. An updated Planning Tool is re-evaluating the projects selected for the 2012 Coastal Master Plan along with new projects proposed by stakeholders through a structured process completed in 2014. The updated Planning Tool will also be used to help formulate and evaluate a more refined set of nonstructural risk reduction projects.

CPRA Planning Tool

The CPRA planning framework combines two sets of analytic capabilities: integrated models of the coastal system and a planning tool. Together, they are used to iteratively support the development of the 2017 Coastal Master Plan. Figure 1 illustrates the framework.

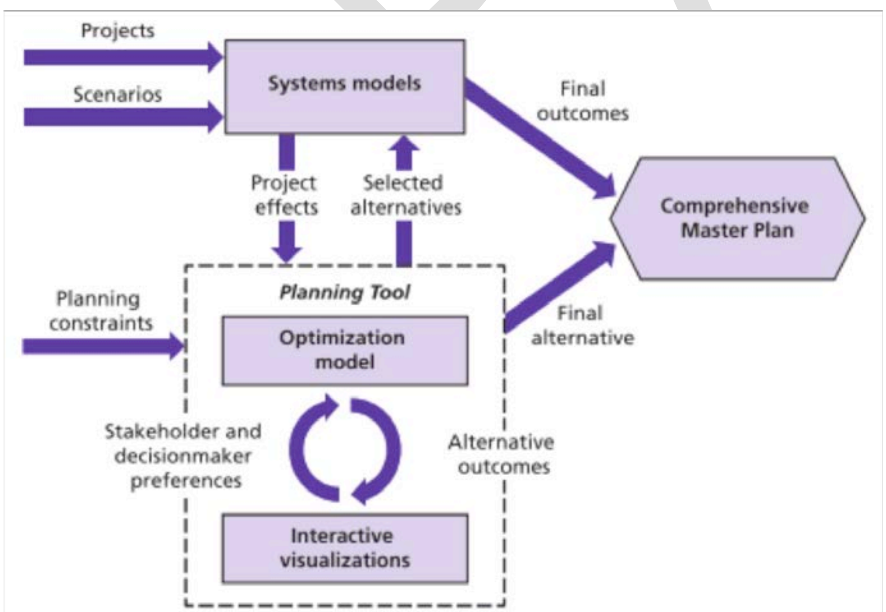

Figure 1: CPRA Analytic Framework.
Source: Groves et al. (2013).

Analysis begins by using the systems models to evaluate how proposed coastal restoration and risk reduction projects would individually affect the coast over the next 50 years relative to no action for multiple future scenarios. Additional calculations provide rough assessments of effects on navigation, communities, the oil and gas industry, fisheries, and other key assets.

The models' results serve as inputs to the Planning Tool, a computer-based decision support software system, along with planning constraints such as availability of sediment, available funding over the next five decades, and the preferences of the CPRA Board and stakeholders. The Planning Tool uses optimization to identify alternatives comprised of the projects that build the most land and reduce the most flood risk while meeting funding and other planning constraints (such as sediment and project compatibilities) and stakeholder preferences. The Planning Tool generates interactive visualizations that summarize information about individual projects and alternatives.

In the last step, the systems models evaluate together alternatives defined by the Planning Tool and informed by stakeholder and decision maker preferences. The specific projects for the final alternative from the Planning Tool and the outcomes estimates by the systems models provide key information to describe the master plan and its effects on the coast.

Planning Tool Support for the 2017 Coastal Master Plan

The 2017 Coastal Master Plan framework, systems models, and Planning Tool will help CPRA design an updated multi-billion, 50-year investment plan to address Louisiana coastal land loss and flood risk challenges. To do so, they consider how the coast would change in the coming five decades with respect to a wide range of ecological and flood outcomes. These changes are impossible to predict with certainty, so the framework, models, and tool evaluate different scenarios representing different plausible futures. The systems models then evaluate hundreds of different projects individually and then as groups of projects – or alternatives. Summaries of these results and other data are provided as inputs to the Planning Tool.

The Planning Tool presents the results of these analyses to CPRA and stakeholders through interactive computer-based visualizations to support deliberations over the many different approaches. As for the 2012 Coastal Master Plan, this approach helps bring the best available scientific information and stakeholder input to support the development of the next edition of Louisiana's Coastal Master Plan. The Planning Tool will perform a variety of functions in support of the 2017 Coastal Master Plan development.

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List of Abbreviations

ADCIRC-SWAN	Advanced Circulation-Simulated Wave Nearshore model
AEP	Annual exceedance probability
BFE	Base Flood Elevation
CLARA	Coastal Louisiana Risk Assessment Model
CPRA	Coastal Protection and Restoration Authority
EAD	Expected annual damage
ESLR	Eustatic Sea Level Rise
EwE	Ecopath with Ecosim model
FWOA	Future without action
FWP	Future with project
GAMS	General Algebraic Modeling System
GIS	Geographic information system
HSIs	Habitat Suitability Indices
ICM	Integrated Compartment Model
IPET	Interagency Performance Evaluation Task Force
LMI	Low to Moderate Income
MCDA	Multi-Criterion Decision Analysis
MIP	Mixed-integer programming
NRC	National Research Council
RDM	Robust Decision Making

1.0 Introduction

Coastal Louisiana faces long-term sustainability challenges due to severe coastal land loss and increasing flood risk. For more than four decades, national and state government agencies, state and local organizations, corporations, and citizen's groups have invested significant resources in mostly local-scale ecosystem restoration and levee protection. The continuing land loss – at a rate of about 75 square kilometers annually – and tremendous impacts from the 2005 hurricanes reemphasized that more action was required and that to be effective it would need to be coordinated as part of a comprehensive plan. Following the devastating 2005 hurricane season, Louisiana released its 2007 Comprehensive Master Plan (CPRA, 2007). The 2007 Coastal Master Plan set a new course for Louisiana by defining four high-level objectives to guide development of a comprehensive strategy:

- Reduce economic losses from storm based flooding to residential, public, industrial, and commercial infrastructure, assuring that assets are protected, at a minimum, from a storm surge that has a 1% chance of occurring in any given year.
- Promote a sustainable coastal ecosystem by harnessing the processes of the natural system.
- Provide habitats suitable to support an array of commercial and recreational activities coast wide.
- Sustain, to the extent practicable, the unique heritage of coastal Louisiana by protecting historic properties and traditional living cultures and their ties and relationships to the natural environment.

These objectives were developed to guide the state's long-term infrastructure investments on the coast. The 2007 Coastal Master Plan did not, however, provide a quantified comparison of costs and benefits for the many proposed projects, consider a wide variety of future scenarios, or define a preferred set of projects to meet these long-term goals. The plan also considered many general project concepts, rather than specific projects with defined physical attributes and costs.

The 2012 Coastal Master Plan (CPRA, 2012) built on the 2007 Coastal Master Plan and introduced a new planning framework to formulate a 50-year, $50 billion investment plan. To guide the planning process, CPRA refined the 2007 Coastal Master plan objectives to the following five:

- Flood Protection – Reduce economic losses from storm-based flooding;
- Natural Processes – Promote a sustainable ecosystem by harnessing the processes of the natural system;
- Coastal Habitats – Provide habitats suitable to support an array of commercial and recreational activities coast wide;
- Cultural Heritage – Sustain Louisiana's unique heritage and culture; and
- Working Coast – Support regionally and nationally important businesses and industries.

CPRA also supported the development of new systems models, to augment existing ones, and a Planning Tool to objectively evaluate and compare projects and formulate groups of projects (i.e., alternatives). CPRA used the Planning Tool in an iterative process with stakeholders to evaluate differences among various alternatives and define the final 2012 Coastal Master Plan.

CPRA is now developing the 2017 Coastal Master Plan, which will build on the 2012 Coastal Master Plan by refining project choices based on new project options, new data and models, and an updated Planning Tool.

1.1 Challenges in Formulating a Long-Term Master Plan for Louisiana

There are numerous challenges that Louisiana is addressing to develop a long-term coastal master plan.

1.1.1 Louisiana Coast Supports Diverse Communities and Natural Resources

Coastal Louisiana is a working coast. It is home to over two million people and is endowed with a large diversity of natural resources, many of which support economic and recreational activities. The dynamic deltaic coast provides vital habitat to hundreds of aquatic and terrestrial species. The coast is also home to large cities, such as New Orleans, with significant existing flood control infrastructure constructed by the federal government, and regional centers, such as Houma, that have little or none; what protection does exist is often constructed and maintained solely by local levee boards. There are also numerous rural and isolated communities. Any decision that affects a community and the environment is subject to debate over goals, priorities, and resource allocation.

1.1.2 Coastal Systems are Complex and will Change in Uncertain Ways

The coastal system is dynamic and interconnected. How it will change in the coming decades is highly uncertain. Drivers of change, such as rates of sea level rise, subsidence, and erosion; future hurricane activity; hydrologic fluctuations and trends; and future human activities are all but impossible to predict in the long run, despite our best scientific understanding of these processes. The ecosystem, species, and society's responses to these drivers thus will remain exceedingly difficult to predict. The specific effects that coastal investments in restoration or risk reduction projects could have on the coast are therefore similarly uncertain.

1.1.3 Wide Range of Approaches to Address Challenges

There are many approaches that could be taken to address these challenges, each with different costs and potential effects on the coast. Options to reduce coastal land loss include mechanical projects that move sediment to rebuild land to more process-based approaches of diverting sediment-rich floodwaters to wetlands in need of sediment nourishment. Other projects target specific areas of need, including bank stabilization, barrier island restoration, oyster barrier reef development, ridge restoration, and shoreline protection. Similarly, flood risk can be reduced by new or improved physical structures, such as levees and floodgates that are designed to block or reroute water. Nonstructural risk reduction measures, such as floodproofing or elevating structures, can reduce risk by increasing the resistance of structures to flooding. Acquisitions of property can also reduce risks by removing assets that could be damaged in a flood.

1.1.4 Hard Decisions

Louisiana faces hard decisions; there is no single solution that will solve every challenge facing the coast. Some activities and ecosystems face greater sustainability challenges than others. In some cases, decisions to focus investment in some areas and not in others will need to be made.

For the 2012 Coastal Master Plan, CPRA made a commitment to using the best available science in a transparent manner to help inform these necessary decisions. CPRA continues this commitment with the 2017 Coastal Master Plan by furthering its efforts in data collection, systems modeling, the Planning Tool, and public outreach.

1.2 CPRA Planning Framework and Tool

The 2012 Coastal Master Plan introduced a new planning framework and decision support tool called the Planning Tool to enable the state to objectively and transparently formulate a long-term plan. In this framework, a suite of systems models are used to estimate how the coastal system and associated flood risks would change over the next 50 years under different scenarios, reflecting uncertainty about key drivers, such a sea level rise. The models also estimate the effects of different restoration and risk reduction projects on a wide range of outcomes.

These models generate a tremendous amount of information relevant to the development of the master plan. The model data, planning constraints, and stakeholder preferences are input to the Planning Tool, and it is used to compare projects and formulate alternatives to support deliberations.

1.2.1 Use of Planning Tool to Support the 2012 Coastal Master Plan

The 2012 Coastal Master Plan used the Planning Tool to compare hundreds of restoration and risk reduction projects and define a 50-year, $50 billion master plan (CPRA, 2012; Groves, Sharon, & Knopman, 2012). To help arrive at this outcome, the Planning Tool helped support four sets of deliberations around the following questions:

1. **Comparison of individual risk reduction and restoration projects**: Which flood risk reduction and restoration projects are most consistent with the objectives of the 2012 Coastal Master Plan?
2. **Formulation of alternatives**: What alternatives (made up of groups of individual projects) can be implemented over a 50-year period to best achieve the objectives of the 2012 Coastal Master Plan, given constraints on funding, sediment resources, and river flow?
3. **Comparison of alternatives**: When compared across all the objectives of the 2012 Coastal Master Plan, which alternative is preferred?
4. **Evaluation of uncertainty**: How will the 2012 Coastal Master Plan perform, relative to its objectives, across several future environmental scenarios?

Specifically, CPRA first used the Planning Tool to help assess the overall benefits and costs of hundreds of proposed protection and restoration projects. CPRA next used the Planning Tool as part of an iterative participatory decision process to develop a large set of different alternatives and then identify a small set of alternatives that were considered as the foundation of the 2012 Coastal Master Plan. There is no "correct" alternative, and the Planning Tool is designed to formulate many alternatives and summarize the key differences among them. These selected alternatives were then run through the systems models again and reevaluated to better understand synergies and differences among the included projects.[1]

After discussions among CPRA management and stakeholders and iterations with the Planning Tool, CPRA defined a single alternative for the January 2012 draft of the Coastal Master Plan. The draft 2012 Coastal Master Plan was released on January 12, 2012, for public review and comment. CPRA held three all-day public meetings and more than 50 meetings with community

[1] The re-evaluation of the 2012 Coastal Master Plan using the systems models occurred after the publishing of the master plan.

groups, parish officials, legislators, and stakeholder groups. Thousands of comments were received and reviewed, and some of the underlying information on the individual projects was updated for accuracy.

Based on this stakeholder input, the Planning Tool was used again to evaluate how adjustments to the included projects and their implementation timing would change final outcomes. Based on a review of this new analysis, refinements were made and the final 2012 Coastal Master Plan was completed. The Louisiana legislature subsequently approved the final 2012 Coastal Master Plan unanimously in May 2012 (CPRA, 2012).

The following three figures summarize key decisions and final outcomes of the 2012 Coastal Master Plan. Figure 2 shows how 2012 Coastal Master Plan funding is allocated across different project types and the number of projects for each type; 109 projects are included in the final alternative. Notably, about 20% of the total funding ($10.2 billion) is allocated to nonstructural risk reduction projects coast wide, and $3.8 billion of funding is allocated to 11 different sediment diversion projects.

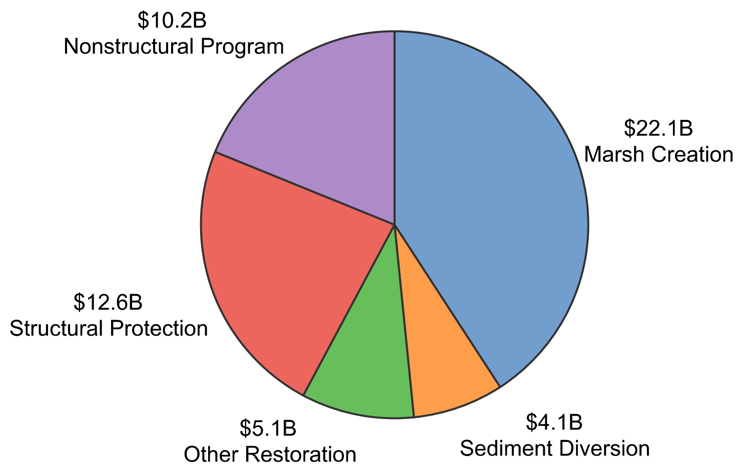

Figure 2: 2012 Coastal Master Plan Funding Allocation across Project Types.
Note: Indicated values are in 2010 U.S. dollars.

Figure 3 shows that the implementation of the master plan is projected to dramatically decrease expected annual damage (EAD)[2] from coast wide flooding, from a currently estimated annual level of $2.2 billion today to between $2.8 billion and $4.8 billion in year 50 with the full implementation of the 2012 Coastal Master Plan. Without the 2012 Coastal Master Plan in place, EAD could exceed $20 billion under the less optimistic scenario. Note that the projected reduction in risk from the 2012 Coastal Master Plan would be due to both restoration and risk reduction projects.

[2] EAD represents the average damage estimated to occur from a storm surge flood event in any given year, taking into account both the projected chance of a storm occurring and the damage that would result.

