hydraulic control structures, which are represented as nodes in the MSE network. Each WCU includes associative references to all inlet and outlet hydraulic flow nodes.

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Louisiana Coastal Area Study

Introduction

Louisiana’s coastal wetlands have lost between 1,500 and 1,900 square miles in the last century. From 1930 to 1990, the coastal zone of Louisiana lost an estimated 3,950 square kilometers, or 1,526 square miles, of wetlands (Boesch et al. 1994). The Louisiana coastal plain contains one of the largest expanses of coastal wetlands in the contiguous United States, making up about 40 percent of the Nation’s coastal marshes—but it has accounted for 90 percent of the total coastal marsh loss in the Nation. This wetland loss has had major adverse effects on the region’s ecosystem and the wetlands are estimated to lose an additional 500 square miles over the next 50 years. This historical and continued loss has affected and will continue to significantly affect the ecology, society, and economy of the region and the Nation. As this natural ecosystem continues to decline, the result will be decreases in various natural functions and values associated with wetlands, including diminished biological productivity and increased risk to critical habitat of Federally-listed threatened and endangered species. The ability of the coastal wetlands to buffer tropical storm and hurricane storm surges will diminish, increasing the risk of significant damage to oil, gas, transportation, water supply, and other private and public infrastructure and agriculture lands and urban areas.

Numerous small-scale restoration projects constructed over the previous 20 to 30 years provided primarily localized remedies. However, this "piecemeal approach" of individual restoration projects constructed with little or no coordination nor evaluation of their role in a "coastal consistency" framework did little to solve the overall problem of the massive loss of wetlands. Given the magnitude of Louisiana's coastal land losses and ecosystem degradation, it became apparent that a systematic approach involving larger projects to restore natural geomorphic structures and processes, working in concert with smaller projects, would be required to effectively deal with the full extent of the degradation and ensure a sustainable coastal ecosystem. In 1998, state and Federal agencies, local governments, academia, numerous NGOs, and private citizens reached consensus on "Coast 2050 – Toward a Sustainable Coastal Louisiana" (LA CWCRTF 1998), a conceptual plan for restoring the Louisiana coast. The Coast 2050 Plan was a direct outgrowth of lessons learned from implementation of past restoration projects and reflected a growing recognition that a more comprehensive "systemic" approach was needed.

The Louisiana Department of Natural Resources (La DNR) and the New Orleans District US Army Corps of Engineers (USACE) initiated the Louisiana Coastal Area (LCA) study in early 2002. The primary objective of the study was to produce a comprehensive program for restoring and maintaining an ecologically sustainable ecosystem for the Louisiana coastal zone; a plan to which Louisiana and the Federal government would be willing to dedicate significant resources to achieve. Numerous Federal, state, and local agencies; various non-government organizations (NGOs); and academic institutions participated significantly in formulating the plan for the LCA study and in recommending plan development. In November 2004, the Louisiana Coastal Area (LCA)–Ecosystem Restoration Study Final Report (USACE 2004) was completed. The recommended plan called for action on several levels. The LCA report presented a strategy for addressing the long-term needs of coastal Louisiana and identified short-term needs and projects that could be implemented to slow the deterioration of the coastal wetlands while the more robust long-term features could be properly developed and implemented.

The role of technology in the recommended plan was evident in the initial development of a new modeling tool to evaluate the cumulative impacts of proposed measures on the ecosystem. In addition, the LCA study team consisted not only of

Louisiana DNR and USACE biologists and engineers, but also biologists, engineers and other specialists from numerous other agencies such as the Louisiana Department of Wildlife and Fisheries, the U.S. Geological Survey, the U.S. Fish & Wildlife Service, the U.S. Environmental Protection Agency, and various academic institutions. Incorporating the technical expertise of these agencies throughout the study, rather than near the end (more commonly done as part of the review and comment process), helped ensure that the most up-to-date technology was used to develop the recommended plan. However, acknowledging that not all the necessary knowledge and technology currently exists, the recommended plan also called for a science and technology program through the LCA project to identify, fund, and develop needed technology and knowledge for direct application to the LCA project. Also included in the plan were continued monitoring and adaptive management over the life of the project to enable future adjustments to the overall plan, as better knowledge and technology became available.

