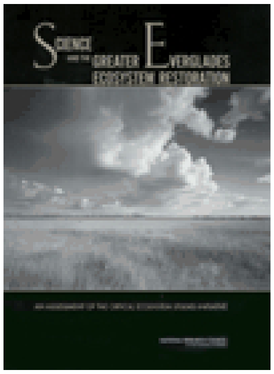

Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystem Studies Initiative

Panel to Review the Critical Ecosystem Studies Initiative, National Research Council

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SCIENCE AND THE GREATER EVERGLADES ECOSYSTEM RESTORATION

AN ASSESSMENT OF THE CRITICAL ECOSYSTEM STUDIES INITIATIVE

Panel to Review the Critical Ecosystem Studies Initiative
Water Science and Technology Board
Board on Environmental Studies and Toxicology
Division on Earth and Life Studies
NATIONAL RESEARCH COUNCIL *OF THE NATIONAL ACADEMIES*

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Panel To Review The Critical Ecosystem Studies Initiative[1,2]

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[1] See Appendix I for panel member and NRC staff biographies.
[2] The activities of the panel were overseen and supported by the NRC's Water Science and Technology Board (lead) and the Board on Environmental Studies and Toxicology (see Appendix H).

Preface

This report is a product of the Panel to Review the Critical Ecosystem Studies Initiative—a panel organized by the National Research Council (NRC) in response to congressional concerns that the restoration of the greater Everglades ecosystem be supported by the best possible science. The Critical Ecosystem Studies Initiative (CESI) has been the primary investment by the U.S. Department of the Interior to provide scientific information to advise restoration decision-making and to guide its own land management responsibilities for South Florida ecosystem restoration. Nevertheless, it is important to recognize that the CESI program investments represent only a small fraction of total South Florida restoration science funding. Even in the years of greatest CESI funding (fiscal years 1998–1999), the program represented just 17 percent of federal and state investments in restoration-related science and monitoring, according to the interagency cross cut budgets (SFERTF, 2002). This study focused on the science components of the CESI program and did not attempt to provide a comprehensive evaluation of all restoration science. Nevertheless, the review was undertaken in the context of the range of ongoing science efforts of the various entities involved in the South Florida restoration program. See the Executive Summary or Chapter 1 for the study's Statement of Task.

To accomplish its review of the CESI program, the panel chose to distinguish between the products of CESI science (knowledge or data generated by CESI-funded research) and the approach used by the CESI to meet the needs of restoration decision-makers, and we focused primarily on the broader of these. The panel did not systematically evaluate the methods or results of individual CESI-funded projects, as this level of detailed analysis was beyond the scope of the panel's charge and the time available. Instead, we concentrated on the processes used by the CESI program to support restoration, such as priority-setting, identifying science gaps, and communicating research results. Examples of CESI-funded research, however, and their contributions to the restoration efforts were examined through several case studies. The fascinating nature of the scientific issues associated with the design of the greater Everglades restoration plan made it a challenge for the panel to stick to its charge and not delve into the topic of the restoration itself. A separate National Research Council committee—the Committee on the Restoration of the Greater Everglades Ecosystem or the CRO-GEE—is charged with providing overviews and technical assessments to the South Florida Ecosystem Restoration Task Force concerning Everglades restoration activities. The panel is grateful to the CROGEE for assisting with the formation of our panel and in providing guidance to our panel. It is noted that CESI panelist, Stephen Humphrey, and I are both CROGEE members.

The findings of the panel are based on discussions with Everglades scientists, managers, and engineers who freely shared their insights into the complex issues surrounding restoration of the greater Everglades ecosystem during three information-gathering meetings. This report is also based on analysis of documents supplied by the CESI program managers, and the report is supplemented by review of pertinent peer-reviewed literature. The CESI panel is grateful to the many individuals who provided assistance in the completion of this study (See Acknowledgements). A special note of thanks is owed to Robert Johnson and William Perry of Everglades National Park. They contributed great time and effort for our meetings and fieldtrips, and they showed remarkable patience with our endless queries. They were forthright with information and provided candid comments on the CESI program, while emphasizing the important products and results. Their input, especially to those not intimately familiar with South Florida restoration, was critical to the development of this report.

The greater Everglades restoration is unprecedented in its scope and complexity, and the challenges faced by restoration scientists will require innovative solutions and long-term commitments. Our panel was struck by the sincere dedication toward restoring the greater Everglades ecosystem by all of the scientists, engineers, and planners who met with us. Their commitment to making the restoration a reality is the common thread among them that has kept the restoration process moving ahead. That same dedication will be required to see the restoration through the next 40 years of planning, design, and construction.

Leading this study was a gratifying experience for me, and I wish to thank the panel members for their enthusiastic participation in this study and their lively debate on many issues relevant to the report. These individuals provided a diverse expertise and a wealth of experience in the many disciplines and topics relevant to this study. Each of them brought a creative and fresh perspective to the study, and each participated in the crafting of the conclusions and recommendations and in the drafting of the report. We were ably supported and guided in our work by the Water Science and Technology Board (WSTB) and the Board on Environmental Studies and Toxicology. Several WSTB staff members played important roles. WSTB director Stephen Parker got us on our way and continued to offer guidance throughout the study. WSTB senior staff officer Will Logan's experience and insight into the greater Everglades ecosystem restoration activities helped to provide clarity to the report. Stephanie Johnson, the study director, helped develop and organize the information-gathering meetings, maintained liaison contacts with DOI and other scientists, and assured compliance with NRC policies. We particularly wish to recognize her extensive editorial efforts and intellectual contributions to this report. Jon Sanders, the project assistant, handled meeting logistics, research, and editorial tasks for the panel. Finally, we appreciate the work of Rhonda Bitterli, who copy-edited our report prior to publication.

The 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 institution in making its published report as sound as possible and to ensure the report meets 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 wish to thank the following individuals for their review of this report: John Cairns, Virginia Polytechnic Institute and State University; Robert Goldstein, Electric Power Research Institute; Lance Gunderson, Emory University; Thomas MacVicar, MacVicar, Federico and Lamb, Inc.; Robert Perciasepe, Audubon; and Rutherford Platt; University of Massachusetts.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by David Moreau, University of North Carolina, and Frank Stillinger, Princeton University. Appointed by the National Research Council, they were responsible for making certain that an independent examination of the report was carefully carried out in accordance with the institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring panel and the institution.

Linda K.Blum, *Chair*

Panel to Review the Critical Ecosystem Studies Initiative

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Many individuals assisted the committee and the National Research Council staff in their task to create this report. We would like to express our appreciation to the following people who have provided presentations to the panel, assisted with information gathering for the report preparation, and served as guides during the field trips:

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John Benjamin (NPS)
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Contents

Executive Summary

The Everglades represents a unique ecological treasure, and a remarkable collaboration of local, state, and federal agencies is currently working to reverse the effects of nearly a century of wetland drainage and impoundment for water supply, flood protection, and development. Although not all parties agree on the details of the effort, there seems to be universal agreement that the best possible science should serve as the basis of planning, implementing, and, ultimately, operating the restoration projects. The path to restoration will not be easy, and clearly there is a large element of uncertainty in this complex undertaking. Good science should be a vital component, as it will increase the reliability of the restoration, help enable solutions for unanticipated problems, and potentially reduce long-term costs.

In the past few years, however, the investment in science and research relevant to the restoration has eroded measurably within some agencies, including one major Department of the Interior (DOI) science program, the Critical Ecosystem Studies Initiative (CESI). Funding for the CESI program has decreased from a maximum of $12 million per year (1998) to its current level of $4 million per year (2002). In response to concerns over the declining science funding and the adequacy of science support for restoration decision making, the U.S. Congress instructed DOI to commission a study by the National Academies[1] to review the science component of the CESI program (see Box ES-1 below for the Statement of Task). The mandated study was carried out by a special panel organized by the Academies between January and December 2002. A summary of the panel's findings follows.

[1] The National Academies consists of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Research Council is the operating arm of the National Academies.

BOX ES-1 STATEMENT OF TASK FOR THE PANEL TO REVIEW THE CRITICAL ECOSYSTEM STUDIES INITIATIVE

An expert panel organized by the National Academies was charged to:

- assess the adequacy (types and funding levels) of science being conducted in the DOI CESI program in light of the scientific activities of other entities and the needs of the overall restoration effort
- provide guidance as to how the science being conducted under the CESI rubric can be better planned, managed, and reviewed and how it can be better coordinated and integrated with relevant work outside the program
- advise DOI with respect to CESI strategic planning
- provide guidance with respect to information management and effective dissemination of science produced in the CESI program to help assure support for decision making during the planning, implementation, and operational phases of restoration.

Although this review focused on the science components of the CESI program, it was undertaken in the context of the full portfolio of science being carried out by the various entities involved in the South Florida restoration. The CESI program is an important component of the overall endeavor, but it could not be assessed alone as a discrete activity.

CESI BACKGROUND

The CESI program was intended to meet the most important science information needs for the South Florida ecosystem restoration in order to support project design, restoration decision making, and planning as it related to DOI lands. Prior to the CESI program's establishment in 1997, the region was rich with agencies conducting scientific and engineering research; however, limited funding, divergent agency missions, insufficient coordination, and compressed timetables left critical voids in the restoration science. The CESI program's “gap-filling” strategy offers agility and flexibility, allowing the program to address emerging research needs and to respond to urgent decision-making timeframes, while also supporting overlooked or underfunded science needs.

From its inception, the CESI program has funded a wide range of studies, including experimental ecosystem research, model development and refinement, ecosystem characterization, environmental impact assessments, restoration planning, and science review. Broadly, science studies funded through the CESI program were intended to provide information about how the ecosystem functions and how the natural system has been altered. The program also aimed to develop tools to predict how the current system might respond to restoration of historic hydrological conditions. Extensive research has been conducted to clarify the linkages between hydrological conditions and ecosystem attributes.

Scientific information derived from CESI studies was intended to inform res-toration planning and decision making. Specific emphasis was placed on early restoration projects, such as the Modified Water Deliveries to Everglades National Park and C-111 projects, which directly impact DOI lands and are scheduled to be completed early in the restoration time frame. These ongoing projects, however, highlight the inherent difficulties of providing effective scientific advice after the project planning process has already begun. Nevertheless, scientific information derived from these early projects can be used to inform larger-scale restoration decisions and improve the design of future Comprehensive Everglades Restoration Plan (CERP) projects.

CESI MANAGEMENT

The CESI program is managed and administered by the National Park Service, but the program is a collaboration among numerous federal, state, and local governments. Such collaboration allows diverse agency perspectives to be considered as the scientific information priorities are determined. The CESI program's organizational structure provides an agile and effective framework for managing the research program. Nevertheless, improvements in CESI management are necessary. Several key areas of CESI management require immediate attention to improve the effectiveness of the CESI program, including the narrow distribution of requests for proposals, an insufficient peer-review process, and limited involvement of expert advisors.

The CESI program must move quickly to address emerging science needs and to meet restoration decision-making deadlines. However, sometimes this fast action occurs at the expense of appropriate proposal development and review. CESI managers can substantially improve the scientific viability of their research products by broadening the distribution of requests for proposals, improving proposal review standards, involving independent reviewers, and improving the review of research products before they are released to users. Expert advisors appointed to CESI program advisory committees should be integrally involved with the proposal review process. CESI managers should also utilize these committees to incorporate diverse advice on the establishment of research priorities and to promote closer coordination with related research and monitoring activities.

Other management changes are needed to increase the effectiveness of the CESI program. Restructuring of research within Everglades National Park should be considered to improve the application of CESI funding across all DOI lands and resources impacted by the greater Everglades ecosystem restoration. The CESI manager should also have direct responsibility for funds allocated by interagency agreement and should seek to improve public awareness of its contributions to the restoration effort through expanded dissemination efforts.

Changes in the CESI management structure are expected to be implemented soon in accordance with an interagency memorandum of understanding among DOI's South Florida science programs. The reorganization is designed to facili tate improved science coordination among DOI agencies, but the proposed management plan needs to include sufficient scientific expertise and agency representation to ensure appropriate prioritization and management of the research funds. The new management structure would be strengthened by the appointment of a senior scientist to coordinate the CESI program. Additional program staff will likely be needed to synthesize and communicate the findings.

UNMET SCIENCE NEEDS

Several areas within the CESI program require additional attention to meet the science needs of the greater Everglades ecosystem restoration effort. This study did not include a complete gap analysis of South Florida science in the evaluation of the CESI program, but broad science information gaps clearly remain, highlighting the need for continued support of the CESI program. Specifically, the CESI program has not adequately supported priority research needs in the areas of social science, water-quality modeling, and contaminants. Despite the CESI program's extensive research on the linkages between hydrological and ecological attributes, significant additional study is required to examine these linkages for a wider range of species and communities, with particular emphasis on ecological performance measures identified by the CERP. Hydrological and ecological models that will provide the basis for scientific advice for restoration planning need continued refinement and additional supporting field-data collection. The CESI program should identify priority research topics in under-funded areas, such as those identified here, and formulate effective research programs based on rigorous peer-review procedures. CESI managers should then develop budget estimates and seek additional funding to support these programs.

The results of scientific research must be synthesized and broadly disseminated to all stakeholders for scientific knowledge to be useful in restoration planning. Synthesis, however, is notably lacking in the CESI program and in other South Florida science programs. The complexity and expanse of South Florida's ecosystems require a multidisciplinary approach to convert observational, experimental, and modeling results into knowledge that spans multiple spatial and temporal scales. Although the CESI program should substantially improve its contributions toward science synthesis, the CESI program is just one of several ongoing science programs that support the South Florida ecosystem restoration. The broader restoration requires a single overarching entity to facilitate comprehensive restoration science synthesis and to coordinate scientific efforts beyond the boundaries of the CERP and of the CESI program. Such an entity would provide scientific vision for the restoration, promote collaboration to maximize the cost effectiveness of science resources, and improve the usefulness of new and existing scientific information.

CESI FUNDING

On the whole, federal investments in the CESI program have produced valuable science, a rich database, and a starting point for a basic understanding of the dynamics of the greater Everglades ecosystem. However, funding for CESI science has been inconsistent and is now far less than is needed to support DOI's interests in and responsibilities for the restoration. Additional funding to improve synthesis and communication of the research results is especially critical. The result of the budget shortcomings has been that difficult choices were made and high-priority scientific research needs have gone unmet. In some cases, the lack of scientific information will have little or no impact on the outcome of the restoration. In other cases, the ecological and economic impacts may be very high.

Scientific research represents an investment in the knowledge base that will support the restoration over its lifetime. Inadequate science support now may result in exponentially increased costs later if failed restoration projects need to be redesigned based on unforeseen consequences of the restoration efforts. With the recommended management improvements, the CESI program provides a good structure to address the restoration's high-priority science needs and urgent scientific questions in order to advise restoration planners. Congress should increase CESI research funding to meet DOI's restoration science needs, contingent upon several high-priority improvements in CESI management. These management improvements are necessary to ensure that new funds are directed in an efficient and effective manner to the proper science priorities and with an adequate peer-review structure in place.

LINKS TO DECISION MAKING

CESI-funded scientific research faces notable barriers in its support for South Florida ecosystem restoration. The greatest of these barriers is the compressed timetable for the CERP and for other restoration projects. Quality long-term ecosystem research will be pressed to meet the time lines set for the restoration effort. Scientists and planners alike recognize that it will not be possible to resolve all scientific uncertainties before the restoration construction begins; thus, increased reliance will be placed on adaptive management to incorporate research results throughout the process of restoration project planning, construction, and operation. Project designs must be sufficiently resilient to accommodate new research findings and allow sufficient operational changes after construction. Nevertheless, restoration managers should reevaluate the current restoration schedule in cases when critical science questions remain that could affect project design decisions beyond their inherent operational flexibility. Researchers must be more responsive to external time pressures for information, and they must be willing to adapt research studies to meet the identified information needs. Meanwhile, new approaches to coordination between restoration planners and researchers will be required to identify emerging and high-priority needs, agree upon workable timetables, and promptly communicate the research findings after the results have been peer reviewed appropriately.

Currently, barriers remain in the dissemination and communication of the research findings to restoration planners and decision makers. Several of these issues broadly affect all of South Florida's restoration science activities, not just the CESI program, and improvements in existing science institutions could greatly improve research communication, prioritization, and coordination for the restoration effort. Passage of the Water Resources Development Act of 2000 altered the political and administrative environment within which the greater restoration process will proceed, and circumstances have changed significantly from those in place when the CESI program was formed in 1997. In the CERP, an organizational framework called RECOVER[2] was created as the primary venue for communicating scientific results to the project planners and engineers responsible for implementation, and the RECOVER team is emerging as one of the potential leading science advisory organizations in South Florida. To facilitate integration of research findings, steps should be taken to assure that sufficient numbers of scientists representing a broad representation of agencies participate in the RECOVER committee process. To support sound prioritization of research and monitoring activities for the South Florida restoration, Congress should consider how to formalize a significant role for DOI on RECOVER while maintaining the broadest possible participation of other restoration stakeholders. Non-CERP projects, however, represent almost half of the total funds estimated for the greater Everglades restoration effort, and these non-CERP activities must be an integral part of restoration-wide science coordination and synthesis efforts.

CONCLUSION

The CESI program provides a strategic framework for addressing restoration science needs, and the suggested management improvements should ensure that the funds are directed in an effective manner (see Chapter 6 for a complete listing of the conclusions and recommendations). Many critical scientific information needs remain, and the value of a science funding program focused on DOI's needs and responsibilities within the South Florida ecosystem restoration is significant. Strategic early investments in ecosystem science should improve the likelihood of reaching restoration goals while reducing the overall cost of the restoration effort. Yet these research investments must also be supported by eco-system-wide science synthesis and mechanisms for integration and coordination. Science synthesis and integration are critical challenges faced by all agencies contributing to South Florida restoration science, and they cannot be solved by the CESI program—or any of the other existing science programs—alone.

[2] REstoration, COoordination, and VERification.

1

Introduction and Background

The greater Everglades ecosystem is recognized globally as a unique ecological treasure. However, driven by population growth and agricultural opportunity, South Florida has been transformed in the last century from a "river of grass" (Vignoles, 1823) (Figure 1–1) into an international center for tourism, agriculture, finance, and transportation. The remnants (less than 50 percent) of the original Everglades now compete for water with urban and agricultural interests and store runoff from these two activities (Figure 1–2a) (Davis and Ogden, 1994). Now unfolding within this twenty-first century social, economic, and political latticework, restoration of the greater Everglades ecosystem is one of the most ambitious ecosystem renewal plans ever conceived (Figure 1–2b).

This chapter outlines the history of the South Florida ecosystem from its environmental decline to the present restoration efforts. It then summarizes the science of the greater Everglades ecosystem, including the history and current role of science in guiding restoration planning and decision making. Finally, this chapter describes the role of the Critical Ecosystem Studies Initiative (CESI) within this scientific and institutional context and provides this panel's study charge.

SOUTH FLORIDA'S ENVIRONMENTAL DEGRADATION

Alteration of the greater Everglades ecosystem began soon after Buckingham Smith reported to Congress in 1848 that draining the Everglades by 4–5 feet would produce a "tropical breadbasket of no trifling advantage to the whole nation" (Smith, 1848; Dovell, 1947). Efforts to reclaim the area for development and human habitation evolved slowly, as the marsh and sloughs were largely impenetrable and uninhabited. The land and water interface fluctuated dramatically with the changing seasons and with cycles of wet and dry years.

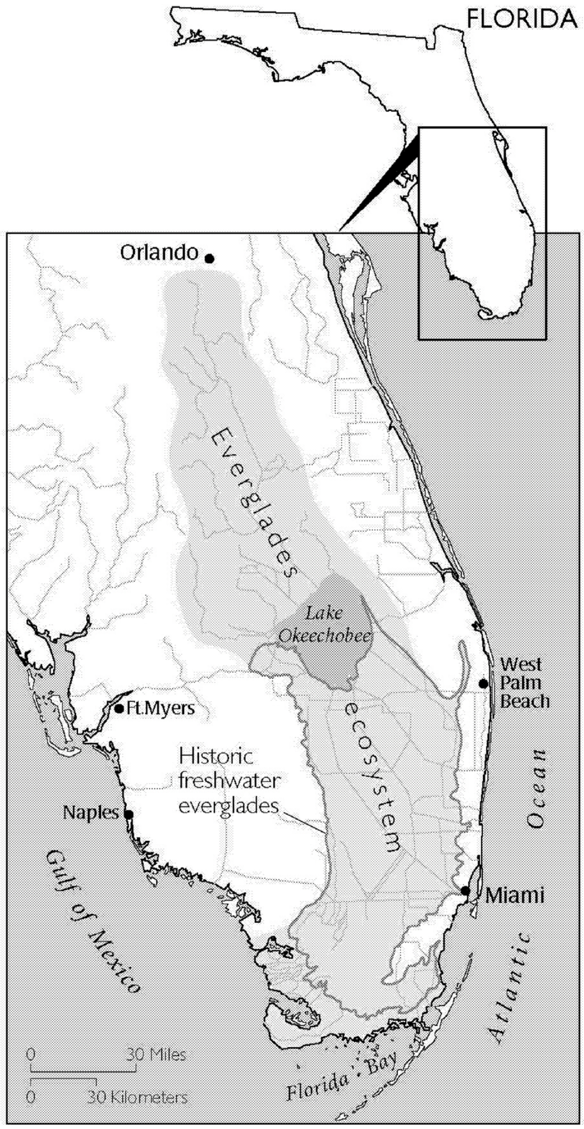

FIGURE 1–1 Greater Everglades ecosystem. SOURCE: USGS, 2002a.

In the mid-1880s, Hamilton Disston, the heir of a Philadelphia family fortune, saw the future of the region in the production of fruits and vegetables to be shipped to burgeoning East Coast cities (Trustees, 1881). He spent a decade ditching, draining, clearing, and planting over 50,000 acres north and west of Lake Okeechobee. He and his crops would have had a virtual monopoly in the northern winter markets, but the economic conditions following the Silver Panic of 1893 put an end to his grand experiment (Blake, 1980). His techniques, however, would ultimately evolve beyond his wildest dreams (Snyder andDavidson, 1994).

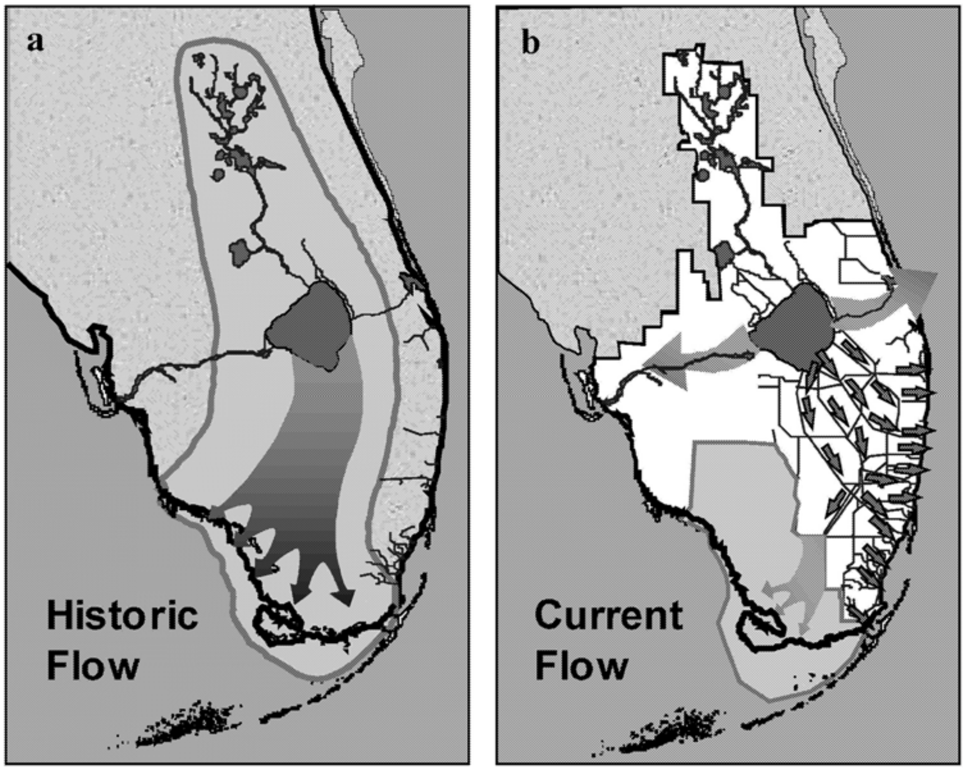

FIGURE 1–2 Schematic maps of water flow in the Everglades, representing (a) current flow and (b) the system as envisioned in the Comprehensive Everglades Restoration Plan.
SOURCE: South Florida Water Management District, 2002d.

