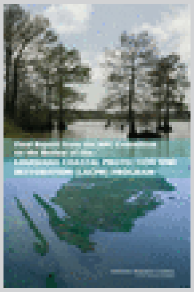

# Final Report from the NRC Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program

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# Final Report from the NRC Committee on the Review of the LOUISIANA COASTAL PROTECTION AND RESTORATION (LACPR) PROGRAM

Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program

Water Science and Technology Board

Ocean Studies Board

Division on Earth and Life Studies

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# Summary

The U.S. Army Corps of Engineers released the Louisiana Coastal Protection and Restoration (LACPR) draft final technical report in March, 2009 (USACE, 2009). The Corps of Engineers conducted this planning study in response to federal legislation passed in November 2005. Public Law 109-103 directed the Corps to "conduct a comprehensive hurricane protection *analysis and design* at full federal expense to develop and present a full range of flood control, coastal restoration, and hurricane protection measures to provide ". . . protection for a storm surge equivalent to a Category 5 hurricane within the project area" and with the provision that ". . . the analysis will be conducted in close coordination with the State of Louisiana and its appropriate agencies" (P.L. 109-103; emphasis added).

The following is the second and final report from the National Research Council (NRC) Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program. The committee's first report was released in 2008. The committee was charged to review two draft reports from the LACPR team and to assess "the hurricane risk reduction framework, alternatives for flood control, storm protection, coastal restoration, and risk analysis" (the committee's full statement of task is listed in Appendix A). This report presents this committee's review and advice for improvements of the LACPR March 2009 draft final technical report.

The proposed comprehensive hurricane protection planning for southern Louisiana entails implementation of a variety of structural, nonstructural, and coastal restoration measures. Examples of structural measures include levees and floodwalls; examples of nonstructural measures include flood insurance and buyouts; examples of coastal restoration measures include the creation or enhancement of wetlands or barrier islands. Evaluating various combinations of these measures, and identifying a preferred plan or course of action, represents considerable technical and other challenges due to the complex natural environment of coastal Louisiana and the tremendous power of land-falling hurricanes that beset the Gulf of Mexico.

Coastal Louisiana covers a vast areal extent and consists of a variety of physiographic features such as estuaries, wetlands, rivers, urban areas, and flood control structures. Furthermore, this is a dynamic landscape that is subject to ongoing sea level rise and future changes in climate. Not only will environmental conditions in this vast region change over time, but social and demographic conditions will change and initiatives such as nonstructural measures for reducing flood risk reduction (e.g., rates of flood insurance purchases; elevating buildings in vulnerable areas; and adoption of zoning measures) will change and evolve in unforeseen ways. LACPR projects thus should be designed with some capacity to adapt to future, changing conditions.

At the same time, it is important that the Corps of Engineers utilize the best technical advice and professional judgment to identify priority protection and restoration alternatives and actions. The Corps of Engineers is the federal government's expert on hydrology and hurricane protection issues in this region and, with this project, the U.S. Congress requested the Corps' expertise and recommendations regarding future hurricane protection *analysis and design*.

Despite being given authority from the U.S. Congress for this project over three years ago, the LACPR draft final technical report does not offer a comprehensive long-term plan for structural, nonstructural, and restoration measures across coastal Louisiana, nor does it suggest any initial, high-priority steps that might be implemented in the short term. Instead, a variety of different types of structural and nonstructural options are presented, with no priorities for implementation.

**The lack of a comprehensive long-term hurricane protection and coastal restoration plan, and the lack of advice on initial high-priority steps and projects, represent substantial shortcomings of the LACPR draft final technical report**.

Comprehensive and effective hurricane protection and restoration in coastal Louisiana will entail cooperation among several entities, but especially between the Corps of Engineers and the State of Louisiana (as called for in the federal legislation). The Corps and the State of Louisiana have issued separate reports on hurricane protection and coastal restoration with what appears to be only limited efforts to synchronize them. Closer cooperation and collaboration between the Corps and the state will be essential for financing, technical planning and project implementation, monitoring, and adaptation.

To help promote cooperative federal-state hurricane protection and restoration, the Corps of Engineers and the State of Louisiana should initiate joint deliberations immediately to agree upon a long-term comprehensive plan—including structural, nonstructural, and restoration projects—and also identify a small number of high-priority projects for initial implementation. It will be important that this cooperative effort not be a lengthy and expensive planning exercise; rather, it should draw upon the voluminous existing research and data on project alternatives derived in the course of the LACPR study, along with previous studies by the Corps, the State of Louisiana, and others. These deliberations should include discussion of the long-term sustainability of project alternatives given past trends and future projections of Louisiana wetland losses owing to erosion and relative sea level rise.

**Before the end of 2009, the Corps of Engineers and the State of Louisiana should agree on the elements of a single comprehensive plan for long-term hurricane protection and coastal restoration. As part of that plan, the Corps and the state should agree on a number of high-priority projects for immediate implementation.**

Other key findings and recommendations from this report include:

- There is a need for more detailed description of sediment availability, including better justification for the assumption that the current shoreline can be maintained in place. The LACPR team should complete a sediment budget for coastal Louisiana and provide better explanation of potential costs and environmental impacts of dredging alternatives.
- There should be a more explicit acknowledgement of ongoing and future coastal erosion trends and their implications for restoration priorities. Rather than focusing energy and resources into trying to maintain the current configuration of southern Louisiana's eroding coastline, the LACPR team is encouraged to focus its protection and restoration plans on high-priority projects.
- The LACPR report should provide a better and more quantitative explanation of the scientific uncertainty associated with projections of marsh and wetlands restoration (including diversions), surge attenuation by wetlands, numerical modeling efforts, and the implications of Mississippi River diversions.
- The high level of uncertainty of the effects of proposed river diversions suggests the need for careful monitoring and evaluation of existing diversions. It also suggests the importance of an

adaptive strategy that can adjust to and build upon new information as more is learned about the responses of these coastal wetlands systems to human interventions.

- Storm surge protection for the City of New Orleans should be designed for a hurricane storm surge event with an expected return interval of 400 to 1,000 years.
- The LACPR team should perform a quantitative risk assessment of the structural protection systems that includes the probability of system failure of the various components including floodwalls, levees, ring levees, and floodgates.
- The LACPR team (and the Corps) should take a more aggressive leadership role in promoting a variety of nonstructural measures that are important to reducing flood risks in coastal Louisiana. Examples of these nonstructural measures include limiting development in flood-prone areas and stronger public education efforts regarding flooding risk in different sections of New Orleans.
- Multi-Criteria Decision Analysis is a potentially useful approach to evaluate projects with important environmental, social, and cultural impacts; however, flaws in the application of these methods to the LACPR study have prevented any convincing results. As applied, the methods do not support the identification of a preferred alternative for any of the planning areas. Furthermore, they do not support the rankings of alternative plans as presented in the LACPR report.
- The LACPR team should more specifically identify and explain the trade-offs between commercial navigation and river diversions for coastal restoration.
- It is encouraging that the LACPR draft final technical report describes the importance of preventing induced development. The report, however, does not adequately demonstrate how these principles will be a prominent part of hurricane protection and coastal restoration actions. Discouraging development in particularly vulnerable areas, whether or not they are protected by levees, is a fundamental principle of flood risk management and reduction. The LACPR should strengthen its cooperation with state and local entities to ensure that the prevention of induced development is accorded a more prominent and meaningful role in future plans.
- The multiple authorizations that govern ecosystem restoration

and hurricane protection in southern Louisiana represent a piecemeal approach and may hinder integrated, adaptive restoration and protection improvements across the region.

# 1

# Introduction

The National Research Council (NRC) Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) program was charged to review two draft reports from the LACPR team and to assess "the hurricane risk reduction framework, alternatives for flood control, storm protection, coastal restoration, and risk analysis" (the committee's full statement of task is listed in Appendix A). This NRC committee's first report was issued in 2008 (NRC, 2008). This is the committee's second and final report and it represents the committee's review of the 'Louisiana Coastal Protection and Restoration Program,' a draft technical report issued by the Corps of Engineers in March 2009 (USACE, 2009). Before discussing and evaluating the LACPR 2009 draft final report, this chapter summarizes this committee's first report (NRC, 2008).

## FIRST REPORT FROM THE NRC COMMITTEE ON THE REVIEW OF THE LACPR PROGRAM

This committee's first report consisted of a review of a draft LACPR report issued in February 2008 (USACE, 2008). This committee met with LACPR staff in New Orleans in March 2008 to discuss that report and the committee's report was issued in May 2008 (NRC, 2008). The NRC report identified areas for improvement in the three main sections—restoration, structural, and nonstructural—of the LACPR draft report (Figure 1 shows the LACPR study region). It also included advice regarding the presentation of key assumptions that were important to the study.

One overarching comment pertained to congressional intent within the 2006 authorizing legislation for the LACPR study. The 2006 Energy and Water Development Appropriations Act (P.L. 109-103) states:

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


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FIGURE 1: LACPR study area of southern Louisiana

> ordination with the State of Louisiana and its appropriate agencies.