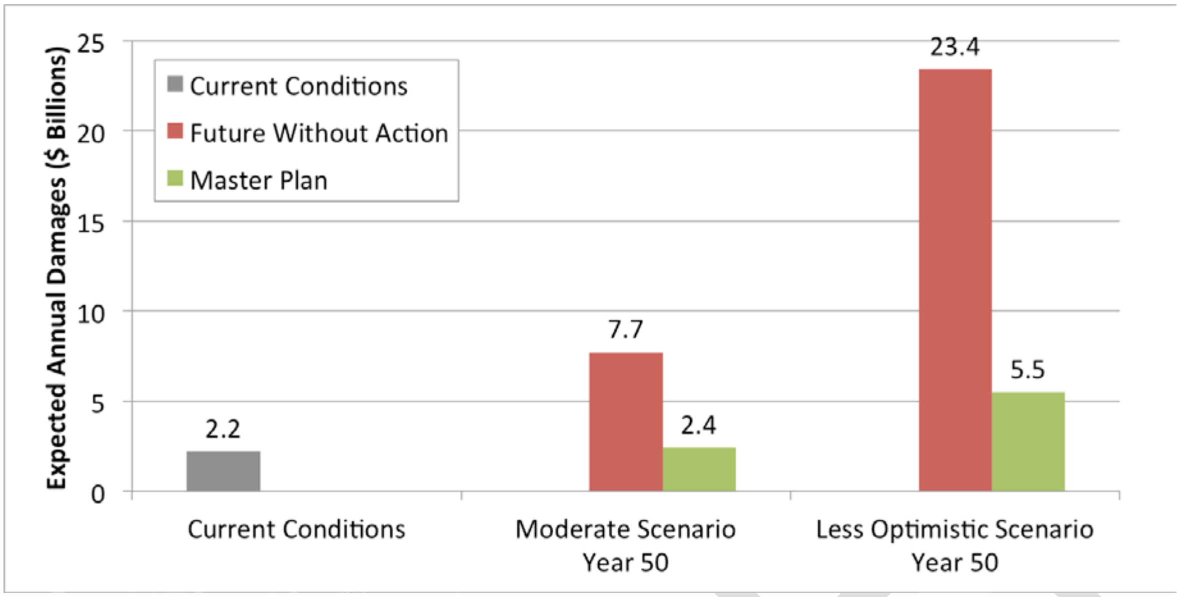

Figure 3: Reduction in Coast Wide Risk with and without the 2012 Coastal Master Plan.
Source: Coastal Protection and Restoration Authority (2012).

Figure 4 graphically illustrates this flood risk reduction under the less optimistic scenario assumptions by showing the change in future 100-year flood depths – or flood depths that would have a 1% chance of occurring in any year – with the 2012 Coastal Master Plan in place, as compared to a future without action (FWOA). The areas marked in blue face deeper levels of flooding; areas marked in orange face less flooding. Of note are the dramatically reduced flood depths projected in New Orleans, a result of several upgrades to the existing system (itself substantially upgraded since Hurricane Katrina). The extensive construction of new levees over broad areas of the central coast could also provide substantial flood depth reduction of between four and 12 feet for 1% annual exceedance probability (AEP) events, given the assumptions of the less optimistic scenario.

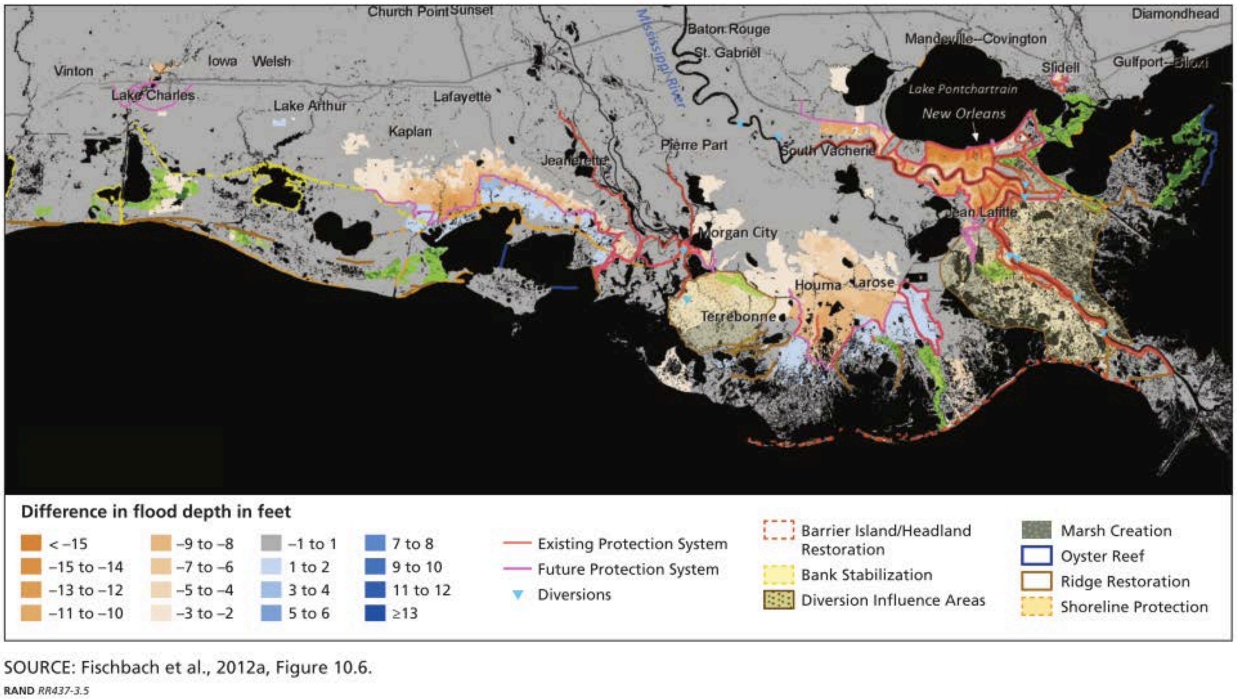

Figure 4: Reduction in 100-year Flood Depths in 50 Years Due to 2012 Coastal Master Plan (Less Optimistic Scenario).

Source: Fischbach et al. (2012, fig. 10.6).

Compared to the FWOA, the restoration projects included in the 2012 Coastal Master Plan could build between 580 and 800 square miles of land over the next 50 years, depending on future conditions, as illustrated in Figure 5. For the moderate scenario, net land loss would be halted in about 20 years, and coast wide land would then begin to increase for the remaining 30 years. For the less optimistic scenario, net land loss would still continue but at about half the rate as without the 2012 Coastal Master Plan. If future conditions are more like those represented by the less optimistic scenario, additional investments would need to be made to achieve sustainability of the landscape.

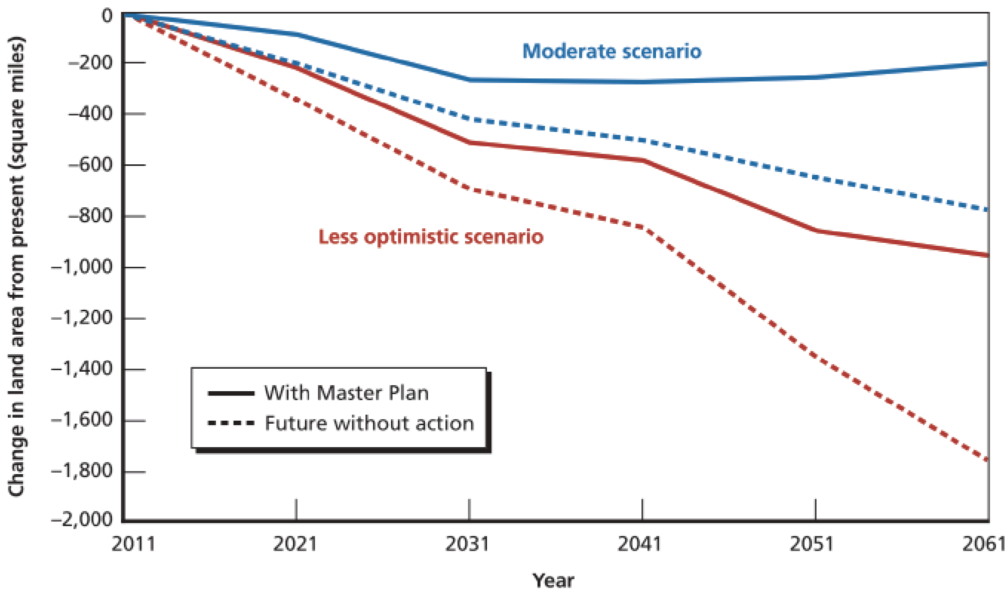

Figure 5: Change in Land Area with and without the 2012 Coastal Master Plan.
Source: Groves et al. (2013).

1.2.2 Use of Planning Tool to Support the 2017 Coastal Master Plan

Since the 2007 Coastal Master Plan, CPRA has procured nearly $15.5 billion to support planning, engineering and design, and construction on 94 restoration and protection projects. CPRA has also continued to invest in data, modeling, and the Planning Tool.

For the 2017 Coastal Master Plan, CPRA is updating its 50-year estimates of coastal conditions reflecting the new projects that have begun and improved data and modeling. The Planning Tool is re-evaluating the projects selected for the 2012 Coastal Master Plan along with new projects proposed by stakeholders through a structured process completed in 2014. In addition, a small set of projects that were high performing but not selected in 2012 due to the budget constraint, will also be re-evaluated. Lastly, the Planning Tool will be used to help formulate and evaluate a more refined set of nonstructural risk reduction projects.

1.3 Purpose of this Report

This is the first draft of the 2017 Planning Tool technical documentation to be included in the 2017 Coastal Master Plan. This draft describes the planning framework and Planning Tool, details the methodology, and outlines how it will be used in the coming months to help formulate the 2017 Coastal Master Plan. This report will be updated through 2016 as the Planning Tool is used to support the 2017 Coastal Master Plan. Specifically, as each step of the analysis is completed, Section 3 of this report will be updated to reflect the analysis and results. Additional appendix items will also be added so that the final version provides complete documentation of the Planning Tool and its use for the 2017 Coastal Master Plan.

2.0 Planning Tool Methodology

The CPRA planning framework combines two sets of analytic capabilities: integrated models of the coastal system and a Planning Tool. Together, they are used to iteratively support the development of the 2017 Coastal Master Plan. Figure 6 illustrates the framework in flowchart form.

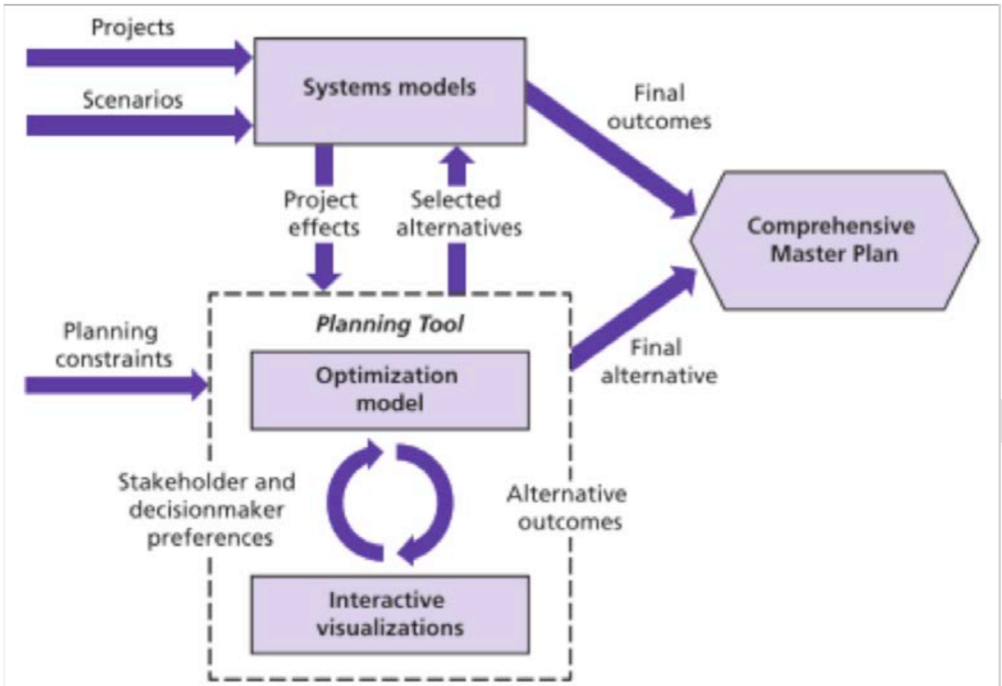

Figure 6: CPRA Analytic Framework.
Source: Groves et al. (2013).

The beginning of the process is represented at the top left of the flow chart. Analysis begins by using the systems models to evaluate how proposed coastal restoration and risk reduction projects would individually affect the coast over the next 50 years relative to no action for multiple future scenarios. Specifically, the systems models estimate the effects that each project would have on the coastal landscape, including barrier islands and wetlands; on future storm surges, waves, flooding, and flood damage; and on ecosystem characteristics, including habitats for different aquatic and land-based species. Additional calculations provide rough assessments of impacts on navigation, communities, the oil and gas industry, and other key assets.

The models' results serve as inputs to the Planning Tool, a computer-based decision support software system, along with planning constraints such as availability of sediment, available funding over the next five decades, and the preferences of the CPRA Board and stakeholders. The Planning Tool uses optimization to identify alternatives comprised of the projects that build the most land and reduce the most flood risk while meeting funding and other planning constraints and stakeholder preferences. The Planning Tool generates interactive visualizations that summarize information about individual projects and alternatives.

In the last step, the systems models evaluate together one or a few alternatives defined by the Planning Tool. The specific projects for the final alternative from the Planning Tool and the outcomes estimates by the systems models provide key information to describe the master plan and its effects on the coast.

This section describes the Planning Tool's theoretical basis, scope of analysis, structure, key inputs, and specific methods for performing its key functions.

2.1 Theoretical Basis

The Planning Tool brings together several well-established planning methodologies in a customized way to meet Louisiana's planning needs. Specifically, the Planning Tool combines elements of Multi-Criterion Decision Analysis (MCDA) and Robust Decision Making (RDM) within an overarching deliberation-with-analysis process.

The National Research Council (NRC) recommends a deliberation-with-analysis approach (NRC, 2009) to support complex environmental planning challenges. This approach uses data and models not to recommend a specific course of action, but rather to help articulate potential outcomes among different reasonable courses of action over plausible futures. These results are then presented to decision makers and stakeholders to support their deliberations. The Planning Tool supports this process by using the results of the systems models and other planning data to make comparative calculations and formulate alternatives and then present interactive visualizations to CPRA and stakeholders as they make decisions about which projects to include in the 2017 Coastal Master Plan.

The Planning Tool generates alternatives that maximize the goals of the 2017 Coastal Master Plan while satisfying a wide range of constraints. MCDA (Keeney and Raiffa, 1993; Lahdelma, Salminen, & Hokkanen, 2000; Kiker et al., 2005; Linkov et al., 2006) is a standard approach to defining alternatives that conform to a set of preferences, as reflected by a corresponding set of weights. Challenges applying standard MCDA to Louisiana's coastal planning problem include:

- Developing quantifiable coastal performance metrics that can be placed on a consistent scale for comparison,
- Interpreting the meaning of a single objective function comprised of tens of different metrics, and
- Deriving weights for each metric that represent the wide range of stakeholder views.

The Planning Tool, therefore, uses a simplified MCDA methodology. Rather than including all decision drivers within an objective function, the Planning Tool uses a simple and easily understood objective function made up of only mid-term and long-term risk reduction and land building, with a corresponding set of weights that equally balances across all four factors. It considers other coastal outcomes as constraints (Romero, 1991). The Planning Tool then uses standard mixed-integer programming (MIP) methods (Schrijver, 1998) to maximize the objective function subject to funding and other planning constraints.

To address the significant uncertainty in estimating future coastal conditions, the Planning Tool supports the comparison of projects and formulates alternatives based on estimates of future coastal conditions for different future scenarios. RDM techniques help evaluate the various alternatives and suggest a robust, adaptive alternative (Groves and Lempert, 2007; Lempert et al., 2013; Lempert, Groves, Popper, & Bankes, 2006; Lempert, Popper, & Bankes, 2003). Specifically, RDM helps identify near-term projects for implementation and specific pathways for future investment based on the evolution of future conditions. The following sections describe how these methodologies are used to support the 2017 Coastal Master Plan.