In 1907, governor Napoleon Bonaparte Broward created the Everglades Drainage District for "draining and otherwise improving the hidden resources of the wetlands of Florida" (Blake, 1980). By the early 1930s, 440 miles of canals dissecting the Everglades had been constructed (Lewis, 1948), spurring population growth along the lower east coast (Dietrich, 1978).

STEPS TOWARD RESTORATION

As drainage of the Everglades proceeded, naturalists chronicled the "senseless vandalism" of the watery wilderness (Simpson, 1920; Small, 1929). Arthur Morgan testified before Congress in 1912 that the "haphazard reclamation of the watershed would finally result in unpredictable confusion in the balance of life in the Everglades" (Blake, 1980). J.K.Small (1929) prophesied, "This reckless and even wanton devastation has now gained such headway, that the future of North America's most prolific paradise seems to spell DESERT." These protests stirred Florida Congressman Mark Wilcox and Ernest Coe, a landscape architect, to pro pose protection of the submarginal lands of the southern Everglades and the Gulf Coast. Their efforts, coupled with those of women's clubs and the Audubon Society, eventually led to the establishment of a park in 1934. However, because of the lack of funding, Everglades National Park (ENP) was not dedicated until 1947, and the park (Figure 1–3) had been reduced by one-third of the original plan to accommodate private land holdings (Blake, 1980).

With input from wildlife reports such as Beard (1938), the Florida Soil and Crop Science Society crafted the first plan for recovery of the Everglades, eventually addressing conservation of soil, wildlife, and vegetation, saltwater intrusion, water levels, data-gathering needs, and institutional problems. These efforts culminated in the “Re-watering Plan” of 1939 (DeGrove, 1958). Among its elements, the plan addressed over-drainage and advocated the reversion of some areas to wetlands (i.e., water-conservation areas).

The Central And Southern Florida Project

The disastrous floods of 1947–1948 in South Florida coupled with postwar labor surpluses led to two related initiatives: in 1948, the U.S. Army Corps of Engineers (the Corps) produced the Comprehensive Plan for the Everglades largely based on the Re-watering Plan, and Congress established the Central and Southern Florida (C&SF) Project for Flood Control and Other Purposes. The project employed levees, water storage, channel improvements, and large-scale use of massive pumps to supplement gravity drainage. The project also installed a 100-mile perimeter levee to separate the Everglades from sprawling urban development, effectively eliminating 160 square miles of Everglades that had historically extended east of the levee to the coastal ridge (Light and Dineen, 1994; Lord, 1993). The project then divided the remaining northern sawgrass and wet prairie into conservation areas, separated by levees, designed primarily for water supply and flood control, with some provision for wildlife habitat and recreation. The Everglades Agricultural Area (EAA) (Figure 1–3) was created out of the mucklands homesteaded by family fanmers since the turn of the century. The added protection afforded by the levee on the south end of Lake Okeechobee and the conservation areas began attracting large-scale agriculture.

This mammoth infrastructure, nearly completed by the early 1960s, was initially viewed by many as providing a balance between humans and nature. The C&SF project did set aside from further development approximately one million acres that were folded into the three water-conservation areas (Figure 1–3). However, it also exacerbated disputes over water deliveries to the park (Rosendahl and Rose, 1981; Parker, 1984). These disputes were tempered when minimum flows to the park were established in 1970, although these flows bore little resemblance to natural hydrological conditions.

Additional hydrological alteration on the eastern boundary of the park, through the construction of the Everglades National Park-South Dade Conveyance System, further threatened the southeastern areas of the park, including Taylor Slough (Figure 1–4). The Corps plan called for installing a major levee and a grid of canals to protect lands east of the park and to carry water from south

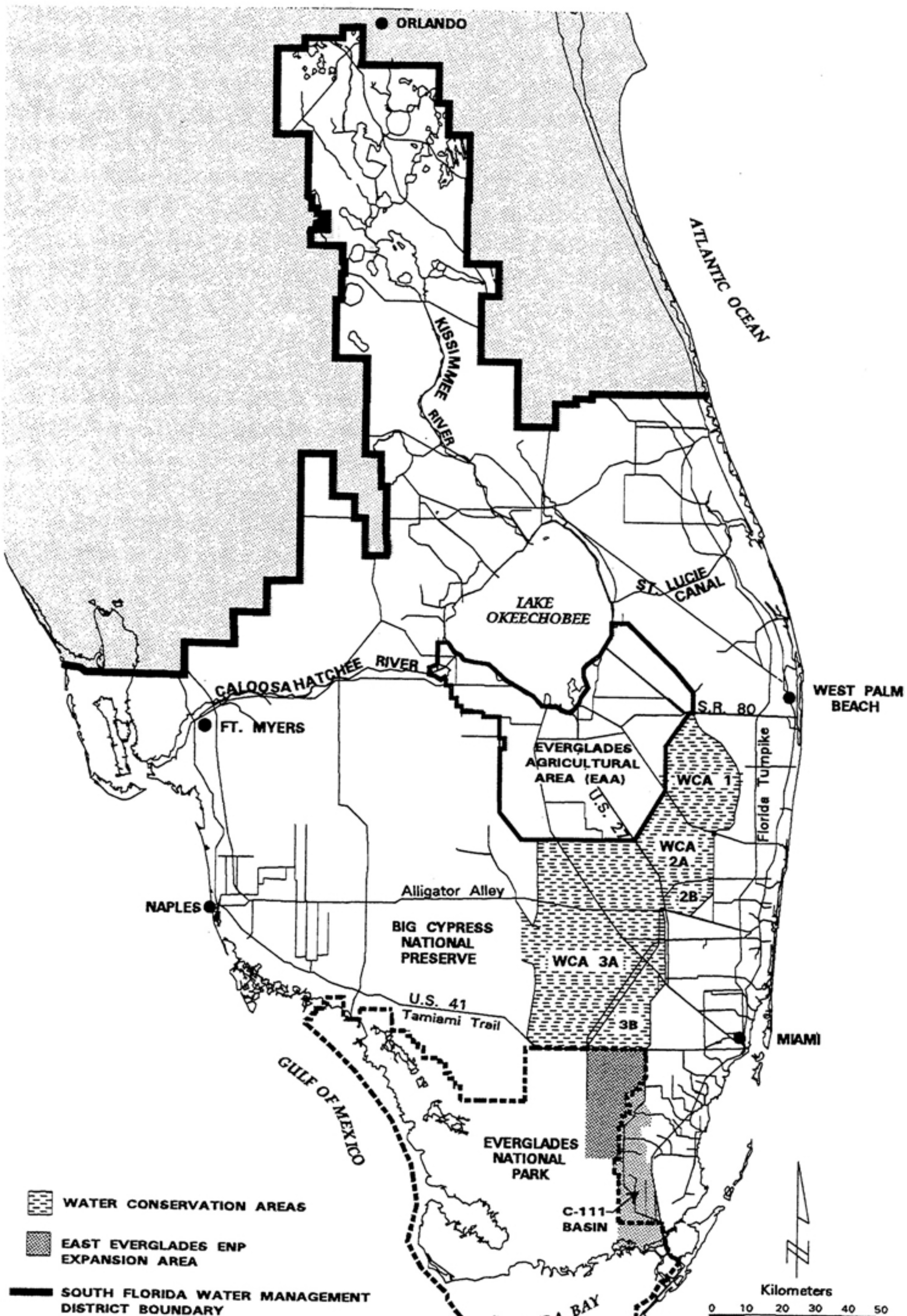

FIGURE 1–3 South Florida features map, including Everglades National Park, water conservation areas, and select structures. SOURCE: Light and Dineen, 1994.

Dade, Homestead, and Florida City into Biscayne Bay, Florida Bay, and Barnes Sound. The National Park Service requested that water drained from the Taylor Slough headwaters be directed to the slough rather than routed to Barnes Sound via Canal 111 (C-111). Ultimately, a gate was installed and minimum monthly flows were established for the Taylor Slough. However, since completion of the system in 1983, water levels and delivery patterns have been a source of controversy between the park, Dade County, the South Florida Water Management District (SFWMD), and the Corps (Light and Dineen, 1994).

Renewed Momentum Toward Restoration

A series of activities, including legislative acts (Box 1–1), provided support and momentum for the restoration of the greater Everglades ecosystem. Major droughts and floods in 1980–1982 created the conditions for Everglades National

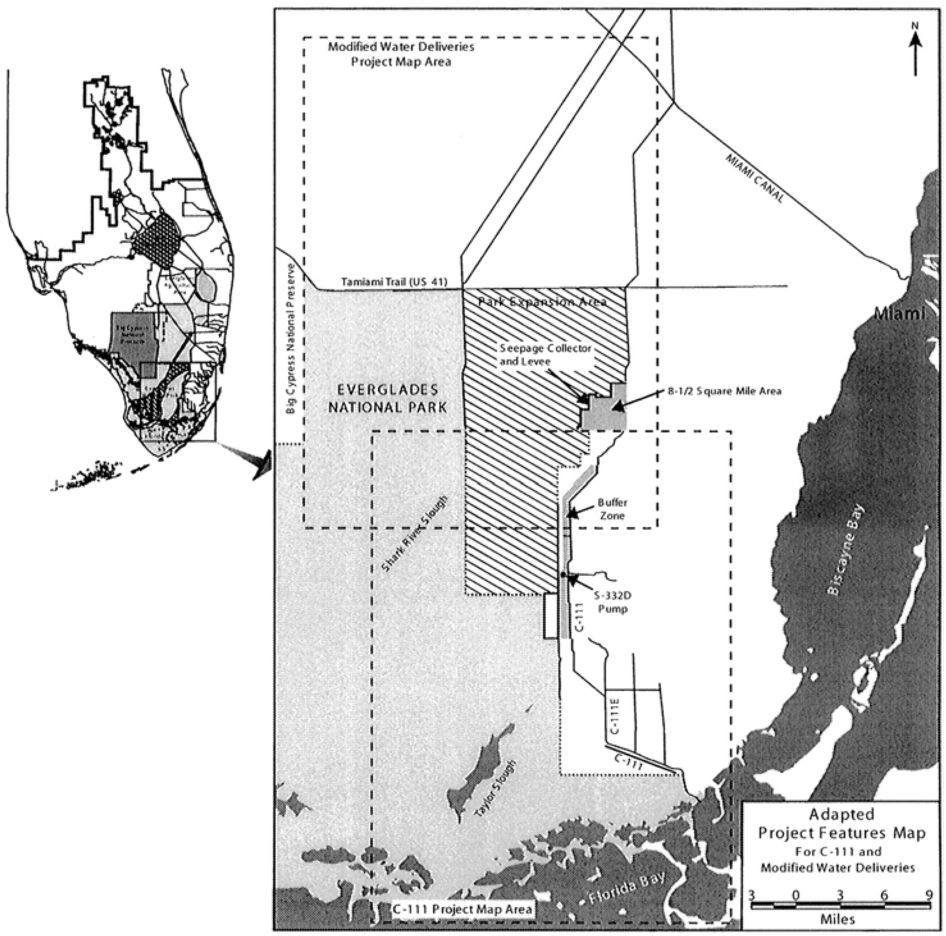

FIGURE 1–4 Map of eastern Everglades National Park showing current restoration activities to remedy impacts of flow diversion through the South Dade Conveyance.
SOURCE: General Accounting Office, 1999.

Park to declare an environmental emergency and propose a plan to respond to its water-supply and water-quality problems (Light and Dineen, 1994). In response to the park's demands for a more natural distribution and timing of water, Congress passed the “Fascell Bill” in 1984. This act authorized a modified water-delivery schedule from the C&SF project to the park and an experimental program for scheduling water deliveries to mimic rainfall patterns in the water-conservation areas (MacVicar and Lin, 1984). This was a turning point in the greater Everglades ecosystem restoration because at this juncture, multiple agencies began to address the park's deteriorating conditions. The Fascell Bill complemented the publication of Arthur R.Marshall's *For the Future of Florida, Repair the Everglades,* commonly called “the Marshall Plan” (Marshall, 1982), and it also complimented the initiation of the state's Save Our Everglades program in 1983 by governor Bob Graham. In 1989, Congress authorized the Everglades Protection and Expansion Act to purchase 107,600 acres of undevelopable land northeast of Everglades National Park (Figure 1–4). The assistance also aided the acquisition of some lands that were either adjacent to or affected by the restoration of natural water flows to the park or Florida Bay (Light and Dineen, 1994).

Starting in 1993, the Corps and the SFWMD began work on the Central and Southern Florida (C&SF) Project Comprehensive Review Study (“Restudy”), which was “initiated to re-examine the C&SF Project to determine the feasibility of modifying the project to improve the sustainability of South Florida” (SFWMD, 2002a). Following a reconnaissance phase, in 1995, a six-year work plan was presented for a feasibility study that would include the development and peer review of computer models and specific hydrological and economic studies. This timetable was thought to be reasonable considering the size of the study area, the need to maintain an ecosystem-based focus, the magnitude of the project, and the complex and controversial issues involved. However, based to some extent on recommendations by the Governor's Commission for a Sustainable South Florida, the Water Resources Development Act (WRDA) of 1996 hastened the Restudy effort by requiring completion of a comprehensive plan by July 1999. This placed some time pressure on providing the necessary science to inform restoration planning.

The Comprehensive Everglades Restoration Plan

The Restudy resulted in a document (USAGE, 1999), termed the Comprehensive Everglades Restoration Plan (CERP), which was approved by Congress in the Water Resources Development Act of 2000 (WRDA 2000). The overarching objective of the plan was to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including flood protection and water supply (Figure 1–2b). Of the 68 projects included in the CERP, approximately 24 directly impact DOI lands, or indirectly affect water inflows (Robert Johnson, NPS, personal communication, 2002).

BOX 1–1 SOUTH FLORIDA ECOSYSTEM RESTORATION: SUMMARY OF MAJOR LEGISLATION

During the last two decades, the Florida legislature and the Congress have enacted a series of laws to redress various environmental harms affecting the South Florida ecosystem. Many of these laws provide the authority under which the state and federal governments operate and fund various programs that collectively comprise the South Florida ecosystem restoration effort.

At the state level, the most significant efforts include:

- **Florida Water Resources Act of 1972.** This act established statewide policy for the allocation of water resources, including the establishment of minimum flows and levels to prevent “harm” to water resources and the ability to reserve water from consumptive use for the benefit of the public health or fish and wildlife.
- **Surface Water Improvement and Management Act of 1987,** codified at Florida Statute chapter 373.453 (2000). The Surface Water Improvement and Management Act required the water-management districts to develop plans to clean up and preserve Florida lakes, bays, estuaries, and rivers.
- **1994 Everglades Forever Act,** codified at Florida Statute chapter 373.4592. The Everglades Forever Act enacted into state law the settlement provisions of federal-state water-quality litigation and provided a financing mechanism for the state to advance the cleanup of the Everglades by constructing 44,000 acres of stormwater treatment areas. The act also requires a rulemaking process to establish a phosphorus criterion in the Everglades Protection Area.
- **Florida Preservation 2000 Act,** codified at Florida Statute chapter 259.101 (2000). The Florida Preservation 2000 Act established a coordinated land-acquisition strategy to protect fish and wildlife and waterrecharge areas.
- At the federal level, the most significant legal authorities include:
- **1989 Everglades National Park Protection and Expansion Act,** codified at 16 U.S.C. § 410r. This act added approximately 107,000 acres of land to Everglades National Park and authorized the restoration of more natural water flows to northeast Shark River Slough through the construction of the Modified Water Deliveries Project.

- **Kissimmee River Restoration Project, authorized by the Water Resources Development Act of 1992 (WRDA 1992),** Public Law No. 102– 580, 106 Statute 4802 (1992). WRDA 1992 directed the U.S. Army Corps of Engineers to take steps to restore the Kissimmee River floodplain, which was disrupted when the river was channelized during the 1960s.
- **Federal Agriculture Improvement and Reform Act of 1996,** Public Law No. 104–127, 110 Statute 1007 (1996). This act appropriated $200 million to the Secretary of the Interior for the purpose of acquiring lands for greater Everglades ecosystem restoration purposes.
- **Water Resources Development Act of 1996 (WRDA 1996).** WRDA 1996 established the intergovernmental South Florida Ecosystem Restoration Task Force to coordinate the restoration effort among the state, federal, tribal, and local agencies involved in the effort and directed the Corps to submit to the Congress a comprehensive review study of the Central and Southern Florida Project for the purpose of modifying the project so as to restore, preserve, and protect the South Florida ecosystem.
- **Water Resources Development Act of 2000 (WRDA 2000),** Public Law No. 106–541. WRDA 2000 authorized the Comprehensive Everglades Restoration Plan for the modification of the Central and Southern Florida Project over the next four decades to increase future water supplies, with the appropriate timing and distribution, for environmental purposes so as to achieve a restored Everglades natural system, while at the same time meeting other water-related needs of the ecosystem.
- SOURCE: Donald Jodrey, DOI, written communication, 2002.

The plan tried to address a series of problems with the existing system. These included excessive diversion of water resulting in too little water being available for some parts of the system and too much being available for others (e.g., the estuaries); nutrient enrichment; and disruption of sheetflow. The CERP also considered future water-supply needs of the region. Major components of the plan include:

- *Increases in water-storage capacity.* New water-storage would be created by constructing surface-water storage reservoirs, adapting existing quarries for storage at the end of their useful lives, and by utilizing a technique called “aquifer storage and recovery.”
- *Improvements in water quality.* Treatment wetlands would be built along the boundaries of the system. In addition, multipurpose “water preserve areas” are planned between the urban areas and the eastern Everglades to

treat urban runoff, store water, and reduce seepage. A "Comprehensive Integrated Water Quality Plan" is planned.

- *Improved water deliveries to the estuaries and the Everglades.* The increases in storage capacity, and some proposed reuse of treated wastewater, would allow the amount and timing of water deliveries to be improved. The salinities of the St. Lucie and Caloosahatchee estuaries would be maintained at more natural levels, and additional water would be sent to Everglades National Park.
- *Restoration of the connectivity of the system.* Many canals and levees within the Everglades would be removed, and parts of the Tamiami Trail (U.S. Route 41) would be rebuilt, to reestablish some of the natural sheetflow of water through the Everglades.
- *Provision for feasibility studies.* Studies are planned to further examine approaches to improve deliveries of fresh water flows to Florida Bay and to evaluate additional environmental restoration needs in southwest Florida, Florida Bay, and the Florida Keys.

Restoration planners are currently refining the mechanisms for assessing the progress toward the restoration goals in the CERP Monitoring and Assessment Plan (USAGE, 2001).

Other South Florida Restoration Projects

As fundamental to the restoration effort as the CERP is, there are many other restoration-related projects either planned or underway (Figure 1–5). They include the following (SFWMD, 2002e):

- *Modified Water Deliveries to Everglades National Park (ModWaters).* The ModWaters project is designed to restore more natural flows through Water Conservation Areas 3A and 3B into Northeast Shark Slough, reconnect Shark Slough and Taylor Slough via surface-water flows across the Rocky Glades, and reduce seepage losses from the southeastern Everglades.
- *C-111 Project.* The C-111 project is designed to restore the hydrological conditions in the Taylor Slough and Eastern Panhandle basins, eliminate damaging freshwater flows to Manatee Bay and Barnes Sound in Biscayne National Park, and maintain flood protection for the C-111 Basin.
- *Kissimmee River Restoration Project.* The purpose of the Kissimmee River Restoration project is to restore the ecosystem and reestablish wetland conditions in the historic floodplain. The restoration is being done through modifications of lake operations, enlargement of some canals and backfilling of another, excavation of nine miles of new river channel, removal of some water-control structures, and land acquisition.

- *Everglades Construction Project.* The Everglades Construction project is composed of 12 interrelated construction projects located between Lake Okeechobee and the Everglades, the cornerstone of which involves six large constructed wetlands. These stormwater treatment areas (STAs) are designed to reduce the levels of phosphorus that enter the Everglades. In addition to the STAs, the Everglades Construction Project contains hydropattern restoration projects that would improve the volume, timing, and distribution of water in the Water Conservation Areas.
- *"Critical Projects"* The category "critical projects" includes a broad range of projects that address issues such as increasing aquifer recharge, reducing seepage, determining the carrying capacity of the Florida Keys with respect to ecosystem and infrastructure, and others.

EVERGLADES SCIENCE

The Everglades has received considerable scientific attention, beginning over 150 years ago, due to its unique character and its economic value. The Everglades is a scientific treasure trove of subtropical biological diversity, including tree islands, mangroves, panthers, crocodiles, and the exotic Caracara to name a few. Meanwhile, water control was the key to development, and whoever sought to master the Everglades for human habitation and development had to learn how

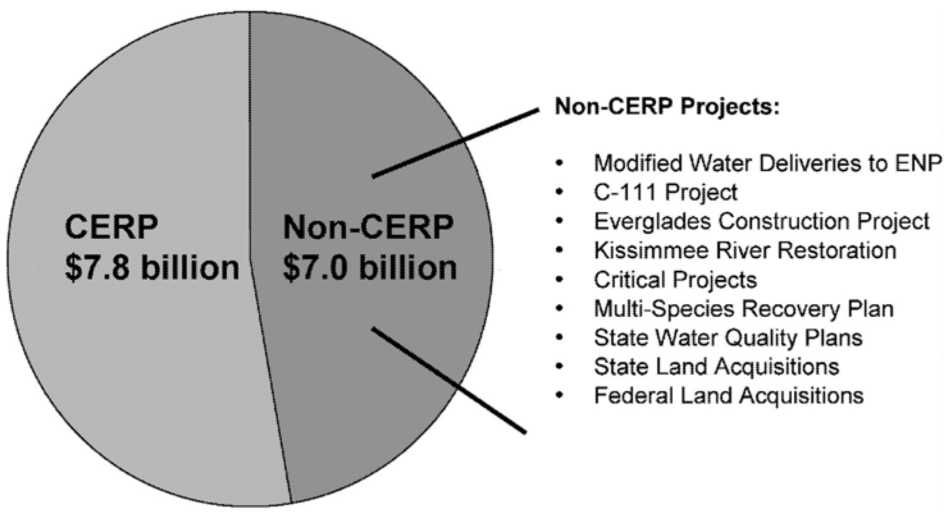

FIGURE 1–5 South Florida restoration projects. SOURCE: Robert Johnson, NPS, per sonal communication, 2002.

to control water. This section offers a brief overview of the contributions of Everglades science and the role of science in the South Florida restoration efforts. Fuller reviews of this literature than are possible here are given in Gleason (1974), Gunderson and Loftus (1993), and Sklar et al., (2002). Reviews of Lake Okeechobee research are given in Steinman et al., (2002); the extensive body of Florida Bay research is also accessible (NOAA, 2002).

The First Century of Science

The earliest scientific records of the Everglades come from expeditions to establish military outposts and campaigns against the Seminole tribe in the early to mid-1800s (Knetsch, 1989). South Florida remained a frontier until the Depression era, and some of the most systematic records on the pre-drainage Everglades are from early land surveys, which provide vivid accounts of presettlement wildlife and vegetation conditions (Willoughby, 1898; Mickler, 1859). Construction surveys from the early 1900s contain some of the best site-level information available about early peat, bedrock, water elevation and vegetation conditions in the Everglades (e.g., Ensey, 1911).

Naturalists including C.Small, J.Simpson, and Arthur Morgan trekked the southern Everglades (Agassiz, 1910; Simpson, 1920; Small, 1929); they recorded new species of plants and animals, documented patterns of feeding, courting, nesting, and migration, and studied site-specific habitat. Soils and vegetation mapping of southern Florida (e.g., Davis, 1943) was conducted in the 1940s, unfortunately after much alteration to the region. This work was followed by other important vegetation studies such as Egler (1952), Loveless (1959), Craighead (1971), and Gleason (1974). To the north, scientists and agricultural engineers from the U.S. Department of Agriculture and elsewhere studied the chemistry, oxidation rate, and productive capacity of the peat (Dachnowski-Stokes, 1930; Evans and Allison, 1942; Stevens and Johnson, 1951), with concerns about overdrainage and muck fires helping to drive the research.

Design problems in the C&SF project, evident by the mid-1960s, spurred the Florida Game and Fish Commission (FGFC), the Fish and Wildlife Service (FWS), Everglades National Park, and later the Flood Control District (predecessor to the SFWMD) to invest more effort in Everglades science. In 1974, the first biological sciences unit in South Florida was established at the SFWMD. In 1976, the park established the South Florida Research Station—one of the first of its kind in the National Park Service. Pivotal research was conducted in the mid-1980s to determine the background levels of nutrients needed to keep the Everglades vegetation from converting to species tolerant of higher doses, such as cattail. The results of this study and the evidence of cattail invasion into WCA-2 raised enough concern that the Department of Justice filed a lawsuit against the state of Florida, which ultimately led to the water-quality restoration efforts described previously for the Everglades Construction Project. Baseline water-quality work was also being done at this time (Waller, 1982).