The 2006 Defense Appropriations Act (P.L. 109-148) states:

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

The 2008 report from this NRC committee acknowledged that, "The congressional language authorizing the LACPR study and report presents some ambiguities for the LACPR team." It also stated that "It is not clear to the NRC committee that the intent of Congress was that, owing to the urgency of providing hurricane protection to the State of Louisiana, the LACPR team was to provide a design for immediate implementation…" The NRC report also states that "The congressional language, despite ambiguities, does request "…analysis and *design*."" (NRC, 2008, emphasis in original).

The report noted that the LACPR draft technical report presented alternatives and methods for comparing various plans, but did not identify a single best course of action. The prior 2008 report from this NRC committee concluded that "The lack of some prioritization of alternatives—based upon their relative merits in terms of costs and restoration and risk reduction potential—constitutes a weakness with the draft technical report." The NRC report also recommended that "Future versions of the LACPR report will be of greater value to the extent that they identify projects of higher priority that promise to yield greater and more immediate benefits in terms of flood risk reduction and ecosystem restoration."

Other key findings and recommendations from the 2008 NRC report include:

**Restoration** — The report noted that the LACPR draft report "provides no evidence that it will be possible to maintain the current landscape given current and prospective future rates of subsidence, degradation, and sea level rise. At the most basic level, there is no analysis of the amount of available sediment relative to the amount that will be required to sustain the wetlands. If wetlands cannot be maintained, the draft report misleads the public into believing that the present coastline can be held in the face of relative sea level rise. All plans that would rely upon maintenance of the existing shoreline then are suspect. Also, if wetlands cannot be maintained, this implies that decision makers and citizens ultimately will have to make hard choices about where restoration can take place and where it cannot."

The report also recommended that "The LACPR study team should develop sediment budgets for the wetlands of coastal Louisiana to determine the feasibility of maintaining coastal Louisiana in roughly its present condition."

**Nonstructural** — The NRC report noted that "The LACPR draft technical report calculates risk reductions from nonstructural measures *assuming 100 percent compliance* by residents of the region. Yet, participation in these programs will be voluntary and actual compliance is likely to be far less than 100 percent." It also stated, "The technical report does not rigorously assess the degree of risk reduction that would be achieved if more realistic participation and compliance rates are applied." The NRC report also found that "Although a great deal of public opinion has been solicited to date by the LACPR staff, the draft technical report provides little evidence of a unified planning effort among these different governmental levels and bodies." The NRC report also noted that the LACPR draft report did "not suggest policies and programs that could be employed to encourage high rates of adoption of nonstructural measures."

**Structural** — The NRC report found that the LACPR draft technical report did "not consider the *potential for structural failure* of levees and floodwalls. As a consequence, the true risk to homes and businesses and people behind structures has not been determined."

That report also included discussion of possible realignment of the lower Mississippi River. Such a proposal would divert sediments that now are lost to the deep water of the Gulf of Mexico, to wetlands across the Mississippi River delta. This type of realignment likely would entail substantial disruptions and costs to commercial navigation. The report noted that "given the scale of coastal restoration envisioned within the LACPR report, and the large amounts of sediment necessary to achieve this restoration, changes to the alignment and levee system of the lower Mississippi River may be required for restoration actions" (NRC, 2008). The report went on to recommend that an evaluation of how a major realignment of the river's mouth may affect sediment capture and diversion be conducted.

The remainder of this report constitutes a review of the LACPR 2009 draft final technical report and is divided into three main sections: the future course of action; key scientific, engineering, and other technical topics; and future hurricane protection planning and project implementation[1].

[1] The LACPR 2009 draft final technical report did not identify any preferred plan or plans. This committee's report thus does not examine cost estimates in the LACPR report, as a review of cost estimates for all the plans that were considered would have had little value.

# 2

# The Future Course of Action

The authorizing legislation for the LACPR—P.L 109-103—was passed in November 2005. It directed the Corps to "present a full range of flood control, coastal restoration, and hurricane protection measures." It also requested the Corps to "conduct a comprehensive hurricane protection analysis and design," implying that Congress expected a proposal for implementation—not just a list of possibilities—by the end of 2007. For its part, the LACPR team has interpreted its project authority as requiring it to present only a range of plans. The LACPR has not proposed, and apparently does not intend to propose, a single plan or a preferred initial course of action. This means that actions for improving hurricane storm surge protection for southern Louisiana will be further delayed.

A Dutch planning team, with modest support from the U.S. Army, conducted its own planning study and issued a 2007 report that included a comprehensive conceptual design for restoration and hurricane protection (Dijkman, ed., 2007). Although that study may not necessarily represent an optimal approach to restoration and protection, it is an example of a clear proposal with a long-term vision on which immediate actions can be based. Furthermore, it appears to be a reasonable effort to address the congressional directive. The LACPR took a different approach, producing a report with no actionable project recommendations.

To design a program for integrated hurricane protection and restoration measures for coastal Louisiana clearly is a complex task. Nevertheless, Congress and the citizens of Louisiana look to the Corps of Engineers and the LACPR for leadership and direction on these issues, and it is incumbent upon the LACPR team to provide advice on future strategic direction and actions. These points were alluded to in this committee's 2008 report, which stated, "Unless some advice regarding promising initial projects for ecosystem restoration, hurricane protection, and buyouts and relocations is provided, the LACPR planning effort will fall short of its potential to offer science-based, analytical advice on hurricane protection and coastal ecosystem restoration."

Whatever the ultimate intent of Congress in the 2006 legislation, and whatever the Corps' interpretation of its authority, it is clear that there is no preferred plan, or even any part of a preferred plan in the LACPR draft final technical report. Nor does the draft final technical report suggest clear priorities for initial restoration, structural, and nonstructural projects and activities. Moreover, in part because of deficiencies in the LACPR methodology for ranking alternatives, there is no reason to think that any of the 27 alternative planning unit-level plans listed by the Corps can be described as a preferred plan.

The authorizing legislation for the LACPR study called for a final technical report to be submitted within 24 months—or in November 2007. The LACPR report, however, still is in draft form as of mid-2009. It is important that the LACPR report be completed with due speed. Any recommendation for a date on which the report should be completed will include a degree of judgment and opinion. In this committee's view, the submission of a final report by the end of 2009 would strike a balance between allowing for additional time to finalize the document while at the same time encouraging the Corps and the State of Louisiana to move quickly to agreement on next steps.

**The lack of a comprehensive long-term hurricane protection and coastal restoration plan, and the lack of advice on initial high-priority steps and projects, represent substantial shortcomings of the LACPR draft final technical report. Before the end of 2009, the Corps of Engineers and the State of Louisiana should agree on the elements of a single comprehensive plan for long-term hurricane protection and coastal restoration. As part of that plan, the Corps and the state should agree on a number of high-priority projects for immediate implementation.**

# 3

# Key Scientific, Engineering, and Other Technical Topics

## SUSTAINABILITY OF THE COASTLINE

### Trends in and Causes of Coastal Erosion

An important assumption underlying the LACPR draft final technical report is that the current configuration of the Louisiana coastline is sustainable:

> Extensive coastal landscapes in Louisiana can be constructed and maintained at a pace sufficient to offset expected future landscape degradation (USACE, 2009, p. 43, main report).

Any program or assessment regarding the future sustainability of Louisiana's coastline must consider historical and future trends in erosion and sea level rise. For instance, Louisiana has lost 1,900 square miles of land since the 1930s (Barras et al., 1994; Barras et al., 2003; Dunbar et al., 1992). Between 1990 and 2000, wetland loss was approximately 24 square miles per year. The projected loss over the next 50 years, with current restoration efforts accounted for, is estimated to be approximately 500 square miles (Barras et al., 2003). As the late coastal expert Shea Penland stated, and as noted in this committee's 2008 report, "The state is rapidly disappearing into the Gulf of Mexico" (Penland, 2005). The Science Board of the Louisiana Coastal Area (LCA) ecosystem restoration program made a similar observation, stating "It is obvious that not all of the coastline can be maintained, much less restored, and not all coastal communities can be adequately protected" (Science Board of the LCA, 2009). Figure 2 illustrates the impact of these rates of land loss and how much additional land is forecasted to be submerged by the year 2050.

Several factors have contributed to these losses, including:

- A reduction in sediment delivery volumes from the Mississippi River as compared to historical rates. The construction of several large dams on the Missouri River in the 1950s and 1960, and the construction of the Missouri River Bank Stabilization and Navigation Project (authorized in 1945) have greatly reduced sediment deliveries from the Missouri River. Prior to those actions, the Missouri River had been the largest contributor of sediment to the Mississippi River of all its tributaries (see Figure 3).
- Construction of flood control structures along the mainstem Mississippi River in Louisiana that prevent the flooding of wetlands by sediment-laden waters, a process that previously helped build and replenish wetlands. Rather, the sediment-laden waters have been confined to move through the lower Mississippi delta to the edge of the continental shelf and then to the deep waters of the Gulf of Mexico permanently removing this sediment from the littoral zone.
- Wetland edge erosion by storms that likely are exacerbated by the larger open water fetch in ever-enlarging interdistributary bays (e.g., Barataria, Terrebonne, Atchafalaya).
- Natural consolidation of soils in Louisiana's coastal wetlands.
- Navigation and pipeline canals cut through the wetlands by the oil and gas industry.
- Offshore disposal of clean dredged materials by the Corps of Engineers.