2.2 Scope of Analysis

The 2017 Coastal Master Plan framework, systems models, and Planning Tool are designed to help CPRA design a multi-billion, 50-year investment plan to address Louisiana coastal land loss and flood risk challenges. To do so, they consider how the coast would change in the coming five decades with respect to a wide range of ecological and flood outcomes. These changes are impossible to predict with certainty, so the framework, models, and tool evaluate different scenarios representing different plausible futures. The systems models then evaluate hundreds of different projects individually and then as groups of projects – or alternatives. Summaries of these results are provided to the Planning Tool. The Planning Tool presents the results of these analyses to CPRA and stakeholders through interactive computer-based visualizations to support deliberations over the many different approaches. As for the 2012 Coastal Master Plan, this approach helps merge the best available scientific information and stakeholder input to support the development of the 2017 Coastal Master Plan.

2.2.1 Time Horizon and Granularity

The CPRA Planning Tool evaluates projects and alternatives over a 50-year time horizon, starting from an initial condition out to 50 years into the future.

As described below, the Planning Tool receives estimates about future conditions for specific slices in time. For ecosystem-related metrics, estimates are received at 5-year intervals. For risk-related metrics, estimates are received for initial conditions and years 10, 25, and 50. The risk estimates are then interpolated to 5-year intervals.

The Planning Tool uses three defined periods of implementation; the first being 10 years long and the second two each being 20 years long:[3]

- Implementation Period 1: Years 1 – 10
- Implementation Period 2: Years 11 – 30
- Implementation Period 3: Years 31 – 50

The Planning Tool compares projects and formulates alternatives by considering the effects of projects on the coast at two time slices:

- Mid-term: year 25
- Long-term: year 50

Figure 7 shows graphically the three implementation periods, with each bar representing a notional project selected for a specific period, and shows the time slices used for project evaluation and alternative formulation. As described below (see Section 2.5.3.2), project effects are offset by the period of implementation. As such, projects implemented in period 3 are only evaluated in terms of their long-term effects on the coast.

[3] For the 2012 Coastal Master Plan, the length of the first two implementation periods was 20 years and the length of the third implementation period was 10 years.

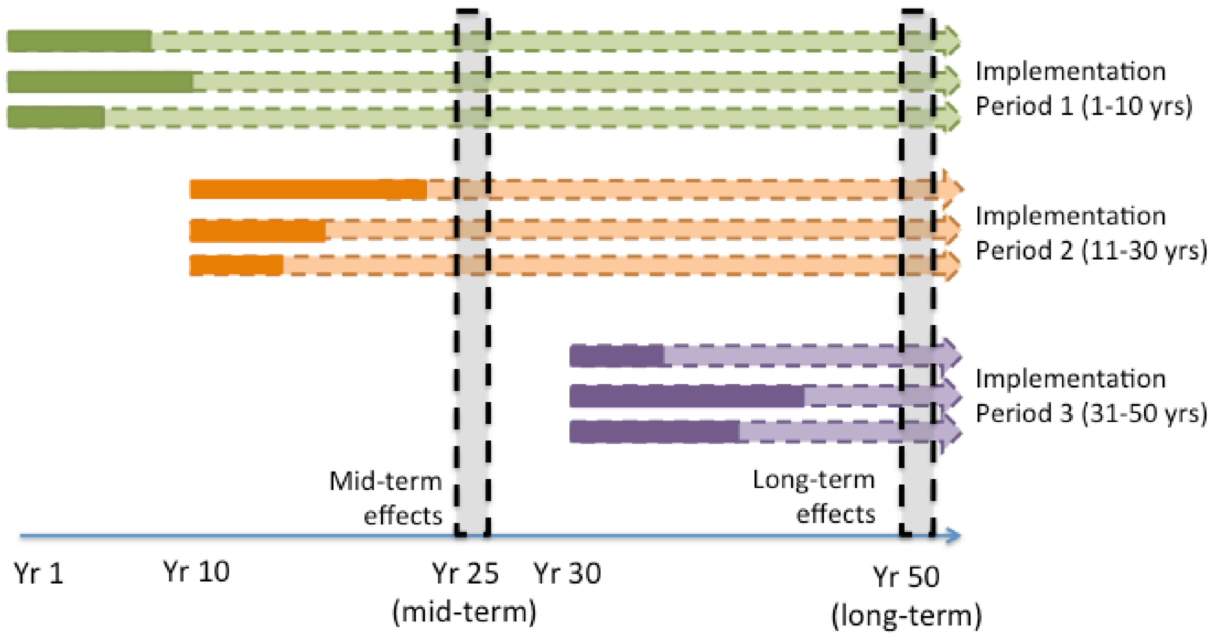

Figure 7: Implementation Periods and Evaluation Time Slices.

Notes: The solid portions of the bars indicate hypothetical engineering, design, and construction times. The dashed portions of the bars indicate ongoing operations and maintenance time.

2.2.2 Systems Models

A suite of systems models provides input to the Planning Tool related to coastal ecosystem and flood risk conditions (see Meselhe et al., 2015 for details on the modeling for the 2017 Coastal Master Plan).

The Integrated Compartment Model (ICM) analyzes landscape and ecosystem performance under different environmental scenarios. It estimates hydrodynamic changes and response in land-water and vegetation. A set of 19 Habitat Suitability Indices (HSIs) are integrated into the ICM and provide estimates of a variety of aquatic and terrestrial species habitat. An Ecopath with Ecosim model (EwE) is used to derive spatially explicit estimates of fish and shellfish relative biomass.

On the flood risk side, the Advanced Circulation-Simulated Wave Nearshore model (ADCIRC-SWAN) estimates storm surge and waves for a large set of simulated tropical storms and hurricanes. The surge and wave results then serve as input to the Coastal Louisiana Risk Assessment Model (CLARA), which translates storm surge into flood depths, as influenced by levees and other structural protection (Fischbach et al., 2012). CLARA then calculates the resultant damages to a wide array of coastal assets. By evaluating the results of different modeled storms, statistical flood risk metrics, such as EAD, are computed.

2.2.3 Decision Drivers and Metrics

The Planning Tool evaluates projects and outcomes based on a large set of metrics that are related to the five master plan objectives listed in the introduction above. Through the 2012 Coastal Master Planning process, however, CPRA defined two factors as decision drivers – land building and flood risk reduction – represented by the land and EAD metrics, respectively. CPRA used the decision drivers to guide the alternative formulation because they are key requirements for all five of the master plan objectives, are well understood, and were shown to simplify the analysis without losing the flexibly for refining the plan. Specifically, CPRA used additional ecosystem and risk metrics as report outputs and to shape the alternatives by constraining the optimization to meet different outcome thresholds. Outcome thresholds were defined through the iterative alternative formulation approach, as described in Section 2.5.4. This same approach is being carried forward for the 2017 Coastal Master Plan.

2.2.3.1 Ecosystem Metrics

The systems models, mentioned above, calculate and supply a wide range of ecosystem metrics to the Planning Tool. These metrics include land, which is a decision driver, and other metrics from the ICM and EwE (Table 1).

Table 1: Ecosystem Metrics.

Source	**Ecosystem Metrics**
ICM	Land (square kilometers) Trajectory of land beyond the planning horizon (difference in land between 10 years after the planning horizon and the end of the planning horizon) (square kilometers) Nitrogen uptake (kg) Species habitat (habitat units) • Oysters, Shrimp (brown/white), Largemouth Bass, Juvenile Menhaden, Spotted Seatrout, Bay Anchovy, Blue Crab, Brown Pelican, Mottled Duck, Green-winged Teal, Gadwall, Alligator, and Crawfish Wetland type (square kilometers) • Freshwater Wetlands, Forested Wetlands, Fresh Marsh, Intermediate Marsh, Brackish Marsh, Saline Marsh, Bare Ground, Upland, Open Water
EwE	Species biomass (tonnes/square kilometer) • Over 20, including Spotted Seatrout, Red Drum, Black Drum, Largemouth Bass, Catfish, Anchovy, Blue Crab, Brown Shrimp, White Shrimp, Gulf Menhaden, and Oyster

All the metrics are aggregated by 11 ecoregions and provided every five years from current conditions to year 50 (Figure 8).

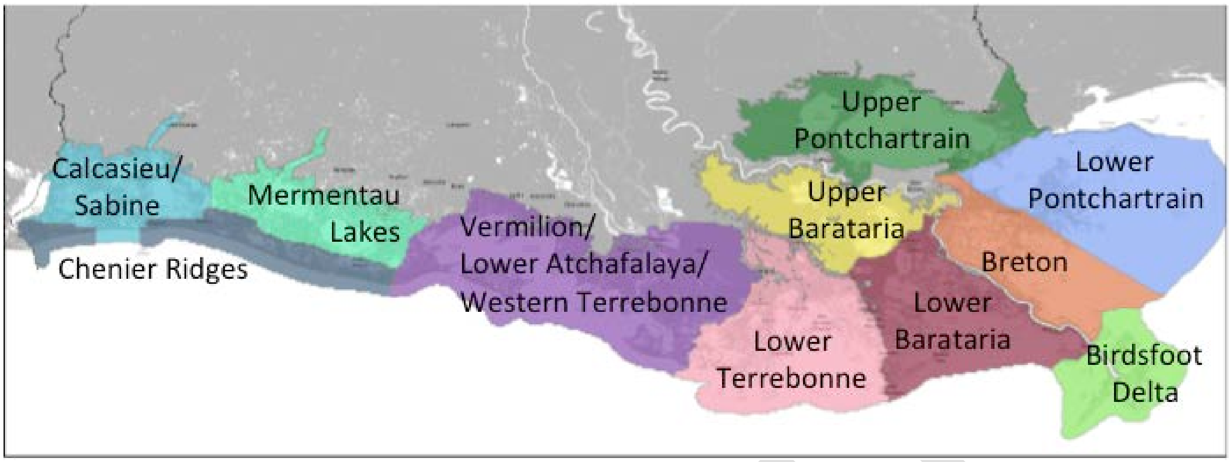

Figure 8: Ecoregions.

2.2.3.2 Risk Metrics

Risk results are provided to the Planning Tool by the CLARA model. They include EAD, which is a decision driver, as well as other risk related metrics (Table 2). The CLARA EAD calculations are probabilistic, and the Planning Tool therefore tracks the mean and standard deviation of the outcomes. Results are aggregated by 54 risk regions and provided for initial conditions and years 10, 25, and 50. See Fischbach et al. (2015) for details on the risk metrics and project areas.

Table 2: Risk metrics.

Source	Risk Metric
CLARA	Expected Annual Damage – EAD ($) • Mean and standard deviation

2.2.3.3 Additional Derived Metrics

There are a few additional metrics used to represent the effects of projects and/or alternatives that are derived from results for the ecosystem metrics, risk metrics, or both metrics. They include:

- Use of natural processes (index)
- Support for navigation (index)
- Support for traditional fishing communities (index)
- Support for oil and gas activities and communities (index)
- Support for agricultural communities (index)
- Social vulnerability (index)
- Flood protection of historic properties (%)
- Flood protection of strategic assets (%)
- Flood depths at various recurrence intervals (e.g., 50-, 100-, and 500-year) and times (i.e., initial condition, year 10, year 25, and year 50) (m)

2.2.4 Scenarios

Two sets of scenarios are being used to reflect uncertainty about future conditions – environmental and risk. All ecosystem metrics are evaluated for each environmental scenario. Similarly, the risk metrics are evaluated for each risk scenario.

2.2.4.1 Environmental Scenarios

For the 2017 Coastal Master Plan, three environmental scenarios have been developed.[4] They are based on variations of the following six variables across plausible ranges established through a review of the literature (see the forthcoming Chapter 2 of Meselhe et al., 2015):

- Eustatic Sea Level Rise (ESLR)
    - Plausible range: 0.14 to 0.83 m over 50 years
- Subsidence
    - Plausible range: spatially variable (same as 2012 regions and values)
- Precipitation
    - Plausible range: -5% to +14% of the 50-year observational record
- Evapotranspiration
    - Plausible range: -30% to historical 50-year observational record
- Tropical Storm Frequency
    - Plausible range: For all tropical storms, -28% to no change
- Tropical Storm Intensity
    - Plausible range: +4% to +23% increase in central pressure deficit

Table 3 summarizes the differences among the three environmental scenarios. See the forthcoming Chapter 2 of Meselhe et al., (2015) for a discussion of how the scenarios were defined. Although tropical storms will be incorporated into the ICM, tropical storm intensity and frequency will only vary in the risk analyses in CLARA.

Table 3: Environmental Scenarios for the 2017 Coastal Master Plan.

Scenario	ESLR (m/50yr)*	Subsidence	Precipitation	Evapotranspiration	Overall Storm Frequency	Average Storm Intensity
	Used in ICM				Used in CLARA	
Low	0.43	20% of range	> historical	< historical	-28%	+10.0%
Medium	0.63	20% of range	> historical	historical	-14%	+12.5%
High	0.83	50% of range	historical	historical	0%	+15.0%

*rate of change is not linear

[4] For the 2012 Coastal Master Plan, two environmental scenarios were used – Moderate and Less Optimistic.

2.2.4.2 Risk Scenarios

Estimates of future risk depend upon the environmental scenario and two additional scenario factors – economic growth and structural protection system fragility (Fischbach et al., 2015).

The economic growth scenarios define how much growth in the number of residential and commercial structures occurs over the 50-year planning horizon and how it is distributed throughout coastal Louisiana. Three growth scenarios reflect a range of plausible future conditions:

- Historical growth
- Concentrated growth
- No growth

The fragility scenarios reflect different assumptions about how structural risk reduction projects will perform. The three fragility scenarios are:

- No fragility
- IPET fragility – the assumptions used in the 2007 Interagency Performance Evaluation Task Force (IPET) study of the New Orleans hurricane protection system performance during Hurricane Katrina (IPET, 2007)
- Morganza to the Gulf fragility – the assumptions used in the 2013 Morganza to the Gulf study (USACE, 2013)

Note that because estimates of the future landscape vary based on the environmental scenarios, all risk calculations will be evaluated across the combination of environmental scenarios and risk scenarios, for a total combination of 27 future conditions.

2.2.5 Projects

The systems models will evaluate 153 structural risk reduction and restoration projects and up to six nonstructural projects for each of 54 nonstructural project areas – first individually and then as a part of alternatives. These projects are distributed across the coast, as shown in Figure 9. To learn more about the process by which CPRA evaluated the list of candidate projects for consideration in the 2017 Coastal Master Plan, see Developing the List of Candidate Projects. As project attribute information was not yet completed by the writing of this draft report, specifics and visualizations of the individual projects will be included in the next draft of the report.

Individual risk reduction projects are evaluated by the risk models (ADCIRC-SWAN and CLARA), and individual restoration projects are evaluated only by the ecosystem models (ICM and EwE). When alternatives are evaluated, the ecosystem models will evaluate all restoration and risk reduction projects together. ADCIRC-SWAN and CLARA will then use the resulting coastal landscape to evaluate storm surge flooding and risk with the alternative's structural and nonstructural risk reduction projects implemented. In this way, the modeled alternatives will capture 1) the effects that landscape changes due to restoration projects will have on risk, and 2) the effects that structural risk reduction projects would have on the ecosystem metrics.

2.2.5.1 Risk Reduction Projects

The 2017 Coastal Master Plan will evaluate 20 structural risk reduction projects.[5] Some were selected in the 2012 Coastal Master Plan, and others are new inclusions.

While the restoration and structural protection projects evaluated in the 2012 Coastal Master Plan were specific and discrete, the nonstructural projects were a representation of mitigation measures that would apply to numerous structures in a specific project area. As described in Section 2.5.1, a new set of nonstructural projects are being formulated for 54 nonstructural project areas for the 2017 Coastal Master Plan. Each nonstructural project will identify the number of structures and costs for elevating, floodproofing, and acquiring properties to reduce flood risk. For each project area, several different project variants will be defined to represent different ways of determining how many and which structures need nonstructural protection measures.