Hydrological research moved forward in parallel. Parker (1984) summarized the hydrology of the pre-drainage system in South Florida. The USGS and SFWMD developed an understanding of the interactions of the Everglades, the surficial aquifer system, and the canals, including problems of seepage and sea-water intrusion. The SFWMD, in cooperation with the Corps, developed the first systems-level hydrological model (South Florida Water Management Model or SFWMM) of the Everglades during the 1970s and early 1980s (MacVicar and Lin, 1984). By the early 1990s, an adapted version of the SFWMM called the Natural Systems Model (NSM), which attempts to simulate the hydrological response of the pre-drainage Everglades using recent (1965–1990) records of rainfall and other climatic inputs, had been developed (Fennema et al., 1994). These models provided essential tools for examining potential restoration strategies.

Adaptive Management and the Beginnings of Everglades Restoration Science

The field of environmental management has recently undergone a major paradigm shift to a framework known as adaptive management (Holling, 1978; Walters, 1986, Gunderson et al., 1995). Adaptive management identifies uncertainties in a complex system and develops ways to test these uncertainties in order to achieve restoration goals. Adaptive management uses research both to refine the system operations and to increase knowledge about the system. An aspect of adaptive management that was highly influential in Everglades science was that of developing conceptual ecological models. Conceptual models provide a tool for converting the policy-level objectives into measurable indicators of the progress of the restoration. These models also make testable assumptions about linkages between what is done to a system (desirable or undesirable) and the resulting ecological responses.

By the mid-1980s, many scientists working in the Everglades were convinced that taken collectively, more than enough science was known to begin restoration. In 1989, the first Everglades Research Symposium was held, addressing how science had advanced over the previous decade. Follow-up workshops led to a broad understanding of the structure and dynamics of the Everglades system (Holling et al., 1994). Restoration alternatives were also screened using a coarse-scale dynamic simulation model that involved a set of hypotheses about how the Everglades functioned under both natural and C&SF project conditions (Walters and Gunderson, 1994). These efforts and many others, captured in Davis and Ogden (1994), became the foundation of the restoration plan.

Although adaptive management would offer a framework for initiating restoration efforts in the face of remaining uncertainties, scientists and planners recognized that many scientific information needs remained. The Science Subgroup (SSG), an interagency science advisory team, issued a series of reports on objectives for the Everglades restoration and accompanying science needs (SSG, 1993, 1994, 1996). The 1996 SSG report supported the Orians et al., (1992) endangered species study conclusion that restoration had to “get the water right,” and it established research on the hydrological system as “the highest priority science.”

The report also outlined a range of long-term research needs, including research on nutrients, pesticides, and mercury contamination, endangered species, habitat fragmentation, and exotic species. This 1996 report is a principal scientific summary document to which CERP-related research is directed.

Role of Science in Restoration Decision Making

As biological, hydrological, and chemical sciences have become increasingly coupled, integrative environmental science (Davis and Ogden, 1994), accompanied by independent peer review, has become an important input for decision making. Unfortunately, water-resource planning, design, construction, and operation have sometimes had difficulty using science as a partner in these activities. Science pertaining to water delivery to the park, the hydrological link between Lake Okeechobee and the Everglades, and water quality standards has not always had a major influence on decision making. A strong case can be made that research traditions and design-related decision making are two cultures in conflict. Research explores the unknown and asks new questions, while design-and construction-related decision making tries to eliminate uncertainty and to answer existing questions. Bringing these two cultures together in a politically charged environment as restoration projects are negotiated, approved, constructed, operated, and modified can be difficult, albeit essential.

The challenge in the greater Everglades ecosystem restoration is that the structure, composition, and dynamics of the resulting landscape will be self defining and not fully predictable. Part of science's role will be to understand the evolving Everglades ecosystem trajectories and guide design and operations toward the goal of a resilient and self-perpetuating domain of ecological stability.

Despite these difficulties, science has had a major influence on decisions affecting the greater Everglades ecosystem at several key junctures. For example, early surveys of South Florida helped justify congressional and state action that led eventually to widespread agricultural and urban development. The work of naturalists from circa 1900–1920s helped justify the establishment of Everglades National Park in 1934. The design of the CERP benefited considerably from the decades of soil science studies, the Re-watering Plan, and the science-supported forums that were engendered over the years. An encouraging example of coupling science and engineering in restoration concerns the Kissimmee River Restoration (KRR) Project. Science influenced the decision-making and design process for the Kissimmee restoration in ways as diverse as incorporating anecdotal history, setting ecological goals, and designing field-scale pilot studies and test floods.

In the last decade, science's role in the process has been formalized in several ways. The Science Subgroup (later evolving into the Science Coordination Team) was established in 1993 by the South Florida Ecosystem Restoration Task Force (SFERTF), which coordinates and develops restoration plans and priorities, as an interagency science advisory team (Florida Center for Environmental Studies, 2000). The agencies leading the CERP (SFWMD and the Corps) have cre ated another science entity called Restoration, Coordination, and Verification (RECOVER) to support the objectives of the CERP. This focus on the CERP makes RECOVER's mandate somewhat narrower than that of the SCT, which reports to the interagency SFERTF. RECOVER's goals are to evaluate and assess plan performance, recommend improvements in the plan's design and operational criteria, review the effects of other restoration projects on the plan's performance, and ensure a system-wide perspective.

Scientific peer review has been incorporated in the process in several ways. The National Research Council's Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) has provided scientific overview and technical assessments of a number of restoration activities since 1999. The WRDA 2000 also called for an independent scientific review panel, not yet established, to review the plan's progress toward achieving its goals. The interagency Florida Bay and Adjacent Marine Systems Science Program has been served by an independent Florida Bay Science Oversight Panel since 1994. The SFWMD has had its major hydrological models reviewed by external panels, and the Science Coordination Team seeks formal external review of its white papers. Also, the Project Delivery Teams for individual CERP components, which have broad participation by agencies and other organizations, review project plans at various stages as they move forward.

Critical Ecosystem Studies Initiative

The Department of the Interior (DOI) has continually played a major role in South Florida ecosystem restoration activities from nineteenth-century USGS mapping to its leadership position in the SFERTF today. DOI has a crucial role in CERP implementation and in the long-term tracking of ecological change. WRDA 2000 required DOI concurrence on the Programmatic Regulations (USAGE, 2002b) and joint progress reports to Congress. In addition, the National Park Service, as the largest land steward in South Florida, has a lead role in evaluating ecological restoration actions on its lands along with the Fish and Wildlife Service, with support from the USGS. Finally, the DOI has the responsibility of carrying out legislative mandates related to the Endangered Species Act, the National Environmental Policy Act, and the Fish and Wildlife Coordination Act.

In anticipation of these increased roles and responsibilities, the DOI (1996) published *A Comprehensive Plan for the Restoration of the Everglades* (not to be confused with the CERP itself). This set forth the rationale to accelerate the scientific research and model development needed to conduct the Everglades restoration and to assist restoration planning. This plan established the guiding principles for the CESI program, which began in 1997. In addition to supporting restoration planning initiatives, the CESI program funded scientific studies intended to (1) elucidate how the natural system functions, (2) identify the ways in which the ecosystem had been altered, and (3) develop modeling tools for examining how the current system might respond to restoration of historic hydrological conditions (DOI, 1996). Because the restoration was operating under the premise that "to resolve the hydrological issues is the first concern" (SSG, 1996), CESI funding supported research efforts such as defining the link between hydrological change and ecological response.

GENESIS OF THIS STUDY AND CHARGE TO PANEL

Since 1993, Congress has provided considerable financial support for the restoration of the greater Everglades, and it has been assured that science would advise the restoration efforts. In 2001, the House Interior Appropriations Subcommittee expressed concern at the gradual decline of the restoration science budget, noting that the funding for a major component of the science program— the CESI—had declined from $12 million per year in fiscal year 1998 to $4 million per year in fiscal year 2002. To address these concerns, that subcommittee, in report language accompanying the FY 2002 Department of the Interior and Related Agencies Appropriations Bill, directed the DOI to contract immediately with the National Academy of Sciences (NAS) to undertake a review of the science component of the CESI program.

Subsequently, the DOI and the National Academies[1] entered into an agreement, enabling the Academies' National Research Council (NRC) to undertake a study to

- assess the adequacy (types and funding levels) of science being conducted in the DOI CESI program in light of the scientific activities of other entities and the needs of the overall restoration effort
- provide guidance as to how the science being conducted under the CESI rubric can be better planned, managed, and reviewed; and how it can be better coordinated and integrated with relevant work outside the program
- advise DOI with respect to CESI strategic planning
- provide guidance with respect to information management and effective dissemination of science produced in the CESI program to help assure support for decision making during the planning, implementation, and operational phases of restoration

To carry out this study, the NRC appointed a special panel organized and overseen by its Water Science and Technology Board and the Board on Environmental Studies and Toxicology. The study schedule was intense with the full panel meeting three times between March and June 2002. A fourth meeting was held with a subset of the panel in August 2002 to facilitate report revision.

At the first meeting, the congressional mandate and concerns that led to the CESI program review were examined. National Park Service (NPS) personnel described the historical conditions, science needs, and restoration objectives in

[1] The National Academies consists of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Research Council is the advisory arm of the National Academies.

the greater Everglades ecosystem. There was also discussion of CESI program objectives, the methods for identifying research priorities, and the selection and review of funded projects.

During the second meeting, the panel addressed the adequacy of science being conducted in the CESI program in light of the needs of the overall restoration effort. This meeting involved discussions with a broad range of agencies active in South Florida, including the National Oceanic and Atmospheric Administration, the USGS, the FWS, the NPS, the Corps, and the SFWMD, on topics such as interagency coordination and integration of CESI projects.

The subject of the third panel meeting was the analysis, synthesis, and results dissemination of CESI-funded research. CESI program planning and management were discussed, as were the ways in which the CESI program and restoration managers could work together to identify extant and emerging research needs in support of strategic planning of the CERP during the design, implementation, and operational phases of restoration. A case study was also examined of the contributions of research (both CESI-funded and others) to C-111 project decision making.

The panel's conclusions and recommendations are based on presentations and discussions from these three meetings (see Acknowledgments), materials provided by the CESI program (e.g., lists of CESI-funded projects, budgets, and program objectives), limited independent analysis (e.g., the time line comparison between CESI projects and related CERP components; see Figures 2–2 and 2–3), the experience and knowledge of the authors in their fields of expertise, and the collective best judgment of the panel. This report summarizes the findings of this review.

It is important to highlight some topics that were outside the charge of this report. The report does *not* evaluate the restoration plan (CERP) or suggest improvements to it. The National Research Council's Committee on Restoration of the Greater Everglades Ecosystem currently provides scientific overview and assessments of restoration activities, such as its current review of the CERP Monitoring and Assessment Plan (NRC, in press). This report also does not provide an assessment of all South Florida science (or even all DOI science related to South Florida) but focuses distinctly on the contributions and areas for improvement in the CESI program in the context of other ongoing science. In order to evaluate the effectiveness of the CESI-funded research, the report discusses the CESI within an adaptive management framework, but the report does not suggest or recommend an adaptive management approach for restoration. Finally, the report does not judge the quality of individual CESI-funded research projects systematically, since such a detailed review was beyond the study charge. The study instead focused on the processes used by the CESI program to support the restoration (e.g., coordination with other science programs, prioritization of CESI research funding, and dissemination of results) and looked broadly at the contributions of several prominent CESI-funded projects.

2

Overview of the CESI Program

To abate the environmental degradation that has occurred in the ecosystems of South Florida, a series of restoration projects are underway or in development, including C-111, Modified Water Deliveries to Everglades National Park (ModWaters), the Kissimmee River Restoration Project, and 68 projects of the Comprehensive Everglades Restoration Plan (CERP). These projects aim to restore the natural system to as near historic conditions as possible in the face of limitations imposed by the loss of over 50 percent of the natural system and competing demands and stresses from the developed environment. However, the path to restoration is not easily implemented, and clearly there is an element of uncertainty in this ambitious undertaking. Good science will increase the reliability of the restoration, enable solutions for unanticipated problems, and potentially reduce long-term costs. To this end, the Department of the Interior (DOI) created the Critical Ecosystem Studies Initiative (CESI) to contribute science and planning in support of the restoration of the greater Everglades ecosystem.

This chapter provides an overview of the CESI program, describing the history and concept behind the initiative and the primary program areas for CESI funding. In addition, the chapter outlines examples of CESI-funded projects and contributions to date and identifies several areas of additional research needs. The chapter also presents an analysis of the timeliness of current and future CESI-funded studies relative to restoration planning needs.

CESI HISTORY AND CONCEPT

In January 1996, the Department of the Interior proposed a plan to "kick-start" the greater Everglades ecosystem restoration effort through increased federal funding and programmatic initiatives. These initiatives were focused on four key areas: (1) federal legislative authority for restoration activities, (2) land acquisition by state and federal governments, (3) scientific research to guide restoration, and (4) cost-sharing among federal, state, and private entities (DOI, 1996). The science component of this plan was developed as the Critical Ecosystem

Studies Initiative with the mission to support studies that provide the physical and biological information, simulation modeling, and planning critical for achieving South Florida ecosystem restoration (DOI, 2000). To accomplish this mission, the U.S. Congress appropriated funds totaling $51,016,000 from FY 1997 through FY 2002 to support the CESI program[1] (William Perry, NPS, written communication, 2002). Congress appropriated these funds to the National Park Service (NPS) budget to support DOI's scientific information and planning needs related to the South Florida restoration and did not intend for CESI funds to meet all restoration science needs (Deborah Weatherly, House Appropriations Committee Staff, personal communication, 2002). Numerous reviews of research in the NPS have stressed the value of a strong research program to gain an understanding of the natural resources under federal stewardship and to develop effective resource management strategies (NRC, 1992; NPS, 1992; NPCA, 1989). Further details on CESI funding are provided in Chapter 4.

The initial intent of the CESI program was to support the feasibility phase of the Restudy, which was initiated in 1995 to assess the feasibility of modifying the Central and Southern Florida (C&SF) Project to restore the South Florida ecosystem. Within this context, the overall objectives of the CESI program were described as follows (DOI, 2000):

- to initiate and accelerate completion of studies required for sound ecosystem restoration to meet critical science information needs in support of the South Florida restoration
- to provide administrative support for coordination, contracting, and review of activities supported by the CESI program
- to develop annual funding requests to Congress to meet anticipated critical studies required for achieving ecosystem restoration

Even though the region was rich with agencies conducting scientific and engineering research, such as the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers (the Corps), the South Florida Water Management District (SFWMD), and the U.S. Geological Survey (USGS), limited funding, divergent agency missions, insufficient coordination, and compressed timetables left critical voids in the restoration science (SSG, 1996) (see Box 2–1). The CESI program was developed to help fill the scientific information gaps and to complement the efforts of other agencies. CESI funds were also available to address newly identified research needs or to respond to urgent decision-making time frames. This gap-filling strategy offers agility and flexibility, allowing the CESI program to respond to emerging restoration science questions, while also supporting overlooked or underfunded science needs. The CESI program supports a science partnership among numerous federal, state, local, and tribal governments with the objective of developing the knowledge base required to address the restoration goals. Several projects have been funded jointly with state agencies, leading to additional opportunities for collaboration. In summarizing

[1] This total includes the $1.717 million that was later reappropriated to support the increased staffing needs of CERP implementation (see Chapter 4).

BOX 2–1 CROSS-CUTTING RESTORATION SCIENCE ISSUES AND GAPS IDENTIFIED BY THE SCIENCE SUBGROUP

The following 19 statements summarize the major cross-cutting issues and gaps in interagency ecosystem-based science support for the South Florida ecosystem restoration identified by the Science Subgroup (1996). A more detailed listing of individual science objectives for the entire region and for South Florida sub-regions is provided in Appendix B, along with a list of related CESI-funded projects.

Ecosystem-wide science management concerns:

1. Flexible and sustained resources are essential to an effective, comprehensive restoration effort. Some critical activities needed at early stages in the restoration process are being neglected for lack of directed resources.
2. A region-wide ecosystem approach to monitoring, support studies, and modeling in a coordinated interagency framework is the only means to attain restoration, but its achievement requires special effort and application of personnel and supporting resources.
3. Critical linkages between sub-regions are not being adequately addressed.
4. Issues of agency authority are at times barriers to focusing efforts at problem sources.
5. Information exchange is a problem, because there is so much information in the hands of myriad sources, including local governments.
6. Monitoring projects by various agencies have not been coordinated or integrated into the restoration effort.

Hydrological and ecological modeling needs:

7. Hydrological models that currently exist or are under development do not have the geographic coverage required to meet region-wide ecosystem management needs or to provide the hydrological information for regional ecological models. Existing hydrological models do not extend to the coast and therefore cannot show how physical and ecological processes in the mangrove zone are affected by water management strategies. Such models are needed to support regional ecological models of wading birds and fish and to provide input to hydrodynamic models of coastal waters.
8. The most suitable current hydrological models cannot be used to test alternatives for the interagency restoration effort on a timely basis.
9. Systems of nested models are needed, in which finer resolution can be provided to address some questions and coarser resolutions can be provided to address others.

the projects and accomplishments of the CESI program and in evaluating the future goals, it is critical to view the CESI program as one component of a larger entity that includes other science initiatives as well as political and socioeconomic issues.

10. Modeling is not well integrated with present scientific studies, and funds for modeling usually do not include sufficient funds for special supporting studies, including verifications.
11. An objective process is needed to evaluate existing models within the context they are being used and to ensure necessary improvements are made.

Ecosystem processes/indicators:

12. Certain key species (e.g., apple snail) or communities (e.g., periphyton) that might be suitable ecological indicators are so poorly studied that they cannot be used as indicators. Furthermore, lack of knowledge about the response of these species or communities to hydrological and nutrient variables may seriously handicap the restoration effort.

Water-quality/contaminants:

13. Phosphorus-dosing studies to examine the effect of loading on ecological balance in higher plant and algal communities need to be augmented by gradient studies and process-oriented studies of nutrient cycling through soils, plants, algae, and the water column.
14. While monitoring for contaminants is extensive, little interpretation of monitoring results is occurring.

Social science:

15. Both tangible and intangible connections between natural and human systems need to be quantified and widely communicated while reinstatement of a sustainable system is still possible.
16. A scientifically based analysis is needed to demonstrate alternative futures under various land and water configurations.

Best management practices:

17. Potential opportunities need to be explored for configurations of land and water that lead to ecosystem restoration and enhanced quality of life and economic sustainability in human communities.
18. There is no coordinated science program to support reduction in agricultural or urban pesticide usage.

Research studies funded through the CESI program were intended to elucidate how the natural system functions, identify the ways in which the ecosystem has been altered, and develop tools for examining how the current system might respond to restoration of historic hydrological conditions. In support of these research goals, studies were funded within the following broad program areas (funding levels are expressed as a percentage of the budget for FYs 1997–2001) (Robert Johnson, NPS, written communication, 2002):

Baseline Research (55%)—Baseline research studies characterize the pre-drainage ecosystem and the defining ecological and hydrological attributes that have been lost. Baseline research studies would include, for example, historical reconstructions to characterize pre-drainage systems and data collection to parameterize models. This category also includes hydrological and ecological process studies and development of appropriate performance measures to characterize the ecological response to hydrological change.

Simulation Modeling (15%)—Simulation modeling supports the development of physical and biological predictive models designed to evaluate proposed structural and operational modification to the C&SF Project. Such modeling includes, for example, studies focusing on model uncertainties and studies to expand the scope of and to refine and improve existing models.

Environmental Impact Assessments (20%)—Short-term environmental impact assessments are used to evaluate proposed structural and operational changes to the C&SF Project while long-term monitoring studies measure ecosystem response to restoration activities. These studies include status and trend reports, long-term biological and physical monitoring programs, regional-scale ecosystem responses, and environmental impact assessments of early-phase projects, such as the ModWaters and C-111 projects.

Planning and Coordination (10%)—Coordination and science peerreview activities were funded in support of the South Florida Ecosystem Restoration Task Force and Working Group. These include funding for strategic planning, science peer review, development of invasive-species control strategies, CESI-sponsored workshops, and support for the Greater Everglades Ecosystem Restoration Science Conference and the Florida Bay Science conferences.

During its first year (FY 1997), the CESI program was used primarily to provide additional resources to important ongoing research programs, under the guidance of the Science Subgroup's *Scientific Information Needs* report (SSG, 1996). In the following years as new science priorities developed based on discussions and workshops held during the Restudy, CESI managers identified additional studies for CESI funding (William Perry, NPS, written communication, 2002).

As restoration plans moved forward, the science objectives of the CESI program gradually evolved to meet changing restoration science needs. In 1996, Congress shortened the original six-year time frame of the Restudy by more than two years to speed the initiation of restoration activities. Although this acceleration of the Restudy predated the CESI program, CESI managers at first primarily funded long-term baseline research projects, which they viewed as vital to restoration planning decisions. The implementation of the $7.8 billion Comprehensive Everglades Restoration Plan (CERP) in 2000, however, affirmed the fast pace of restoration and led to a change in CESI funding priorities. The recent draft Programmatic Regulations also assigned DOI concurrence and consultation responsibilities in CERP planning, and required DOI to report jointly[2] to Congress every five years "concerning the benefits to the natural system" (USAGE, 2002b). CESI managers now prioritize future studies by their contribution to restoration decision making as it relates to federally managed lands and resources. The long-term CESI-funded research projects were generally continued because of the interest in optimizing the resources already invested and because the same information would also be useful to CERP planning (DOI, 2001). Current CESI research priorities are still linked to the latest Science Subgroup report (SSG, 1996), as it represents the latest comprehensive, multiagency assessment of region-wide science needs (William Perry, NPS, written communication, 2002).

A vitally important component of DOI's responsibilities in the South Florida restoration will be to assist in evaluating the ecosystem response to the restoration projects once they begin operation, with specific focus on the restoration's effects on federally managed lands and resources. To accommodate CERP time lines and activities, the CESI program plans to reduce its support for baseline research and model development. Instead, CESI managers will place greater emphasis on the information and tool-development needs of CERP-related environmental impact assessments and long-term monitoring in support of adaptive management (DOI, 2001).

CESI PROGRAM AREAS, PROJECTS, AND ACCOMPLISHMENTS

The CESI program was established to accelerate ongoing studies and to initiate research needed to support the restoration. A total of 155 CESI projects have been funded, and over $45 million has been obligated as of March 2002 (for a complete list of projects, see Appendix A). Some of these projects are ongoing and extend beyond FY 2002. Nearly all of the funded projects fall under one of the CESI program's 12 broad program categories (DOI, 2001; SFERTF, 2002):

1. Ecological Processes/Indicator Species
2. Ecological Models
3. Coastal and Estuary Systems
4. Hydrological Models
5. Landscape Patterns, Processes, and Modeling
6. High-density Topographic Surveys
7. Contaminants and Biochemical Processes
8. Water Quality and Treatment
9. Water Quality on Tribal Lands
10. Water Resources Planning, Impact, and Mitigation Assessment (Social Science)
11. Science Information and Dissemination

[2] With the U.S. Army Corps of Engineers and the Environmental Protection Agency.

12. Restoration and Science Planning, Coordination, and Review (includes invasive-species control strategy)

These categories were developed using the guidance provided in a series of reports by the Science Subgroup (1993, 1996) that identified South Florida ecosystem scientific objectives and information needs for the restoration. Technical workshops and consultation with regional experts provided additional input that refined the CESI program categories and research priorities. Links between specific CESI-funded projects and the science objectives identified by the Science Subgroup (1996) are provided in Appendix B as one framework for viewing the CESI program's contributions to filling information gaps.

The CESI program has placed particular emphasis on supporting research to improve the understanding of South Florida's ecosystem structure and function[3] in order to provide a basis for predicting the ecosystem's response to restoration of historic hydrological conditions. This emphasis is evident in the large numbers of projects funded within the Ecological Processes/Indicator Species and Coastal and Estuary Systems program categories, as well as studies within the Landscape Patterns category (Figure 2–1). Projects within these categories have contributed fundamental information on the linkages between ecological, hydrological, and water-quality attributes (see Appendix B). Examples include a study on the spatial and temporal response of vegetation to hydrological restoration in Taylor Slough (Armentano et al., 2000) and research on nutrient limitation to primary productivity in Florida Bay (Fourqurean and Zieman, in press).