## Treatment of Coastal Erosion Issues in the LACPR Report

An assumption that "extensive coastal landscapes in Louisiana can be constructed and maintained" (USACE, 2009; main report, p. 43) in the face of these erosion trends will require that the State of Louisiana be provided annual volumes of sediment comparable to a significant fraction of the Mississippi River's historical sediment load. That is, millions of cubic of yards of sediment will have to be provided annually to the

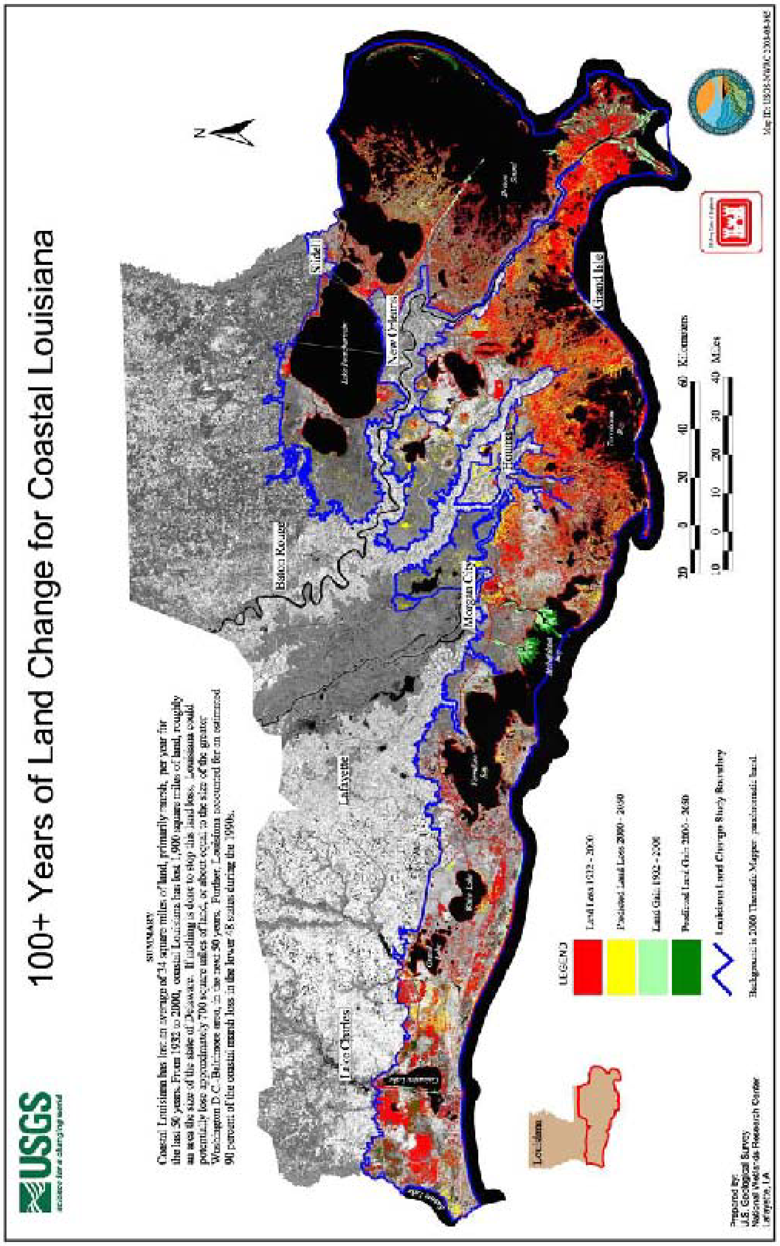


FIGURE 2: 100+ years of land change for coastal Louisiana.
SOURCE: U.S. Geological Survey (2003).

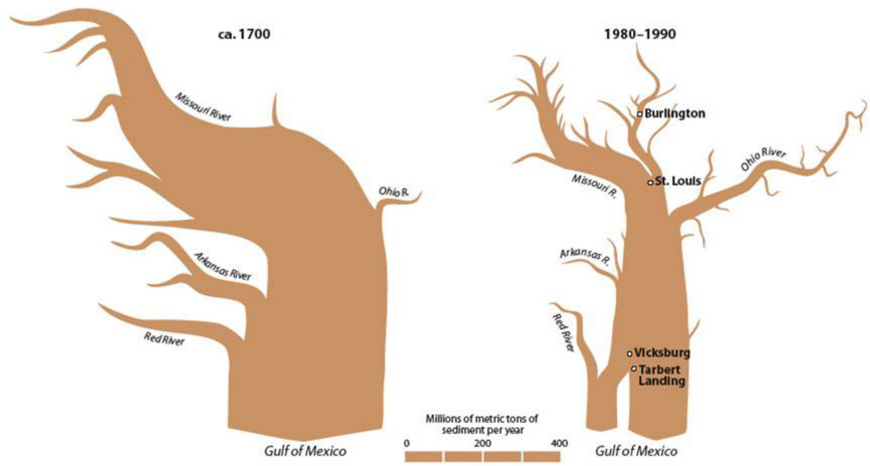


FIGURE 3: Mississippi River suspended sediment discharge, around 1700 (estimated) and 1980-1990. Values in millions of metric tons per year. Widths of the river and its tributaries are exaggerated to reflect relative sediment loads. SOURCE: Meade (1995).

coast, whether from the Mississippi River or from other sources. Furthermore, these required amounts will increase over time because of the increasing rate of sea level rise. These materials will have to be placed in a way that fosters marsh growth with its attendant organic contribution to wetlands accretion.

The LACPR draft final technical report suggests, but does not convincingly demonstrate, that wetlands losses can be countered and the current Louisiana coastline sustained. The LACPR draft final technical report proposes a dredging program with six dredges working around the clock, 365 days per year (USACE, 2009, p. 44, main report). Each dredge was assumed to produce 900 acres of land per year, with the six dredges thus producing 5,400 acres. This is equivalent to 8.4 square miles—an amount less than rate of annual erosion losses of roughly 24 square miles. Moreover, although this dredging program may be theoretically possible, the question is whether it is economically feasible or environmentally acceptable, particularly since offshore sources and lake bottoms are identified as the source of some of the dredge materials (and therefore would entail long and costly transport of sediment).

There is no existing sediment budget that accounts for the amounts and the locations of sediment sources and sediment losses to erosion each year in coastal Louisiana. Results from this sediment budgeting can be used to provide a best estimate of the amount of material necessary to maintain the coast. The LACPR team currently is developing a regional sediment budget for coastal Louisiana, which is explained as:

> The USACE is currently developing a Regional Sediment Budget for coastal Louisiana; however, the final budget is not expected to be completed until July 2010. Based on rough calculations, the LACPR team concluded that adequate sediment sources are available to implement proposed no net loss coastal restoration plans but acquiring those resources involves trade-offs (e.g. costs and environmental impacts) (USACE, 2009, p. 10, main report).

Without a credible sediment budget, a goal to achieve "no net loss" (USACE, 2009; main report, p. 43) seems questionable, even with extensive dredging. It is worth noting that a sediment budget is not simply a calculation of inflows vs. outflows but also would consider the distribution and character of wetlands and barrier shorelines being considered for future maintenance.

A previous report from the National Research Council entitled *Drawing Louisiana's New Map* (NRC, 2006) reviewed the Corps of Engineers' 2004 Louisiana Coastal Area (LCA), Louisiana—Ecosystem Restoration Study. That NRC report concluded that it is not feasible to maintain coastal Louisiana in its current form and that the Corps should modify its plans and educate stakeholders about other approaches that will need to be taken:

> The Mississippi River delta is inherently dynamic and large. Even maintenance of the status quo would require unreasonable quantities of sediment to travel great distances at unreasonable cost. No reasonably scoped effort will bring back the Mississippi River delta of historical times. Those responsible for restoration efforts in Louisiana will have to clarify that if these projects are executed successfully, the future delta will contain all of the landform types that exist today; however, those landforms will be smaller in size, and some will be located in different places than today. To conserve resources and focus effort where it will be most beneficial, some presently inhabited regions may have to be abandoned or re-

> located. If this is undertaken in a carefully planned manner that view processes on the scales of decades rather than years, the impacts to individuals and communities can be minimized (NRC, 2006. p. 41).

That report also found that:

> Achieving no net loss is not a feasible objective because the social, political, and economic impediments are extensive; the sediment supply is limited; and the affected area is large. . . These facts have to be broadly appreciated to avoid widespread disappointment with the LCA projects (NRC, 2006, p. 162-163).

The LACPR team maintains that the goal of achieving no net loss of the coastal landscape of south Louisiana is technically feasible. This NRC committee, however, is skeptical whether such an effort is achievable or economically sustainable in the long run and whether it can be accomplished without substantial adverse environmental impacts. Further, the pursuit of this goal would consume considerable levels of financial resources for restoration and protection efforts, some of which might be better spent on other high-priority projects as determined by the LACPR and the State of Louisiana.