CLARA estimates the effects on flood risk of both types of risk reduction projects – structural and nonstructural – in terms of flood depths, EAD, etc. using the same approach.

2.2.5.2 Restoration Projects

For the 2017 Coastal Master Plan, 133 restoration projects of the following types are being evaluated:

- Bank Stabilization
- Hydrologic Restoration
- Ridge Restoration
- Shoreline Protection
- Oyster Barrier Reef
- Marsh Creation
- Sediment Diversion
- Barrier Island Restoration

[5] The Planning Tool is considering two versions of the Larose to Golden Meadow project and three versions of the Morganza to the Gulf project.

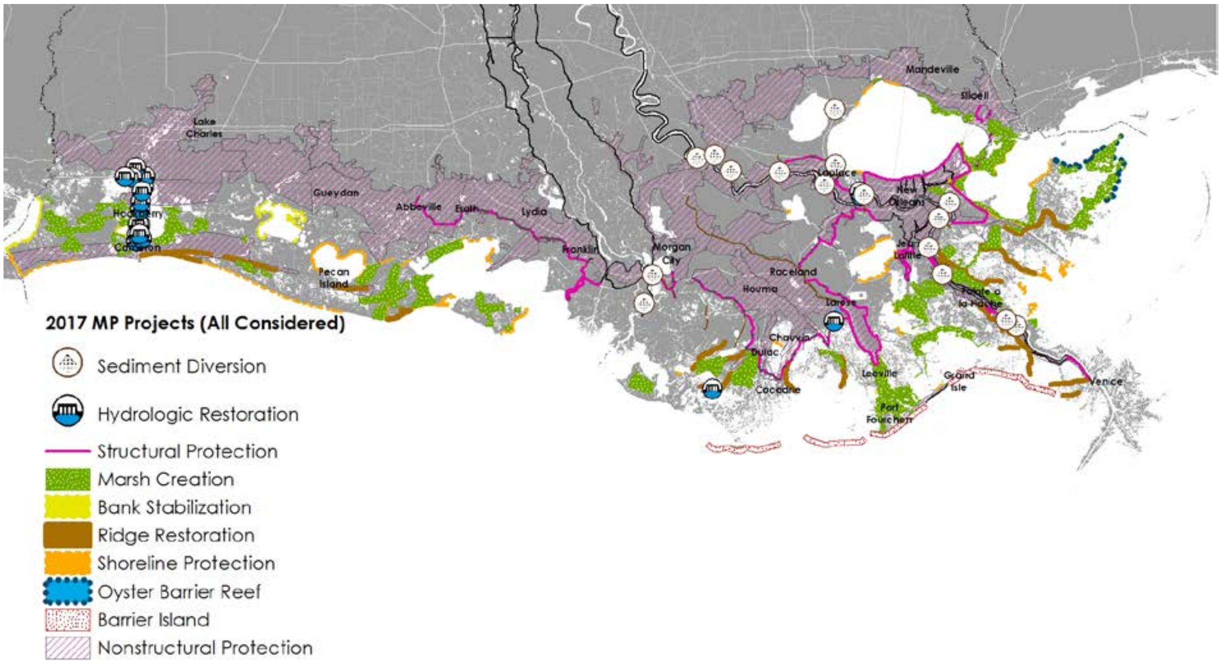

Figure 9: Restoration and Structural Protection Projects to be Evaluated.

2.3 Planning Tool Structure

The Planning Tool consists of three discrete elements –a database, an optimization model, and an interactive visualization package. Information is provided to the Planning Tool via structured input data sheets and user specifications of alternatives (Figure 10).

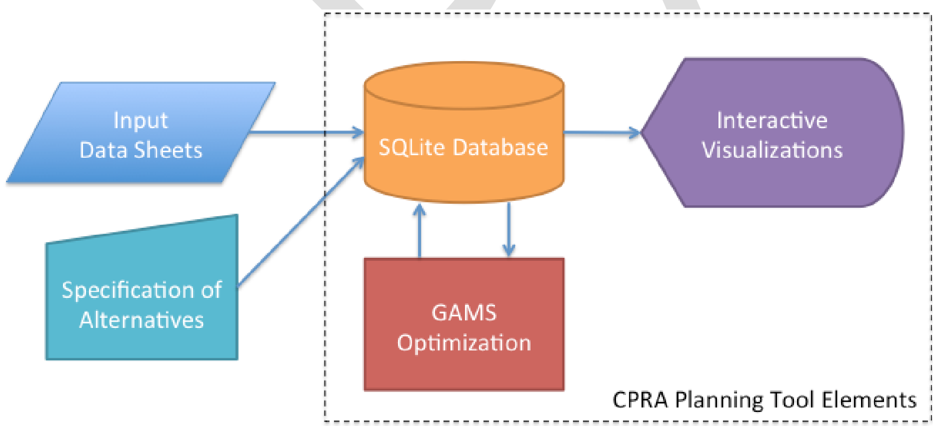

Figure 10: Planning Tool structure.

2.4 Data

To describe the functions of and calculations performed by the Planning Tool, it is helpful to first define and describe the data that are used as inputs as well as those generated by the Planning Tool. There are several different types of data:

- **Project attributes** – information about projects
- **Outcomes** – estimates of coastal conditions without and with the implementation of projects by the systems models with respect to specific metrics
- **Constraints** – information about limitations that affect how projects can be selected as part of an alternative
- **Alternative formulation specifications** – instructions for how the Planning Tool should assemble alternatives
- **Alternative results** – Planning Tool results specifying the projects to be implemented in each period for each alternative; estimated outcomes for each alternative

For the 2017 Planning Tool, all this information is stored in a structured SQLite database.[6] The SQLite database consists of a series of tables containing data structured around a defined variable naming convention. The database structure supports the easy development of derived tables through specific database queries. The Planning Tool optimization engine and visualizations use these derived tables as input. All data stored in the database includes metadata detailing the origin of and date of the data. The SQLite database format is also portable, allowing it to be transferred to others systems for archiving or other analyses.

The subsections below describe each data source.

2.4.1 Project Attribute Data

Attribute data for each project described in Section 2 is developed to support the Planning Tool analyses. Key attribute information includes:

- Project basics
  - Name, location, type, etc.
- Project costs (present $)
  - Planning, engineering, and design
  - Construction
  - Annual operations and maintenance
- Project phase durations (years)
  - Engineering and design
  - Construction
- Project sediment requirements and sources
- Project incompatibilities

[6] More information about SQLite can be found at www.sqlite.org. The 2012 Planning Tool database was comprised of several different MySQL databases, as the approach taken by the Planning Tool underwent significant changes during the development of the 2012 Coastal Master Plan.

For two project types, Marsh Creation and Barrier Islands, the amount of sediment required to construct a project could vary depending on when the project is implemented and the future conditions (reflected by the environmental scenarios). The provisioning of sediment for these projects is also a major cost driver. Therefore, for these projects, separate estimates of sediment requirements and construction costs are provided to the Planning Tool by scenario and implementation period. For some implementation periods and environmental scenarios, the landscape conditions may not be suitable for a project to be built at all – the water levels may be too deep, for example. In these cases, sediment requirements and costs are null, and the project is indicated as infeasible for the specific implementation period.

Projects that require sediment for construction are also assigned one or more specific sources from which sediment can be acquired (see Section 2.4.5). As described below in section 2.4.5, the sediment sources are limited. This information is also stored in the Planning Tool database for use by the optimization routine.

Some projects evaluated by the Planning Tool are not designed to be implemented in conjunction with others. For example, different nonstructural project variants for the same project region are under development. Only one of these project variants could be implemented for a given project area. The Planning Tool therefore also receives attribute information indicating which projects cannot be selected to be implemented together. This information is stored in the Planning Tool database for use by the optimization routine.

A set of scripts, developed in R (an open-source statistical programming language), are used to extract these data from a set of tables and geographic information system (GIS) layers provided by CPRA. An appendix to this report will provide an inventory of the key scripts.

2.4.2 Future Without Action Conditions

The systems models estimate coastal conditions without projects for each environmental and risk scenario, and they summarize this information for the Planning Tool. Ecosystem outcomes are aggregated by 11 ecoregions and provided every five years to year 50 (Figure 8, above). Risk outcomes are aggregated by 54 risk regions and provided for current condition, and years 10, 25, and 50 (Table 2, above). See Section 2.2.3.2, above, for details about the regions.

These data are provided to the Planning Tool team via .csv files, with each data element identified by metric, region, time slice, and environmental or risk scenario. Another set of R scripts read these data into the Planning Tool database.

2.4.3 Future With Project Outcomes

The systems models also estimate coastal conditions for each environmental and risk scenario with each individual project implemented, assuming that engineering and design begins in year 1. For example, a marsh creation project that takes 2 years to design and engineer and 6 years to construct is modeled by adding the project into the landscape at year 8. The results at year 10, thus, reflect the effects of the project after 2 years of completion.[7]

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[7] Note that in 2012, projects were modeled assuming construction was completed in year 0. The Planning Tool then offset benefits to account for design, engineering, and construction time, when assembling alternatives. For the 2017 analysis, this step is now unnecessary.

The future with project (FWP) outcome information is summarized and stored in the Planning Tool database in the same way as the FWOA condition (see Section 2.4.2), except with an additional identifier indicating the project.

2.4.4 Project Effects

For metrics with FWOA and FWP estimates, the Planning Tool calculates the project effects by subtracting the FWOA condition from the FWP estimate for each region, time slice, and scenario:

$$ProjectEffect_{p,t,r,m,f} = FWP_{p,t,r,m,f} - FWOA_{t,r,m,f}$$

where p = the project; t = time slice; r = *region*; m = metric; and f = scenario.

For example, the land project effect in a region in which there are 100 units of land in FWOA and 110 units when the project is implemented (FWP equals 110) is 10 units (110-100).

Project effects for some metrics are estimated in terms of changes from an unspecified baseline. For example, the systems models do not separately estimate a FWOA support for navigation metric. Rather, the FWOA condition is used as part of the way the metric assesses the effect of the project on support for navigation. For this type of metric, CPRA provides estimates of each project's effect on the metric (e.g., support for navigation) directly.

2.4.5 Constraints

The Planning Tool considers two types of constraints – implementation constraints and outcome constraints. Implementation constraints are related to factors that limit how many or which projects could be implemented. The key implementation constraints are:[8]

- Funding
- Sediment

Funding constraints are defined with respect to risk reduction projects and restoration projects separately and for each of the three implementation periods. CPRA provides the Planning Tool team with a table that includes a number of different funding scenarios, each defining a complete set of funding constraints.

For initial analysis, three funding scenarios are to be evaluated (Table 4). Note that in the Low Funding scenario, 80%of the period 1 funding would be allocated to restoration projects.

[8] For the 2012 Planning Tool, river use constraints were also used to limit the number and proximity of sediment diversion projects selected for a given alternative. For the 2017 Coastal Master Plan analysis, the set of possible sediment diversion projects is sufficiently restricted as not to require the application of a river use constraint.

Table 4: Preliminary Funding Scenarios.

	Low Funding ($40 billion)		High Funding ($70 billion)		High Funding #2 ($70 billion)	
	Restoration	Risk Reduction	Restoration	Risk Reduction	Restoration	Risk Reduction
Implementation Period 1	$6.4B	$1.6B	$7B	$7B	$7B	$7B
Implementation Period 2	$8B	$8B	$14B	$14B	$21B	$21B
Implementation Period 3	$8B	$8B	$14B	$14B	$7B	$7B

Sediment constraints are defined by a set of 78 individual sediment sources (i.e., borrow areas). For sources that are not within the Mississippi River channel, a single amount of sediment is specified. For Mississippi River-based sources, sediment is considered renewable. These sources are assigned a 5-yearly renewable volume. Both types of sediment constraints are stored in the Planning Tool database in a simple table containing the amount of sediment available for each implementation period.

The Planning Tool uses outcome constraints during alternative formulation to consider the effects of a project with respect to outcomes other than land and EAD. These constraints use the project effects results (Section 2.4.4) together with user-specified outcome constraints (Section 2.4.6). Section 2.5.3 describes how both types of constraints are used in the alternative formulation process.

2.4.6 Alternative Specifications

For the alternative formulation function, CPRA and the Planning Tool team will develop specifications for each alternative to be formulated. The specifications are recorded in an Excel-based table and include the following information:

- Meta data about the alternative
  - Intent narrative
  - Date of formulation
  - Date/version of data
- Description of objective function
- Budget scenario
- Environmental scenario (for formulation)
- Risk scenario (for formulation)
- Outcome constraints
- Hand-crafted project inclusions or exclusions

In the Planning Tool database, each alternative is assigned a unique ID number so that alternative results can be cross-referenced to the specifications used to formulate them.

For example, the baseline alternatives that maximize mid-term and long-term risk reduction and land for each of the three environmental scenarios would be specified as shown in Table 5.

Table 5: Example Specification for Three Baseline Alternatives.

Alternative ID	**1**	**2**	**3**
Formulation Date	11/1/2015	11/1/2015	11/1/2015
Data Source	Version P1	Version P1	Version P1
Objective Function	Max land/EAD; 50/50 MT/LT	Max land/EAD; 50/50 MT/LT	Max land/EAD; 50/50 MT/LT
Budget Scenario	$50 billion proportional	$50 billion proportional	$50 billion proportional
Environmental Scenario	ES-01	ES-02	ES-03
Risk Scenario	RS-01	RS-01	RS-01
Outcome constraint	P3 land sustainability > 0.01	P3 land sustainability > 0.01	P3 land sustainability > 0.01

2.4.7 Alternative Results – Projects and Estimated Outcomes

When the Planning Tool formulates an alternative, it defines which projects are implemented in each of the three implementation periods. Each project that is specified to be implemented begins accruing engineering and design costs in the first year of the implementation period. Construction costs are incurred immediately following engineering and design. Lastly, operations and maintenance continue through the end of the 50-year planning horizon (year 50). These results are stored in the Planning Tool database.

The Planning Tool also calculates for each alternative the expected outcomes for land, EAD, and select metrics at a 5-year interval for ecosystem metrics and at initial condition and years 10, 25, and 50 for risk metrics. See Section 2.5.3.4 for information on the specific calculation.

Other outputs from the alternative formulation calculations include:

- The cost for all restoration and risk reduction projects by implementation period (constrained by the funding scenarios)
- The required sediment by source and implementation period (constrained by the sediment source volumes)[9]

These outputs will help CPRA and stakeholders understand why the selected projects are selected. These results are stored in the Planning Tool database.

2.5 Functions

The Planning Tool performs a variety of functions in support of the CPRA master plan development, as listed and summarized in Figure 11. The subsequent subsections provide more detail for each function.

[9] This information can help determine if limited sediment availability is influencing the selection of projects for a specific alternative.