Many CESI-funded ecological studies have also contributed to the development of science-based performance measures. Performance measures are selected as quantitative indicators of the condition of the natural system and will be used in the design of monitoring programs to evaluate ecosystem changes resulting from restoration activities. The CESI program has supported a number of ecological monitoring studies to characterize the ecosystem state and its relationship to other hydrological or water-quality attributes. CESI researchers have developed extensive datasets, that can (and should) be used to address scientific questions regarding ecosystem processes. Although these CESI-funded monitoring and assessment projects are often highly site-specific, researchers can optimize the knowledge gained from these investments by conducting the studies and analyzing the findings in the context of the greater Everglades ecosystem.

There has been much emphasis on both ecological and hydrological modeling by the CESI program. This is reflected not only in the large number of projects in the Hydrological Modeling and Ecological Modeling program categories but also in the related Topographic Surveys program categories. Selected high-density topographic surveys were funded by the CESI program to provide the There has been much emphasis on both ecological and hydrological modeling by the CESI program. This is reflected not only in the large number of projects in the Hydrological Modeling and Ecological Modeling program categories but also

[3] Structure is related to the species in the ecosystem and the distribution of individuals among those species. Function is related to the processes carried out by an assemblage of organisms in an ecosystem and the rates at which the processes occur.

in the related Topographic Surveys program categories. Selected high-density topographic surveys were funded by the CESI program to provide the high-accuracy elevation data (within a vertical accuracy specification of 15 cm) necessary to support the existing hydrological models over the low-relief landscape of South Florida. This topographic data collection currently in progress will require many years to complete.

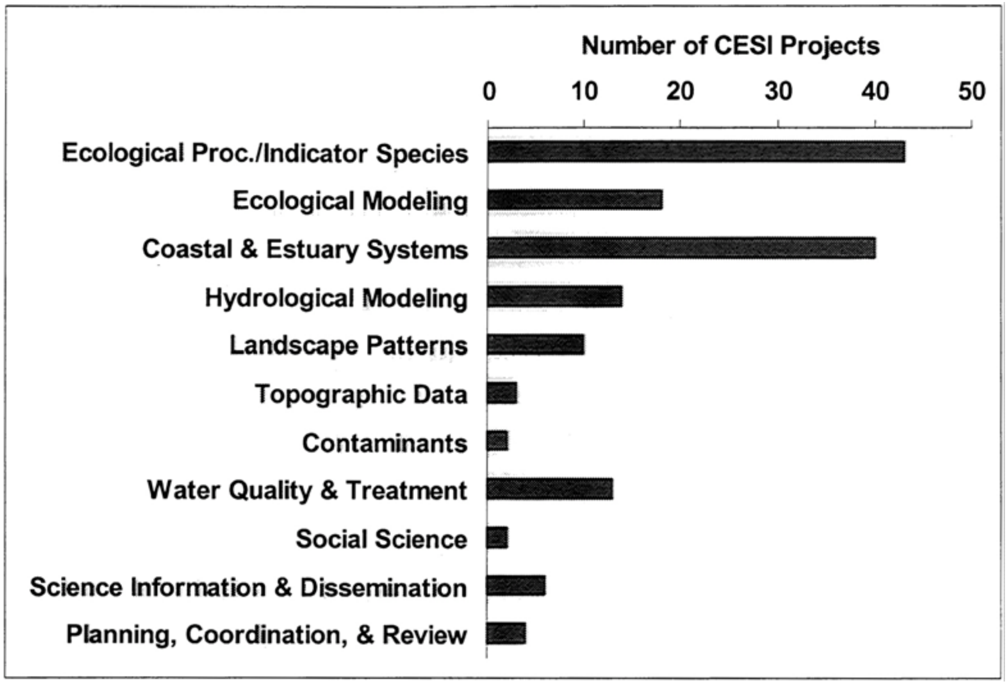

FIGURE 2–1 Number of CESI-funded projects by program category for projects conducted between 1997 and March 2002. The program category for Water Quality on Tribal Lands has been combined here with other water quality and treatment research program categories (William Perry, NPS, written communication, 2002).

Improved understanding of the hydrological processes in the coastal Everglades is essential to developing predictive flow models for these areas. The South Florida Water Management Model (SFWMM) is the primary hydrological modeling tool used to determine impacts of restoration projects on the natural system, but the model stops well inland of the southwest coast. The predictive capabilities of the SFWMM along the coastal areas are also limited by the coarse 2×2 km grid size of this model, the large time step, and the absence of tidal influence or density-driven flows (NRC, 2002b). CESI-supported modeling efforts and related process-based research, including the work on the Southern Inland Coastal System (SICS) model and the Tides and Inflows in the Mangroves of the Everglades (TIME; http://time.er.usgs.gov) model, attempt to provide this linkage between the SFWMM domain and that of models being developed for Florida Bay. Nevertheless, much work remains to improve the usefulness of these models for restoration planning (USGS, 2002b). Other CESI hydrological modeling studies have worked to improve the understanding of historic hydrological condi tions, including research on the geological and ecological history of buttonwood ridge and recently funded efforts to refine the Natural Systems Model.

Ecological models will be critical for defining relationships among water levels, flow, hydroperiod, water quality, wildlife, and vegetation at the individual, community, and landscape levels. Despite emphasis on ecological modeling in the CESI program, ecological models have yet to provide good representation across the system. The principal ecological models, Across Trophic Level Systems Simulation (ATLSS; http://www.atlss.org), consist of a series of species-and process-specific models that are linked across a range of scales. These models are generally robust, but focus primarily on target species. One current constraint in the refinement of ecological modeling is the lack of field data to define the necessary linkages between hydrological and ecological attributes. Field research conducted within the Ecological Processes/Indicator Species program category is designed to provide biological data necessary to refine the ATLSS models (SFERTF, 2002).

The CESI program has supported studies to examine the impact of water quality on ecosystem vegetation and insect communities. South Florida's wetlands are adapted to highly oligotrophic (low-nutrient) conditions. Exposure of these vegetative communities to phosphate-enriched water substantially alters community composition and productivity (Davis, 1994; Noe et al., 2001). As a result, the CESI program's water-quality research has focused primarily on phosphorus. For example, the CESI program has funded research to determine the assimilative capacity for phosphorus within canals through the Seminole tribe. In addition, the CESI program has also funded assessments of mercury contamination, investigations of the effectiveness of new water-treatment technologies, and the development of water-treatment modeling tools. Although solute- and nutrient-transport modeling is recognized widely as an important science information need related to the restoration efforts (USGS, 2002b; SSG, 1996), water-quality modeling represents a topic with minimal support from the CESI program. The large uncertainty about nutrient and contaminant transport resulting from the restoration projects makes this area of inquiry a high priority. Coordination among ongoing research efforts, however, will be critical to maximize the cost effectiveness of science resources. Total phosphorus dynamics have been incorporated into the latest version of the Everglades Landscape Model (SFWMD, 2002c), and current models should be evaluated to determine the most effective and timely approach to incorporate other nutrient-and solute-transport capabilities.

CESI funding for research on other contaminants, including metals, pesticides, and other organic anthropogenic compounds, has been limited. There are only two CESI-funded contaminant studies now, and one of these studies is a screening exercise to identify high-risk contaminants in the ecosystem. Once compounds and pathways are identified, CESI managers intend to expand the Contaminants program category. Recent research has identified endocrine-disrupting chemicals that may pose a threat to wildlife populations in the environment (NRC, 2000). For example, research on the endangered Florida panther has raised concerns that bioaccumulated contaminants, such as organochlorines, could contribute to observed reproductive abnormalities (Facemire et al., 1995). Contaminants research, specifically related to organic anthropogenic compounds, represents an information gap that has not been adequately addressed by the CESI program to date.

Very few social science projects have been funded by the CESI program even though the Science Subgroup prominently identified social science as a cross-cutting scientific information gap (Box 2–1). Social phenomena such as population growth and changes in land use and water use have been major causes of the decline of the South Florida ecosystem, and social responses will be required to restore the ecosystem. Predictions of future changes in the ecosystem and opportunities for restoration depend on economic activities and on the trajectories for population growth. Likewise, restoration will inevitably impact the urban and agricultural environments. The difficulty of restoring a complex ecosystem is that social and scientific problems are woven into an inseparable mix (Wilson, 2002). The CESI program could make a much-needed contribution to the restoration effort by funding increased research in the areas of social and economic science.

The CESI program strives to communicate findings from CESI-funded research studies to restoration managers, planners, and stakeholders so that the policy and management decisions necessary to advance ecosystem restoration can be informed by the best available science. To support this objective, the CESI program added the Science Information and Dissemination program category in FY 1999. This program category was established to develop a data-management system to improve accessibility of hydrological and ecological data collected within the CESI program (SFERTF, 2002). Projects to support this objective, however, were not initiated until 2001 and, thus, are only in their early stages. Efforts are now underway to develop a query-based database to improve access to the large quantity of scientific information available. As of mid-2002, little broad dissemination of the CESI research has occurred, hindering the usefulness and public awareness of the CESI program's research products. The USGS has the capability and a demonstrated record of producing high-quality, readable reports that could serve as a model for providing usable summaries of CESI research. CESI-funded efforts currently underway through the USGS to establish a web site and fact sheets that summarize CESI activities should help with this communication problem.

Some CESI-sponsored restoration activities were outside the scope of this review, which focuses on the science components of the CESI program. Those activities not considered in this review include development of invasive-species control strategies, support for the Office of the Executive Director of the South Florida Ecosystem Restoration Task Force, and funding for the National Research Council's Committee on the Restoration of the Greater Everglades Ecosystem.

To assess the CESI program's overall contributions to the South Florida restoration, it is informative to consider some areas of research that were not supported by the CESI program. The CESI program has not funded engineering design studies that would identify restoration project alternatives and determine the impacts of those options. The CESI program also has not supported research intended to improve the structural design of the restoration projects, such as the development of automatic control systems or pilot programs for aquifer storage and recovery (NRC 2001; NRC 2002a). These areas may still represent gaps within the restoration knowledge base, but the CESI program has generally considered these topics to be under the responsibility and expertise of the Corps or the SFWMD. Instead, the CESI program's efforts have emphasized development of ecological and hydrological modeling tools and research to determine the hydrological attributes required to restore the ecosystem as nearly as possible to historic conditions, so that appropriate project designs can be developed to meet these restoration objectives.

FIGURE 2–2 CESI funding has helped support research groups from Florida International University, who are studying ecosystem responses to different concentrations of phosphorus at flume sites in Shark River Slough, ENP and Loxahatchee National Wildlife Refuge (FIU, 2003).

Since the authorization of the CERP in the Water Resources Development Act of 2000, the CESI program has specifically tried to fund research where there were scientific questions to be answered that could inform design, implementation, and management decisions to support ongoing restoration projects. Much of the CESI funding was focused on ModWaters, C-111, and the Everglades Construction Project, which directly impact DOI lands and are scheduled to be completed early in the restoration time frame. The decision to focus CESI science on these early projects was a pragmatic one, but scientists admittedly were in a position of playing “catch-up” to the process of project design. This focus, however, was established knowing that the research findings would also inform subsequent restoration activities. One example of the CESI program's applied research emphasis includes the Everglades Construction Project, which was designed to address water-quality concerns in the Everglades Agricultural Area, with a goal of constructing water-treatment areas (over 47,000 acres of artificial wetlands) at the source (FDEP, 2002). Nutrient-threshold research, sponsored in part by the CESI program, was initiated to determine plant community response to various phosphorus concentrations (Figure 2–2). This research will help advise the state of Florida's decision in setting maximum allowable nutrient concentrations to protect downstream ecosystems. This research represents just one example of how science can both inform decision making and improve the likelihood of meeting restoration goals.

Science conducted in support of the Everglades Construction Project represents an example of early research investments that could reduce the total long-term restoration costs. Pilot projects designed as experiments provide information that can be used to inform larger-scale restoration decisions and improve the design of future CERP projects. CESI research on ecosystem response in these early restoration projects, such as C-111 and ModWaters, should also provide valuable findings that will inform and improve future project design.

Although the study did not include a systematic review of individual research projects, it is the judgment of the panel that the CESI program has funded many high quality studies that have made important contributions to Everglades restoration. The federal investment has produced useful science, a rich database, and the starting point for acquiring a basic understanding of the dynamics of the Everglades ecosystem.

SUMMARY OF RESEARCH NEEDS AND CESI PROGRAM DIRECTION

The CESI program is currently restructuring its emphasis, moving from research and development to model applications and data collection in order to support the evaluation of the CERP and related restoration projects as they are implemented over the next 30 or more years. The restructuring includes increased support for refinement and application of simulation models. The CESI program also plans to emphasize development of tools for conducting environmental impact assessments and scenario testing, such as habitat suitability models. At current funding levels and with increasing demand for CERP-related monitoring and assessment, CESI staff foresee little available CESI funding to support future experimental or applied research. Continued research in areas closely related to the South Florida ecosystem restoration objectives provides a strong scientific foundation for future decision making and allows the science knowledge base to develop so that scientists and planners can respond to new and emerging concerns. In addition to model development and environmental assessments, effective use of CESI funding would support fundamental research that has high value to the restoration, with specific emphasis on issues that reflect DOI's interests and restoration responsibilities. Alternate non-CESI funding sources are needed to help support DOI's CERP-related monitoring needs, so that the CESI program will not have to abandon important research on the intersections between hydrological attributes and ecosystem processes and functions.

The CESI program has worked to address South Florida's scientific information needs for six years, but many gaps remain, and other questions require significant additional study to appropriately inform the restoration effort. Broad research gaps exist in areas such as social science, contaminants, and the devel opment of useful predictive solute- and nutrient-transport models, highlighting the importance of continued research funding to address critical restoration science needs. Meanwhile, despite the CESI program's contributions to examining the linkages between hydrological characteristics and ecological attributes, significant additional study is required to delineate these relationships for a wider range of species and communities, with particular emphasis on CERP-identified ecological performance measures. In order to inform the restoration effort, these relationships will need to be incorporated into modeling tools, since the CERP aims to restore the natural system primarily by restoring appropriate hydrological conditions. Enhancements to and improved linkages between ecological and hydrological models are also needed, and much work remains to improve information synthesis, dissemination of research findings, and broad accessibility of scientific and monitoring data. The CESI program should identify priority research topics in under-funded areas, such as those identified here, and formulate effective research programs to meet these needs. CESI managers should then develop budget estimates and seek additional funding to support these programs.

Although this report identifies many areas where additional research is needed, a complete and updated assessment of scientific information needs for the South Florida ecosystem restoration, along with research priorities, would be extremely valuable to the restoration effort. Such an effort would improve coordination among the multiple agencies engaged in South Florida ecosystem science and would support wise investment of limited science resources. Recent efforts by the Science Coordination Team and the Science Program for Florida Bay (SCT and SPFB, 2001), the CERP RECOVER team, the Greater Everglades Ecosystem Research conference, and the USGS (USGS, 2002b,c) reflect contributions toward this goal. Depending on future resources, a thorough review of the current ecosystem-wide science needs, conducted principally by local experts most familiar with the South Florida restoration and related ecosystem science, could also provide essential guidance to the CESI program.

CESI staff have identified a number of research and science synthesis objectives for the CESI program in the coming years to address critical restoration science needs (Appendix C). These science objectives identified by the CESI staff have not been reviewed for this study, but are provided as broad estimations of the CESI program's future financial needs (see Chapter 4) and as the basis of evaluations of the timeliness of CESI research.

EVALUATING THE TIMELINESS OF CESI RESEARCH

If scientific information is to inform the design and implementation of the projects within the South Florida ecosystem restoration, the research results ideally should be available well in advance of project planning. All scientific uncertainties, however, cannot be resolved before restoration begins, or science could only document the decline of the Everglades. Adaptive management enables the restoration to move forward in the face of existing scientific uncertainties by encouraging continued learning and project designs that offer operational flexibility. Nevertheless, project design changes will be much easier and less costly if they are made before construction has begun. Therefore, a comparison of time lines between restoration projects and related CESI studies was undertaken in this review to ascertain whether CESI research has produced results within the optimal time frame for restoration decision making and whether the CESI program can continue to generate information that meets the compressed timing of the greater Everglades ecosystem restoration.

The CESI program has made a significant contribution of scientific information to the restoration knowledge base. While some CESI research, such as the development of water-quality-treatment models (Walker and Kadlec, 2002), has contributed directly to project design and planning needs, most CESI studies have contributed more broadly by defining appropriate restoration targets and by improving the understanding of important processes within the ecosystem. Therefore, this time line comparison does not reflect a precise analysis of research deliverables but, instead, is intended as an assessment of the timeliness of new scientific information developed through the CESI program.

The time-line analysis was based on specific linkages between each CESI study and the related scientific information needs of one or more CERP or non-CERP projects (see Appendix A). These linkages were assigned by the CESI coordinator under the guidance of the CESI's CERP science objectives, which had been determined through a consensus process with representatives from the Fish and Wildlife Service, USGS, and NPS (DOI, 2001). An assessment of the priority (high, medium, or low) of the science information needs with respect to DOI land management interests was also assigned for each linkage. When a single CESI study was determined to be relevant to multiple restoration projects, the highest-priority restoration projects were used as the basis of the time-line comparison. For example, if a CESI study was viewed as contributing high-priority information to both the C-111 project and the Florida Bay Feasibility Study, but only low-priority information to the Lakebelt Pilot Study, the CESI study would be compared to both high-priority linked projects (C-111 and Florida Bay Feasibility Study).

Selecting specific dates that would appropriately reflect project-planning needs and the availability of the scientific results required a few assumptions. The scientific information generated by CESI studies was assumed to be available for use in restoration project design by the end of each CESI project. Publication activities, admittedly, can delay the communication of results beyond this date, but these anticipated delays were not easily predictable and were considered minor in the overall analysis. For the restoration timetable, two dates were used in the analysis to bracket the window of time from project planning through construction (SFWMD, 2002a). The start date for a restoration project reflects when research results would be most useful, since project planning would be in its earliest stages. The restoration project end date, when construction is expected to be completed, reflects the date after which adjustments to project design would likely be quite difficult and costly if these changes fell outside of the project's inherent operational flexibility.

Two datasets were analyzed for this time-line comparison: one set for CESI research projects that were started between 1997 and 2001 (Appendix A) and one set for projects that CESI managers have recommended be started between 2002 and 2006 (examples listed in Appendix C). For the time period 1997–2001, there were 130 projects included in the analysis and a total of 203 comparisons, since all comparisons were made separately and many projects were deemed highly relevant to more than one restoration project. In the 1997–2001 time-line comparison, CESI results were expected to be available by the restoration project start date for only 14 percent of the comparisons. Where delayed, the CESI research was expected to arrive an average of 7.3 years after the restoration projects had begun (Figure 2–3a). However, when the CESI research availability was compared to restoration project completion dates, only 3 percent of CESI projects were delayed, and only by an average 1.3 years (Figure 2–3b).

This time-line analysis shows that most CESI research science arrived in the midst of project planning and implementation, but before project completion. Because the CESI program has focused its contributions on early non-CERP restoration projects that have clear implications for DOI lands, it is not surprising that the CESI program could not provide research results in advance of the start dates for these restoration projects. Projects such as C-111 and ModWaters were started before the CESI program was even created. The implication of this disjunction between restoration planning and the availability of scientific information are discussed at length in Chapter 5. Admittedly, the modeling tools and knowledge contributed by the CESI program will be useful to many other CERP projects, including several that are more than a decade away, so the CESI research efforts will be available to advise important planning and design decisions for these future CERP projects. Nevertheless, the timing of CESI's current research results relative to ongoing restoration planning efforts creates clear challenges, demanding open communication between planners and scientists, a collaborative environment, and highly flexible project design (Chapter 5).

As the accelerated CERP time line continues to move forward, CESI projects will be further challenged to produce results even in advance of project construction. For the 2002–2006 proposed CESI projects, there were 74 proposed research projects analyzed in 135 comparisons with restoration projects. This analysis shows that research findings from 100 percent of these CESI studies would arrive after the start of the highest-priority associated restoration projects, by an average of 7.4 years (Figure 2–4a). All research projects in the upcoming CESI phase will be completed after the engineering design phase has started, since CERP project implementation will soon be moving at a fast pace. Of these proposed CESI projects, 48 percent of the needed results would also arrive after the project had been constructed, by an average of 2.7 years (Figure 2–4b). This time-line discrepancy will impact the ability of science to inform the restoration planning process, putting tremendous faith in adaptive management to handle new recommendations from later scientific discoveries (Chapter 5).

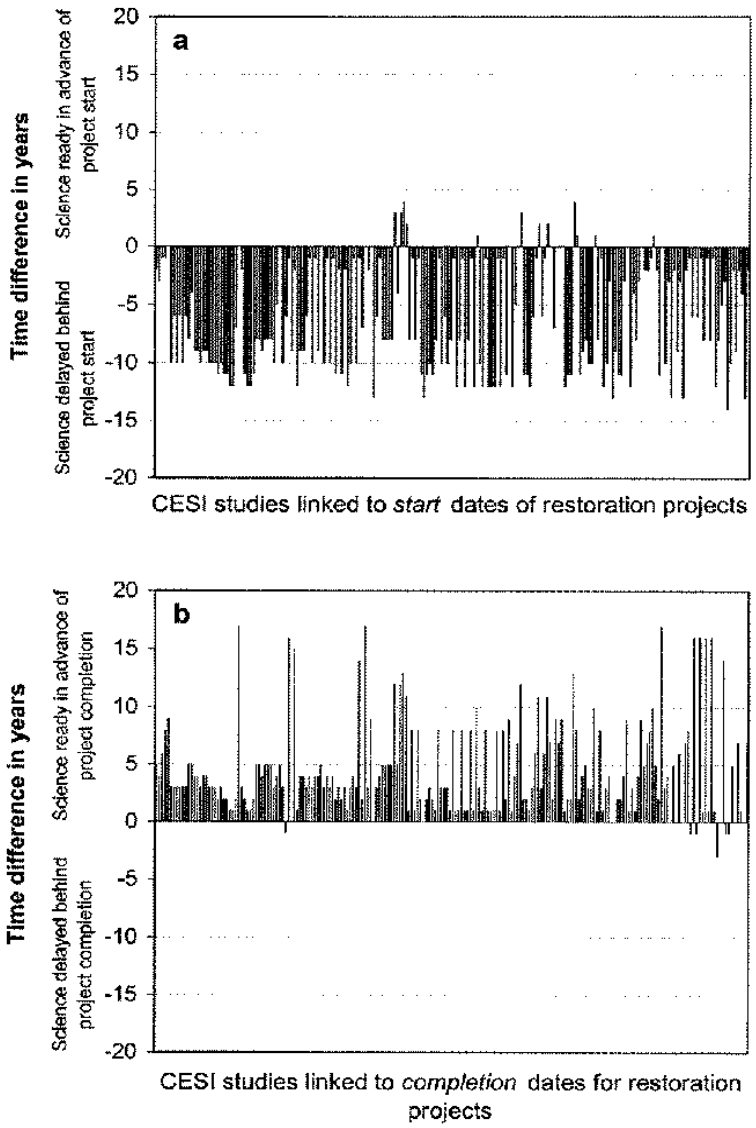

FIGURE 2–3 A comparison between when research results will be available from CESI projects initiated between 1997 and 2001 and (a) starting dates and (b) completion dates for corresponding restoration projects. The difference is plotted in years for each comparison. Positive values mean that research results will be available in advance of the restoration project start or completion dates. Negative values mean that the research results will be delayed relative to the specified restoration project start or completion dates. (CESI project data source: William Perry, NPS, written communication, 2002; restoration project data source: SFWMD, 2002f).