**The LACPR team should complete a sediment budget for coastal Louisiana. They also should provide a better explanation of potential costs and environmental impacts of dredging alternatives.**

**Rather than focusing energy and resources into trying to maintain the current configuration of southern Louisiana's eroding coastline, the LACPR team is encouraged to focus its protection and restoration plans on high-priority projects.**

## ADDRESSING SCIENTIFIC UNCERTAINTIES IN RESTORATION

Restoration efforts in ecosystems as large and complex as those in coastal Louisiana entail many scientific uncertainties and unknowns. The mean and the oscillating water levels required to sustain various types of habitat are not known to a great level of precision. Sedimentation rates necessary to establish specific ecosystems are not well known. Most importantly, the prediction of the location and extent of coastal wetlands that can provide a given level of storm surge reduction involves processes and parameters that are not fully understood or quantified. This section addresses some examples of scientific uncertainties that require more detailed consideration in the LACPR planning study.

There are many contributions to uncertainty in the modeling of waves and surge and in the modeling of marsh creation by diversion. With modeling efforts of this magnitude, the level of uncertainty is understandably high. Therefore, it is important for model uncertainty to be quantified and to be propagated through the decision process. With regard to marsh creation, the uncertainty must acknowledge and reflect the lack of validated predictive models. The existing models, as applied within the LACPR study, contain unsupported assumptions (see below), and the lack of validation needs to be recognized and accounted for when utilizing model results.

### Uncertainty in surge/wave models

Most of the LACPR evaluations regarding both structural and nonstructural alternatives are based on the estimations of water levels along the Louisiana coastal area. These water levels are obtained from numerical models. It thus is important that these models represent all important physical processes in trying to emulate natural conditions.

The LACPR team used reasonably well-tested numerical models for tide and storm surge modeling and for modeling short waves in deep and shallow environments. The ADCIRC model was used to calculate water level associated with storm surge and the WAM and STWAVE models were used to calculate wave heights. The LACPR study does not consider the frictional dissipation due to bottom and vegetation interaction in STWAVE simulations. The LACPR report justifies this decision by stating that the STWAVE results that include friction have been known to underestimate wave heights at "some locations inshore of coastal marsh areas." This argument suggests that STWAVE does not properly model the physical processes in these areas. Because waves are important factors in structural performance and also contribute to hurricane surge, modeling them accurately is important to the LACPR study and its results. Further analysis of the sensitivity of both surge and wave model friction would provide additional insight into the role of wetlands and associated nearshore areas in attenuating waves and surge.

## Marsh Modeling

A significant portion of the LACPR coastal restoration plans relies on the use of diversions of sediment-laden flows from the Mississippi River channel into adjacent wetlands. Although such diversions may ultimately be efficient in helping create and restore wetlands ecosystems, the efficacy of such diversions has not been demonstrated clearly in the LACPR report, either through a study of existing diversions or via modeling analyses. Given that restoration activities are affected by nutrient reintroduction, water quality issues are of great importance and also should be accounted for and tracked in restoration planning, projects, and monitoring (Twilley and Rivera-Monroy, 2009).

The modeling of marsh-creation contains several poorly supported assumptions. First, the estimation of the areal footprint impacted by a given diversion is chosen by subjective consideration only (USACE, 2009, p. 59, Summary). These estimates would be more reliable if they had a strong quantitative basis for estimating the area of a footprint of a given project, based either on derived estimates or on observations of existing marsh-building diversions. Second, the sedimentation model assumes a turbulence structure that is identical to open channel flow. This is inappropriate in a vegetated system, and will likely produce significant errors in the estimation of how marsh-building sediment is distributed from a diversion. Third, the total amount of river water diversion—525,000 cubic feet/second—is over 40 percent of the total channel flow. Because of the obviously large impact on main channel flow, the extent to which upstream diversions impact downstream diversions and promote sedimentation within the main channel should be considered; that is, the presence of upstream diversion creates greater uncertainty regarding the potential success of downstream diversions and may affect river sedimentation.

Finally, the success of diversions will be predicated on the impact of future sea level rise, as newly created wetlands will need to keep pace with rising sea levels. Increased sedimentation as a result of diverting water from the river already is a concern to maritime interests. For example, the construction of the West Bay diversion, near Head of Passes, has been blamed by some for increased shoaling near the Pilottown Anchorage.

**The LACPR report should provide a better and more quantitative explanation of the scientific uncertainty associated with projections of marsh and wetlands restoration (including diversions), surge attenuation by wetlands, numerical modeling efforts, and the**

**implications of Mississippi River diversions.**

**The high level of uncertainty of the effects of proposed river diversions suggests the need for careful monitoring and evaluation of existing diversions. It also suggests the importance of an adaptive strategy that can adjust to and build upon new information as more is learned about the responses of these coastal wetlands systems to human interventions.**

## ENGINEERING CONCEPTS

### Levels of Protection

The Corps of Engineers has been authorized by Congress to make repairs to the New Orleans hurricane protection system. Repairs and strengthening of the system are being carried out by the Corps of Engineers' "Task Force Hope" team with a goal to provide protection against hurricane storm surge with a 100-year recurrence interval, or the surge associated with a hurricane expected to occur on average once in 100 years, for New Orleans by 2011. The term "100-year recurrence interval" is a frequently used term to describe an event that has a one per cent chance of occurring in any given year. Similarly, a 500-year recurrence interval refers to an event that has a 0.2 percent chance of occurring in a given year, while a 20-year recurrence interval refers to an event that has a 5 per cent chance of occurring in a given year. These are average measures and a storm surge with a 100-year return period may occur more, or less than, once in a given 100-year period.

The probabilistic nature of hurricane statistics is complicated by long-term changes in climate and other environmental variables. Changes and variability in the behavior of the climate system imply that long-term averages and extreme values may shift over time—a concept referred to as 'nonstationarity' (for further discussion of hydrologic nonstationarity and its implications for water management, see Milly et al., 2008).

The standard of providing protection against the 100-year flood is an important one within the National Flood Insurance Program. It has been applied both in New Orleans and widely across the nation as a *de facto* safety standard. In areas in which storm surges that exceed the capacity of the hurricane protection system (e.g., levees) do not pose a major public safety concern, cause extraordinary property damage, or imperil evacuation routes, this 100-year standard may be reasonable. However, for heavily populated cities such as New Orleans, where hurricane protection system failure has been shown to be catastrophic—this level of protection is insufficient.

The Association of State Floodplain Managers (ASFPM) 2007 report, *Levees: The Double-edged Sword*, provides helpful guidance on this subject. That report explains, for example:

> In those cases in which a levee is found to be an appropriate measure to protect urban areas or to be credited for protection, the levee should be constructed to a high level of protection. As described in various reports, the level of the 500-year flood, plus freeboard, is considered an appropriate *minimum* protection standard with urban areas. . .
>
> There is now widespread misunderstanding of the true risks associated with levees. This in turn has helped lead to the current over-reliance on structural solutions to reduce the impact of flooding, and to the creation of a false sense of security among those living, working, or seeking to build in areas behind levees. …. Communication of the residual risk associated with any levee is key to public understanding and acceptance of appropriate public safety and flood risk reduction policies in the nation (ASFPM, 2007; italics added).

In addition to the ASFPM report, the National Research Council recently issued a report on the New Orleans hurricane protection system, including the presentation of key lessons learned during Hurricane Katrina (NRC, 2009). That report considered the issue of flood protection criteria for New Orleans, concluding that:

> The 100-year level of flood protection is a crucial flood insurance standard. . . For areas in which catastrophic levee failure is not a major public safety concern, and where large floods would not imperil evacuation routes, the 100-year standard may be appropriate. For heavily-populated urban areas, where the failure of protective structures would be catastrophic—such as New Orleans—this standard is inadequate (NRC, 2009).

This committee agrees that providing protection from storm surge with an expected recurrence interval of 100 years is inadequate for New Orleans. In its first report (NRC, 2008), this committee noted that the LACPR draft technical reports defined 'Category 5' protection as falling in the range of a 400-year to a 1,000-year event, a point that the LACPR reiterated in its 2009 draft technical report:

> USACE policy guidance memorandums directed that a set of measures be presented that could reduce risk across a range of storm surge events including 100-year risk reduction, a "low Category 5" event or Hurricane Katrina-like event (estimated as a 400-year surge event) and a "high Category 5" event (estimated as a 1000-year event) (USACE, 2009; p. 3, main report.).

In its 2008 report this committee recommended that the LACPR team focus on producing designs and plans based on storms with return intervals associated with Category 5 storms. As defined by the LACPR, this would encompass storm surges from 400 to 1,000-year recurrence intervals, consistent with the authorizing 2006 legislation. This design standard would provide New Orleans with protection from storm surge that is comparable to the level of protection provided to the city from the levees along the Mississippi River, which provide protection against riverine floods with a 700- to 800-year recurrence interval.

The first priority of comprehensive hurricane protection and coastal restoration for southern Louisiana should be to ensure protection against storm surges with 400- to 1,000-year recurrence intervals in the City of New Orleans, where the population density and the property at risk are the highest. This level of protection could be provided by raising and strengthening levees alone or by a combination of levee repair and elevating structures behind them.

**Storm surge protection for the City of New Orleans should be designed for a hurricane storm surge event with an expected return interval of 400 to 1,000 years. The 2007 report from the Dutch engineers found that even higher levels of protection are economically justifiable.**

## Limited Consideration of System Failure

The low-lying, and in many areas subsiding, topography of southern Louisiana makes the region particularly vulnerable to flooding. Although low-lying areas above sea level may flood during severe storms, many areas in southern Louisiana lie below the average level of the adjacent waterbodies of Lake Pontchartrain, Lake Borgne, and the Mississippi River. There is an elaborate system of flood control structures, such as levees and floodwalls, in the region to help protect against storms and high water.