LCA Study Plan and Recommendations

In response to the continuing loss of wetlands in the Louisiana coastal zone and the concern about eventual ecosystem collapse, the State of Louisiana (through the Louisiana DNR) and the USACE initiated, in early 2002, the Louisiana Coastal Area (LCA) study. The primary purpose of the LCA study was to analyze the problems, their causes, and possible alternatives to reduce or eliminate future deterioration of the wetlands and to develop a plan to begin to rebuild the wetlands. Building upon past efforts such as Coast 2050, the intent was to produce a report, nearing a feasibility-level study, which could be processed through the Administration and presented to Congress as a basis for authorization and funding of a long-term plan for coastal restoration. The study report (USACE 2004) was completed in November 2004 and was included in both the House and Senate versions of the proposed 2006 Water Resources Development Act (WRDA). While WRDA 2006 was not completed, it is anticipated that the LCA project will be included in a subsequent WRDA. Passage of the WRDA bill will authorize the LCA plan and, with appropriations of funding, allow the LCA plan to begin implementation.

The LCA-recommended plan set priorities for near-term projects, expanding knowledge and capabilities through a 10-year Science and Technology (S&T) Program with demonstration projects and expanding the authority and funding to beneficially use more of the dredged materials taken from navigation channels. In addition, the plan provided for large-scale, long-term restoration studies and measures for which current levels of analysis and design were not adequate for deciding whether to proceed with implementation. The LCA plan, with an estimated cost of just under $2 billion, is briefly described in the following paragraphs. Both LaDNR and the USACE stress that this is just the first step in a longer process, and when additional studies and designs are completed it is anticipated that Congress will be asked to authorize and fund more major projects. The recommended plan features of the LCA Report (USACE 2004), broken down into several major categories, are listed below with their estimated 2004 costs:

Initial Near-Term Critical Restoration Features	$ 864 million
Additional Near-Term Critical Restoration Features	$ 762 million
Science and Technology Program	$ 100 million
Science and Technology Demonstration Projects	$ 100 million
Beneficial Use of Dredged Materials	$ 100 million
Modification of Existing Structures Studies	$ 10 million
Large-Scale, Long-Term Restoration Studies	$ 60 million
Total	**$1,996 million**

The initial near-term critical restoration features consist of five individual projects designed to meet critical ecological needs of the Louisiana coastal area in critical locations. Delaying action at these locations would result in continued losses in these areas and would thus require greater restoration costs when these areas were eventually addressed. Three of the projects divert freshwater from the Mississippi River into marsh areas to reduce salinity intrusion and help build marshes. A fourth project would restore a critical reach of barrier islands. The fifth project, consisting of shore protection, would temporarily address continued erosion of the Mississippi River Gulf Outlet (MRGO) channel, a deep-draft navigation channel, constructed in the 1960s, linking the Port of New Orleans with the Gulf of Mexico. Continued erosion of this channel's banks would increase salinity intrusion into this area with further losses of marshes. Normally, Congress would require the completed decision documents before authorizing the individual projects. However, a significant amount of engineering and design as well as environmental analysis has been conducted for these features from earlier efforts. The LCA plan recommends that Congress authorize these features, subject to completion of a decision document that would then be approved by the USACE Chief of Engineers. Significant time can be saved by such a programmatic authorization and construction could begin within the first five years after authorization.

The additional near-term critical restoration features consist of an additional 10 individual projects for which initial analyses have begun but have not proceeded to the point where a final decision should be made. These features include various measures such as additional river diversions of freshwater and sediment, marsh creation/restoration, and barrier island restoration designed to improve water and sediment management in the marshes. When analyses and designs of these features are completed, decision documents would then be passed to Congress for authorization and appropriation in future WRDA's.