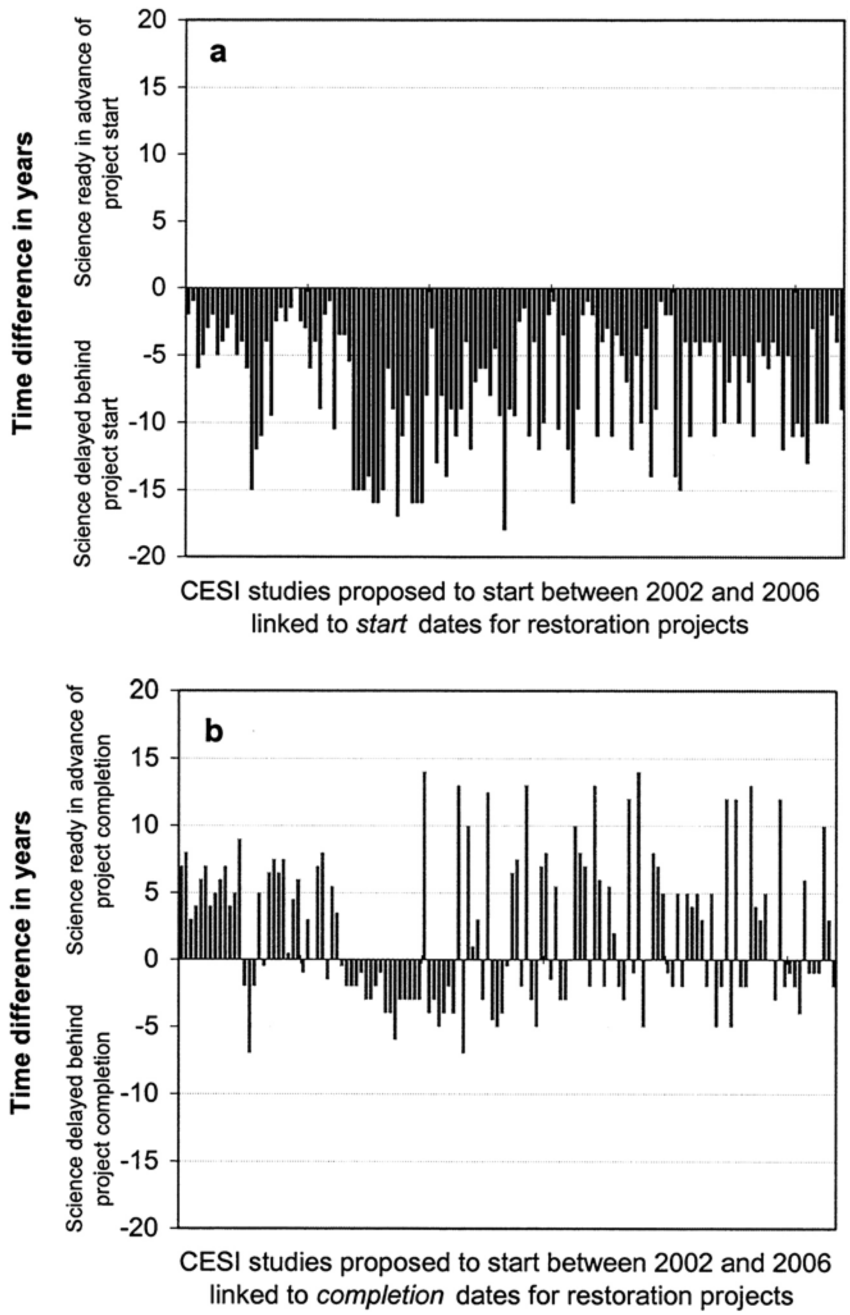

FIGURE 2–4 A comparison between when research results will be available from CESI projects that CESI managers have proposed be started between 2002 and 2006 and (a) starting dates and (b) completion dates for corresponding restoration projects. The difference is plotted in years for each comparison. Positive values mean that research results will be available in advance of the restoration project start or completion dates. Negative values mean that the research results will be delayed relative to the specified project dates. (CESI project data source: William Perry, NPS, written communication, 2002; restoration project data source: SFWMD, 2002f).

3

CESI Program Management

This chapter provides an overview of the administrative structure Critical Ecosystem Studies Initiative (CESI) and the processes used for managing CESI research activities. The chapter includes an evaluation of several management issues, including organizational structure, program coordination, accountability, and peer review, and it offers recommendations for improvements. Comments are also provided on the Department of the Interior's (DOI) proposed reorganization of the CESI program.

CESI MANAGEMENT STRUCTURE

The CESI program is intended to meet the most important DOI science information needs for South Florida ecosystem restoration. The program is administered by Everglades National Park, but it is structured to provide a means for coordinating research, priorities, and budgets with the other agencies and initiatives involved in the restoration process (DOI, 2000). The superintendent of Everglades National Park serves as the CESI manager and is the DOI official charged with assuring that program funds are administered properly and that CESI projects contribute useful scientific information to inform the management and restoration of DOI lands in South Florida. The CESI manager is expected to seek counsel and advice on research priorities from the executive director of the South Florida Ecosystem Restoration Task Force (SFERTF) as a means of coordinating CESI priorities with those of other agencies.

The CESI coordinator serves as the lead scientist for the program. Program category managers, who are scientists or science managers within DOI, assist the coordinator and administer specific components of the initiative (Figure 3–1). Management of CESI program categories was an additional responsibility given to staff already employed by DOI agencies in South Florida. The CESI coordinator works closely with the program category managers to develop science objectives and priorities, solicit and review research proposals, and coordinate with other federal, state, and local agencies. Program advisory committees, made up of subject matter experts (from universities, DOI, and other agencies), were established for each program category to assist the program category managers in the review of research plans and proposals.

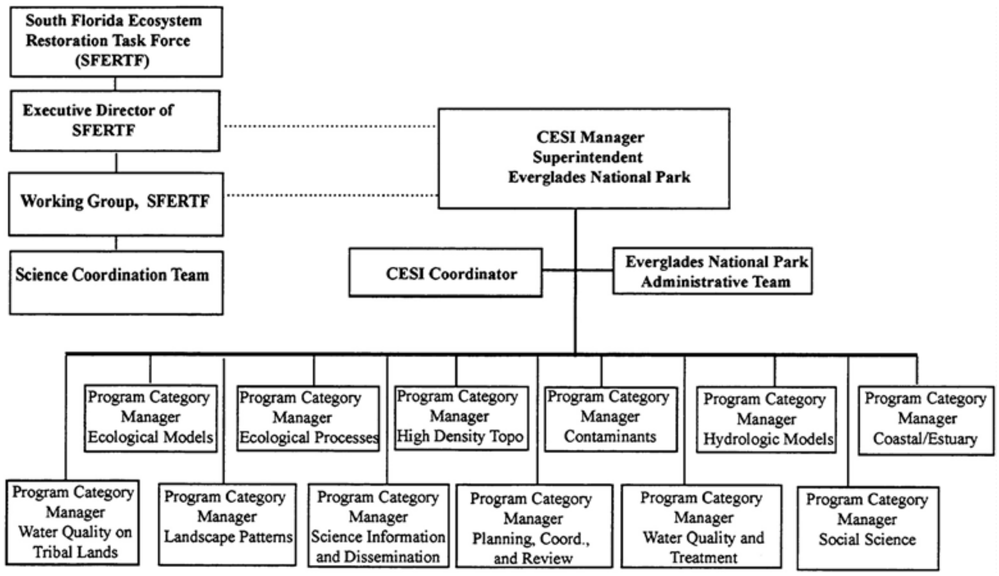

FIGURE 3–1 CESI management structure. SOURCE: Adapted from DOI, 2000.

Setting CESI Funding Priorities

Funding for the CESI program is provided through an annual DOI budgeting process (details on CESI financial resources are provided in Chapter 4). The CESI manager submits an annual budget request after consultation with program category managers, the executive director of the SFERTF, and the Science Coordination Team (SCT). The budget consultation process is intended to provide the CESI manager with current information on restoration activities, scientific information needs, and research priorities.

After the annual CESI budget is approved by Congress, the CESI manager evaluates the program objectives in light of funding availability. Priority objectives for individual CESI program categories are developed in consultation with the program category managers, the program advisory committees, the SCT, and the executive director of the SFERTF (Figure 3–2). The CESI manager then determines final allocations for each of the program categories with advice from the executive director of the SFERTF, in order to coordinate the program funding with science budgets of other agencies (SFERTF, 2002). Based on these determined priorities and available funding, managers develop or revise long-term

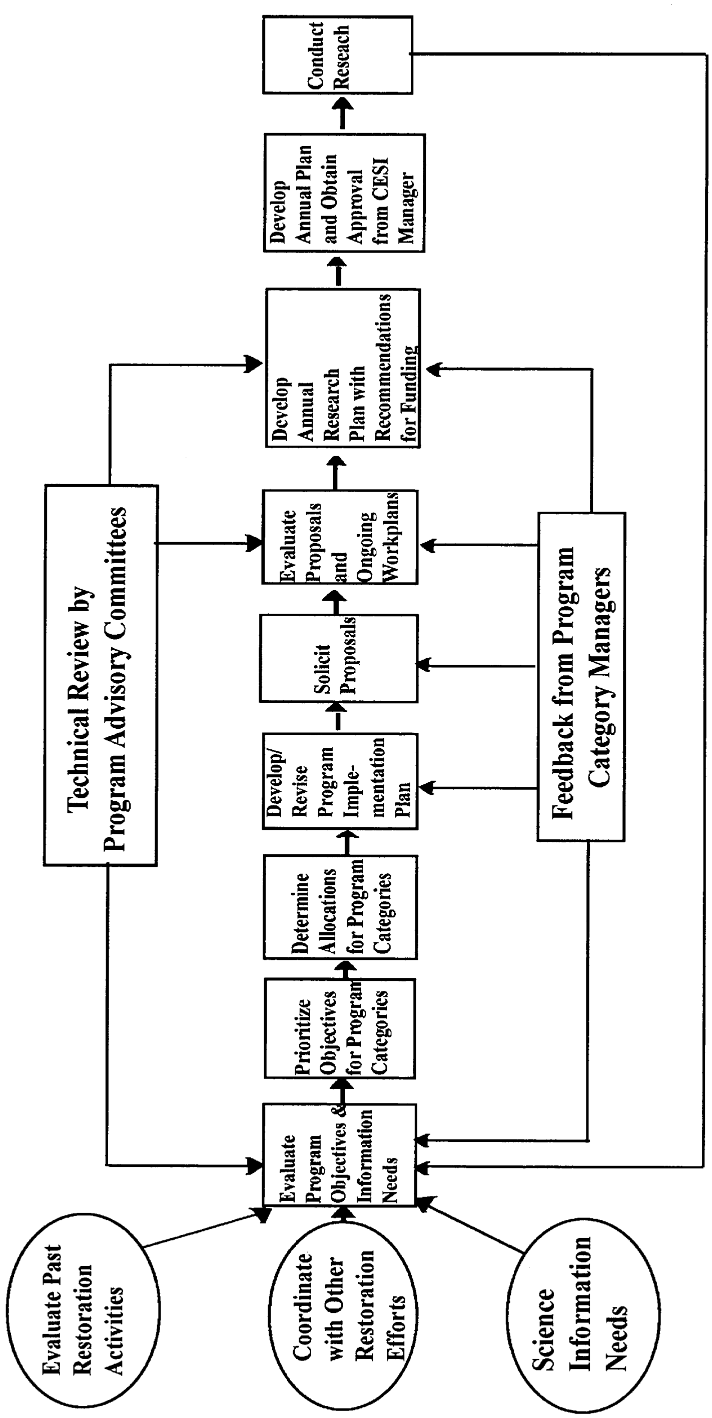

FIGURE 3–2 CESI research implementation process. Developed based on information in DOI, 2000.

program implementation plans that identify high-priority research needs for each program category (DOI, 2000).

There are opportunities for CESI management activities to be reviewed at several levels. The CESI coordinator, DOI science managers, the CESI manager, and the SFERTF executive director review the research priorities developed by the program category managers. Program category managers are responsible for periodically convening workshops and symposia to review category objectives and accomplishments. Program advisory committees are available to review research plans, identify unmet needs, review project proposals, and recommend funding priorities. The Science Coordination Team also meets annually to review the CESI program's priorities and direction.

Proposal Funding Process

Program category managers develop requests for proposals for the highest-priority objectives in each program category, and the CESI coordinator notifies potential researchers of the program's interest in receiving proposals on particular topics. Notification goes to a limited set of agencies involved in South Florida ecosystem research and to several universities in the region. The agencies are primarily the U.S. Geological Survey (USGS), the Fish and Wildlife Service (FWS), and the National Park Service (NPS); the universities are primarily Florida International University and nine institutions (most located in Florida) that are designated by DOI as Cooperative Ecosystem Studies Units.[1] Researchers in other locations who have extensive experience in South Florida are also notified.

Proposals are received, reviewed, and recommended for funding by the CESI program category managers with assistance from the program advisory committees. The usual period between solicitation of CESI proposals and decisions on funding has been about 30 days (William Perry, NPS, personal communication, 2002), a time period much shorter than that encountered in other grant programs of similar magnitude. The proposals are evaluated based on their importance in supporting the South Florida ecosystem restoration effort and the likelihood that the proposed research can be executed as specified. Both ongoing multiyear projects and new proposals must receive positive technical reviews before they are submitted to the CESI manager in an annual research plan.

Recommendations for the CESI program to support research proposals are submitted through the CESI coordinator to the CESI manager for funding approval. Documentation of committee reviews and the relationship between the proposed project and restoration objectives must be submitted with the proposal. Then, the CESI coordinator develops a cooperative agreement or other instrument for allocating the funds for a project and submits it to the director of the South Florida Natural Resource Center (SFNRC) for consideration. If the director of SFNRC approves the instrument and if it meets the requirements of the Everglades National Park administrative offices (e.g., contracting office), it is

[1] Cooperative Ecosystem Studies Units are structured to promote working collaboration among federal agencies and universities to provide research, technical assistance, and education for resource stewards (NPS, 2002).

sent to the CESI manager for final approval. The results produced by funded research feed back into the annual evaluation of program objectives and data information needs, as well as into the development of revised research implementation plans, thus beginning a new cycle in the research implementation process (Figure 3–2).

From its inception, the CESI program supported several projects that were funded outside of the competitive-proposal process. These programmatic projects (e.g., tribal water quality and development of an invasive-species control strategy) are managed out of the executive director's office and receive no direct oversight by the CESI coordinator or other science managers. Although they are funded by the CESI program and are important to the restoration effort, these projects are not included in the annual research plan. The funding of such programmatic projects has led some people to criticize the CESI program for allocating funds without appropriate controls on expenditures and the delivery of products.

EVALUATION OF CESI MANAGEMENT

The research being produced by the CESI program is making important contributions to the restoration knowledge base and is helping provide the science needed to inform restoration planning and management decisions. Nevertheless, there are some problems with the mechanics of the CESI program that need to be addressed to improve the quality and effectiveness of the supported research. These issues are described below, along with recommendations for improvement.

Current Organizational Structure

The CESI program has a fairly efficient process for program management and administration. The formal program advisory committees and outside consultation on the CESI program's plans (by the SCT, DOI managers, and the executive director of the SFERTF) facilitate essential coordination with other research and monitoring efforts. Although these advisory committees were established to ensure program quality, not all program categories receive the same scrutiny. For example, on one hand the Coastal and Estuary Systems category has an active advisory committee with wide agency participation that evaluates CESI proposals and hosts external symposia for determining research needs. On the other hand, program categories that primarily support internal agency efforts (e.g., the Ecological Modeling and Landscape Patterns program categories) tend not to fully utilize their program advisory committees for advice or review. All program category managers should be required to work closely with formal program advisory committees in order to enable additional input from outside experts and to promote closer linkages with other South Florida ecosystem monitoring and research activities.

Since the Comprehensive Everglades Restoration Plan (CERP) was authorized in 2000, the administrative landscape for South Florida ecosystem science coordination has changed. Currently, the CESI program depends on consultation with the SCT, the executive director of the SFERTF, and other DOI science managers to coordinate CESI science with the science initiatives of other agencies. In the CERP, RECOVER[2] was established "to organize and apply scientific and technical information" to support CERP decision-making (SFWMD, 2002b) (see Appendix D). Clearly, RECOVER will play a major leadership role in future coordination of restoration science. However, many details about RECOVER are still in development, and the science needs of non-CERP projects (nearly half of the restoration effort) do not fall under its purview. RECOVER does not replace the contributions of the CESI program, but CESI managers must coordinate closely with the RECOVER teams so that limited science resources are used wisely. Effective coordination with RECOVER will enable CESI science priorities to be developed in an appropriate and informed context, while addressing DOI's particular restoration science needs.

The South Florida Natural Resource Center (SFNRC), located in Everglades National Park (ENP), currently has the primary responsibility for managing the CESI program and also provides research relevant to NPS interests in South Florida. However, there are questions about the center's ability to objectively serve the needs of all NPS lands in South Florida because of its administrative linkage to ENP. At one panel meeting, managers of Big Cypress and Biscayne national parks and Loxahatchee National Wildlife Refuge expressed eagerness for more CESI research to be conducted on DOI lands. The land managers interviewed, however, acknowledged a number of hurdles faced in obtaining CESI funds to conduct research outside of ENP, including lack of research staff and poor communication of CESI proposal requests. Scientific research is broadly recognized as a critical component in the development of effective natural resource management strategies (NRC, 1992; NPS, 1992). The long-term nature of the restoration process and the need to continuously adapt management techniques to environmental change make DOI-specific research and environmental assessment all the more critical.

The NPS could address these concerns and improve the effectiveness of the CESI program to protect DOI's numerous land-management interests by removing the SFNRC from the organizational and supervisory structure of Everglades National Park. The current SFNRC research director should work cooperatively with the park superintendents in South Florida but should have organizational and fiscal autonomy. This suggested reorganization is consistent with the recommendation by the National Research Council in its report *Science and the National Parks* (NRC, 1992) that "the National Park Service should revise its organizational structure to elevate and give substantial organizational and budgetary autonomy to the science program." Strikingly similar recommendations were made in the *Report by the Advisory Committee to the National Park Service on Research* (NRC, 1963). Given the enormously complex political, ecological, and land-management patterns in South Florida, those previous NRC recommendations may be particularly important to this arm of NPS research.

[2] REstoration, COordination, and VERification

Accountability and Public Communication

Additional improvements in CESI management are needed to address concerns over accountability and public awareness of the CESI program's contributions. Approximately 70 percent of CESI funds are obligated to federal or state agencies through interagency agreements. The USGS, the SFERTF, and the FWS are the largest recipients of CESI funds through interagency agreements. The remaining funds are allocated to universities through noncompetitive cooperative agreements (William Perry, NPS, personal communication, 2002). There are well-established accountability procedures in place through the Everglades National Park contracting office for the cooperative agreements managed by the NPS. However, the CESI manager does little monitoring of work funded by interagency agreements because these instruments generally transfer large sums of money in very broad categories and leave the responsibility of allocating and reviewing expenditures to the receiving agency. When funds are allocated through an interagency agreement, the CESI manager has little power to assure that the work is accomplished on schedule or that the funding is focused on the identified priorities. Interagency agreements are relatively weak documents that for the most part rely on the good will of cooperating agencies. Therefore, consideration should be given to providing the CESI manager with more direct responsibility for assuring that funds allocated by interagency agreement are used to address the identified research priorities in a timely manner.

Although the CESI program has provided valuable information in support of the South Florida ecosystem restoration, its contributions have not been documented adequately to Congress and the general public. Interagency funding agreements may, in part, lead to reduced awareness of the CESI's contributions. University scientists receiving CESI funding through agencies other than the NPS have sometimes been unaware of the original source of the funds because the CESI program was not appropriately acknowledged. Also, a large portion of CESI research dollars has gone to support existing programs within the USGS, resulting in little public recognition of the CESI program's contribution. This may lead to the perception that the CESI program has been used to replace base funding for the USGS and that few new products and programs have been developed through the program. CESI funds are provided to the executive director of the SFERTF, who has public relations expertise on staff. It would seem appropriate that this office would promote the importance of the CESI program to the restoration effort.

Peer Review

Science depends on peer review for quality assurance and credibility. Effective peer review is the hallmark of science in service to the public good, especially for highly visible programs such as the CESI. Peer review is often thought of as solely a judgmental process, but in science, review provides essential guidance to investigators. Peer review ensures that researchers observe two of the most basic tenets of science: that the process is philosophically correct and that it is free of practical bias. Early peer review identifies potential problems with the conduct of the work and improves the process of reaching defensible conclusions. At the conclusion of the research, peer review assesses the quality of the work and the viability of results. An “ideal” peer review system is outlined in Box 3–1. In practice, peer review processes are always imperfect, and the CESI program faces the challenge of appropriately reviewing scientific results under notable time pressures. However, such paradigms are useful if they are seen as goals for which to strive. In that spirit, the following discussion focuses on ways that the CESI program could improve the reliability and objectivity of its peerreview process and thereby strengthen its scientific research program.

In the CESI process, formal requests for proposals are not widely dispersed to researchers but are instead generally limited to the South Florida ecosystem science community. This regional proposal-distribution process restricts the potential quality and breadth of CESI researchers. CESI managers have expressed concern that they have nearly exhausted the existing pool of South Florida researchers. Broadening the distribution of proposals would also help bring new talent and energy to the region's science questions.

The CESI program must move quickly to address emerging science needs and to meet restoration decision-making deadlines. However, at times this fast action happens at the expense of appropriate proposal development and review. The usual period between requests for CESI proposals and funding decisions has generally been short, but some proposal solicitations have occurred only days or weeks before funding, with skeletal proposals submitted and approved under the time constraints. Once approved, projects are funded on a year-to-year basis, with likely renewals because most projects are initially funded to extend over several years. To maintain public credibility and ensure wise investments of CESI funding, the CESI program must adhere to the highest standards for proposal review (see Box 3–1). CESI proposal funding should be based on prior evidence of successful research, timely conduct, and a strong publication record.

The CESI program does not have a well-established and published process for proposal or research reviews. CESI program advisory committees evaluate the funding proposals, apparently with input from a limited number of reviewers recruited by the program category managers. Although the CESI reviewer-selection processes are not completely clear, there seems to be limited independence between the reviewers and the reviewed. The same agencies are often involved in both aspects of the process with a very limited and closed system of scientists. The identity of reviewers is typically held confidential for specific proposal reviews, but as a whole the CESI program also does not publish the names of reviewers, whose qualifications could be used to build public confidence in the outcome of the process. The clients for reviews include researchers and managers, but in the CESI program, there does not seem to be a standard reporting process that encourages extensive feedback between reviewers and authors.

The most serious shortcoming in the existing CESI peer-review process is that managers generally assume that the results and conclusions resulting from the approved research are of acceptable quality, and they pass them directly to

BOX 3–1 AN IDEAL PEER-REVIEW SYSTEM

The foundations of an ideal peer-review system (NRC, 2002c) are described below. The CESI program should use the following framework to enhance the credibility, and therefore the usefulness, of its research findings. Although peerreview systems must be flexible to meet different situations and time frames, the following typical questions can help in the construction of an optimal process:

- When should the review occur?
- Who should review—who are the experts?
- Who should choose the reviewers?
- What is reviewed?
- Who are the clients for the review?
- How are the results transmitted?

When should the review occur? Peer review ideally occurs at least twice in major projects: during the planning stages before large amounts of resources are committed to the project, and near the end, before the results are made widely available. In the planning stage, peer review helps avoid problems that might be overlooked by scientific planners, and it helps sharpen research questions. The evaluation of research proposals is an ideal time for this initial peer review. Peer review at the conclusion of the research, but before the general release of the results, is also essential. The release of faulty conclusions confuses and misleads the consumers of the research, the general scientific community, decision makers, planners, and the public. This peer review at the end of the research can identify mistakes, strengthen the credibility of the research by pointing out additional interpretations, and clarify communication of the results.

Who should review—who are the experts? To be effective, reviewers must be seen by fellow scientists, decision makers, and the public as demonstrably competent in their field. They should be experts in the scientific field that is being evaluated, with technical expertise sufficient to evaluate the questions, methods, data, and conclusions of the work. It is often helpful to have reviews by experts with research experience in the same geographic region as the research, because science is a general process widely shared in the research community. However, reviewers may be effective in evaluating research even if the reviewer specializes in a different geographic region. In many specialized fields, it is difficult to ensure that reviewers have no connection whatsoever to the investigators. This is particularly true in environmental science, where multiple authorship and team-based research is common. Reviewers should not presently be collaborating with the investigators whose work is under review, nor should they be in a teacher/student or advisor/student relationship with the investigators. The reviewers and investigators also should not be in the same university or agency department. Naturally, the reviewers should not have financial interests in the outcome of the research.

users in the planning and management communities without detailed technical review (William Perry, NPS, personal communication, 2002). CESI program managers hope that researchers will eventually publish their results in the refereed literature, and they assume that publication will occur because most researchers operate in institutions (e.g., universities and the USGS) that reward the production of refereed publications. The result, however, is that "gray literature" (unrefereed reports) is likely to surface in public and in the hands of managers and decision makers without review. A typical research project includes con

Who should choose the reviewers? Independence of reviewers begins with a defined reviewer-selection process. Although authors might nominate some reviewers, the majority of reviewers should be chosen without the influence of the authors whose work is being evaluated. Reviewer selection is most effective if it is overseen by a general project director or monitor with the input of scientists not directly involved in the investigation. The project monitor should be in an organizational position that is superior to the researcher. Reviewer selection would thus have organizational authority and scientific legitimacy.