A breach of the hurricane protection system will have very different consequences for land areas above sea level as compared to those below sea level. In the former case, inundation will occur only during the event itself with water receding thereafter; flood depths will depend on the duration of the storm, the size of the breach, and the surge elevation outside the protection system. However, in areas below sea level, inundation will continue until the breach is repaired and the water is pumped out; flood depths will depend primarily on the water level in the adjoining waterbody. The flooding of New Orleans after Hurricane Katrina—via waters from Lake Pontchartrain that flowed through breaches in floodwalls that line the city's outfall and navigation canals—is a poignant example of this and a sobering reminder that failure of the hurricane protection system is a key component of the residual risks that attend hurricane and flood protection systems.

The LACPR draft final technical report does not consider the possibility of failure when evaluating water levels and flooding associated with storm surge. Rather, all analyses presented in this report, whether to determine system configurations that meet 100-, 400-, and 1,000-year water levels, or to evaluate these system configurations for different storm occurrence frequencies, assume perfect system performance. Although well-designed protective structures together with diligent maintenance and repair efforts will reduce the likelihood of failure, assuming zero probability of failure is unrealistic and unacceptable, especially for areas where such failure would subject lands to unabated filling from an adjacent waterbody.

A significant portion of the hurricane protection plans within the LACPR draft final technical report call for the construction of levees protecting different cities and municipalities. New Orleans is one of the nation's largest metropolitan areas protected by levees and many of the structures within its hurricane protection system are being raised and strengthened in the wake of Hurricane Katrina. In addition to levees (or ring levees) being proposed for Houma and Morgan City, costly levees are proposed for even smaller communities such Delcambre and Erath.

In assessing flood risks for coastal Louisiana, the LACPR draft final technical report does not incorporate the probability of system failure as part of the risk assessment. The current approach highlights the use of a "qualitative" assessment of failure potential based on the total levee length, number and size of hydraulic structures, and overtopping. Moreover, the LACPR draft final technical report assumes that structural measures can be built to perform reliably to specified risk reduction levels; therefore, hydrologic stages assume no possibility of structural failure or breaching of levees. Abundant historical experience shows, however, that structural failure can occur, with an increasing likelihood in larger storms. This has been recognized in the work of the Interagency Performance Evaluation Task Force (IPET), which conducted an extensive evaluation of the performance of the New Orleans hurricane protection system during Hurricane Katrina and under future storm conditions (IPET, 2008).

It is likely that any conclusions regarding overall system performance of the proposed protection systems will be grossly misleading without appropriately (and quantitatively) accounting for the probability of failure of the structural protection systems. By not accounting for the possibility of structural failure in its analysis, the LACPR draft final technical report underestimates the residual risk in the hurricane protection options that have been presented. Depending on the significance of this underestimate, it may discourage supplemental nonstructural mitigation efforts such as voluntary relocation and the elevation of structures, and may enhance a false sense of security for those living behind these structures.

**The LACPR team should perform a quantitative risk assessment of the structural protection systems that includes the probability of system failure of the various components including floodwalls, levees, ring levees, and floodgates. These probabilities of failure should be performed for a range of hazard levels and a range of structural designs.**

## OTHER TECHNICAL ISSUES

### Formulation and Evaluation of Alternatives

The LACPR planning area is divided into five planning units (PU1, PU2, PU3a, PU3b, PU4; see Figure 4) based on geographic areas and delineated such that there is minimal interaction between units. Within each planning unit, numerous potential plan components were identified. These potential components were combined into a large number of alternative plans. The best-performing alternative plans were then identified on the basis of analysis, experience, and judgment. The result was a total of 111 alternative planning unit-level plans, ranging from 33 alternative plans in PU2 to 13 alternative plans in PU3a.

The alternative plans fall into five categories:

- **No-action alternatives**, which assume continued loss of coastal lands.

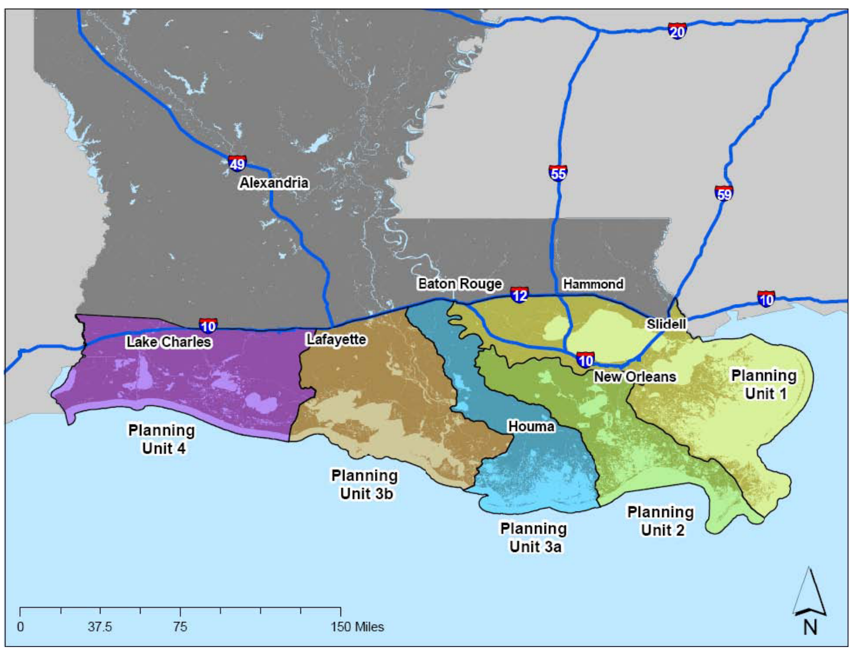


FIGURE 4: LACPR planning area and planning units.
SOURCE: USACE (2009).

- **Coastal restoration alternatives**, where the only actions taken are preservation and restoration of coastal lands.
- **Nonstructural alternatives**, which combine nonstructural measures with coastal restoration. The nonstructural measures considered consist of buyouts and/or raise-in-place measures for structures that meet certain criteria.
- **Structural alternatives**, which combine levees, floodwalls, flood gates, etc., with coastal restoration.
- **Comprehensive alternatives**, which combine coastal restoration, structural measures, and complementary non-structural measures.

Alternative plans are further differentiated by the level of protection provided. Plans assume protection from storm surges having recurrence intervals of 100 years, 400 years, or 1,000 years. As the level of protection rises, implementation costs increase but expected residual damages decrease.

The result of the evaluation phase should be to identify the preferred alternative plan for each planning unit. The LACPR team elected to stop short of this outcome. Instead, the report narrows the list to five or six alternative plans for each planning unit (27 in all). This is followed by some discussion of the tradeoffs existing among these plans. Finally, the 27 alternative planning unit-level plans are assembled into seven coast-wide plans.

## Evaluation

As a basis for evaluation, the LACPR team characterized each of the alternative plans in terms of ten metrics. Five of these are relatively direct cardinal measures of plan impact, such as the average number of people impacted per year, lifecycle cost of the plan (annualized $/year), or residual damages (annualized $/year). Four metrics are cardinal proxies for actual impact, such as number of archeological sites protected or acres of wetland impacted. One metric (indirect environmental impact) is measured on an arbitrary ordinal scale, ranging from -8 to +8. An ordinal scale differs from a cardinal scale in that ordinal measures reveal only rank ($1^{st}$, $2^{nd}$, $3^{rd}$, etc.) and provide no information on the difference between alternative measures. For example, a horse might win a race by a nose or by ten lengths; the ordinal measures for the first two horses are still $1^{st}$ and $2^{nd}$.

The LACPR team first attempted to identify preferable alternative plans through the use of Multi-Criteria Decision Analysis (MCDA). It was intended that stakeholder workshops could be used to assign weights to the ten metrics and that these weights could then be applied to the actual values of the metrics for each alternative plan. The weighted sums of the metric scores would then be used to rank the alternatives. This committee's prior 2008 report addressed the first estimates of metric weights, noting flaws in the process of obtaining these weights through direct elicitation. The Corps subsequently employed, in a single set of workshops, a swing weighting approach that produced somewhat better results.

Swing weighting is considered preferable to direct elicitation because it provides respondents with an understanding of the possible range of each of the metrics. To determine swing weights, respondents are asked to rank metrics based on the relative desirability of "swinging" the value of each metric from its least preferred to its most preferred level, compared to the swing from least to most preferred for each of the other metrics. The metric which is judged to have the most desirable "swing" is assigned a weight of 100. Then the respondent is asked to compare the importance of the range ("swing") of the next most important metric and to state the relative desirability of this range as a fraction of the desirability of the most favored metric. The weight for the second metric is 100 times this fraction. This process continues until weights have been derived for all metrics. Swing weighting is considered to be a reasonable compromise between the need for rigor and ease of use (Edwards and von Winterfeldt, 1986)

In retrospect, the resulting stakeholder weights exhibit a number of inconsistencies. The implied tradeoffs between cost and benefit are suspect because of the low priority that stakeholders gave to life cycle costs. Application of the same weights to nonstructural and structural projects may be inappropriate since the metrics do not reflect plan characteristics such as political and social acceptability, visual amenity, or other factors that may diverge significantly between the two kinds of approaches. There is also some concern that respondents may have been confused by some metric definitions, especially where signs reversed (some metrics were to be minimized while others were to be maximized). Finally, the number of stakeholders that participated in this process was very low—there were 114 stakeholder participants (USACE, 2009, p. 12, Summary). The fundamental issue of how adequately a group of 114 stakeholders represent the interests of the roughly 2.3 million people that inhabit the coastal Louisiana study area was not addressed in the draft final technical report.