The LCA's S&T Program and Demonstration Projects provide a mechanism to improve the science and tools necessary to adequately plan and design a plan for a sustainable ecosystem. While the knowledge and technology base of coastal ecology is substantial, scientists, engineers, and ecologists do not know everything necessary to completely design and plan ecosystem restoration. The S&T Program will have a Science Director who will bring together the appropriate academic and research elements necessary to resolve scientific uncertainties concerning restoration causes and effects and to develop the science and modeling tools necessary to reduce uncertainty about ecosystem interrelationships and project the expected benefits and impacts of proposed features. Demonstration projects will be designed to resolve uncertainties or demonstrate project effectiveness on small scales before application to larger, more costly systems.

The Beneficial Use of Dredged Material feature would provide an additional $100 million over 10 years to increase the amount of dredged material used for creating marsh. The USACE's New Orleans District currently only beneficially places for marsh restoration about 20 to 25 percent of the approximately 70 million cubic yards of material per year dredged to maintain the authorized navigation channels in southern Louisiana. Under the existing beneficial use program policies and due to limited funding for maintenance dredging, the District cannot significantly increase its dredging costs to beneficially dispose of the dredged material. Beneficial use has thus normally been limited to areas near the maintained waterways. Interior marshes or open-water areas several miles or more away from these waterways cannot normally be reached with the disposal techniques without significantly increasing costs. This program would provide additional funds for the extra costs of moving the dredged material greater distances and give greater flexibility in restoring or preserving interior marshes. Use of this program would also significantly reduce the amount of dredged material disposed of offshore with little or no environmental benefits.

The LCA plan would also include studies to identify structures that could be changed structurally or operationally to provide or improve the structures' abilities to contribute to the ecosystem, in most cases with little or no changes to the original objectives of the structures. Such changes could be used to reduce salinity intrusion or divert additional freshwater or sediments to help restore or protect threatened areas.

The LCA plan also includes large-scale, long-term studies that not only have the potential to make macro-scale changes in the ecosystem but also macro-scale changes to the existing uses of the system. An example would consist of creating a new tributary of the Mississippi River to form a new "delta" either east or west of the existing river. Such a feature could potentially divert up to one-third or more of the average flow and sediment of the Mississippi River. Such large-scale studies would have to demonstrate that the proposals were technically feasible and had major benefits to the coastal ecosystem while determining and addressing any adverse impacts such proposals would have to the users and stakeholders of the existing ecosystems, streams, and receiving marshes. Unintended adverse impacts to the coastal and riverine ecosystems from such proposals would also be addressed by these studies.

Science and Technology Program

Technology played a significant and prominent role in the LCA study. At the beginning of the LCA study, the study team recognized that, while the current science and technology knowledge and abilities relative to coastal ecosystems are substantial, there was still a need for further advancements to reduce the scientific uncertainties and expand the engineering technology for coastal restoration. To address these needs, the recommended LCA plan included a 10-year S&T Program funded for up to $100 million. A major component of the S&T Program would include demonstration projects to deepen knowledge and improve the technology for coastal restoration. The LCA S&T Program would provide a strategy, organizational structure, and process to facilitate integration of science and technology into the decision-making processes of the LCA Project Execution Teams. Implementation of the S&T Program would ensure that the best available science and technology available were used in the planning, design, construction, and operation of LCA Plan features.

Uncertainties may be related to data availability, science, modeling, and other analytical tools; socio-economic impacts; implementation; technical methodology; resource constraints; cost; or effectiveness of restoration features. Uncertainties may also be related to development and refinement of forecasting tools. Major roles of the S&T Program will be to identify and prioritize critical areas of uncertainty, to formulate the most appropriate means of resolving uncertainties, and to ensure focused data collection aimed at resolving these areas of uncertainty. Results would be used to make recommendations to the LCA program regarding program and project refinements in light of the reduced uncertainty. Critical areas of uncertainty identified by the study team, academics, or agency personnel would be proposed to the S&T Office Director. However, the S&T Office would not be constrained to targeting only these needs, but rather would be open to facilitating the pursuit of new technology, experimentation, and innovative ideas when suitable for the advancement of the LCA program. Areas of uncertainty would be prioritized based on how much resolving the uncertainty would advance the LCA Program.