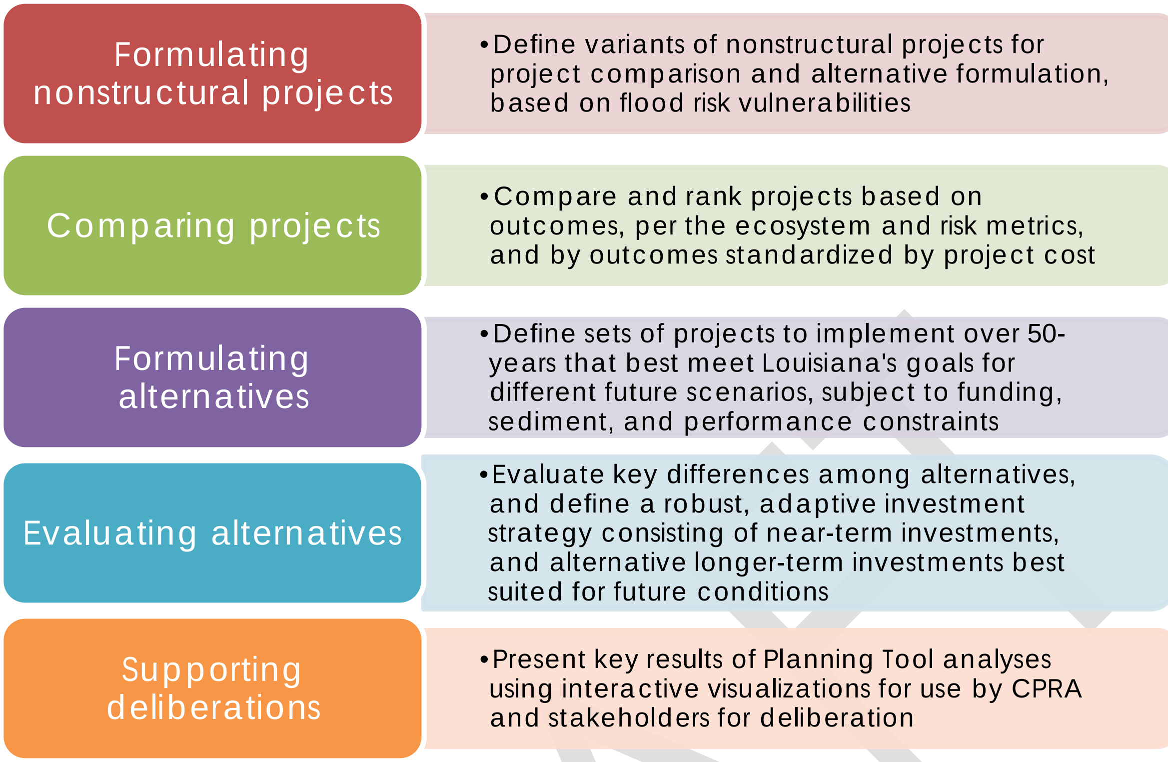

Figure 11: Planning Tool Key Functions.

2.5.1 Formulating Nonstructural Projects

For the 2017 Coastal Master Plan, CPRA developed a set of nonstructural projects (or variants) across the coast. The project variants specify nonstructural mitigation designed for different elevation standards and considerations of community characteristics, such as low to moderate income (LMI) households in the project areas. A wide range of nonstructural projects will enable the Planning Tool to identify the level of nonstructural investment that, when combined with the structural risk reduction projects, most cost-effectively reduces risk. In some areas, only a low level of nonstructural mitigation will be appropriate. In other cases, more extensive nonstructural mitigation will be required to reduce risk in vulnerable communities.

Nonstructural project variants were developed for a new set of 54 nonstructural project areas defined for the 2017 Coastal Master Plan (see Fischbach et al., 2015). These nonstructural project areas were defined to consider interactions among structural and nonstructural projects at an appropriate spatial scale. Each nonstructural project area is contained within one of the 54 risk regions shown in Figure 12.

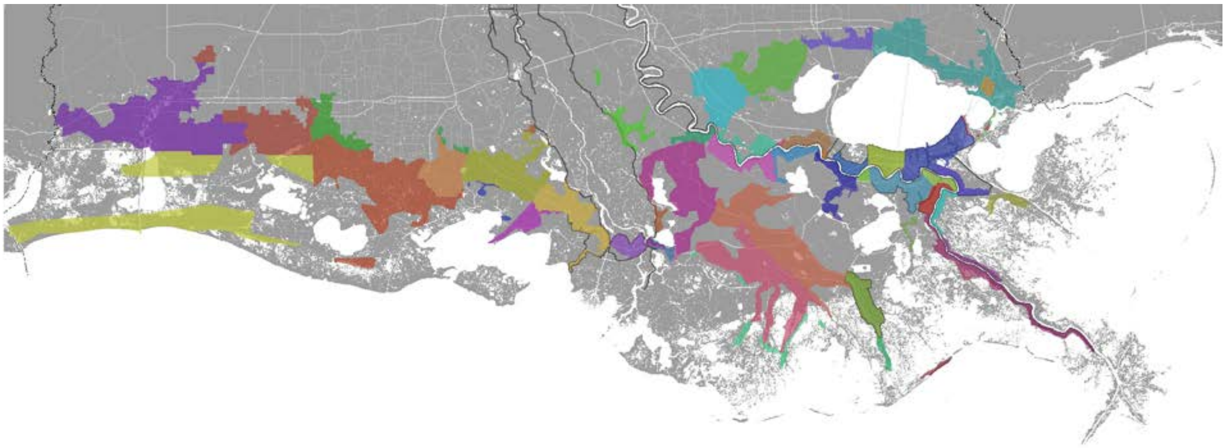

Figure 12: Nonstructural Project Areas for 2017 Coastal Master Plan.

Risk Mitigation Elevation Standards

To identify the nonstructural project variants different risk mitigation elevation standards were considered. Each elevation standard was based on CLARA estimates of the 100-year flood depth, plus 2 feet of freeboard, at three specified future time periods – current condition, year 10, and year 25 – and for each of the three environmental scenarios described above. CLARA considered elevation standards based on the following seven conditions:

- Current condition
- Year 10, Low environmental scenario
- Year 10, Medium environmental scenario
- Year 10, High environmental scenario
- Year 25, Low environmental scenario
- Year 25, Medium environmental scenario
- Year 25, High environmental scenario

CLARA used the calculated elevation standard at each grid-point (see below) to specify the type of mitigation for each structure:

- Commercial structures are to be floodproofed where the elevation standard is less than 3 feet
- Residential structures are to be elevated where the elevation standard is between 3 and 14 feet
- Residential structures are to be acquired if elevation standards is greater than 14 feet

Grid-Point Analysis for Different Elevation Standards

CLARA defined nonstructural mitigation for a set of grid points within the study domain. There are 90,373 total grid points in the CLARA study area for coastal Louisiana, although not all grid points have structures that are at risk to flooding. The grid has a minimum resolution of 1 km^2, with higher than 1 km^2 resolution in areas with a high density of census blocks, population, and assets

(Fischbach et al., 2015). Each grid point is associated with one of the 54 nonstructural project areas, as seen in Figure 13.

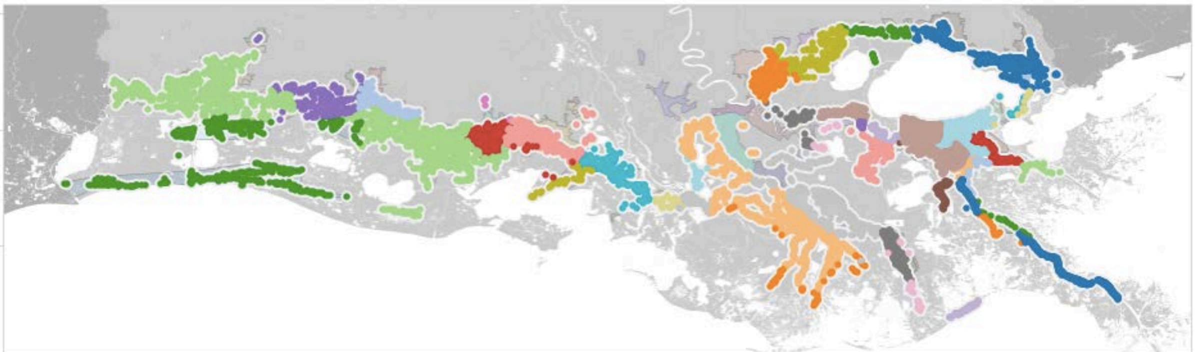

Figure 13: Grid Points Used to Define Nonstructural Projects.

The CLARA team calculated for each grid point, a set of mitigation actions based on the seven different elevation standards, assuming an 80% participation rate. For each grid point and elevation standard, CLARA calculated:

- Number of structures mitigated (flood-proofed, elevated, acquired)
- Cost of mitigation
- Reduction in EAD from the nonstructural mitigation for years 10, 25, and 50, for each environmental scenario[10]

This information, along with estimates of the 100-year current and future flood depths, the percent of LMI households, and the number of repetitive and severe repetitive loss properties, was then passed to the CPRA Planning Tool for evaluation by CPRA.

Defining Nonstructural Project Variants

The Planning Team next defined a set of rules that would apply to all 54 nonstructural project areas and define variants for each project area. Each variant consists of a unique set of nonstructural projects across the coast. The Planning Tool assisted in this process by interactively showing how specific rules would lead to different sets of nonstructural projects, as described below.

Each variant was defined based on the following user-specified information in the Planning Tool:[11]

- Elevation standard (i.e., year and environmental scenario for 100-year flood estimate)

[10] To manage the number of total scenarios evaluated at this step, we assumed historical growth and the no fragility scenarios. Differences in FWOA risk under alternative growth and fragility scenarios are small across the coast. Note that as described below, all risk reduction projects (including nonstructural projects) will be evaluated across all growth and fragility scenarios.
[11] CPRA chose not to define variants based on repetitive and severe repetitive loss properties but rather to use this information for context when defining the variants.

- Constraint on the inclusion of grid points based on the percentage of LMI households
- Constraint on the cost-effectiveness of mitigation for each grid point, where cost-effectiveness is defined by the current-year EAD reduction divided by the cost of the nonstructural mitigation

For each set of rules, the Planning Tool depicts the number of structures floodproofed, elevated, and acquired for each grid point. Figure 14 shows these results for a variant with an elevation standard based on current 100-year flood depths.

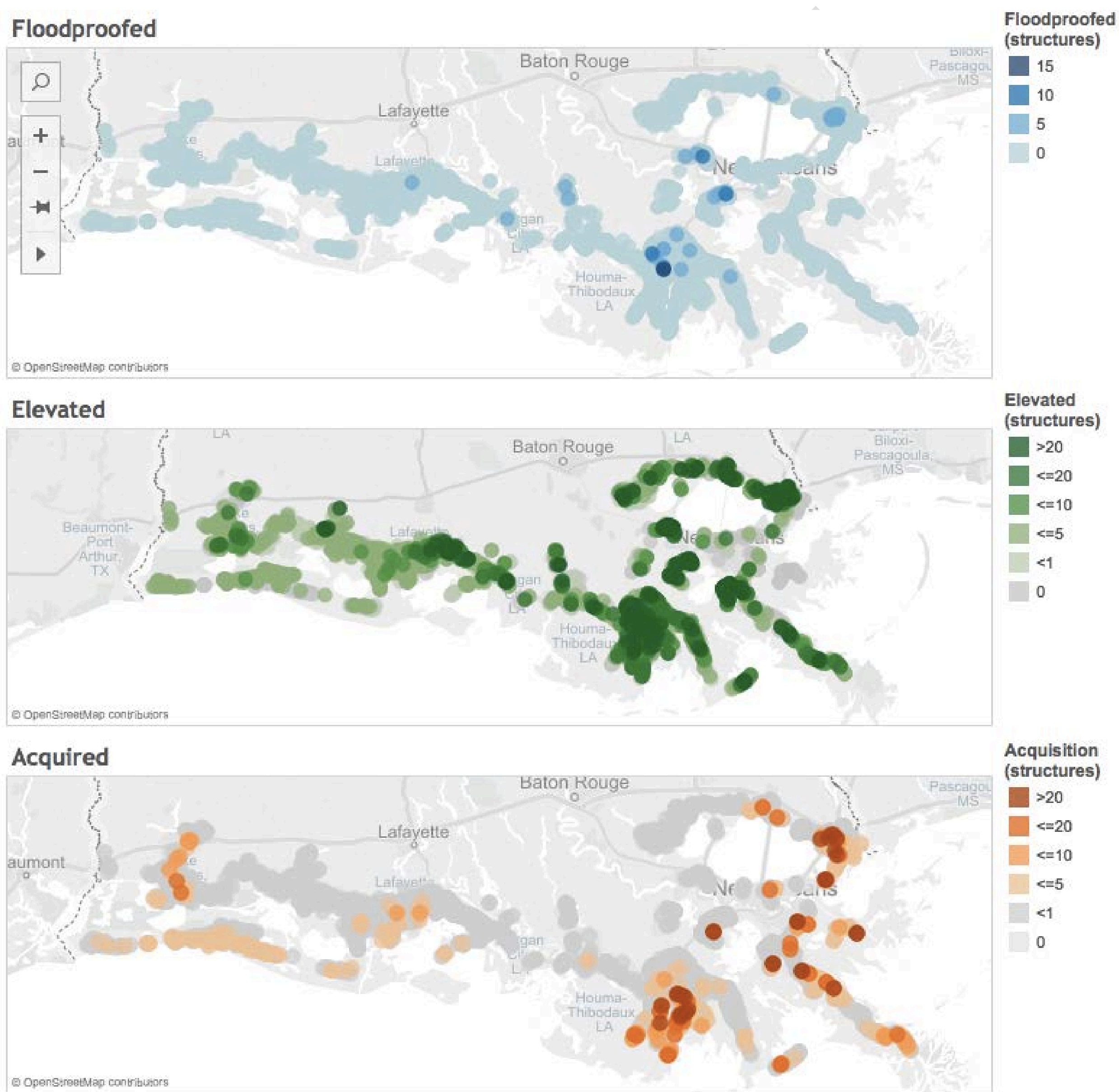

Figure 14: Number of structures mitigated by grid point for nonstructural project variants based on current 100-year flood depths.

For each variant, the Planning Tool can also show for the included grid point's additional vulnerability information such as the LMI households, repetitive loss and severe repetitive loss properties, current 100-year flood depths, and year 50 100-year flood depths (Figure 15).

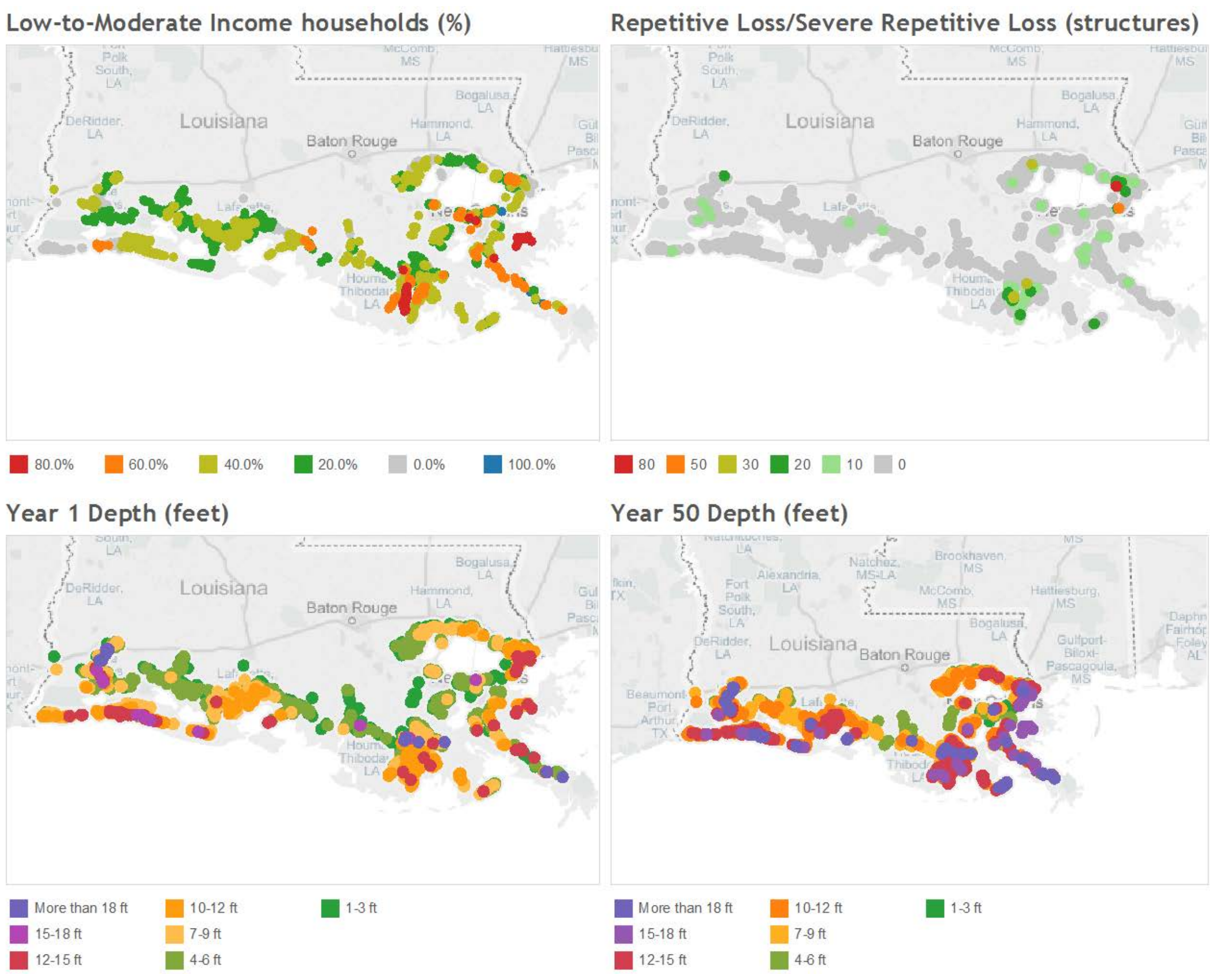

Figure 15: Vulnerability attributes for each grid point for variant with elevation standard based on current 100-year flood depths.