As a result of these and other shortcomings, the LACPR-defined metrics combined with the stakeholder weights did not produce a ranking of alternative plans that the LACPR team had confidence in, or that seems reasonable (USACE, 2009, p. 12, Summary). The LACPR team noted that further iterations of the MCDA process could improve the result, but that available time and resources did not permit that option. This committee is more skeptical, believing that substantial redesign of the MCDA process is needed, including extensive use of focus groups to redefine and refine metrics, not just additional iterations of the existing process.

Nevertheless, the LACPR team attempted to make use of the MCDA results by combining them with other scoring and ranking approaches. Nine additional decision criteria were defined, including direct and indirect environmental impacts, various measures of cost and cost effectiveness, and various measures of residual risk. These criteria are measured in various ways, including dollars, risk/cost ratios, wetland acres, and ordinal rankings (MCDA results, indirect environmental impact).

All of the measures, both cardinal and ordinal, are normalized to a 0-1 scale. Note that the MCDA results are already the result of rescaled metric measures, which are then weighted and summed, and rescaled again in this exercise. Armed with these additional criteria and rescaled results, the LACPR team performed 13 different rankings of the alternative projects in each planning unit. All these rankings included the MCDA results, but with a relatively minor weight. Four rankings were performed on the basis of weighted ordinal ranks; the number of included criteria and the weights applied differed from one to the other. Next, nine more rankings were performed where weights were applied, not to ordinal ranks, but to the normalized scores (in some cases derived from ordinal ranks). Again, these rankings differed in that they included different sets of criteria and applied different weights. The final choice of the preferred projects was based on observed consensus among the 13 rankings. Those projects (usually five) were chosen that appeared most often at the top of the individual rankings. The effect of this is to reduce the number of planning-unit level projects from 111 to 27. Unsurprisingly, given the method used, the rankings were quite consistent.

The deficiencies in the application of MCDA have been noted above and are acknowledged by the LACPR study team. Unfortunately, the attempt to salvage the results of this flawed exercise has introduced more problems, rendering the end result even less useful. One problem that runs through this process is the repeated weighting of ordinal numbers. Since an ordinal number reveals only order (1st, 2nd, etc.) it is, strictly speaking, not possible to perform arithmetic operations on such a measure. To do so is to treat the ordinal number as though it were cardinal. This may be acceptable in limited circumstances. For example, an MCDA approach may use an ordinal metric measure that is roughly proportionate to the true cardinal value, so that treating it as cardinal number does not significantly bias the result. But the LACPR report rankings begin with a weighted ordinal measure, combine it into another ordinal measure, then weight it again before combining it into still another ordinal measure. Whatever information was revealed by the first measure is likely to be significantly distorted, if not lost altogether.

The 13 rankings produced in the LACPR report contain no useful information regarding the relative desirability of the alternative plans. The apparent consensus among the rankings simply reflects the commonality of the metric definitions and underlying assumptions. It does not provide any corroborating evidence for the rankings. Accordingly, the 27 alternative plans presented in Table 15-1 of the Technical Report may not necessarily be preferable to the 111 alternatives from which they have been chosen.

**Multi-Criteria Decision Analysis is a potentially useful approach to evaluate projects with important environmental, social, and cultural impacts; however, flaws in the application of these methods to the LACPR study have prevented any convincing results. As applied, the methods do not support the identification of a preferred alternative for any of the planning areas. Furthermore, they do not support the rankings of alternative plans as presented in the LACPR report.**

## Nonstructural Measures

The draft final technical report lacks specificity with regard to a number of the alternatives it proposes for further consideration. For example, many of the alternatives suggested for further consideration involve nonstructural protection. Simply announcing that a nonstructural measure—such as elevating buildings—can reduce flood damages will not necessarily result in buildings being elevated. The LACPR report does not deal with actions needed to actually persuade households to voluntarily take part in such a nonstructural protection program, such as informing households of the risks they face, formulating standards for cost-effective elevation and other nonstructural mitigation measures, training and certifying contractors/inspectors to conducting on-site audits to identify appropriate actions households might take to reduce risk, providing financial assistance to households to undertake cost-effective actions, and so forth. The report also lacks clarity as to who should undertake such a program (i.e., the state, local governments, nonprofit entities, or the Corps).

The LACPR draft final technical report acknowledges many of the recommendations offered in this committee's previous, 2008 report—such as the need for measures to counter induced development behind levees and to prevent new and more intensive development from occurring in the future in high hazard areas whether or not protected by levees. However, recognition of a problem does not necessarily solve it. These problems are also not solved by stating that the issues of induced development and prevention of development in high hazard areas are a state, not federal, responsibility. Since the State of Louisiana lacks state regulations that address either issue, they likely will not be addressed without more direct federal action.

The previous, 2008 report from this committee noted that there was precedent to employ many different nonstructural measures to help reduce development in areas subject to frequent flooding:

> The LACPR draft technical report would be stronger if it proposed an integrated set of measures for limiting future increases in vulnerability. These would include comprehensive plans prepared by parishes and municipalities that assess the suitability of land for development and propose policies for limiting development in areas deemed unsuitable due to the risk of flooding. Potential policies that are regularly used for this purpose throughout the United States include: (1) zoning regulations that limit the intensity of development to a level appropriate for the degree of flood risk; (2) subdivision regulations with flood-hazard mitigation provisions; (3) building regulations that require additional freeboard beyond that mandated by the National Flood Insurance Program; (4) public acquisition of land for open space, habitat protection, and outdoor recreation; (5) public acquisition of easements that limit the amount of development possible in the future; and (6) location of new public infrastructure (e.g., roads and water and sewer lines)

> such that it does not induce or support unsafe new development in flood-hazard areas (NRC, 2008).

There is ample precedent for federal requirements of state and local land-use planning and regulation to limit induced development and prevent development of high hazard areas as a condition for federal participation in the construction of hurricane protection levees (see ASFPM, 2004 for case studies of contemporary flood risk management actions in several U.S. communities). This would be similar to the National Flood Insurance Program's requirement of local regulations to prevent development in floodways and to elevate buildings to the 100-year base flood level as a condition for offering flood insurance to the residents of a community.

**Implementation of a variety of nonstructural measures will be essential in better managing and reducing flood risks in southern Louisiana. The LACPR team and the Corps of Engineers should take a more aggressive leadership role in a variety of nonstructural measures that are important to reducing flood risks in coastal Louisiana. Examples of these nonstructural measures include limiting development in vulnerable areas and stronger public education efforts regarding flooding risk in different sections of New Orleans.**

# 4

# Future Planning and Project Implementation for Coastal Restoration and Hurricane Protection

## ADAPTIVE PLANNING AND IMPLEMENTATION

Due to the complex interactions of estuaries, wetlands, rivers, levees, sea level rise, and future changes in climate, plans within the LACPR project should be designed with some capacity to adapt to future, changing conditions. Not only will environmental conditions in this vast region change over time, but social and demographic conditions will change and initiatives such as nonstructural measures for reducing flood risk reduction (e.g., the adoption of flood insurance; the elevating of buildings in vulnerable areas; the number of structures that are relocated) will change and evolve in unforeseen ways.

Monitoring of various physical and ecological change, as well as compliance with and success of various nonstructural programs, will be an important part of successful future adjustments in coastal restoration and hurricane protection. Monitoring of the performance of the hurricane protection system should be part of the system's ongoing maintenance and there should be regular considerations for altering the system in response to any adverse impacts. This is particularly true in the face of the LACPR study assumptions of no net loss of coastal lands. The outcomes from diversions will have to be monitored in order to adjust and improve future actions. Following up and adjusting programs related to compliance with nonstructural flood risk reduction initiatives and incentives will also be important to their future performance and effectiveness.

## TRADE-OFFS BETWEEN DIVERSIONS AND NAVIGATION

The LACPR draft final technical report proposes nearly two dozen diversions to permit up to 525,000 cubic feet/second of sediment-laden water to leave the Mississippi River and flow into the wetlands for land building (USACE, 2009, p. 43, main report). These diversions would operate during the flood season. The diversion of this much water from the river would cause the river's flow rate to decrease. This would reduce the river's scouring ability and would lead to additional shoaling.

Diversions are featured within the LACPR report as a major supplier of sediment for restoration purposes (USACE, 2009, p. 219-220, main report). Diversions have large implications for the navigation sector, however, and the trade-offs between diversions and keeping water in the channel to support navigation are prominent, important issues. Removing river water to create diversions for wetlands restoration, while also maintaining full navigational uses of the river, means that dredging costs will rise. Increased diversions imply reduced benefits for navigation, and vice versa. Despite the importance of these trade-offs, the LACPR team has conducted little analysis of them to date:

> It should be noted that the LACPR team has not determined the cumulative impacts that multiple diversions may cause on the system. Nor has the team quantified the impacts on navigation or flood control on the Mississippi River (USACE, 2009, p. 219-220, main report).