What is reviewed? Specific products of scientific research are the subjects of peer review: written documents that outline the plan or that summarize the nature and results of the investigation. Reviewers may also require access to data or other materials that support the specific product under review as part of their evaluation.

Who are the clients for the review? There are three sets of clients for peer reviews of research supporting projects such as the restoration of the greater Everglades ecosystem: the originating researchers, managers of the research (i.e., the CESI program category managers), and the public or its representatives. The originating researchers should have access to comments of peer reviewers and should be able to respond to the comments either by making adjustments in the product under review or by formally responding to the comments with a full explanation. Managers of the research use the peer-review comments to evaluate the research and the researchers, with implications for future investments. The public or its representatives should have access to the final decisions of peer review in cases where there is massive public investment. In public discourse, the final decision of peer review is critical in establishing the credibility of scientific results.

How are review results transmitted? The results of peer review should be in writing and should be transmitted to the authority that selected the reviewers. The transmission of the reviewer comments to researchers should be by an authority that is organizationally superior to the researchers, and that authority should require a written response to reviewer comments. Researchers may choose to accept reviewer comments and make changes in the product under review. Alternatively, the researchers may not be in agreement with the reviewer comments, in which case the researchers should explain in writing why the comments are not reasonable.

cepts, methods, analysis, and the drawing of conclusions. Even though a project may have been reviewed several times over the course of study, the all-important analysis of data and interpretation of the results from which conclusions are generated cannot be reviewed until the project is finished. Different experts can reasonably differ on the interpretation of results, so that thoughtful review is essential to ensure that the conclusions transmitted from researchers to decision makers are sound, reasonable, and scientifically defensible. An independent peer review upon the conclusion of the research process in CESI investigations will assure restoration planners and decision makers that they can work confidently from reliable research.

In recognition of the need for timely availability of research findings and the delays associated with journal publications, the CESI program should develop a mechanism for fast-track independent review of the most critical research findings. Research conclusions in the form of a draft manuscript or "white paper" could be evaluated by this mechanism if there is insufficient time for a peerreviewed article to be produced.

CESI managers can substantially improve the scientific viability of their research products by instituting a formalized peer-review process that includes a broadly based request-for-proposal process, improved proposal-review standards, widely solicited independent reviewers, a periodic collective identification of the reviewers, and reviews of science findings before they are released to users. The appointment of a peer-review monitor, perhaps in the role of a senior scientist, would streamline the peer-review process while at the same time enriching the process and increasing its accountability.

The manager of a peer-review process must evaluate the parameters necessary for an appropriate review, including the diversity of expertise and independence of the reviewers, and the complexity, cost, and duration of the review. Each of these parameters is a function of the combined influences of the project magnitude and risks associated with decisions based on the outcome of the project (NRC, 2002c). The greater Everglades ecosystem restoration is one of the largest, most expensive projects of its kind in the world. It is also a project with substantial risk, because the outcomes are largely unknown and untested. For these reasons, the science supporting the restoration requires peer review that adheres to the highest standards and that demonstrates independence of reviewers with great diversity of expertise.

Future Organizational Plans

In early 2002, a memorandum of understanding (MOU) among DOI bureaus was developed to more effectively coordinate research activities in South Florida (see Appendix E). The purpose of the MOU is to coordinate DOI research, monitoring, and planning efforts in support of the South Florida ecosystem restoration. The MOU was intended to maximize the value of DOI funds and ensure that research products produced both are high-quality and are responsive to the land-management needs of the NPS and FWS. Both the CESI program funds and the

USGS place-based studies funds (see Chapter 4) would fall under the management guidelines of the MOU, creating a new structure to manage the majority of DOI's investments in South Florida ecosystem science, likely beginning in 2003.

The current MOU implementation plan proposes to significantly revise the existing CESI management structure (see Appendix E). The MOU implementation plan calls for the creation of a Science Coordination Council (SCC), and discussions are underway informally to establish a Science Steering Committee, to replace the CESI manager, program category managers, and associated program advisory committees. Although these plans are currently under development, at this point the proposed management teams seem to lack an appropriate composition of scientists and agency representatives. There are few scientists on the proposed SCC, as these members consist of senior managers from the NPS, USGS, FWS, SFERTF, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, South Florida Water Management District, and Native American tribes. The responsibilities defined for the SCC and any associated steering committees will require the most knowledgeable scientists and science managers from a wide representation of South Florida science agencies, who can identify the priority science needs, select qualified researchers, and negotiate funding. The implementation plan for the MOU, as currently proposed, has the potential to push science further into the background rather than into a direct advisory role on restoration activities.

Lessons can be learned from early CESI management problems that arose under a similar team-based approach. Previously, the Science Coordination Team was used to set CESI's research priorities, but concerns arose as to whether some members might be prioritizing increased funding for their own agencies above actual science needs. In response to these concerns, responsibility for setting CESI priorities was given to the CESI manager. The Science Coordination Council (SCC) will need to take great care to prevent similar issues from arising. A senior scientist serving in the role of the CESI coordinator but working closely with the SCC and any associated steering committees could help retain the appropriate focus on addressing the critical science gaps. The senior scientist ideally should not be affiliated with any one particular agency but would offer respected leadership among all South Florida ecosystem science entities. A similar leadership structure, for example, was instituted to manage research at the Grand Canyon (see Chapter 5, Box 5–3). The research management proposed in the MOU will also need to be supported by designated staff located in South Florida to synthesize and communicate the research findings. If care is taken to address these important organizational issues, the MOU could improve the coordination of research in South Florida.

DOI has considered managing CESI funding through the USGS rather than the NPS. The USGS is a strong science agency, supporting extensive basic and applied research in South Florida. Because the USGS has no management or regulatory mandate, the agency generally is perceived to be neutral on resource management issues and therefore more credible with respect to science. Nevertheless, this impartiality can sometimes result in alternate prioritizations of science needs and slow delivery of research products, which are needed within narrow time frames to resolve planning questions. DOI interests in the South

Florida ecosystem restoration are tied to its stewardship of federal resources and its consultation and concurrence responsibilities for the CERP described in the draft programmatic regulations (USAGE, 2002b). The CESI program must produce the best possible science that is responsive to DOI needs and external restoration planning deadlines and therefore demands appropriate involvement of all relevant DOI agencies in future program managment. DOI managers should carefully consider these concerns when weighing future administrative reorganizations. Any effort to remove the administration of the program from those with the most vested interests in the CESI program's results (resource managers and scientists in South Florida) is likely to create as many problems as it solves.

In summary, this review concluded that the CESI program has developed an efficient process for program management, but several changes are needed to improve the quality and effectiveness of the science that the CESI program supports. Two high-priority management improvements have been identified that can be made quickly and inexpensively. First, the CESI program should adhere to and substantially improve its standards for proposal review by establishing a wider distribution of requests for proposals, an independent proposal-review process, and funding criteria based on prior evidence of timely conduct of research and publication of the results. Second, the CESI program must broaden the involvement of expert advisors in the priority-setting and proposal-review processes by fully utilizing its program advisory committees and coordinating closely with the SCT and RECOVER. Additional CESI management changes are needed in order to develop an effective peer-review system for CESI research results, improve the accountability of funding allocated through interagency agreements, increase the public awareness of CESI contributions, and more effectively address DOI restoration science needs outside of Everglades National Park. As DOI refines its new interagency management plan for CESI funds, care should be taken to assure that the leadership involves strong scientific expertise and appropriate agency representation.

4

Financial Resources

An assessment of opportunities for strengthening the Critical Ecosystem Studies Initiative (CESI) requires an understanding of the financial support for the initiative. The programs defined in Chapter 2 for the accomplishment of science in the service of restoration in South Florida and the program management improvements proposed in Chapter 3 require financial resources. This chapter provides a brief overview of the financial resources of the CESI program by describing the congressionally appropriated funds over the life of the program, the distribution of those funds by project activity, and other sources of funding for science research affecting the greater Everglades ecosystem and the restoration effort. The chapter also provides an evaluation of the current financial resources for the CESI program.

CESI FINANCIAL RESOURCES

In January 1996, Secretary of the Interior Bruce Babbitt published *A Comprehensive Plan for the Restoration of the Everglades* (DOI, 1996). The plan proposed that a total of $100–$ 150 million per year in additional funding be provided to the Department of the Interior (DOI) for FY 1997–2002 to accelerate restoration progress within three areas:

1. land acquisition ($40–$60 million per year)
2. infrastructure projects ($40–$60 million per year)
3. modeling and scientific research ($20–$30 million per year)

With DOI support for the proposed plan, the CESI program was initiated in FY 1997. Although the initial research costs were assessed at $20 million per year or more to address the science and information gaps, DOI requested $12.8 million for the first year. Congress initially appropriated $7.2 million for the CESI program, with $12 million appropriated in FY 1998. Although CESI managers had requested large sums for research, they were not prepared to actually manage these amounts, and therefore they were slow in dispersing the research funds. Additionally, because of disruptions in the congressional budget process (including governmental “shutdowns”), funds became available very late in 1997. These two forces resulted in relatively slow allocation of initial CESI funds to researchers, even though construction activity was moving forward and needed information from research projects.

The history of congressionally appropriated funds for the CESI program shows that there has been a decline of funding over recent years (Table 4–1). After the first year, the program reached its peak funding level of $12 million for FY 1998 and 1999, followed by large reductions in funding in FY 2000 and again in FY 2002, leading to the present level of funding of $4 million per year. These reductions in funding came at a time when the demand for scientific results to provide guidance for planning and construction in the restoration efforts was increasing.

The reductions in funding for the CESI program shown in Table 4–1 resulted from declining budgetary requests to Congress. The CESI funding requests were decreased for four reasons (DOI, 2002). First, the CESI program had been slow in spending its initial infusions of funding. The reasons outlined above were not obvious to the Office of Management and Budget (OMB) or DOI budget managers, and they were concerned that the CESI program simply could not manage a larger flow of funding. Second, there were serious concerns about the strategy and effectiveness of the CESI program. OMB managers wanted to see clearly defined linkages between money spent and useful, measurable scientific out-comes—an exercise that is always difficult for science. Many ecological research projects require years of data collection, and the restoration benefits derived from this critical information were likely to be at least a decade away. Third, funding tradeoffs occurred within DOI to provide additional funds for activities related to the Comprehensive Everglades Restoration Plan (CERP), including land acquisition and staffing needs, by subtracting funds from the CESI program. Land acquisition was an attractive magnet for funding, because it involved matching funds from the state of Florida. Finally, DOI continually balances competing requests for other projects completely outside the issue of Everglades restoration with requests for CESI funds. Political and economic pressures provide potent forces that enter this process at all levels. By considering these four issues in future budget requests, CESI managers may be able to compete more effectively for research funding within DOI.

All of the funding associated with the CESI program does not go for direct support of scientific research (Figure 4–1). As with most research, a portion is relegated to administration of research personnel and resources. For the CESI program, this portion is relatively low—only 6 percent of total costs for 1997– 2002. These funds are used to support the position of the CESI coordinator and to fund CESI administrative expenses. Additional nonresearch expenditures include $1.7 million in CESI funds that were reprogrammed in FY 2001 to address CERP-related needs within DOI. These reprogrammed CESI funds were combined with new CERP-designated funding[1] to meet critical DOI staffing needs for inform restoration planning, adequate numbers of staff were needed to communicate the available research findings to the restoration planning teams, and CESI funding was reallocated to address this need.

TABLE 4–1 Original Congressionally Appropriated Funding for the CESI Program, Fiscal Years 1997–2002

Fiscal Year	Total CESI Funding	Appropriations for Planning, Coordination, and Review[a]	Fraction of CESI Funds for Planning, Coord., and Review (%)
1997	$7,200,000	$47,500	0.7
1998	12,000,000	1,140,000	9.5
1999	12,000,000	570,000	4.8
2000	7,908,000	603,250	7.6
2001[b]	7,908,000	982,110	12.4
2002	4,000,000	531,050	13.3
2003 request	4,000,000	Not available	Not available

[a]Appropriations for planning, coordination, and review do not include allocations to support tribal water quality studies or CESI administrative costs.
[b]FY 2001 appropriation was later reduced to $6,191,000 due to budget reprogramming for CERP.
SOURCE: SFERTF (2002); William Perry, NPS, written communication (2002).

CESI funding was also used to support restoration planning, coordination, and review activities. During 1997–2002, these planning funds have averaged 9 percent of the CESI program's total expenditures (Figure 4–1), although their percentage of the yearly budget has generally increased as the CESI budget has declined (Table 4–1). The South Florida Ecosystem Restoration Task Force, rather than the National Park Service, managed the funds used for restoration planning, and these funds were allocated on a noncompetitive basis. Total nonresearch expenses for the CESI program, including administration, CERP implementation, and planning, coordination, and review costs, average 19 percent of the CESI budget over FY 1997–2002. More than $3 million in CESI funds were also provided to fund water-quality research and monitoring by the Seminole and Miccosukee tribes. Although these funds were distributed through noncompetitive allocations as a part of DOI's trust responsibility to Native American tribes, the funds were used for data collection and scientific research and were classified as research in this analysis.

[1] CERP-designated funding for the National Park Service amounted to $2.5 million in FY 2001 (including the $1.7 million reappropriated from CESI) and $5.5 million in FY 2002 and in FY 2003 (requested). The Fish and Wildlife Service also received CERP-designated allocations of $651,000 in FY 2001 and $3.35 million in FY 2002 and in FY 2003 (requested) (SFERTF, 2002).

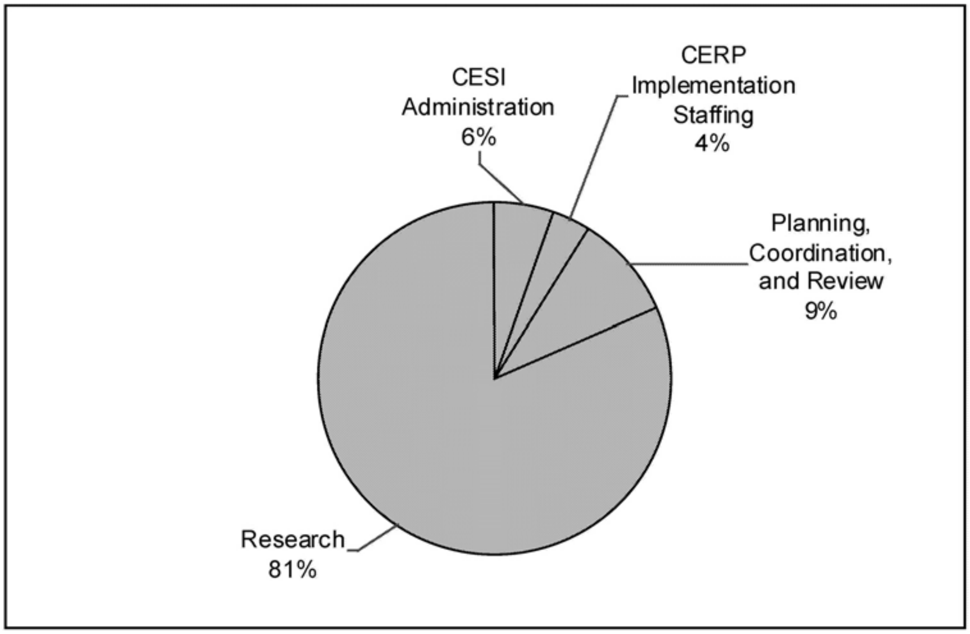

FIGURE 4–1 End uses of CESI funding, averaged over the period 1997–2002.
SOURCE: William Perry, NPS, written communication, 2002.

Four sponsoring agencies received CESI funding for scientific research during FY 1997–2002: the U.S. Geological Survey (USGS), the National Park Service (NPS), the Fish and Wildlife Service (FWS), and the U.S. Environmental Protection Agency (EPA) (Figure 4–2a). These sponsoring agencies completed a portion of the work themselves, while also contracting with universities, other federal, state, and local government agencies, consulting firms, and nonprofit organizations to conduct the studies needed (Figure 4–2b). The USGS and NPS together received nearly all of the CESI funding (96 percent) as sponsoring agencies, while the USGS and universities received the largest portions of the funding to conduct the research. The USGS has both sponsored the largest portion of CESI funded research and conducted the greatest fraction of the research.

The CESI program's expenditures by program category highlight its strongest and weakest areas of research contributions (Figure 4–3). Specifically, the program categories of Ecological Processes/Indicator Species and Coastal and Estuary Systems have received the highest allocations of funding to date, followed by Ecological Modeling. Research programs that have received the fewest allocations include Science Information and Dissemination, Contaminants, and Social Science. Examples of CESI research contributions from these various program categories and an assessment of remaining research needs are described in Chapter 2, while individual project's and their costs are detailed in Appendix A. More than one sponsoring agency usually engages in any given research category. The USGS has received the majority of the funds to support Ecological Modeling, Hydrological Modeling, and Topographic Data, but it is also a primary agency in the Coastal and Estuary Systems and Ecological Processes/Indicator Species program categories along with the NPS (Figure 4–3). The FWS and the NPS have sponsored research on population success and long-term monitoring of

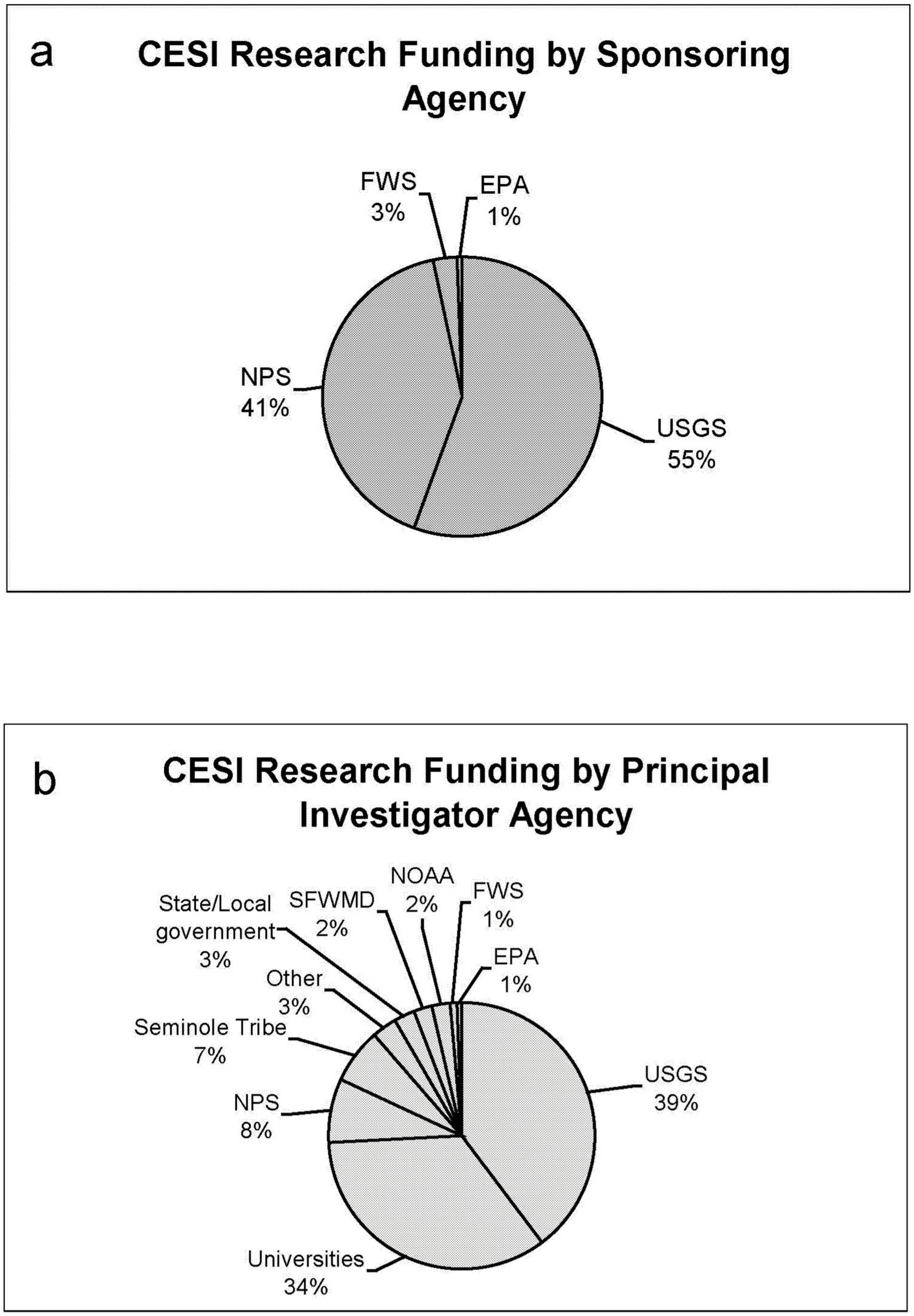

FIGURE 4–2 Breakdown of CESI research expenditures (a) by sponsoring agency and (b) by agency of the lead principal investigator, reflecting the agency responsible for conducting the research. SOURCE: William Perry, NPS, written communication, 2002.

ecosystem species, reflected under the Ecological Processes/Indicator Species and Landscape Patterns program categories. The NPS has also sponsored all of the research in the Contaminants, Water Quality and Treatment, and Social Science program categories.

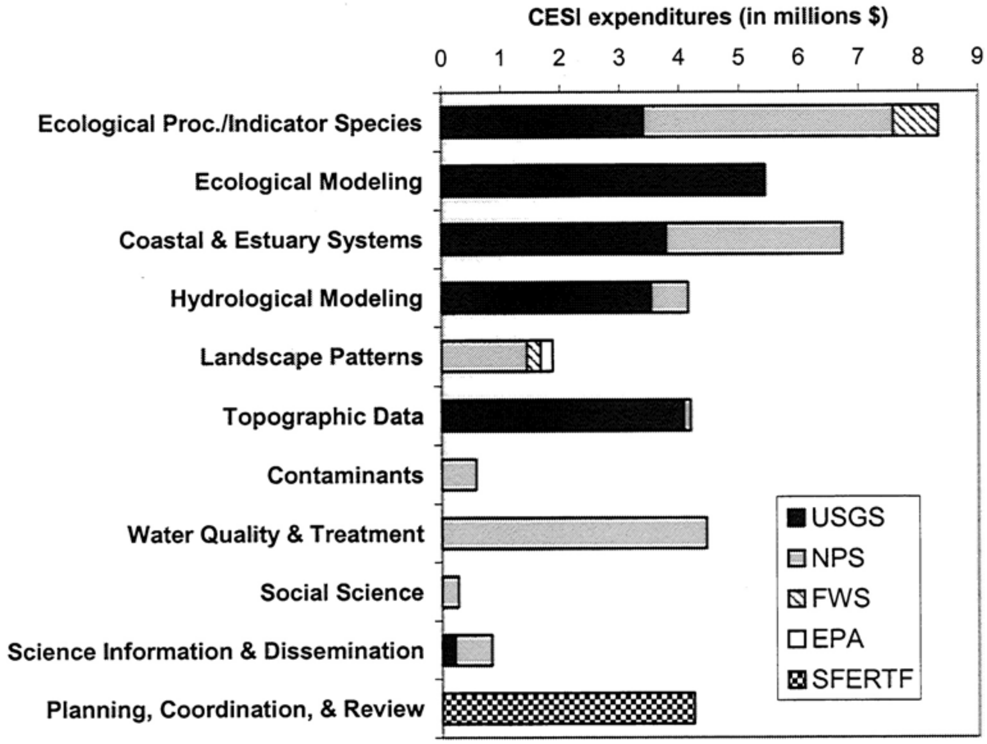

FIGURE 4–3 CESI expenditures subdivided by sponsoring agency. CESI program area funds obligated as of March 2002. Funding within each category has been subdivided by sponsoring agency. The Water Quality and Treatment and Water Quality on Tribal Lands program categories have been combined under Water Quality and Treatment. The projects under Planning, Coordination, and Review are nonresearch costs and represent the appropriated amounts. SOURCE: William Perry, NPS, written communication, 2002.

The CESI program is not the only source of funding for South Florida ecosystem science. Within DOI, "place-based" research in the South Florida region by the USGS (http://sofia.usgs.gov/) has a distinct focus on the greater Everglades ecosystem, and much of what is learned from the effort is applicable to restoration. During the past three years, funding for the USGS South Florida place-based research has grown from $6.5 million to about $8 million per year while annual funding for the CESI program has declined from $12 million to $4 million. The USGS funding increase cannot be viewed as a replacement for the CESI budgetary decline, however, because the USGS place-based research topics were selected independently from the overall CESI strategic funding plan. An evaluation of USGS South Florida place-based research investments and their support for the restoration science needs was not feasible within the scope of this review.