The S&T program and its Director would work with the LCA program management and study team to review and assess goals and objectives of the LCA program and to identify S&T needs to help the LCA Plan meet those goals and objectives. The S&T Program would manage and coordinate science projects for data acquisition and monitoring, data management, modeling, and research to meet identified scientific needs of the LCA Plan. The program would establish and maintain independent science and technology advisory and review boards and conduct scientific evaluations, assessments, and peer reviews to ensure that the science implemented, conducted, or produced by the S&T Program meets an acceptable standard of quality, credibility, and integrity. In addition, the S&T program would coordinate with other research efforts, such as the Louisiana Governor's Applied Coastal Research and Development Program, and other state and Federal R&D entities. The program would also incorporate lessons learned and experiences (pros and cons) of other large-scale ecosystem restoration science and engineering programs such as the Everglades, Chesapeake Bay, and Calfed. The program would establish performance measures for restoration projects and monitor and evaluate the performance of program elements. The S&T program would also prepare scientific documents including a periodic Science and Technology Report and conduct technical workshops and conferences.

Through the S&T program, an improved scientific understanding of coastal restoration issues would be gained and be infused into planned or future restoration planning, projects, and processes conducted by the LCA project study team.

Demonstration projects represent one of several strategies that the S&T program would employ to reduce uncertainties. Demonstration projects may be necessary to address uncertainties not yet known and discovered in the course of individual project implementation or during studies of large-scale and long-term restoration concepts. The S&T Director would prepare documents that would identify major scientific or technological uncertainties to be resolved and a monitoring and assessment plan to ensure that the demonstration project would provide results that contribute to the overall LCA program effectiveness. After design, construction, monitoring, and assessment of individual demonstration projects, the lessons learned would be applied to improve the planning, design, and implementation of other Louisiana coastal zone restoration projects. Under the LCA program, these demonstration projects would be funded up to $100 million over 10 years, with no single demonstration projects exceeding $25 million.

CLEAR Modeling

For the LCA study, modeling tools were developed to assess the impacts—both beneficial and adverse—the various proposed restoration measures would have on the Louisiana coastal ecosystem. The knowledge of how coastal ecosystems function has grown dramatically over the past 50 years. However, it would be inaccurate to state that we know enough about how the various components of the ecosystem interact with each other and react to various natural and man-made changes. Therefore, it would be difficult to say with certainty how an ecosystem the size of the LCA study area will respond to numerous, combined, or overlapping restoration measures. Restoration projects to date have generally focused on small areas or localized ecosystems much smaller than the LCA study area.

While many of the results would be expected to carry over to a larger scale, the overlapping or cumulative impacts of many restoration measures could produce many unintended impacts. As such, the LCA study team considered it critical to develop a new modeling approach and apply it to assess the overall ecosystem response to proposed measures. A large number of academic scientists and ecologists (from Louisiana State University, University of Louisiana at Lafayette, University of New Orleans, and others), working with the other resource agencies, developed an LCA Ecosystem Model to evaluate and assess multiple combinations of restoration strategies and measures for the study. The model became known as the CLEAR model (Coastal Louisiana Ecological Assessment and Restoration).

Developing and evaluating coastal restoration features of the LCA to achieve this goal required linking the changes in environmental drivers (processes such as riverine input) to specific restoration endpoints (hydrodynamic, ecological, and water quality) using a variety of modeling approaches. The linkage of numerous proposed restoration measures and the projected results of these measures were provided by the development of the CLEAR Model. The modeling system consists of five major steps in the evaluation process. In Step One the frameworks that approximate the degree of change in environmental settings to achieve planning scales (reduce, maintain, increase, etc.) were developed. In Step Two the frameworks were provided to an ecosystem modeling team (consisting of agency and academic experts) for estimates of change in five modules: (1) hydrodynamics, (2) land building, (3) habitat switching, (4) habitat use, and (5) water quality. Each module required knowledge of existing conditions and the ability to predict changes in the landscape based on assumptions of how the ecosystems respond to coastal processes. In Step Three each module produced a set of endpoints specific to the environmental conditions of the particular coastal measures. Many of these endpoints became the input to other modules. Step Four used the endpoints of these five modules in a series of ecosystem benefit calculations to determine specific types of ecosystem response. Finally, in Step Five the original restoration frameworks were evaluated using a collection of the benefits and compared to the original restoration objectives.