**The LACPR team should more specifically identify and explain the trade-offs between commercial navigation and river diversions for coastal restoration.**

Current dredging in order to support commercial navigation yields large amounts of sediment from the bed of the Mississippi River. This sediment, if not contaminated, constitutes a valuable resource for the replenishment of wetlands and where possible should be put to beneficial use. The importance of capturing sediment or limiting its loss is a point that has been made previously in a number of reports. Historically, overbank flooding has provided sediment to the wetlands, but flood protection by levee fortification has eliminated overbank flooding and consequently resulted in the loss of most sediment to the deep waters of the Gulf of Mexico. Minimizing the loss of this sediment off the continental shelf wilI be important to the success of efforts to preserve and restore Louisiana's coastal wetlands.

## FUTURE SETTLEMENT AND INDUCED DEVELOPMENT

A frequent consequence of levee construction is human settlement of areas behind levees, as these areas may be seen as safe for development and habitation. This phenomenon may take place in previously undeveloped and uninhabited areas; similarly, it may occur in flood-damaged areas such as New Orleans, where settlement or resettlement may take place behind strengthened and raised levees.

The negative consequences of this 'induced development' were noted in this NRC committee's 2008 report, where it was stated that "Plans that encourage people to move into hazardous areas put them at risk in future hurricanes" (NRC, 2008). The Association of State Floodplain Managers likewise has concluded that levees "are inappropriate as a means of protecting undeveloped land for proposed development" (ASFPM, 2007).

The LACPR draft final technical report explains the importance of preventing induced development behind levees (USACE, 2009, p. 25, main report). The LACPR report explains the ways in which induced development was addressed in its report and the LACPR team deserves credit for recognizing the importance of limiting new settlement in hazardous areas. The LACPR report also appropriately recognizes the value of other related nonstructural measures, such as relocations, in significantly and reliably reducing flood risk (USACE, 2009, p. 36, Summary).

Even though the concept of preventing induced development is endorsed, another portion of the LACPR report explains that "the population of South Louisiana is expected to increase" (LACPR, 2009, p. 38, main report). Population growth and redevelopment policies are of course beyond the Corps' responsibilities; nevertheless, a program for reducing flood risks that sought to prevent induced development in vulnerable areas would state clearly the reasons why the most vulnerable areas of southern Louisiana should be avoided and not resettled. There are of course many parties encouraging population growth in the region, but efforts to resettle people back into vulnerable areas will increase the flood risks to the city and its inhabitants and will not improve public safety.

**It is encouraging that the LACPR draft final technical report describes the importance of preventing induced development. The report, however, does not adequately demonstrate how these principles will be a prominent part of hurricane protection and coastal restoration actions. Discouraging development in particularly vulnerable areas, whether or not they are protected by**

**levees, is a fundamental principle of flood risk management and reduction. The LACPR should strengthen its cooperation with state and local entities to ensure that the prevention of induced development is accorded a more prominent and meaningful role in future plans.**

## CONSTRAINTS OF THE CURRENT LEGISLATIVE SETTING

The Corps of Engineers has responsibilities for numerous restoration and hurricane protection projects in southern Louisiana, under multiple authorizations. Although this reflects the traditional process of project authorizations through federal Water Resources Development Acts, it represents a piecemeal and poorly coordinated approach to ecosystem restoration and hurricane protection. If these projects are to be developed and implemented in a coordinated fashion across all of coastal Louisiana, this current situation of multiple authorizations—which may entail lengthy re-authorization processes if the Corps wishes to adjust operational goals—will hinder comprehensive, collaborative, and adaptive restoration and protection.

The LACPR draft final technical report indicates that the majority of the improvements identified for final consideration therein could be implemented under the multiple, existing authorizations for hurricane protection across southern Louisiana, either directly or by utilizing project change orders and that the remainder could be handled by new authorizations; however, it is not clear that this is advisable.

A good precedent for authorizing legislation for large-scale, adaptive ecosystem management projects, such as those that are needed to protect southern Louisiana into perpetuity, is the Comprehensive Everglades Restoration Plan (CERP). Authorized in the Water Resources Development Act of 2000 (WRDA 2000), the CERP is a 50/50 funding partnership with the State of Florida with a goal to "restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection" (WRDA 2000, Section 601).

In addition to the enabling legislation, an accompanying report from the U.S. Senate Committee on Environment and Public Works explains the rationale and value of the CERP in promoting an adaptive approach to large-scale ecosystem management:

> The committee does not expect rigid adherence to the Plan as it was submitted to Congress. This result would

> be inconsistent with the adaptive assessment principles in the Plan. Restoration of the Everglades is the goal, not adherence to the modeling on which the April, 1999 Plan was based. Instead, the committee expects that the agencies responsible for project implementation report formulation and Plan implementation will seek continuous improvement of the Plan based upon new information, improved modeling, new technology and changed circumstances (U.S. Senate Committee on Environment and Public Works, 2000).

From the outset of comprehensive restoration efforts in the Everglades, the Corps and the State of Florida recognized that they were charged to implement a large, complex portfolio of projects over decades and in the face of substantial scientific uncertainty. Their approach was to build in adaptation based on a major analytical and modeling effort and to seek congressional approval for a unique type of program authorization. The LACPR program is similar to the Everglades Restoration Plan in its spatial extent, hydrologic and ecologic complexity, and uncertainties regarding outcomes of future ecosystem restoration and hurricane protection efforts. The LACPR, however, presently lacks the kind of authorization that allowed CERP to move forward with a flexible, adaptive program.

Current legislation for coastal Louisiana hurricane protection and ecosystem restoration does not explicitly promote or provide for comprehensive and adaptive planning. Examples of important scientific and planning principles that could be more explicitly encouraged include:

- There is a need to shed many outdated concepts such as levee height specifications that are tied to the Saffir-Simpson scale or the standard or maximum probable hurricane;
- Protection should be cast in a risk-based framework (e.g., 1,000-year protection) that is coordinated although not necessarily equal throughout the region;
- A mechanism is needed to specifically monitor changing environmental conditions (e.g., due to sea level rise and subsidence) and incorporate the findings into ongoing protection and restoration efforts in order to achieve successful, long-term adaptation;
- It should be possible to modify plans as new technologies,

such as improved hazard models, are developed;

- Projects should include beneficial use of all dredged materials (also see USACE, 2009, p. 225, main report);
- There should be a requirement of external review of new or substantially modified projects and periodic external review of existing projects;
- It is necessary to clearly delineate the roles of the federal and state governments in the collaborative design and development of a comprehensive system that includes coastal, structural, and non-structural protections and ties together initial system design and construction with long-term maintenance and operations using adaptive management.

**The multiple authorizations that govern ecosystem restoration and hurricane protection in southern Louisiana represent a piecemeal approach and may hinder integrated, adaptive restoration and protection improvements across the region.**

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# Appendixes

# Appendix A

# Statement of Task Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program

This NRC committee will review the evaluations being conducted as part of the Louisiana Coastal Protection and Restoration (LACPR) program. These studies are being conducted by the U.S. Army Corps of Engineers in close coordination with the State of Louisiana. Congress has directed the Corps of Engineers, New Orleans District, in partnership with the State of Louisiana, to compile a 24-month technical comprehensive hurricane risk reduction analysis and design. The Corps and the State of Louisiana thus are evaluating a wide range of flood control, coastal restoration, and hurricane protection measures in this study. The LACPR study began in early 2006 and an interim report was issued in July 2006. The LACPR team plans to issue a draft report in December 2007 and a final report in Spring 2008.

The NRC committee will review all aspects of these latter two reports, including assessment of the hurricane risk reduction framework, alternatives for flood control, storm protection, coastal restoration, and risk analysis. These two LACPR reports will include several technical appendixes (e.g., cost estimates, engineering studies, draft EIS, design appendixes, and public outreach strategy) that will be part of this review. Given the large number of supporting and supplemental documents that are being produced by the Corps and various other parties, the NRC committee will also review supplemental documents as the committee sees fit and within its time and resource constraints.

The NRC committee will issue two reports that include conclusions, findings, and recommendations for improving the LACPR study.

This project is sponsored by the U.S. Army Corps of Engineers. The approximate start date for the project is June 11, 2007.

UPDATE 1-16-08: The project duration has been extended. The first report is expected to be issued by February 2008 and the final report by later in 2008.

UPDATE 3-17-08: The project duration has been further extended. The first report is expected to be issued by late April 2008.

UPDATE 03-24-09: The second report is expected to be issued in summer 2009, following review of the final report of the LACPR program which was provided to the NRC committee in early March 2009.

# Appendix B

# Acknowledgement of Reviewers

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the NRC in making its published report as sound as possible, and to ensure that the report meets NRC institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following for their review of this report: Mead A. Allison, University of Texas; Donald F. Boesch, University of Maryland Center for Environmental Studies; John J. Cassidy (retired), Bechtel Corporation; Gerald E. Galloway, University of Maryland; Robert A. Holman, Oregon State University; David H. Moreau, University of North Carolina; William K. Nuttle; Denise J. Reed, University of New Orleans; and Robert R. Twilley, Louisiana State University.