Additional investment in Everglades-related research includes funds for ecosystem research provided by the National Science Foundation (NSF). The NSF supports individual investigators in basic science projects related to the greater Everglades ecosystem, as well as long-term investigations by a large group of researchers associated with the Florida Coastal Everglades Long Term Ecological Research (FCE-LTER) project (http://fcelter.fiu.edu/). The LTER work is ecosystem-oriented and is driven by basic questions about the biology of the system. Some of the outcome of this work is useful for restoration planning, although LTER's emphasis is on basic science. The South Florida Water Management District (SFWMD), U.S. Army Corps of Engineers (the Corps), National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency, and Florida Marine Research Institute also contribute valuable scientific research related to the restoration effort. According to the 2001 Cross Cut Budget, sizable financial allocations have been made for these agencies' restoration-related research and monitoring programs. The largest investments have come from NOAA and the SFWMD. In FY 2001, the NOAA budget for scientific research on the marine environment exceeded $5 million, and the SFWMD allocated more than $40 million for both research and monitoring efforts (SFERTF, 2002).

EVALUATION OF CESI FINANCIAL RESOURCES

In general, it appears that the early science funds for the CESI program were sufficient to initiate the needed research, but the smaller budgets of recent years have been inadequate to support full development of the science to support fast-moving restoration planning. Additionally, insufficient staff resources exist to provide the necessary synthesis, dissemination, and integration of existing CESI data. In the coming years, monitoring and environmental assessments, and the research associated with designing and interpreting the results of these activities, will place an extra burden on the CESI budget. Original estimates of the requirements for science (DOI, 1996) were far larger than the amount of support that has been provided, and as a result many of the identified science gaps remain unaddressed (see Chapter 2). CESI managers have identified additional research and monitoring objectives to address some of these gaps for FY 2002–2006 (Figure 4–4, examples in Appendix C). Although discussions are needed with experts from the scientific and restoration community to review these objectives, existing funding levels will meet less than a third of the CESI program's anticipated needs. Meanwhile, these identified science needs merely represent a snapshot in time, and funding must also be available to address the most critical new restoration-related science questions as they arise. The CESI program should identify priority research topics in under-funded areas and formulate effective research programs based on rigorous peer-review procedures. CESI managers should then develop budget estimates and seek additional funding to support these programs. Recommended CESI management and program improvements for synthesis, peer review, and dissemination will also place new demands on current funds (see Chapters 3 and 5).

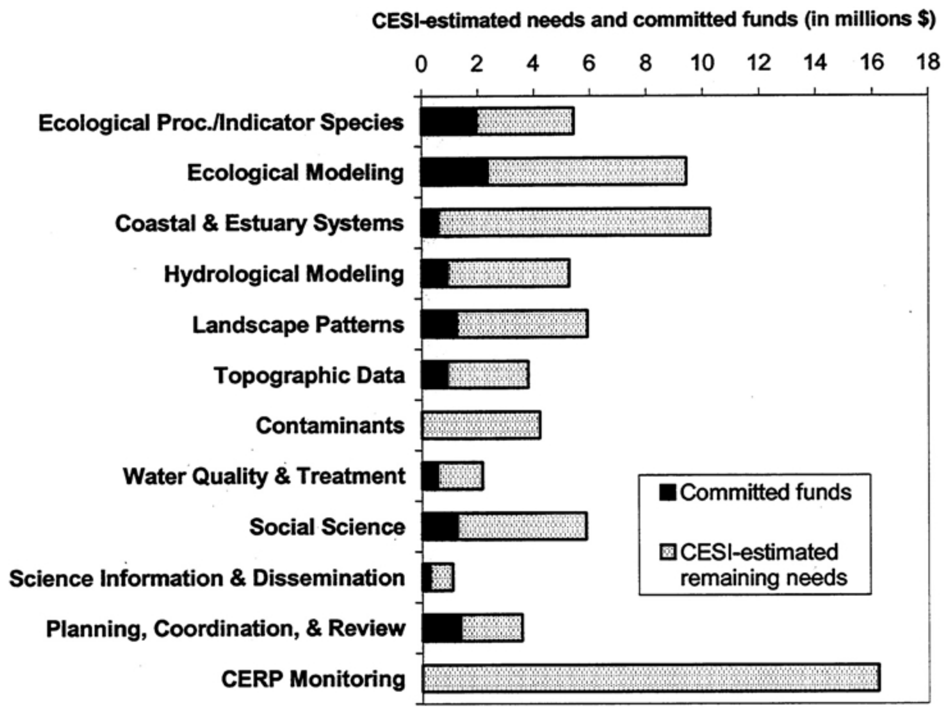

FIGURE 4–4 CESI-estimated funding needs by program category over the period FY 2002—FY 2006 and currently committed CESI funds. Note that currently committed funds include CESI budget carryovers from previous years, since committed funds exceed current budget of $4 million for FY 2002. Water-quality technology remaining needs may be an underestimate because of some missing data within this category. Also, interagency program support was not included in this analysis. SOURCE: William Perry, NPS, written communication, 2002.

Early scientific research can reduce uncertainly in restoration planning and, therefore, represents an investment toward the likelihood of achieving the restoration goals. Inadequate science support now may result in exponentially increased costs later if failed restoration projects must be redesigned based on unforeseen consequences. Scientific research and environmental assessments will also provide a critical foundation for DOI's future consultation, concurrence, and reporting responsibilities for CERP (USAGE, 2002b). The CESI program has provided an agile, multi-agency approach to address many of the restoration's science information gaps, providing a rich database, enhanced understanding of South Florida's ecosystem dynamics, and improved modeling tools for restoration planning and decision making. Congress should increase CESI research funding to meet DOI's current restoration science needs, contingent upon making the recommended management changes outlined as first-priority improvements in Chapter 3. These changes include (1) adhering to and substantially improving the standards for proposal dissemination and review and (2) broadening the involvement of expert advisors in the priority-setting and proposal-review processes. These management changes can be made both quickly and inexpensively and will substantially strengthen the program, ensuring that new research funds are directed efficiently to appropriate science priorities and with an adequate peer-review structure in place. Other recommended management and programmatic changes outlined in this report (e.g., enhanced dissemination, strengthened synthesis, improved funding accountability, and development of an independent fast-track peer-review process; see Chapters 2, 3, and 5) are no less critical but may require additional time or resources to implement. The restoration science needs are simply too important and too urgently needed to delay the contributions from additional research funding. Nevertheless, future CESI allocations should be contingent upon noted progress toward these recommended improvements.

An additional concern for financial management of science to support the South Florida restoration is the distinction between research and monitoring. Research seeks explanation, and its ultimate purpose is prediction. It is a complex activity that often involves hypothesis testing and model building. Monitoring provides fundamental data input for science (and management) activities, but monitoring is best used in the context of answering scientific questions with ongoing synthesis and analysis. Such analysis of ecosystem monitoring data will ultimately discern the impact of restoration activities. Research and monitoring should not be confused with each other in CESI management and financial planning.

In summary, this review shows that funding for CESI science has been inconsistent and inadequate. Funding is now far less than the existing needs for science to support DOI's interests for the restoration. Funding in the late 1990s was depressed within DOI based on concerns about the effectiveness of the CESI program and because of countervailing economic pressures, including the budgetary demands of CERP implementation. The result of these budget shortcomings has been that CESI science has been limited in its potential contributions to inform restoration management and decision making. The implications of inadequate early science investments in the South Florida ecosystem restoration will ultimately be borne by taxpayers over the next 5–30 years.

5

CESI Science in the Greater Everglades Ecosystem Restoration

This chapter provides an assessment of Critical Ecosystem Studies Initiative (CESI) science support for South Florida ecosystem restoration. The role of learning from research and the integration of scientific findings into the restoration process are emphasized. This chapter also discusses recommendations for increasing the effectiveness of the CESI program and the broader need for improved coordination and integration of scientific research in the greater Everglades restoration. The C-111 project (see Chapter 1) is used to illustrate many of the CESI-related contributions to the overall restoration process.

The large scientific, engineering, and political uncertainties associated with a restoration project of the scope and complexity of the Comprehensive Everglades Restoration Plan (CERP) are widely recognized by the plan's scientists, engineers, and managers (NRC, in press):

> In particular, the relationship between hydrological regime and ecosystem composition, structure and function remains somewhat hypothetical given the greatly reduced size and altered proportions and flow ways of the modern system and the degradation of water quality. Exogenous factors such as sea-level rise, continuing human development of southern Florida, the spread of invasive exotic species, and atmospheric mercury deposition may confound the best restoration designs. There is the added uncertainty associated with some of the proposed engineering solutions such as large-scale aquifer storage and retrieval, not to mention the uncertainty of project funding over its 30-year plus duration. Also some uncertainties can only be resolved by taking action—comprehension will always lag behind reality; action will inevitably have to be taken without full knowledge of how the ecosystem will respond. Ecosystems are moving targets and interventions themselves will create change, which can only be understood in retrospect.

It is these uncertainties that necessitated that an adaptive management strategy for the restoration of the greater Everglades ecosystem be embraced, leading Congress to require that an adaptive management approach be the foundation of the CERP in the Water Resources Development of Act of 2000 (WRDA 2000). As noted in Chapter 2, the CESI program was originally funded to provide science support for the Restudy, which later became the CERP. Consequently, any evaluation of the CESI science program must be done with an adaptive management approach in mind.

Adaptive management fundamentally is learning in the midst of doing and is central to the CERP, as the restoration plan is an outline of activities that will be filled in with details as experience informs subsequent steps. Just as adaptive management is dependent upon integration of scientific knowledge into the ongoing processes of project planning, evaluation, construction, and operation, continual research and synthesis are integral to adaptive management. Given an unknown future, restoration will require a research framework that continues to develop an understanding of the ever-changing dynamics between environment and society and between the ecosystem and hydrological processes. This will require a continuous cycle of not just monitoring and experimentation, but also regular and frequent synthesis of the findings. Monitoring, experimentation, and synthesis together can increase the reliability of current knowledge, address information gaps and surprises, provide new knowledge to understand emerging as well as old problems, and speed up the process of adaptive management (Holling et al., 1998).

Walters and Holling (1990) describe three adaptive management approaches (Box 5–1): (1) trial-and-error, (2) active adaptive management, and (3) passive adaptive management. The CERP relies on a passive adaptive management approach (Aumen, 2001; Applebaum, 2002), although some have classified the Everglades restoration as "ecosystem management" (Harwell, 1998; Blumenthal and Jannick, 2000). Regardless of the specific adaptive management approach ultimately adopted for use in the CERP, the complexity and extended time for implementation of the restoration necessitates that the restoration management plan be founded on four critical elements (NRC, in press)[1]:

1. clear restoration goals
2. sound conceptualization of the system
3. effective processes for learning from future actions
4. explicit feedback mechanisms for refining and improving management based on the learning process

Science contributes to elements 1 and 4 and is the foundation upon which elements 2 and 3 are based. There is a long history of scientific input towards the identification of restoration goals and the conceptualization of ecosystem function. Effective processes for learning and for integration of learned knowledge into management (also termed feedback mechanisms) have proved to be more challenging. The following sections describe the role of science within this fundamental restoration management framework and evaluate the contributions of the CESI program to this process in South Florida.

[1] It is important to note that successful application of an adaptive management framework requires more than just these four elements (e.g., collaborative working relationships, trust). These four elements, however, assure that the basis for adaptive management has been established.

BOX 5–1 THREE APPROACHES TO ADAPTIVE MANAGEMENT

Walters and Holling (1990) define three approaches to adaptive management:

1. The **trial-and-error approach** (also referred to as an evolutionary approach) is a set of haphazard choices early in the management plan with refinements being made later in the plan based on the subset of choices that yield the more desirable results.
2. **Active adaptive management** uses the available data to construct a range of models that then are used to predict short-term and long-term ecosystem responses based on small- to large-scale “experiments.” The combined results of modeling and experimentation are used by policy makers to choose among alternative management schemes to identify the best management plan.
3. **Passive adaptive management** is based on historical information that is used to construct a “best guess” model of the system response. The management choices are based on the model with the assumption that the model is a reliable reflection of the system response. Passive adaptive management looks at only one model of the system and monitors and adjusts, while active adaptive management considers a variety of alternative models.

SCIENCE CONTRIBUTIONS TO DEFINING GOALS

Formulation of the overarching goals and objectives of restoration is the province of policy makers, but science contributes to this process by helping to establish what constitutes realistic goals and objectives. In the case of the Restudy, the goals were to enhance ecological values and to enhance economic values and social well-being. The objectives associated with these goals are the following (SFWMD, 2002a):

- Enhance Ecological Values

— Increase the total spatial extent of natural areas
— Improve habitat and functional quality
— Improve native plant and animal species abundance and diversity

- Enhance Economic Values and Social Well-Being

— Increase availability of fresh water (agricultural/municipal and industrial)
— Reduce flood damages (agricultural/urban)
— Provide recreation and navigation opportunities
— Protect cultural and archaeological resources and values

Numerous scientific investigations preceding and during the Restudy were used to conclude that achievement of these goals and objectives would require delivery of the right amount of water, of the right quality, to the right places, and at the right time (SFERTF, 2000). The CERP provides the cornerstone of the greater restoration effort, as the overarching goal of the CERP is to “Get the wa ter right." Science will play a critical role in the restoration by determining the specific hydrological and ecological targets to ensure the "water is right." Although it may seem to be a straightforward objective, getting the water right is a difficult charge for such a large and complex ecosystem that has suffered extensive spatial losses and anthropogenic modification. Alterations to the natural system (e.g., soil loss, urban and agricultural development) have made it so that even if all the canals and structures were removed, the historic flow could not be restored. Thus, it is essential that the complex interrelationships between hydrological attributes and ecosystem function continue to be researched so that clear and achievable restoration objectives and targets can be established within the limits imposed by the physical realities of the current environment.

CESI-funded projects have contributed to the identification of restoration targets primarily through the examination of historical data. For example, the CESI-funded project *Analyzing Historical Data to Set Restoration Targets for Wading Bird Nesting in South Florida* was instrumental in setting wading bird targets for the CERP Monitoring and Assessment Plan (USAGE, 2001). Other CESI-funded projects have had a similar effect on identifying restoration targets through direct experimentation and monitoring related to tree island evolution, animal population dynamics and distributions, exotic vegetation distribution and control, and water quality.

SCIENCE AND CONCEPTUALIZATION OF ECOSYSTEMS

Conceptualization of an ecosystem undergoing restoration represents a vital step in the restoration process. Conceptual descriptions of an ecosystem highlight the organization of major ecosystem components and create a framework for understanding the multicausal nature of ecosystem dynamics, including explanations of anthropogenic effects (see Appendix F). The conceptual models of the CERP's Monitoring and Assessment Plan (USAGE, 2001) are based on series of hypotheses that vary widely in the degree of uncertainty associated with the causal relationships, thereby identifying gaps in understanding and areas where additional research is needed. These conceptual models also establish a basis for selecting restoration performance measures. Additional value will be realized if the conceptual models are refined and model uncertainties reduced. Furthermore, development of simulation models that use the conceptual model assumptions as starting points would provide other valuable opportunities to examine uncertainties associated with restoration activities and management actions.

CESI-funded science has contributed to the development of several of the CERP conceptual models (USAGE, 2001), particularly the Florida Bay, the Marl Prairie & Rocky Glades, and the Mangrove Fringe models (e.g., Thayer et al., 1999; Boyer et al., 1999; Chen and Twilley, 1999; Lorenz, 1999, 2000; Ross et al., 2000; Trexler and Loftus, 2000; Turner et al., in press; Trexler et al., in press). The contributions span a wide range of topics, including individual population dynamics, food webs, climate, and landscape-scale vegetation dynamics, and they reflect a diversity of research approaches, such as modeling, analysis of historical monitoring data, and direct experimentation. Understandably, CESI-funded projects have played a lesser role in conceptual model development for the physiographic regions outside Everglades National Park. Yet, CESI projects have been integral to the development of the systemwide conceptual model, and new research generated by the CESI program promises to provide additional valuable information for model refinement (John Ogden, SFWMD, personal communication, 2002).

Continued support for research directly related to testing the conceptual models, and building upon the conceptual framework through simulation models is essential. Support for research that narrows the uncertainty associated with hypothesized ecosystem behavior will likely reduce the occurrence of unexpected ecosystem responses from restoration activities. These areas of high uncertainty represent important research gaps that the CESI program is poised to address. Regular reevaluation of all the models' hypotheses will provide an opportunity for synthesis and for generation of new knowledge on which to base management decisions.

A ubiquitous challenge to understanding causes of environmental change is how to address both natural and social phenomena within a single explanatory framework (Little, 1999). To maximize the usefulness of the ecosystem conceptual models, it is essential that both anthropogenic and natural systems drivers be an integral part of the models. Research examining socioeconomic sustainability of the Everglades has been modest at best and, as a result, socioeconomic science has had little impact on restoration decision-making. Only two CESI studies have specifically addressed the direct relationships between the built and natural system. When systematic social science analysis is absent, managers are forced to ignore or guess the social impacts of their decisions or to rely on those members of the public who present testimony in public forums (Hanna, 2000). Neither is an ideal decision-making process. Research projects that aim to monitor and assess socioeconomic sustainability are needed. These relationships are too important to be ignored.

LEARNING AS THE FOUNDATION FOR RESTORATION MANAGEMENT

The CERP component of the greater Everglades ecosystem restoration effort relies on adaptive management and new learning to support development of project-specific details with time. For this approach to be effective, learning must be embedded in all phases of the restoration from planning, engineering design, and project construction to operation and management of the system. In addition to incorporating new knowledge about ecosystem processes into restoration activities and exploring emerging technologies, it will be necessary to distinguish ecosystem responses to management from responses to natural and anthropogenic environmental changes. The learning process must depend on a strategy that effectively combines experimental research, monitoring, and modeling with a high level of attention to data synthesis, information management, and periodic resynthesis of scientific information throughout the implementation and operational phases of the CERP (Box 5–2). Clearly, there is a critical need for science to guide the learning process that will accompany restoration.

BOX 5–2 TOOLS FOR LEARNING

There are three main tools for embedding learning into long-term restoration projects (NRC, 1999b), such as the restoration project underway in the greater Everglades ecosystem:

1. integrated assessment models
2. long-range development scenarios
3. regional information synthesis

Integrated assessment models describe our current and evolving understanding of how the environmental-societal system works; thus, they enable society to redefine problems and to gain analytical insight, and they inform the decision-making process. More specifically, these models allow examination of uncertainties in the understanding of ecosystem processes and interconnections, and they allow the evaluation of the potential implications of these uncertainties for past and impending decisions (see Appendix F). Application of these models to assist in restoration decision making requires simplification to avoid having the models become so bogged down by details that analyses cannot produce usable results (Holling, 1978; NRC, 1999b).

Long-range development scenarios provide a way to examine management options to determine how robust they are to potential surprises. Long-range development scenarios are not predictions of the future, nor are they mere projections from the present. Rather, they sketch alterative long-range visions of how the system could change given what is known about trends, uncertainties, and possible surprises. Long-range development scenarios also describe the pathways by which conditions might change. They make explicit the assumptions about values, lifestyles, and institutions and reveal the range of possible futures that should be contemplated. For example, in the South Florida restoration effort, development and population growth will influence water-supply needs, and long-range scenarios can help to bracket a range of possible outcomes, preparing the restoration planners for unanticipated changes. Given an unknown future and the long-term commitment to the greater Everglades ecosystem restoration, long-range development scenarios are a central component of adaptive management.

There has been little emphasis in the CESI program or other South Florida research on detailed scientific evaluation of how various courses of management action (or inaction) might impact restoration efforts. Some CESI funding has gone to long-term modeling and ecological studies that are potentially useful in scenario development. Making long-range scenario testing a priority in the CESI program would encourage systematic explorations of uncertainties and their implications and would help in the identification of the management actions that are most likely to lead toward Everglades restoration.

Regional information synthesis involves developing an interdisciplinary, systemwide understanding of the major physical, biological, and social processes that affect the sustainability of the greater Everglades ecosystem. Several synthesis approaches that have been used to examine ecosystems in the past are applicable to the South Florida ecosystem. These include synthesis of descriptive data, correlations of ecological data with changes in environmental conditions, mechanistic models to make large-scale predictions, and a combination of these methods (Hobbie, 2000). Synthesis of descriptive data, the simplest form of synthesis, might involve descriptions of changes in the characteristics of ecosystems (e.g., organic matter accumulation) and in physical factors (e.g., hydroperiod) over time. Statistical correlations between biological responses and environmental factors may take the form of periphyton response to phosphorus loading. Integrated Geographic Information System databases are particularly useful for analyzing large, disparate datasets over time and space. Mechanistic simulation models could be used to predict a single process (e.g., rate of mercury methylation) or interrelated processes (e.g., wading bird nesting coupled with a hydrological model). Sophisticated models that combine simulation modeling with descriptive and correlative methods are also possible—e.g., the Everglades Landscape Model (www.sfwmd.gov/org/wrp/elm/), which combines hydrodynamics, nutrient transformations, and translocation with plant production and community composition responses. Each of these approaches offers opportunities to enhance our understanding of the complex interactions of the physical, chemical, and biological factors that characterize the greater Everglades ecosystem, ultimately facilitating South Florida restoration activities by reducing uncertainties about overall ecosystem response.

Research, Monitoring, and Modeling as Part of Learning

From its inception, the CESI program has supported learning that has value to restoration activities, including work to define the linkages between hydrology and ecology and efforts to develop and refine modeling tools for support of the restoration efforts. For example, the CESI program helped fund the development of the Dynamic Model for the Everglades Stormwater Treatment Areas, which is being used to assess the expected water-treatment performance of the detention ponds under construction on the eastern edge of Everglades National Park (Walker and Kadlec, 2002). Information gained from this model will assist restoration planners as they evaluate the need for additional water-treatment options. Research on aquatic communities in the Rocky Glades area and studies to delineate the relationship between water flow and aquatic species (e.g., invertebrates and fish) have provided insights that have helped to reshape the objectives of the C-111 restoration project (e.g., Trexler and Loftus, 2000; Acosta and Perry, in press; Chick and Trexler, in review). Although many CESI studies preceded CERP authorization, these studies and others like them have generated information that ultimately will contribute to the restoration knowledge base, particularly with respect to the linkage between hydrology and populations of special concern (e.g., endangered and threatened species as well as keystone species).

The Department of the Interior (DOI) is ultimately responsible for preserving federal lands and resources. In this light, DOI agencies must be able to adequately quantify ecosystem response to project design, operation, and management efforts once restoration projects begin operation. To support the DOI's future restoration responsibilities,[2] a strategic shift in the emphasis of the CESI program is planned, moving from experimental studies and model development to monitoring, model application, and environmental impact assessment. The proposed change in focus for setting CESI funding priorities is a concern. As the restoration progresses, there will be a critical need for studies that develop an understanding of the causes and consequences of unexpected ecosystem responses in order for adaptive management to be supported. Both monitoring and research are central to an adaptive management approach (Ehrlich and Daily, 1993) and require adequate financial and staffing resources.

Synthesis as Part of Learning

The complexity of ecosystems—the broad spatial extent, long response times, multiple scales, large number of components, and nonlinear system dynamics—creates a situation that requires a transdisciplinary approach to convert observational, experimental, and modeling results into knowledge. Synthesis is the process of accumulating, interpreting, and articulating scientific results, thereby converting them to knowledge or information. Synthesis must be a prominent feature of the scientific effort in any restoration activity to ensure that crucial scientific information will be available to support management decisions and policy formulation. A strong information synthesis capability supported by a well-designed information management system will make it possible to learn from interactions among restoration projects and across the entire South Florida ecosystem. Synthesis in complex multidisciplinary settings will reveal risks and uncertainties that must be understood so that appropriate resiliency will be incorporated into restoration plans. Synthesis is essential to the greater Everglades ecosystem restoration as it will enable ongoing learning when change is common and uncertainty is high. In the absence of synthesis, the restoration will become “data-rich but information-poor.”