Preliminary Nonstructural Project Variants for 2017 Coastal Master Plan

To assist in the development of a range of nonstructural project variants, the Planning Tool summarized the nature of the mitigation, costs, and damage reductions for up to six different specifications. Using this functionality, CPRA defined the six project variants shown in Table 6. These variants focus primarily on different elevation standards, although variant 5 also includes grid points with more than 30% LMI households.

Table 6: CPRA defined nonstructural project variants.

Variant	Elevation Standard		Additional Constraint
	Time slice	Environmental Scenario	
1) Current Conditions	Current conditions	n/a	n/a
2) Year 10, Low	Year 10	Low	n/a
3) Year 10, Medium	Year 10	Medium	n/a
4) Year 10, High	Year 10	High	n/a
5) Year 10, Medium, LMI	Year 10	Medium	LMI > 30%
6) Year 25, Medium	Year 25	Medium	n/a

Evaluating Nonstructural Project Variants

The CLARA model will next evaluate each nonstructural project for current conditions and years 10, 25, 50, and across the environmental scenarios and risk scenarios. These nonstructural project variations are compared to each other and the structural risk reduction projects (see Section 2.5.2). They are then also included in the Planning Tool's process of developing risk reduction alternatives (see Section 2.5.3).

2.5.2 Comparing Projects

The Planning Tool compares individual projects based on systems model estimates of their effects on the coast and the effects scaled by total project cost. Rankings of projects by outcomes and cost-effectiveness for key metrics provide CPRA and stakeholders with a first-order assessment of which projects could most efficiently help achieve Louisiana's goals.

A project's effect on the coast is the difference between the FWP outcome and FWOA outcome for a given metric, time slice, and region:

$$ProjectEffect_{metric,timeslice,region,p} = FWP_{metric,timeslice,region,p} - FWOA_{metric,timeslice,region}$$

The Planning Tool calculates cost-effectiveness for the mid-term (year 25) and the long-term (year 50).[12] These calculations assume that the projects are implemented at the initial condition, and that the project effects take into account the time required to design, engineer, and construct each project. To calculate cost-effectiveness, the effects are scaled using 50-year project costs, which include planning, design, and construction costs, plus operations and maintenance costs through the 50-year time horizon. The Planning Tool can also consider how

[12] In the 2012 Planning Tool, projects were compared based on a near-term (year 20) time slice instead of a mid-term time slice (year 25).

different project costs, reflecting uncertainty in the cost estimates, would affect the project rankings.

Mid-term and long-term cost-effectiveness for each restoration project, p_e, is calculated as:

$$MidtermCostEffectiveness_{ecometric,p_e} = \frac{CoastwideProjectEffect_{ecometric,year25,p_e}}{ProjectCost_{p_e}}$$

$$LongtermCostEffectiveness_{ecometric,p_e} = \frac{CoastwideProjectEffect_{ecometric,year50,p_e}}{ProjectCost_{p_e}}$$

where the *CoastwideProjectEffect* is equal to *ProjectEffect* summed over all ecoregions. *ProjectCost* is the 50-year cost of the project and is calculated as the sum of the costs for engineering and design (*EDcost*), construction (*Constructioncost*), and operations and maintenance ($OMannualcost$) for the remaining number of years in the 50-year planning period after the project is constructed:

$$ProjectCost_{p_e} = EDcost_{p_e} + Constructioncost_{p_e} + OMannualcost_{p_e} \times \left[50 - \left(EDtime_{p_e} + Constructiontime_{p_e}\right)\right]$$

For risk reduction projects, p_r, the Planning Tool calculates mid-term and long-term EAD cost-effectiveness scores in a similar way as for restoration projects:

$$MidtermCostEffectiveness_{riskmetric,p_r} = \frac{CoastwideProjectEffect_{riskmetric,year25,p_r}}{ProjectCost_{p_r}}$$

$$LongtermCostEffectiveness_{riskmetric,p_r} = \frac{CoastwideProjectEffect_{riskmetric,year50,p_r}}{ProjectCost_{p_r}}$$

In general, all restoration projects will be compared based on the same set of ecosystem metrics and all risk reduction projects will be evaluated based on the same set of risk metrics. There may be some minor exceptions, which will be identified as the modeling results are completed. For example, to better show how nonstructural projects that are of lower cost-effectiveness than other structural projects may be selected in regions where there are no structural options, the Planning Tool could delineate the project comparisons by those areas with and those without structural risk reduction projects. This comparison would highlight the most cost-effective nonstructural projects in areas without structural protection options.

The Planning Tool stores these results in the database and uses them for interactive visualizations (see Section 2.5.5).

2.5.3 Formulating Alternatives

The Planning Tool develops alternatives – defined as sets of projects to implement in each of the three implementation periods – that best achieve CPRA goals, subject to implementation and performance constraints. There is no “correct” alternative, and the Planning Tool is designed to formulate many alternatives and summarize the key differences among them. Some alternatives might vary key implementation constraints such as project funding. Others will consider the effects on land or EAD outcomes if requirements for performance with respect to other metrics, such as shrimp habitat, are added. The Planning Tool is flexible and can be modified to respond to CPRA and stakeholders interests.

2.5.3.1 Overview

In general, the Planning Tool uses an optimization model to select the restoration and risk reduction projects that will maximize mid-term and long-term land building and EAD reduction. For the 2012 Coastal Master Plan, the Planning Tool defined the optimal projects for all three implementation periods simultaneously. While this process ensured that projects were selected so that near-term and long-term benefits were as high as possible, the procedure in some cases specified that highly cost-effective projects be delayed to later implementation periods.

For the 2017 Coastal Master Plan, the Planning Tool instead selects the optimal projects for each of the three implementation periods, in turn. This procedure ensures that the best projects are selected in the first implementation period, the next best in the second, and so on. CPRA believes that this approach makes the most sense given the significant uncertainty about how precisely the Coastal Master Plan will be implemented over the coming decades. Of paramount concern to CPRA is defining and implementing projects now that will most efficiently put Louisiana on a trajectory of sustainability.

The procedure first selects projects to implement in period 1 (years 1-10). The Planning Tool assumes that these projects are implemented beginning in year 1 and that cost and sediment requirements for the first 10 years of each project must be met by period 1 funding and sediment sources. Cost and sediment requirements can also span more than one implementation period, and any additional sediment and cost requirements must also be met by the funding and sediment sources in that later implementation period. Therefore, the available sediment and funding budget for the following implementation period is adjusted before the Planning Tool identifies projects for implementation in period 2 (years 11-30). Constraints pertaining to project compatibilities are also imposed.

The Planning Tool next selects projects to implement in period 2 (years 11-30). Any project not selected in the first implementation period is a candidate for selection. These projects are assumed to begin engineering and design in year 11 and accrue costs from that year forward. The Planning Tool ensures that all funding and sediment requirements are met. After selecting projects from implementation period 2, the same steps are performed to identify projects to implement for period 3 (years 31-50). Figure 16 shows this three-step process graphically.

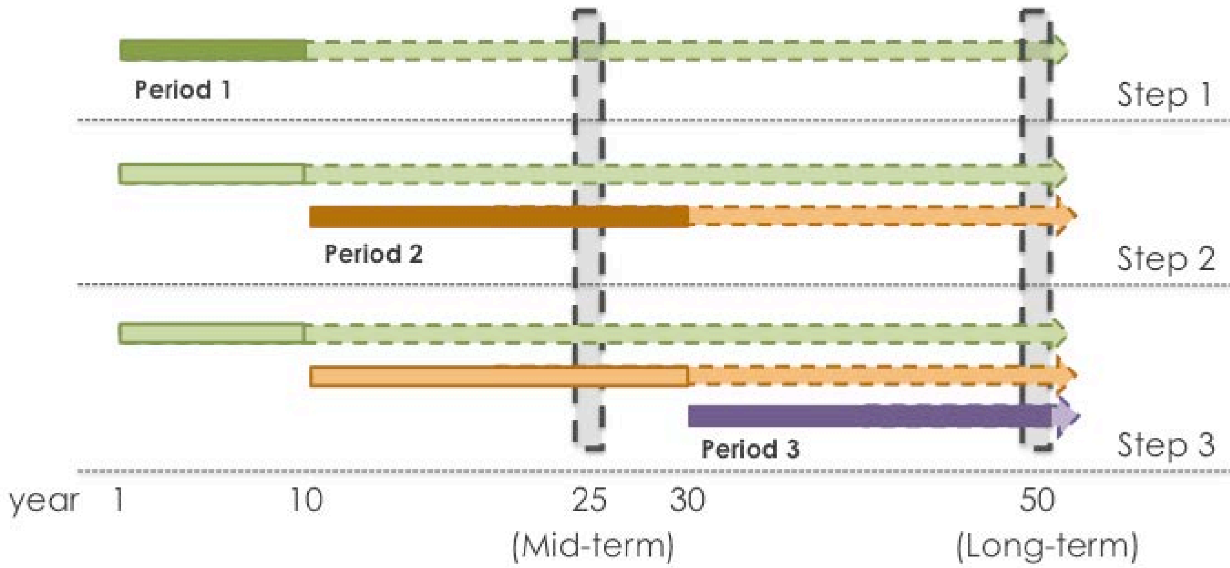

Figure 16: Schematic Illustrating Sequential Optimization Procedure.

In addition to maximizing mid-term and long-term land and EAD reduction, other performance constraints are considered in this process. First, since a project implemented in period 3 will only reach a life span of 20 years at the end of our evaluation period (50 years), a constraint on sustainability of land is added to ensure that these restoration projects are projects whose positive effects will persist or grow beyond year 50. The sustainability of land constraint limits restoration project selection in period 3 to those projects that have stable or increasing land effects between modeled years 40 and 50. Currently, there is no sustainability constraint imposed on risk reduction projects, as the risk effects of projects are only estimated for years 25 and 50. CPRA will review the projects selected during the alternative formulation process and if necessary propose adjustments based on a qualitative assessment of the sustainability characteristics of the selected risk reduction projects.

Other performance constraints can also be imposed when formulating alternatives 1) to better understand whether improvements in other metrics could be achieved at a minimal effect to the decision drivers, land and EAD reduction, and 2) to ensure that specific outcomes are achieved while maximizing land and EAD. Iterative alternative formulation and review of these results will support CPRA deliberations.

2.5.3.2 Data Processing

Project attribute information from CPRA and project effects information from the systems models are key inputs to the Planning Tool for alternative formulation. Before using these data to formulate alternatives, two sets of calculations are required. First, each project's cost and sediment requirements must be distributed over time in order to determine how much applies to each implementation period. The Planning Tool distributes engineering and design costs evenly across the duration of the engineering and design period, and does the same for construction costs. It then applies the annual operations and maintenance cost to each year after construction is complete. Table 7 provides an example for a project's costs and duration for each phase, and Figure 17 shows how these costs are distributed annually depending on the period of implementation.

Table 7: Example Project Phase Costs and Duration.

	Costs	Duration
Engineering and Design	$10M	5 years
Construction	$140M	7 years
Operations and Maintenance	$1M/year	Until year 50

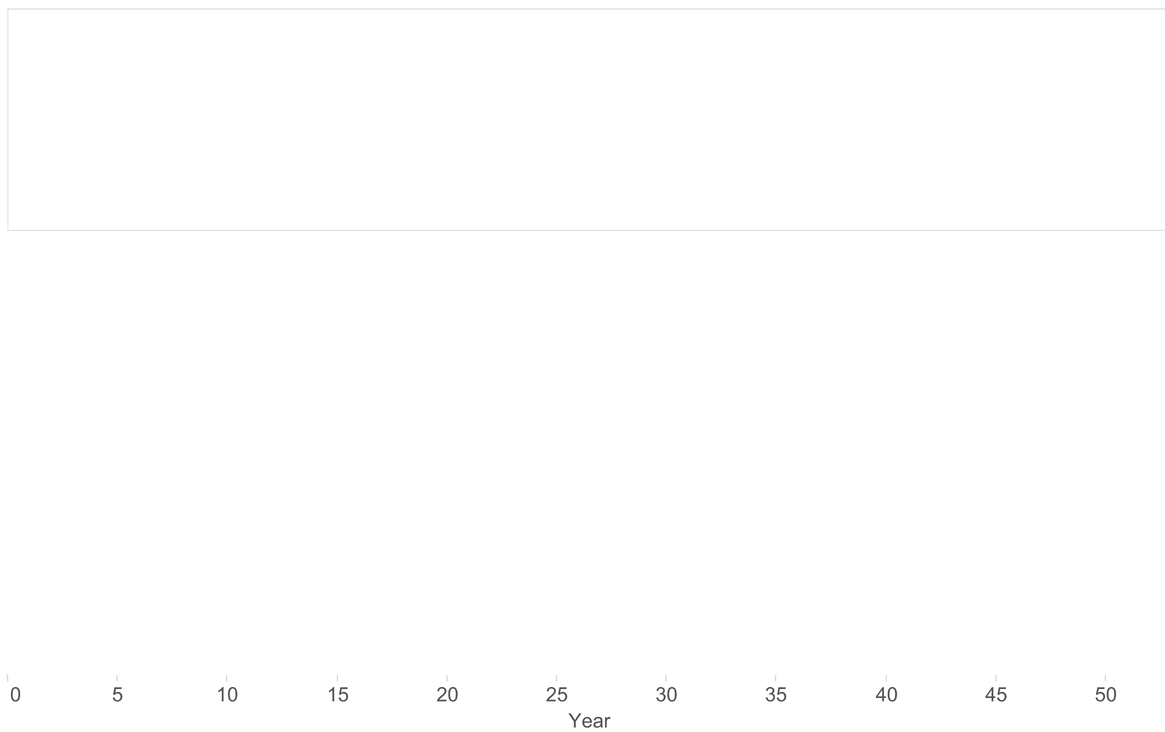

Figure 17: Example Distribution of Project Costs for Three Periods of Implementation.

For a project's sediment requirement, the total requirement is simply distributed evenly across the years in which the project would be constructed, depending on the implementation period.

The next step is to calculate the Offset Project Effects matrix, which specifies a project's effect for each metric when implemented in each of the three implementation periods. Calculating this matrix requires shifting of estimated project effects by the implementation period and, for risk reduction projects, interpolating project effects to 5-year intervals. Note that the Planning Tool assumes that if a project is implemented in the 2nd or 3rd implementation periods, then the effects in the mid-term (year 25) and long-term (year 50) are equal to the modeled effects, shifted by 10 years and 30 years earlier, respectively (Table 8). Effects for intermediate time periods are estimated similarly.