Although these reviewers provided constructive comments and suggestions, they were not asked to endorse the report's conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Frank H. Stillinger, Princeton University, who was appointed by the NRC's Report Review Committee and by David A. Dzombak, Carnegie Mellon University, who was appointed by the NRC's Division on Earth and Life Studies. Drs. Stillinger and Dzombak were responsible for ensuring that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments received full consideration. Responsibility for this report's final contents rests entirely with the authoring committee and the NRC.

# Appendix C

# Water Science and Technology Board

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# Appendix D

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# Appendix E

# Biographical Sketches for the Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program

**Robert A. Dalrymple (NAE)** is the Willard and Lillian Hackerman Professor of Civil Engineering at the Whiting School of Engineering of Johns Hopkins University. He works in the area of coastal engineering, with specific interests in numerical modeling of coastal processes, including nearshore hydrodynamics. His current interests are water wave modeling, tsunamis and their impact on shorelines, and the interaction of water waves with the sea bed, specifically mud bottoms. The creation of appropriate waves in the laboratory setting–such as in three-dimensional wave basins–is a sideline activity. He received his A.B. in engineering sciences from Dartmouth College, his M.S. degree in ocean engineering from the University of Hawaii, and his Ph.D. degree in civil and coastal engineering from the University of Florida.

**John J. Boland** is a professor emeritus in the Department of Geography and Environmental Engineering at Johns Hopkins University. His fields of research include water and energy resources, environmental economics, and public utility management. Dr. Boland has studied resource problems in more than 20 countries, has published more than 200 papers and reports, and has coauthored two books on water demand management and three others on environmental management issues. Dr. Boland is a registered professional engineer. He has served on several NRC committees and boards, including the Water Science and Technology Board, of which he was a founding member (1982) and past chair (1985-1988). He is a life member of the American Water Works Association and past chairman of its Economic Research Committee. Dr. Boland received his Ph.D. degree in environmental economics from Johns Hopkins University.

**Raymond J. Burby** is a professor in the Department of City and Regional Planning at the University of North Carolina-Chapel Hill. Dr. Burby is a fellow of American Institute of Certified Planners. He has been an author or editor on 14 books and published extensively in planning and policy journals including, among others, *Journal of the American Planning Association*, *Journal of Planning Education and Research*, *Journal of Policy Analysis and Management*, and *Journal of Environmental Planning and Management.* He is currently principal investigator on a study of urban growth boundaries funded by the National Science Foundation and P.I. on another NSF-funded project designed to improve the quality of applied research on disasters and mitigation of natural and technological hazards. He received his Ph.D. degree in planning from the University of North Carolina-Chapel Hill.

**John T. Christian (NAE)** is a consulting engineer in Waban, Massachusetts. His primary area of interest is geotechnical engineering. Much of his early work involved developing and applying numerical methods such as the finite element method. He has also worked on reliability methods for geotechnical applications, soil dynamics, and earthquake engineering on a broad range of civil engineering projects. Dr. Christian's current interests are largely focused on the use of reliability techniques in geotechnical engineering and on earthquake engineering. Much of his work in industry was associated with power generating facilities, including but not limited to nuclear power plants. He received his B.S., M.S. and Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology.

**Reginald DesRoches** is associate chair and professor in the School of Civil and Environmental Engineering at Georgia Tech University. Dr. DesRoches studies and develops mitigation strategies to reduce risks from earthquakes, particularly, earthquakes in the central and southeastern United States. His specific research interests include seismic resistant design and retrofit of bridges, protective systems for buildings and bridges, performance of transportation networks, and structural applications of smart materials. He is currently a member of the NRC Board for Infrastructure and the Constructed Environment. Dr. DesRoches received his Ph.D. degree in structural engineering from the University of California, Berkeley.

**Charles G. Groat** is the John A. and Katherine G. Jackson Chair in Energy and Mineral Resources, Department of Geological Sciences, and professor of Geological Sciences and Public Affairs at the University of Texas. Dr. Groat has over 25 years of involvement in geological studies, energy and minerals resource assessment, groundwater occurrence and protection, geomorphic processes and landform evolution in desert areas, and coastal studies. From 1998-2005 he served as the 13th Director of the U.S. Geological Survey. At the USGS he emphasized integrated scientific approaches to understanding complex natural systems and the use of these understandings in management decisions. Dr. Groat is a member of the Geological Society of America, American Association for the Advancement of Science, American Geophysical Union, and the American Association of Petroleum Geologist. He received his Ph.D. degree in geology from the University of Texas at Austin.

**Philip L.-F. Liu** is a professor of civil and environmental engineering at Cornell University. Dr. Liu's current research interests include fluid dynamics and nonlinear water waves. He is also currently the Kwoh-Ting Li Chair Professor at the National Central University, Taiwan, which is the highest-level professorship in the university. Dr. Liu is also a fellow with the American Society of Civil Engineers and the American Geophysical Union, and is a member of the International Association for Hydraulic Research. He received his B.S. degree in civil engineering from National Taiwan University, his S.M. in civil engineering from the Massachusetts Institute of Technology, and his Sc.D. in hydrodynamics from the Massachusetts Institute of Technology.

**Richard A. Luettich** is director of the Institute of Marine Sciences at the University of North Carolina at Chapel Hill. His research deals with modeling and measurement of circulation and transport in coastal waters. Dr. Luettich's modeling efforts have emphasized the development and application of unstructured grid solution techniques for geometricaly complex systems such as sounds, estuaries, inlets and inundated regions. He has co-developed a circulation and storm surge model that has been applied extensively for modeling storm surge in the Southern Louisiana and New Orleans areas. Dr. Luettich has also participated in the development of components of the national Coastal Ocean Observing System. He received his B.S. and M.S. degrees in civil engineering at the Georgia Institute of Technology and his Sc.D. in civil engineering from the Massachusetts Institute of Technology.

**Robert H. Meade** is research hydrologist emeritus at the U.S. Geological Survey. His studies have centered on land subsidence in central California; transport and storage of sediment in Orinoco and Amazon Rivers of South America; transport and deposition of sediment in estuaries (including Mississippi River mouth); assessment of pollutants and sediments in Mississippi River. He received his B.S. in geology from the University of Oklahoma and his M.S. and Ph.D. degrees in geology from Stanford University.

**James T. Morris** is a professor of biological and marine sciences at the University of South Carolina. Dr. Morris is also the director of the Belle W. Baruch Institute for Marine and Coastal Sciences and the Class of '32 Distinguished Professor of Marine Studies at the university. His research spans basic and applied aspects of the physiological ecology of plants adapted to wetland habitats and the biogeochemistry and systems ecology of wetlands, primarily salt and freshwater intertidal wetlands. He received his Ph.D. degree from Yale University.

**Heidi Nepf** is a professor in the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology. She focuses her research on physical mechanisms which affect transport and fate of contaminants and nutrients in lakes, wetlands, and coastal zones, as well as vegetated flow dynamics. Dr. Nepf received her B.S. degree from Bucknell University, and her M.S. and Ph.D. degrees from Stanford University.

**Joan Oltman-Shay** is president and senior research scientist at Northwest Research Associates, Inc. in Bellevue, WA. She has spent much of her career performing field and model studies of nearshore wave and current dynamics and the interplay with morphology and sediment dynamics. Her work has centered on the analysis of data from in-situ arrays of pressure and current sensors designed to study the surface gravity wave field and the wave-averaged current field. Her current research includes remote sensing of nearshore environmental parameters (satellite, airborne, and land-based). She received her B.A. degree in applied physics and electrical engineering from the University of California, San Diego, and both her M.S. degree in applied ocean sciences and Ph.D. degree in oceanography from the Scripps Institution of Oceanography.

**Asbury H. Sallenger, Jr.** is is a research oceanographer at the U.S. Geological Survey in St. Petersburg, FL and is also the Chief of the USGS

National Coastal Change Hazards Assessment that examines the processes of storm and long-term coastal change hazards throughout the United States using innovative technology such as airborne lidar (light detection and ranging) mapping. His research interests include nearshore sedimentary and wave processes, coastal erosion, and sediment transport. He received both his B.A. degree in geology and his Ph.D. degree in marine science from the University of Viriginia.

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**Jeffrey Jacobs** is a scholar with the NRC Water Science and Technology Board. Dr. Jacobs's research interests include policy and organizational arrangements for water resources management and the use of scientific information in water resources decision making. He has studied these issues extensively both in the United States and in mainland Southeast Asia. Prior to joining the NRC he was a faculty member at the National University of Singapore and at Texas A&M University. Since joining the NRC in 1997, Dr. Jacobs has served as the study director for over twenty NRC reports. He received his B.S. degree in geography from Texas A&M University, his M.A. degree in geography from the University of California, Riverside, and his Ph.D. degree in geography from the University of Colorado.

**Michael J. Stoever** is a research associate with the Water Science and Technology Board. He has worked on a number of studies including Desalination: A National Perspective, the Water Implications of Biofuels Production in the United States, and the Committee on Independent Scientific Review of Everglades Restoration Progress. Mr. Stoever received his B.A. degree in political science from The Richard Stockton College of New Jersey in Pomona, New Jersey. He joined the NRC in 2006.