The CLEAR Model was used to evaluate the cumulative impacts of the proposed restoration comprehensive plans on individual subprovince areas. Some of these comprehensive plans were used in the final array of measures for the LCA recommended plan. Many of the possible combinations predicted land creation (or at least reduction in loss rates), but often with undesired results in many of the subprovinces, such as over-freshening of the estuaries with reductions in fisheries resources. However, overall the model allowed the study team to evaluate, at least on a preliminary scale, the numerous combinations of restoration measures and their predicted impacts on the LCA ecosystem.

The CLEAR Model represents a significant advancement in the ability to evaluate coastal ecosystems. However, the model development and resolution obtained during the LCA study allowed only macro-scale estimates of how proposed comprehensive restoration plans would impact the coastal processes and provide for a sustainable coastal landscape. Future models will be developed during subsequent LCA studies to enable the evaluation of proposed measures on areal and ecosystem scales at a much finer resolution. This will allow analysis and evaluation and help reduce the scientific uncertainty of the impacts of such measures on the ecosystem linkages and performance. Model development will be constantly improved as extensive monitoring and adaptive management principles will also be employed to improve the knowledge base and reduce scientific uncertainty to improve the CLEAR ecosystem model and its ability to predict outcomes of planned restoration measures.

Co-Located Team

Traditionally, a USACE study will consist of a study team, known as a *Project Delivery Team* (PDT), primarily of multi-disciplinary USACE employees. During the study the PDT works with the various local, state, and Federal agencies and with the various stakeholders and sponsors of the study. However, these other groups often have only limited input to the study before the development of initial plans or once a draft report is put out for public review and comment. While this may result in the development of a good plan, one that will meet the study objectives and still address affected stakeholders' concerns, this process is usually time-consuming, often requiring significant modifications to the proposed plan to address issues not fully analyzed during the study.

It quickly became apparent that neither the USACE nor the Louisiana DNR had all the required knowledge and expertise necessary to develop a comprehensive coastal restoration plan that would meet the objectives of the LCA study. Clearly, the combined knowledge of other Federal, state, and local agencies would be necessary. The LCA PDT sought the expertise and knowledge of these agencies and other organizations that were active in defining the coastal loss problem, its causes, and potential solutions. The PDT established a co-located Team for LCA in which individual representatives of many of the other agencies literally worked fulltime or part-time on LCA at the New Orleans District offices for the duration of the study. The intent of the co-located team was to use an interagency team to evaluate proposals and work on issues directly and efficiently. The goal was to improve communication among agencies and groups, streamlining the normal bureaucratic channels to gain feedback, concurrence, and/or objections to the direction of the study and individual proposed features in a timelier manner. In addition, the best available knowledge, science, and technology could be employed to develop the comprehensive plan. Representatives of the USACE, La DNR, La Department of Wildlife and Fisheries (La W&F), U.S. Environmental Protection Agency (EPA), the U. S. Geological Survey (USGS), the U.S. Fish & Wildlife Service (USF&W), and the National Resources Conservation Service (NRCS) participated on the co-located team.

The co-located team provided enormous advantages to the study and development of the recommended plan. First, the team was able to pull from the knowledge and abilities of a staff with much more diverse capabilities than normally applied to conduct the study. Second, many issues between agencies which in the past would require weeks if not months to resolve were usually resolved in a few days unless they required senior management to resolve. Even then, by having members of those agencies on the PDT, issues were normally resolved more quickly and effectively. Third, agency members became more familiar with the practices, concerns, and policies of each other's respective agencies and developed strong working relationships. This agency networking had additional benefits in that other agencies' employees (not working on LCA) had associates working directly with representatives of other agencies. More than once co-located team members helped resolve non-LCA issues from their agencies by linking their representatives more directly with other agencies.

Co-located teams should be considered for major watershed-based studies, particularly if there are a large number of stakeholders with very divergent interests. The use of co-located teams would not be practical for relatively small studies with