Table 8: Modeled Results Used to Approximate Effects of Projects Implemented in Each of the Three Implementation Periods.

	Select time slices for offset effects						
Implementation Period	Initial condition*	Year 5	Year 10	Year 25 (mid-term)	Year 30	Year 40	Year 50 (long-term)
1 (years 1-10)**	Initial condition	5	10	25	30	40	50
2 (years 11-30)	n/a	n/a	0	15	20	30	40
3 (years 31-50)	n/a	n/a	n/a	n/a	0	10	20

* For some metrics, results are provided at the end of year 1, not initial condition.
** Note that there is no offset of results for implementation period 1.

For risk reduction projects, the systems models report effects at initial condition and years 10, 25, and 50. Therefore, the Planning Tool must interpolate the effects for those time slices in which the offset year is not one of those provided by the systems models (i.e., initial condition and years 10, 25, or 50). This is done first, assuming project implementation in period 1. Then estimates for projects if implemented in periods 2 and 3 are made by shifting the period 1 estimates in time by the implementation delay.

For structural risk reduction projects, benefits are assumed to begin once construction is completed. As risk results are provided only at discrete time slices (i.e., years 10, 25, and 50), risk results for the year after construction is completed are assumed to be equal to the risk reduction results reported for the next reported year (i.e., years 10, 25, or 50). Benefits are then linearly interpolated between all later reported time periods.

For example, if the planning, design, and construction time is 15 years, then the project effects from years 15 to 25 are equal to those reported by the systems model at year 25. Benefits between years 25 and 50 are interpolated from the model results reported at years 25 and 50. Figure 18 illustrates the interpolation and offsetting procedure for a structural project if implemented in each of the three periods. In this example, CLARA provides to the Planning Tool zero risk reduction for years 0 and 10, a moderate amount of risk reduction in year 25 (left vertical bar) and even more risk reduction in year 50. The red line shows the level of interpolated risk based on the rules described above for the cases in which the project is implemented in each period. Note that the benefits for implementation periods 2 and 3 are simply those estimated for implementation period 1, shifted by the implementation delay.

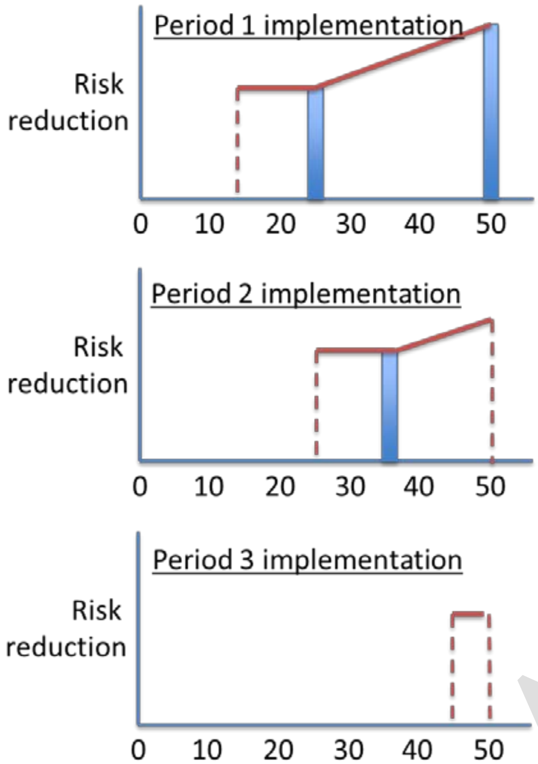

Figure 18: Illustration of Interpolation and Offsetting Procedure for a Structural Risk Reduction Project.

For nonstructural projects, it is assumed that the numbers of structures mitigated increases steadily through the construction period. Therefore, risk reduction is assumed to increase linearly from zero, at the beginning of the implementation period, to the first reported level of risk reduction – either in years 10, 25, or 50. Figure 19 illustrates the interpolation and offsetting procedure a nonstructural risk reduction project with the same construction duration (15 years) and modeled effects as shown for a structural project in Figure 18. Note that since the construction period of the nonstructural project is assumed to take 15 years in this example, the CLARA model would only reports risk reduction in years 25 and 50, as shown in Figure 19.

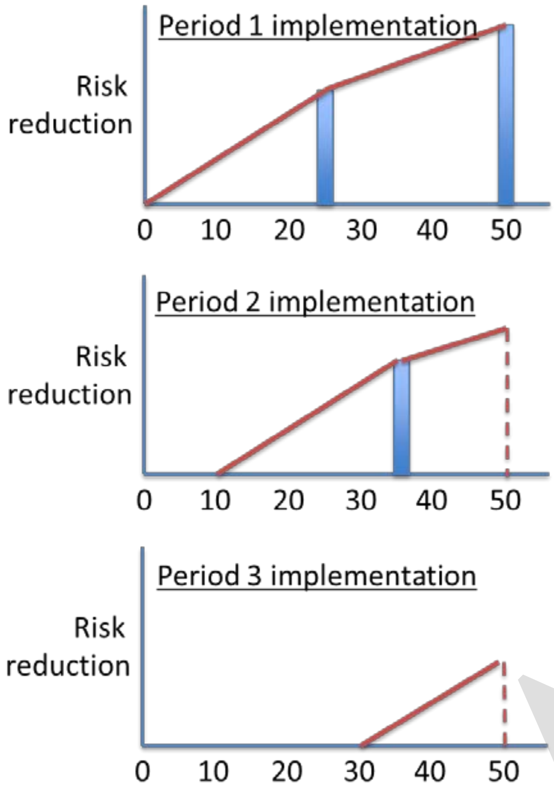

Figure 19: Illustration of interpolation and offsetting procedure for a nonstructural risk reduction project.

For restoration projects, project effects are provided to the Planning Tool at 5-year intervals, so no interpolation is required.

2.5.3.3 Optimization Calculation

The Planning Tool selects projects for each implementation period using an optimization model developed in GAMS.[13] Specifically, GAMS solves a mixed integer program in which the decision variables are binary choices, *I*, to implement or not implement a project in one of the three implementation periods, *i*. The objective is a simple function including mid-term and long-term land and risk reduction. The algorithm maximizes the objective function subject to available funding and sediment, and some additional constraints defined below:[14]

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[13] GAMS (General Algebraic Modeling System) is a high-level modeling system. It consists of a language compiler and a stable of integrated high-performance solvers. CPLEX is used in this application.

[14] Note, that for some variables, like EAD reduction, there is a theoretical-maximum that could be achieved in each risk region – zero risk. Therefore, the function above limits the total EAD reduction for a region to the FWOA level of risk, as indicated by the "*".

$$Max \sum_{p_r}\left[-\left(offset\_effect^{*}_{EADreduction,i,year25,p_r} + offset\_effect^{*}_{EADreduction,i,year50,p_r}\right) \times I_{i,p_r}\right]$$

$$+ \sum_{p_e}\left[-\left(offset\_effect_{land,i,year25,p_r} + offset\_effect^{*}_{land,i,year50,p_e}\right) \times I_{i,p_e}\right]$$

by choosing $I_{i,pr}$ = {1 or 0}, subject to the following funding constraints:

$$\left(\sum_{p_r} I_{i,p_r} \times Cost_{i,p_r}\right) \leq RiskFunding_i$$

$$\left(\sum_{p_e} I_{i,p_e} \times Cost_{i,p_e}\right) \leq RestorationFunding_i$$

and sediment constraints (for restoration projects), for each sediment source, *s*:

$$\left(\sum_{p_e} I_{i,p_e} \times SedimentRequirement_{i,p_e,s}\right) \leq SedimentSource_{i,s}$$

and sustainability of land constraint for implementation period, *i=3*, for each restoration project, p_e:

$$\left(\sum_{p_e} I_{i,p_e} \times offset\_effect_{m=sustainability\_of\_land,i=3,p_e}\right) \geq g$$

where *g* is some specified threshold for the sustainability of land metric.[15]

The Planning Tool includes additional constraints to ensure that only one of a set of mutually exclusive projects is implemented.

Note that for non-Mississippi River sediment sources, the total amount of available sediment is made available in implementation period 1. Sediment not used in period 1 is available in implementation period 2 and so on. For river sediment sources, the Planning Tool takes the 5-yearly renewable amount and sets the total available sediment to be 2 times the 5-yearly amount for implementation period 1 and 4 times the 5-yearly amount for implementation periods 2 and 3. There is no carryover of unused sediment between the implementation periods.

The Planning Tool is flexible and may be adjusted to ensure that a desired mixture of projects is selected for the 2017 Coastal Master Plan. For example, if a particular type of project is not as cost-effective in terms of land (for restoration projects) or EAD (for risk reduction projects) as others; the Planning Tool might define alternatives without sufficient project diversity. While this did not occur in the 2012 Coastal Master Plan process, if it does, additional constraints could be

[15] In testing of this method using 2012 data, a value slightly larger than 0 was used to exclude projects that exhibited no or declining land effects between 2040 and 2050.

added that require a minimum amount of expenditure on each project type. This approach could be used to ensure that sufficient nonstructural projects are selected even if they are formulated to emphasize the targeting of particular vulnerabilities, such as LMI properties, at the expense of cost-effectiveness.

2.5.3.4 Optimization Outputs

For each alternative, the Planning Tool defines the projects to implement and estimates the expected outcomes coast wide with respect to key metrics for each alternative.

Expected outcomes are calculated using an additive assumption, per the following formula:

$$Expected\_outcome_{m,t,r} = FWOA_{m,t,r} + \sum_{p} offset\_effect_{p,m,t,r}$$

where *FWOA* is the future without action outcome; *m* is a specific metric (e.g., land); *t* = time slice (e.g., year 10); *r* = region; *p* = selected projects from the alternative. The *offset_effect* for metric, *m,* is the project effect offset by the implementation period defined for each specific project, *p,* time slice, *t*, and region, *r* (see Section 2.5.3.2 and Table 8, above).

The expected outcome calculation is performed only for those metrics that have FWOA values and can be reasonably assumed to be additive. As outputs are generated, whether or not they are additive will be assessed and stored in the Planning Tool database.

Interactive visualizations show comparisons of the projects selected and the estimated outcome across the alternatives, as described in Section 2.5.5.

2.5.4 Evaluating Alternatives

2.5.4.1 Comparing Alternatives of Different Specifications

The Planning Tool helps CPRA to compare different alternatives through visualizations that compare:

- Project selection across implementation periods
- Expected outcomes

The 2012 Planning Tool, for example, formulated a set of alternatives that included different constraints on the *Use of Natural Processes* metric score for selected projects. By evaluating both the projects included in the different alternatives (Figure 20) and the effect on EAD reduction, compared to FWOA (Figure 21), CPRA gained valuable insight into how to specify an alternative that reduced risk and used natural processes.

Figure 21 shows, for example, the differences between EAD and constraints placed on the use of the natural processes metric. When no constraint is applied, EAD is reduced as much as possible. Once the use of a natural processes criterion threshold is greater than a value of -2.0 (i.e., less negative, moving to the right of the graph), progress toward reducing EAD begins to decrease significantly.[16] This occurs because the Planning Tool ceases to include major cross-basin levee

[16] The use of natural processes decision-criterion score is calculated by summing all the included projects' use of natural processes criterion scores (described in CPRA, 2012c, Appendix B,

alignments that score less than -2.0 for the use of natural processes decision criterion. Figure 20 shows which risk reduction projects are included for alternatives that include different constraint levels on the use of natural processes decision criterion. Applying a constraint greater than or equal to -2.4 significantly changes the alternative by replacing the extensive Southwest GIWW levee alignment with the much smaller Lake Charles levee alignment along with additional nonstructural protection projects for the western portion of the state. Even tighter constraints on natural processes (values even farther to the right on the graph) eliminate additional levees, including the Lafitte Ring Levee (at ≥-2.0), Lake Charles 500-Year Protection (at ≥-1.6), Morganza to the Gulf (High) (at -0.8 and ≥0), and Lake Pontchartrain Barrier (Low) (at ≥-0.4).

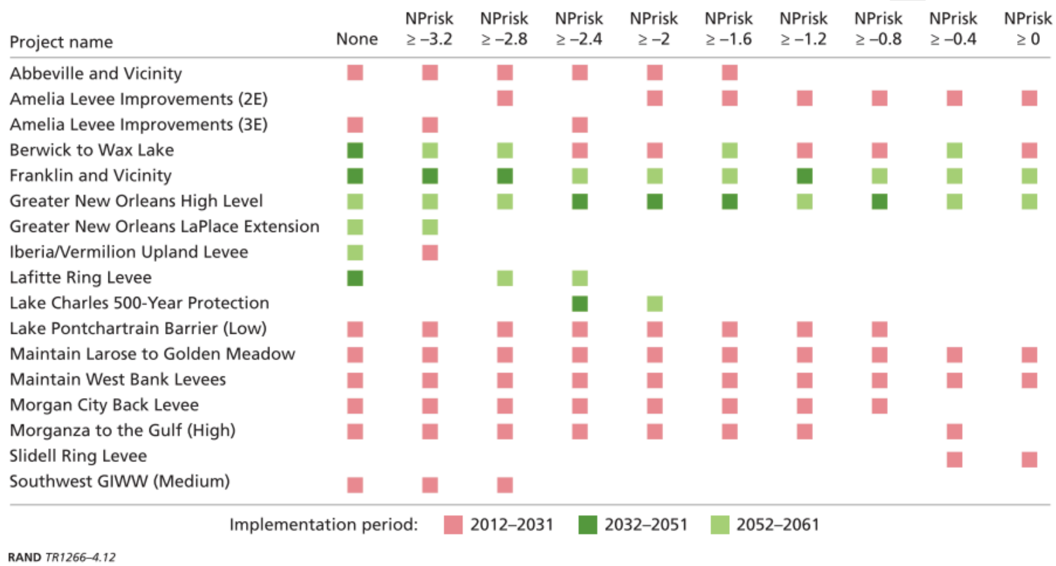


Figure 20: Structural Risk Reduction Projects Included for Alternatives Generated by Imposing Constraints on the *Use of Natural Processes*, from 2012 Coastal Master Plan Analysis.

Source: Groves et al. (2012).

Attachment B6). An alternative's use of natural processes criterion score is meaningful only to compare with other alternatives.

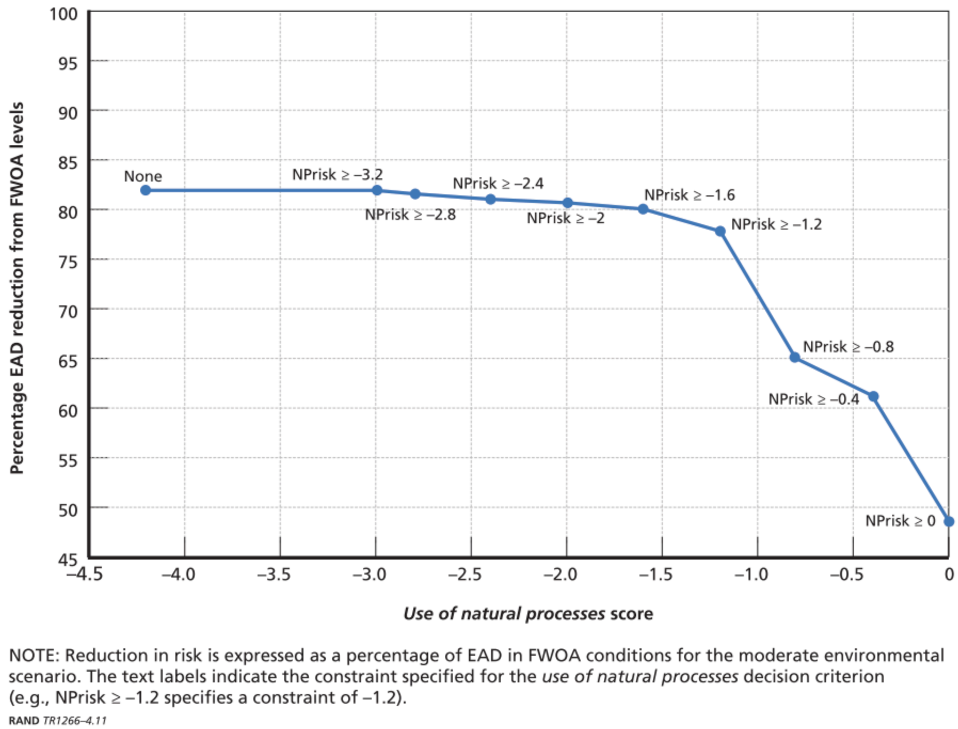
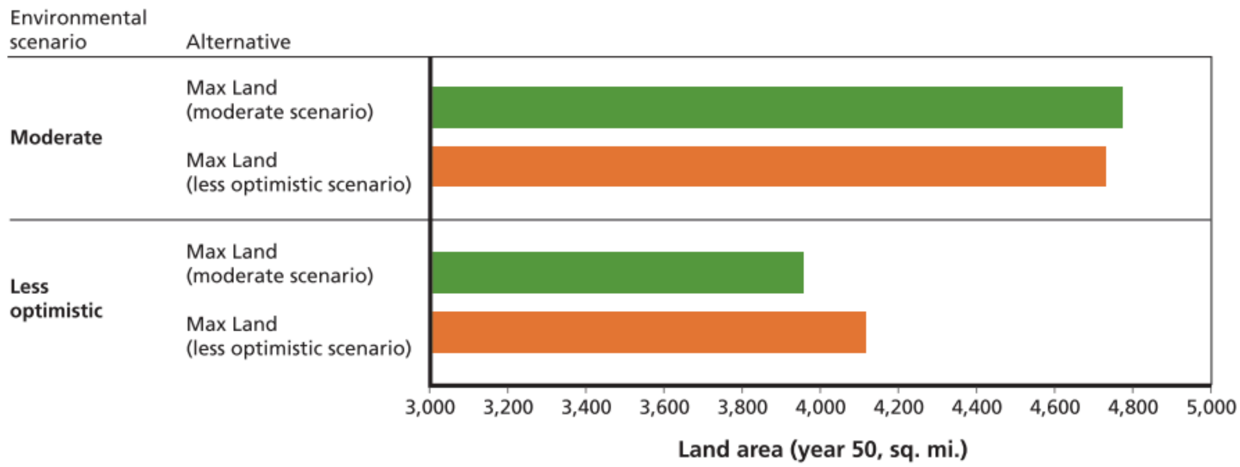


Figure 21: Reduction in EAD Versus the *Use of Natural Processes* Metric for Ten Alternatives.
Source: Groves et al. (2012).

2.5.4.2 Defining a Robust, Adaptive Master Plan

The 2017 Coastal Master Plan analysis will develop alternatives not only across different specifications, but also for each environmental and risk scenario. In 2012, only two environmental scenarios were evaluated. The results were therefore relatively straightforward to evaluate. The Planning Tool compared how the alternative formulated in one scenario would perform in the other, and vice versa (Figure 22). This analysis showed that the projects that were best suited for the *Moderate* scenario (green bars in Figure 22), performed much less well in terms of land under *Less Optimistic* scenario conditions (lower pairs of bars in Figure 22), than those projects that would be best for the *Less Optimistic* scenario (orange bars in Figure 22). However, the projects best suited for the *Less Optimistic* scenario, in contrast, performed only slightly worse in the *Moderate* scenario than those projects best suited for the *Moderate* scenario (upper pair of bars in Figure 22).



RAND *TR1266-4.10*

Figure 22: Comparison of Land Area in year 50 for Alternatives Developed to Maximize Land for the Moderate Scenario (Green Bars) or Less Optimistic Scenario (Orange Bars).
Source: Groves et al. (2012).

For the 2017 Coastal Master Plan, CPRA may use the Planning Tool to identify a robust, adaptive alternative. A robust, adaptive plan is one that is designed to perform well across many plausible futures, and accomplishes this by defining different decision pathways, which specify how the plan's implementation would change – or adapt – depending on how the future unfolds.

For the 2017 Coastal Master Plan, the Planning Tool may use this approach by implementing these steps:

1. Develop an alternative for each scenario.
2. Identify a set of projects to implement in period 1, based on which projects are selected for implementation in the first period across most or all evaluated scenarios. These are called the *period 1 low regret projects*.
3. Develop another set of alternatives for the scenarios, this time fixing the *period 1 low regret projects*.
4. Compare the different sets of the projects selected for period 2 (year 11-30) and period 3 (year 31-50), and define the potential projects, best suited for each scenario.

Figure 23 shows an illustration of such a robust, adaptive plan. As described in Section 3, this approach will be tested early in the analysis iteration. If this approach is shown to be helpful to CPRA deliberations, then the Draft and Final 2017 Coastal Master Plan will be defined using these adaptive elements. Note that the 2017 Coastal Master Plan may identify one of the pathways as "in the plan" and show the others as different pathways that could be taken if warranted by future conditions. If this adaptive management approach is not used, the approach taken for the 2012 Coastal Master Plan would be taken – combining the results from different Planning Tool alternatives, with expert judgment to select a single set of projects for implementation periods 2 and 3.

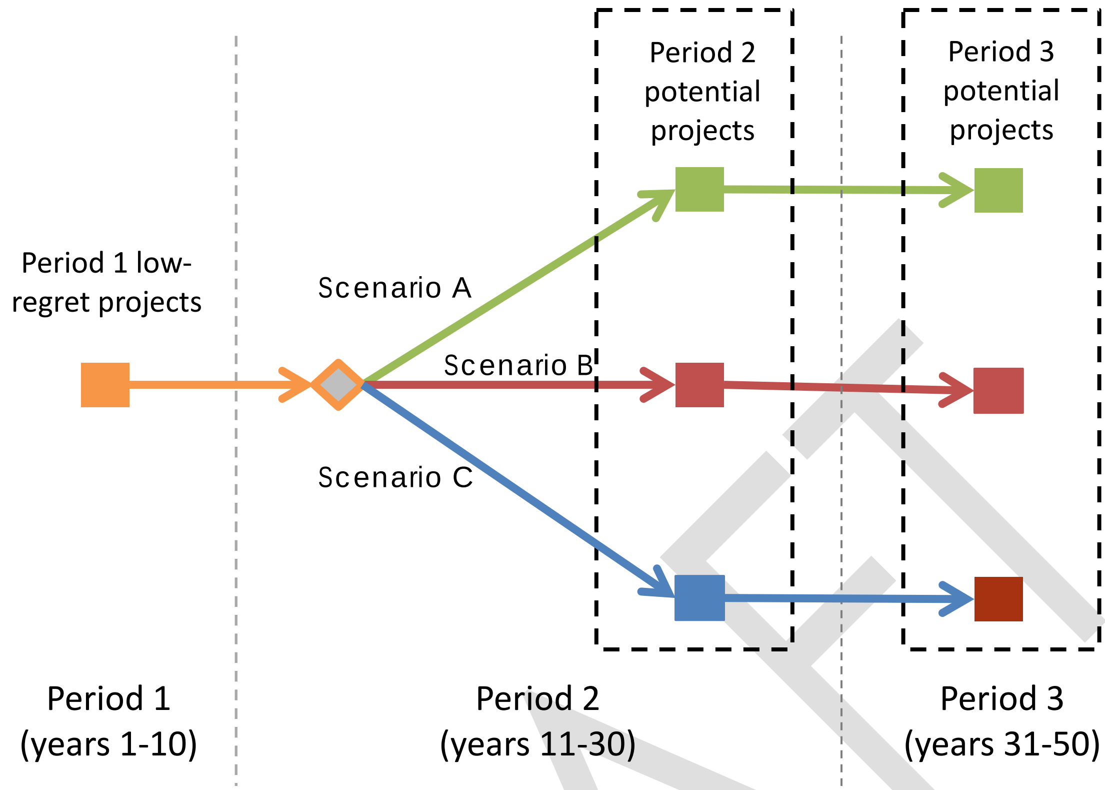


Figure 23: Illustration of a Robust, Adaptive Master Plan.

2.5.5 Supporting Deliberations

The Planning Tool analyses, described above, are by their nature exploratory and do not present simple conclusions. Projects are numerous and can be compared across different metrics, regions, and time periods. Alternatives are comprised of different combinations of projects and have differential effects across the coast. The Planning Tool, thus, helps CPRA and stakeholders explore the analytic results, see the key differences, and support deliberations through interactive visualizations and iteration (Figure 24).

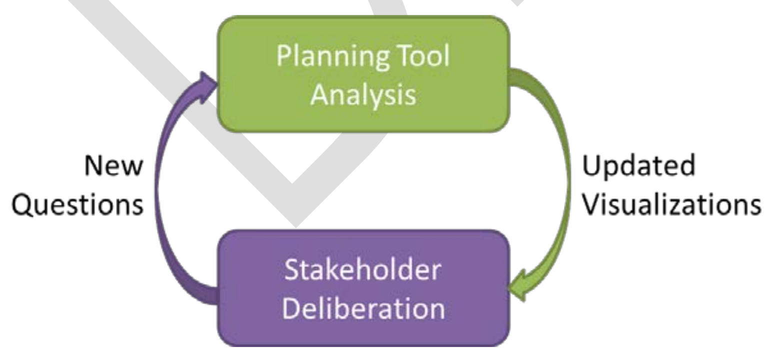


Figure 24: Deliberation with Analysis.

The Planning Tool's visualizations are developed using Tableau, a business analytic data analysis and visualization platform.[17] Tableau connects directly to the Planning Tool SQLite database and provides a flexible interface to develop custom interactive graphics. The visualizations are packaged in workbooks and made available via a website. Figure 25 shows the welcome screen for a previous version of the 2012 Planning Tool results. The boxes along the top of the screen are headings for different visualizations. In the coming months, as data is provided to the Planning Tool, the 2017 visualizations will be used to support deliberations as described below.

Figure 25: 2012 Planning Tool Welcome Screen.

Through this iteration, new questions are asked of the Planning Tool, which then is used to develop new analyses and updated visualizations. As described in Section 3.0, CPRA expects to conduct multiple iterations of this process to develop the 2017 Coastal Master Plan.

3.0 Planning Tool Analyses for 2017 Coastal Master Plan

This section will be developed using the results of the Planning Tool analysis. For the current draft, this section outlines the upcoming phases of analysis, key questions to be addressed, and planned analysis and deliberation.

[17] Details on Tableau can be found at the developer's website: www.tableausoftware.com.

3.1 Future Without Action Conditions

As with the 2012 Coastal Master Plan, the 2017 analysis will begin by establishing a set of baseline outcomes for the FWOA conditions.

3.1.1 Key Questions

- What is the range of projected coastal land loss over the next 50 years across the environmental scenarios without new investments or management?
- What is the range of projected flood risk across the coast over the next 50 years across the risk scenarios without new investments or management?
- What other key environmental and infrastructure assets are at risk?

3.1.2 Analysis and Deliberation

The Planning Tool will provide summaries of how ecosystem conditions and risk would change over the coming 50 years for the different scenarios. Visualizations summarizing the ranges of changes without action over time will support deliberations over the extent of the problem and key outcomes of concern.

3.1.3 Results

Results will be documented in subsequent drafts.

3.2 Comparison of Individual Projects

CPRA is developing attribute information, including costs, for all projects to provide to the Planning Tool. The systems models will also provide to the Planning Tool projections of the individual effects of projects on the ecosystem metrics and risk metrics. The Planning Tool will use these data to compare individual projects.

3.2.1 Key Questions

- How do risk reduction projects rank with respect to mid-term and long-term risk reduction cost-effectiveness? How do the rankings change under different scenarios?
- How do restoration projects rank with respect to mid-term and long-term land building cost-effectiveness? How do the rankings change under different scenarios?
- How do structural and nonstructural projects compare in terms of benefits?

3.2.2 Analysis and Deliberation

The Planning Tool will calculate project cost-effectiveness for key metrics and provide visualizations to highlight project rankings and comparisons. These results will support deliberations over which projects seem to be most effective and how different scenarios affect the results.

3.2.3 Results

Results will be documented in subsequent drafts.

3.3 Alternative Formulation Phase I

The Planning Tool will develop several sets of alternatives for consideration by CPRA and stakeholders. Phase 1 will focus on straightforward alternatives that maximize EAD reduction and land area, under different environmental, risk, and funding scenarios. One or two alternatives will subsequently be modeled by the systems models and the results will be returned to the Planning Tool for comparison.

3.3.1 Key Questions

- Which projects are always and never selected?
- How does project selection change across funding scenarios in which both the total available funding and the allocation between risk reduction and restoration projects changes?
- Can Louisiana achieve sustainability of the landscape by year 50? If so, under which environmental and funding scenarios?
- How much 50-year risk can be reduced under the environmental, risk, and funding scenarios?
- Which projects are selected in the first implementation period for most or all the environmental and risk scenarios for a given funding scenario (i.e., low-regret period 1 projects)?
- Are the projects selected under scenarios with larger funding inclusive of those selected with less funding, or are different projects selected when funding is greater? Which project decisions can be made contingent on the ultimate available funding?
- To evaluate the additive assumption in the Planning Tool, are the coast wide benefits of select alternatives, as estimated by the systems models, significantly different from the coast wide benefits estimated by the Planning Tool?

3.3.2 Analysis and Deliberation

The Planning Tool will formulate a series of alternatives that maximize land and EAD reduction for the different environmental, risk, and funding scenarios. Visualizations will show the performance of these alternatives with respect to land, EAD, and select other metrics. Visualizations of differences between funding levels and land and EAD outcomes support discussions about funding requirements to meet CPRA goals. Visualizations showing differences in performance across different metrics will support discussions about for which future outcomes are less desirable. Comparisons of projects across the alternatives will be reviewed to identify low-regret period 1 projects.

3.3.3 Results

Results will be documented in subsequent drafts.

3.4 Alternative Formulation Phase 2

In Phase 2, alternative specifications will include additional performance constraints to achieve better outcomes with respect to the metrics identified in Phase 1. The draft master plan will be defined based on these alternatives.

3.4.1 Key Questions

- Can performance be improved for select metrics without sacrificing land building and EAD reduction outcomes?
- Which projects are excluded and included when performance constraints are added?
- Does the draft master plan perform adequately across the scenarios?

3.4.2 Analysis and Deliberation

The Planning Tool will formulate additional alternatives that maximize land and EAD reduction while also imposing performance constraints for select metrics. Visualizations will show the performance of these alternatives with respect to land, EAD, and the selected other metrics. Visualizations of differences between land and EAD outcomes and the additional metrics will support discussions about the appropriate constraints to apply for select metrics. Comparisons of projects across the alternatives will be reviewed to re-identify low-regret period 1 projects. Different pathways will be identified for second and third period implementation. One alternative will be selected to be the basis for the draft master plan. The draft master plan will be modeled by the systems models and results passed back to the Planning Tool.

3.4.3 Results

Results will be documented in subsequent drafts.

3.5 Alternative Formulation Phase 3

The final round of alternative formulation focuses on refining the draft master plan to formulate the final master plan. In this phase, specific projects may be specified to be included or excluded (hand-crafted elements).

3.5.1 Key Questions

- What additional adjustments need to be made to the draft master plan?
- What would the performance of the final master plan be across the range of scenarios?

3.5.2 Analysis and Deliberation

The Planning Tool will be used to refine the draft master plan. Analysis of the different projects selected for the different scenarios will be performed to finalize the low-regret period 1 projects and period 2 and 3 pathways. Final visualizations will help convey the sequencing of the different projects across the coast.

3.5.3 Results

Results will be documented in subsequent drafts.

4.0 Conclusions

The planning framework and Planning Tool will help CPRA and its stakeholders develop the 2017 Coastal Master Plan. More conclusions will be added as results of the analysis are added in subsequent versions of this report.

4.1 Key Limitations

This section will be completed after the 2017 analysis is performed.

4.2 Future Development

This section will be completed after the 2017 analysis is performed.

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