Restoration-wide synthesis presents challenges to information management and coordination, and it also poses difficult scientific questions, especially over multiple spatial and temporal scales. However, the long time and large spatial extent over which the restoration is occurring mandate that restoration synthesis be done at multiple scales. Systemwide synthesis is not simply a process of linear aggregation from small to large scales because the ecosystem attributes are not uniform or scale-invariant. Two central challenges faced by restoration scientists are to quantify events and processes that operate on more than one scale

[2] DOI's concurrence, consultation, and reporting requirement responsibilities for the CERP are derived from “its stewardship role over federal lands and natural resources involved in the restoration” (USAGE, 2002b).

and to identify general procedures for aggregating (and disaggregating) data on different scales. While long, slow processes frequently "control small and fast ones, the latter occasionally 'revolt' to affect the former" (Holling, 1996). Clearly, a mechanism for accomplishing ecosystem-wide synthesis must be created that seeks a good multidisciplinary balance of senior scientists with adequate time to devote to ecosystem-wide synthetic activities. Such a mechanism must also offer the independence necessary to most effectively synthesize the findings of research and integrate that knowledge into the restoration decision-making process. Regardless of who is responsible for synthesis, the science can not be integrated into the restoration if synthesis does not occur.

In order to address this critical gap in synthesis, priority must be given to fostering an interdisciplinary, systemwide understanding of the major physical, biological, and social processes that affect the sustainability of the greater Everglades ecosystem through review of existing scientific information. This effort will require sufficient staff to handle the complex coordination of data and also to integrate, synthesize, and communicate those results to restoration planners. Additionally, adequate support for synthesis requires a means of integrating massive amounts of data, including methods for accessing and archiving data. The importance of data management and the challenge that this represents must not be underestimated, and it requires immediate attention. One approach to synthesis could include an entity with the capability to accumulate past and future research and monitoring results from a broad array of sources while serving as a locus for enhancing understanding of the restoration impacts on the whole ecosystem. The CESI program could serve a significant role in such a coordinated initiative by providing data and by supporting the collaboration of investigators in restoration-wide synthesis efforts.

Currently, synthesis to inform South Florida restoration decision making and management is lacking, especially at the large spatial and long temporal scales, even though there were strong synthesis efforts during the Restudy. The 1996 Science Subgroup report (SSG, 1996) provided key guidance for development of the CERP and the CESI research agenda, but the unifying focus provided by that report has since dissipated. The current lack of focus on synthesis largely seems to stem from the accelerated restoration schedule, but synthesis has also been limited by inadequate institutional support. At the level of the greater ecosystem restoration, inadequate support for the Science Coordination Team (SCT) (formerly the Science Subgroup) and its organizational obligation to advise the South Florida Ecosystem Restoration Task Force has hindered synthesis. Recent efforts toward synthesis have been made by the REstoration, Coordination, and VERification (RECOVER). The RECOVER Adaptive Assessment Team is currently refining an ecosystem-wide conceptual model as part of the CERP Monitoring and Assessment Plan (MAP). Although the systemwide model has lagged behind models for the nine major physiographic regions of the Everglades and continued refinement is needed, the system-wide conceptual model represents a valuable contribution to science synthesis. RECOVER also includes a Regional Evaluation Team that has been tasked with evaluating the effects of the restoration plans on the entire system (see Appendix D). The intellectual and organizational contributions of the Regional Evaluation Team toward science synthesis are still un der development, but the focus of RECOVER may not adequately address all restoration synthesis needs, since RECOVER is specifically designed to support CERP decision making. Although some important steps toward synthesis are currently underway, restoration scientists in general have been forced to respond to situations of immediate importance or threat rather than build a long-term, ecosystem-wide perspective. This might have the unfortunate effect of fostering continued exploitation of the natural ecosystem—an outcome that could potentially be avoided if broader synthesis were to be embraced.

Few CESI-supported studies have taken synthetic approaches or have applied them at regional scales or across long time frames. A review of current CESI studies shows that the vast majority of the studies are disciplinary, autecological, or geographically limited, although there are several exceptions. The CESI program has funded several large ecological modeling studies designed to synthesize understanding of broad-scale ecological processes and population dynamics in the greater Everglades ecosystem, such as the Across Trophic Level System Simulation models. Progress on these models, however, has been slow, as the development of comprehensive, large-scale models supported by ecological fieldwork requires a large investment of resources and extensive data collection. Other CESI program efforts also have provided a foundation for synthesis through extensive funding of the Florida Bay Program Management Committee, the Greater Everglades Ecosystem Research conferences, and other topic-specific workshops. These multidisciplinary activities offer the opportunities for interaction and coordination necessary to stimulate synthesis. Within these conferences and workshops, there has been substantial effort and funding invested to summarize the results among investigators; however, there is little evidence of true synthesis.

Examination of the CESI program's role in supporting C-111 project decision making also reveals shortfalls in support for regional synthesis of research findings. National Park Service (NPS) and Fish and Wildlife Service scientists have provided some level of information synthesis in support of their own land-management needs. However, the institutional structure to assimilate ongoing research findings with previous studies or to coordinate CESI science with complementary research underway at other agencies is weak. No central information management system exists to support information synthesis of South Florida's vast ecosystem monitoring and research data. The result is that land managers must currently make special efforts to seek out relevant CESI research, identify other related studies and their results, and interpret the findings to draw regional conclusions. Clearly, only the land managers most closely connected to the CESI research could begin to tackle this task.

The CESI staff acknowledge this problem and hope to use part of the new CERP-designated funding to hire staff for NPS synthesis activities. However, synthesis is a restoration-wide need, requiring a more comprehensive solution. CESI funding has been proposed for several science information management and synthesis projects in 2003 (Appendix C). These efforts will be helpful in organizing the vast amounts of existing information, but without an effort to interpret both CESI- and non-CESI-funded research results into useful information for management, research may not be adequately considered in restoration deci sions. Until an improved restoration-wide mechanism for science synthesis is developed, the CESI program must bear the responsibility for synthesis of science within National Park Service lands and the wildlife refuges while working to ensure that this information is available for integration with other science programs across the greater Everglades ecosystem to support the restoration effort.

INTEGRATION OF NEW KNOWLEDGE INTO RESTORATION EFFORTS

Integration of the knowledge generated by synthesis into the ongoing processes of restoration planning, evaluation, construction, and operation will require effective communication and coordination among the restoration scientists, engineers, planners, and managers, who traditionally have operated in separate spheres. However, the complexity of the greater Everglades ecosystem restoration effort and the substantial uncertainty regarding ecosystem response to hydrological change necessitate feedback throughout the process. As new research findings are gained, that information will need to be communicated effectively to planners and managers to ensure the highest chances of achieving restoration objectives. Likewise, design, planning, or management questions that emerge during the restoration may require additional research studies. In response to new understanding about ecosystem processes, it may be necessary to alter project designs or change the operations to ensure attainment of the restoration goals. The continuous cycle of feedback from research, monitoring, data analysis, and synthesis is recognition that the application of scientific information to restoration activities must be an ongoing process in the effort to reach restoration objectives.

CESI Contributions to Integration

CESI projects have contributed useful scientific information to advise South Florida ecosystem restoration decision-making. For example, CESI research findings have contributed substantially to the recent planning of the C-111 project, providing important information on the linkages between hydrological and ecological attributes, described previously in this chapter. These contributions, however, were possible only because of the active involvement of DOI scientists in the project planning and design process (see Appendix G). The CESI program has been funded to provide the necessary science support for DOI's interests in the restoration, but the program is not responsible for bringing that science to the decision-making table. Nevertheless, science will be more likely to enter the planning and decision-making process if it is communicated broadly in an easily understandable and accessible manner. The CESI program has not been as successful in communicating the findings of CESI-funded research to the greater restoration community (see Chapter 2). The resulting lack of awareness of relevant CESI research may hinder the effectiveness of CESI science to support the restoration effort.

Barriers and Challenges to Integration

Although examples exist of successful integration of research findings into restoration decision-making, the integration of science into the greater Everglades ecosystem restoration faces notable barriers and challenges. These include the accelerated timetables of the restoration, lack of adequate institutions, and cultural differences among scientists, engineers, planners, and managers.

Accelerated Timetables of Restoration

Arguably, the greatest barrier to the integration of science into restoration is the compressed timetable for the CERP and other restoration projects. Discrepancies in the time lines between the project design decisions and the generation, analysis, and synthesis of research results create broad tensions. These include tensions between broadly based and highly focused research strategies, between multidisciplinary and disciplinary research, and between generalizable and region-specific issues. Quality long-term, large-scale ecosystem research will be pressed to meet the time lines set for the restoration effort, and certain compromises between project design/ construction and scientific knowledge will be required along the way.

To inform restoration project design and implementation, research findings *ideally* should be available well in advance of the project planning. As the accelerated CERP time line continues to move forward, many CESI projects will not be able to produce results in advance of restoration design. Where critical science questions remain that could dramatically affect project design, one option would be to delay the engineering design phase and accelerate the necessary science. After all, scientific research represents an investment toward improving the likelihood of attaining the restoration goals, and design changes after construction can be costly and difficult. For example, the options for restoring flow across Tamiami Trail range from constructing a series of bridges and culverts along the highway to constructing an 11-mile skyway in order to permit unobstructed flow. Extensive investments in science are needed now to advise this decision-making, as there will be little inherent flexibility in the final product to allow for significant modifications after construction has begun. The recently announced delay in the start of the Water Conservation Area 3 Decompartmentalization and Sheet Flow Enhancement Project combined with the current legal delays in ModWaters may provide a window of opportunity for building a solid foundation of science to support Tamiami Trail planning decisions, if research investments are made quickly and wisely.

A difficulty lies with deciding how much science is enough to proceed and when decision-making should be delayed. These decisions must be made on a case-by-case basis based on a careful evaluation of the risks of proceeding without specific scientific information versus the perceived benefits. Often this difficult risk-benefit evaluation is ignored so that project deadlines can be met. Inadequate early assessment of critical scientific issues ultimately tends to result in these concerns emerging later, causing lengthy project delays, interagency conflict, and much higher project costs. The C-111 project is one example where planning has been difficult and delayed, because the original project objectives and design plans were not well-coordinated with the ecosystem science concerns (Appendix G). In all restoration projects, consideration should be given to developing pilot projects where possible in order to test the full-scale project design before construction begins, like the pilot projects currently being planned for the Aquifer Storage and Recovery project. Pilot projects represent an important opportunity to incorporate a component of active adaptive management into the restoration that could reduce long-term costs and significantly improve the impact of restoration projects. However, the recognition that it will not be possible to resolve all scientific uncertainties before the restoration construction commences is critical; thus, project designs must be sufficiently resilient to accommodate new research findings and allow sufficient operational changes after construction.

Just as flexibility in engineering design is needed, scientists must also work to become more responsive to external time pressures for information and must be willing to adapt research studies to meet the identified information needs. New approaches to coordination among scientists, engineers, planners, and managers will be required to identify emerging and high-priority needs, to agree upon workable timetables, and to communicate the research findings after the results have been appropriately peer reviewed. CESI scientists will have to work closely with the CERP project delivery teams (PDT), the RECOVER teams, and the SCT to assure that CESI projects link directly to future restoration efforts and address the most pressing restoration science needs.

The compressed timetable for the CERP and other restoration projects and the resulting lag in availability of research results relative to the start of restoration project planning (see Chapter 2) reiterate the necessity of developing an effective approach to adaptive management in the early stages of South Florida ecosystem restoration. This current lag in timing is true not only for CESI science, but also for science being conducted by other agencies in South Florida. Significant changes in the restoration program have occurred since the CESI program was first proposed. At the time the CESI program was proposed, the Restudy was scheduled to be completed in 2001. However, at the same time Congress approved the CESI program, it also targeted the Restudy for completion in 1999. This guaranteed that the disjunction between implementation schedules and the time needed to address scientific uncertainties would be in conflict, exacerbating the existing cultural tensions between restoration planners, engineers, and scientists. While additional CESI funding to support research, synthesis, and management needs can alleviate some of the timing issues affecting the availability of CESI science for integration, some reconsideration of the CERP schedule to address critical science issues may also be a prudent decision that could reduce total long-term restoration costs.

Institutions to Support Integration

"Institutions are the norms, expectations, and rules through which societies figure out what to do and organize themselves to get things done" (NRC, 1999a).[3] The lack of an effective institutional framework to support science integration and synthesis was noted as a problem in the environmental restoration of the Colorado River in the Grand Canyon (NRC, 1996; see Box 5–3). A similar problem characterizes the greater Everglades ecosystem restoration, but coordination between scientists and restoration planners stands out as a particular concern. As important operational and design decisions become imminent, a formalized process for coordinating and involving scientific research in the restoration planning will be critical. The RECOVER team has been created to address these needs and "organize and apply scientific and technical information in ways that are most effective in supporting the objectives of the Comprehensive Everglades Restoration Plan" (SFWMD, 2002b). The RECOVER has been organized into six interagency, interdisciplinary task teams and an overall leadership team (see Appendix D). The three chairs of each of these task teams include one representative from the U.S. Army Corps of Engineers (the Corps), the South Florida Water Management District (SFWMD), and another agency with specific interest in the tasks assigned to the group. Other members of the teams are drawn from scientists actively involved with the CERP.

At this point, a well-developed, formal process does not exist to assure that researchers are linked to the CERP project delivery teams and RECOVER task teams. Currently, there are insufficient numbers of DOI scientists to participate in the large number of CERP and RECOVER teams (56 project delivery teams and 6 RECOVER teams) as these scientists are overcommitted with their existing workloads and additional CERP responsibilities. Funding recently allocated to DOI for CERP-related projects, including funding for the hiring of many additional employees, will help reduce this problem, although continued attention is needed to ensure adequate involvement of researchers in the restoration planning and implementation process. Given the decades it will take for greater Everglades ecosystem restoration, it is critical that the CERP-designated funds recently allocated to the base operations of the U.S. Geological Survey, NPS, and Fish and Wildlife Service be continued. This will ensure that there is a continuous source of funds to support the involvement of the researchers and scientists necessary for full and complete integration of the restoration objectives of DOI with those of other agencies and programs.

It is the panel's opinion that DOI may not have sufficient representation among the RECOVER team leadership commensurate with its interests and involvement in the restoration process. DOI, as the steward of federal lands, has primary responsibility for protecting and preserving a large portion of South Florida's natural ecosystem. The recent draft Programmatic Regulations also required DOI to report jointly to Congress every five years "concerning the benefits to the natural system" (USAGE, 2002b). As such, DOI must be integrally involved in the prioritization of research and monitoring activities, which are vital to assessing whether the restoration is meeting its ecological goals as well as ensuring compliance with federal mandates such as the Endangered Species Act.

[3] Note that the term "institution" does not necessarily imply an agency or group of individuals. It also refers to the "the rules of the game in society" (North, 1990, cited in McCay, 2002) or societal rules and governance systems as well as societal patterns of behavior, norms, and values (McCay, 2002).

DOI also contributes a considerable portion of the scientific research and data collection related to the restoration —through the USGS, FWS, and NPS—and has invested heavily in science to support the restoration through the CESI program. Defining the exact mechanism of this increased leadership is beyond the scope of this study, but it is incumbent on Congress to consider how best to formalize a significant leadership role for DOI on the RECOVER while maintaining the broadest possible participation of other restoration stakeholders.

Establishing a Collaborative Culture

Restoration of the greater Everglades ecosystem represents a bold collaboration of organizations with historically different cultures and goals, now gathered in a shared undertaking. The degree to which the myriad of federal, state, and private groups in South Florida need to coordinate, collaborate, and cooperate has never before been attempted. Such collaboration is inherently difficult. Cultural differences among agencies with unique missions can hinder the design and implementation of restoration at many levels. Lack of agreement on basic restoration goals has made many restoration projects more difficult and has led to failure in others. Consensus on broad restoration goals often masks disagreements over values, managerial style, and priorities—disagreements that can lead to conflicts over project design and operation. Even the definition of restoration success can be interpreted widely among various agencies according to their different missions and cultures.

Collaboration, however, requires the existence of values that are held in common by all of the parties involved. In South Florida, there is a strong consensus that ecosystem restoration is needed, desirable, and beneficial to each participating group. Such a consensus is the first, crucial step in collaboration. Much of the difficulty in working cooperatively can be found in the next step of effective collaboration: merging divergent visions sufficiently so that each group agrees upon the same definition of restoration.

Although it may appear simple, merging visions among different groups is difficult and can only be accomplished through an iterative process that takes time and patience. For example, among those involved in the South Florida restoration, some view restoration from the perspective of implementing projects that provide flood control and water supply in addition to restoration goals; others view the effort in the context of pursuing as full and as extensive a restoration scenario as possible while deemphasizing individual human services the restoration may provide. In this example, though the goal of restoration is the same, the visions behind that goal are still far apart. These visions can merge but will do so only after repeated discussions, negotiations, experiments, and debates. Sometimes, more formal facilitation may be required to find solutions where none seem apparent.

Cultural differences among various groups (e.g., planners, engineers and natural scientists) form additional barriers to effective collaboration. Managers of the South Florida ecosystem restoration must recognize the inherent chal lenges of interagency and interdisciplinary cooperation and work to build a collaborative culture in support of the restoration goals. The RECOVER program is a response to this need and promises to utilize team-based guidance of project design and operation. However, this team-based process will only succeed if all participants (and their agency leaders) agree upon the restoration goals and are committed to working together to accomplish these goals. Disagreements will occur along the way, and formalized processes are needed to resolve these conflicts, such as the conflict-resolution process currently underway related to the C-111 project (Appendix G). A formalized process for conflict resolution would encourage full participation in the RECOVER process, assuring team members that their input will be fairly heard. Wodraska and Von Haam (1996) noted that in the history of the South Florida ecosystem restoration, ambitious conflict resolution efforts have offered the greatest hope for finding solutions that are at least partly amenable to all parties. The alternative to consensus building is litigation, a process that is slow and divisive. With litigation there are always winners and losers, which promulgates an increasingly antagonistic environment through which the parties involved in restoration must negotiate.

ROLE OF THE CESI AND OTHER SCIENCE PROGRAMS IN THE GREATER EVERGLADES ECOSYSTEM RESTORATION

Congress intended for the CESI program to provide reliable scientific knowledge about the natural system and its potential response to management actions to inform the policy and planning decisions made during the feasibility phase of the Restudy (personal communication, Deborah Weatherly, House Appropriations Committee Staff, 2002). Over time, the CESI program developed a broader mission to meet DOI's restoration science needs, but at no time was the intent ever for CESI funds to meet all restoration science needs. Other agencies, such as the South Florida Water Management District, National Oceanic and Atmospheric Administration, and Environmental Protection Agency, contribute scientific research and monitoring to inform the restoration efforts. Other management structures, such as the RECOVER team, are tasked to identify priority science needs and advise restoration planning. The CESI program must work to coordinate with other agencies within this framework, while focusing on its own science priorities. Currently, no single entity adequately addresses the science management and coordination needs for the entire restoration. The RECOVER team is emerging as one of the potential leading science organizations in South Florida. Nevertheless, the RECOVER team's charge “to establish and maintain an effective link between science and the CERP” (SFWMD, 2002b) suggests a limited role, since the CERP currently represents only about half of the funds being spent on South Florida ecosystem restoration (see Figure 1–5). To facilitate comprehensive restoration science synthesis across the multiple restoration science programs currently in place, the broader restoration requires a single overarching entity to provide scientific vision and coordinate scientific efforts beyond the boundaries of RECOVER and the CESI program.

Circumstances have changed significantly compared to those in place when the CESI program was authorized in 1997. Many non-CERP restoration projects were well underway when the CESI program was created to support the feasibility phase of the Restudy, but the Water Resources Development Act of 2000 (WRDA 2000) affirmed the fast pace of the South Florida ecosystem restoration efforts. At the same time, WRDA 2000 altered the political and administrative environment within which the greater restoration process will proceed. The effect of these changes has been to redefine traditional agency roles to such an extent that a reexamination of DOI's role as a contributor to the greater restoration science is needed.

The current CESI program provides a strategic framework for addressing critical DOI science needs. The value of a science program focused specifically on DOI's needs and responsibilities within the South Florida ecosystem restoration is great, since the CESI program is the principal vehicle by which the NPS and FWS can evaluate how restoration activities might impact Everglades National Park and other federal lands and resources in South Florida. However, critical challenges faced by the CESI program (including ecosystem-wide science synthesis, integration, and coordination) are shared by all agencies contributing to South Florida restoration science. These issues cannot be solved by the CESI program, nor by any of the other existing science programs, alone.

South Florida restoration managers should consider the benefits of a central and independent restoration science entity that strives to inform the greater restoration effort (including the CERP, current non-CERP initiatives, and future restoration projects) with the best science available. Such a central science body could serve as a resource for scientific information, provide a mechanism for science coordination, and create a forum for visionary science synthesis. This entity should not have influence over, or responsibility for, restoration policy and decision making. Instead, it should serve as an impartial resource for scientific advice. The benefits of an external oversight and review board to provide unbiased advice and perspective to the body should not be overlooked. Furthermore, such a group would need substantial funding to leverage research to address priority science needs of the entire ecosystem, and to support science synthesis and the dissemination of scientific information to restoration decision makers. In light of the compressed restoration timetable and until some improved central mechanism for science synthesis and coordination is developed, the CESI program should strive to strengthen synthesis and dissemination, contributing as best as it can to these large and vital restoration needs.

Restoring the greater Everglades ecosystem requires integration of massive amounts of information for a highly complex system. At the same time, planners must work to design restoration solutions despite limited understanding of cause-and-effect relationships and little experience with the efficacy of the proposed management actions. The initial restoration plan will include setbacks, as some implemented solutions will not yield the intended outcomes. Therefore, the restoration program should be designed with alternative plans clearly in mind and should be accompanied by pilot projects designed for learning, so that the plan can be modified and improved over time. The time frame for restoration is extraordinarily long (30 or more years for the restoration projects and perhaps more than a century for ecosystem response), so advice from scientists with steadfast purpose, continuity, and independence from changing policy im purpose, continuity, and independence from changing policy imperatives will be critical elements. Synthesis and integration are essential to enable management agencies to adapt to emerging knowledge, correct mistakes, and minimize waste of public funds.

BOX 5–3 POTENTIAL LESSONS FOR THE CESI PROGRAM FROM THE GRAND CANYON

There are remarkable parallels between the restoration of the greater Everglades ecosystem and other complex environmental restoration projects. Similarities are particularly strong between restoration of the greater Everglades ecosystem and restoration efforts for the greater Yellowstone ecosystem, the CalFed project in north central California, the restoration of Chesapeake Bay, and the restoration of the Colorado River in the Grand Canyon (NRC, 1987, 1996, 2002d). The example of the Grand Canyon is described because of its implications for the conclusions of this report regarding the greater Everglades ecosystem.

The restoration of the Colorado River in Grand Canyon National Park was brought about by mechanisms for environmental change similar to those in the Everglades. Economic growth stimulated the construction both of Glen Canyon Dam on the Colorado River and of water-control structures in South Florida. In South Florida, these hydrological changes rippled through the complex ecosystem, ultimately resulting in landscape changes, adjustments in vegetation, and degradation of the support for a variety of plants and animals, including the endangerment of several species such as the Cape Sable seaside sparrow and the Florida panther. In the Colorado River in the Grand Canyon, the hydrological changes produced impacts on the river landscape, adjustments in riparian vegetation, and extensive changes in the biological system, contributing to the endangerment of several species of fish and of the southwestern willow flycatcher. In both cases, the deleterious effects were well advanced before the impacts were observed and before remedial actions were sought.

The two projects involve enormous complexity. In the case of Glen Canyon Dam, there is one very large facility to be managed, but the dam controls the entire flow of the Colorado River in the center of a watershed that is more than 200,000 square kilometers in extent, services more than 300 electrical utilities, controls water flows for distribution downstream to West Coast users, and directly affects 20 million people. The Everglades case is closer to a large metropolitan zone, and is a direct supplier of water to the human population of South Florida. The SFWMD uses a large number of structures to control an annual yield of water that is less than that controlled by Glen Canyon Dam. The two cases are therefore different from an engineering standpoint, but they are similar in their complexity and magnitude.

The institutional responses were also similar in the Grand Canyon and greater Everglades cases. Although the natural systems are components of national parks in both cases, the National Park Service (NPS) has only a partially controlling role in each case. For the Grand Canyon, the primary environmental research and restoration engine was Glen Canyon Environmental Studies (GCES) of the Bureau of Reclamation, later replaced by the Grand Canyon Monitoring and Research Center (GCMRC) of the USGS. Like the Comprehensive Everglades Restoration Plan, the GCES and GCMRC were multiagency efforts to learn how the ecosystem operated and how to improve it. In both cases, the objective was to establish enabling hydrological conditions, and therein lay the conflicts between water management and restoration objectives.

Vested interests in water supply and flood control must be balanced with restoration goals in the greater Everglades case, while vested interests in water supply and hydroelectric power generation were balanced with restoration in the Glen Canyon example. In both cases, restoration is not possible without some economic sacrifice by existing water users.

In both cases, the larger context of institutions surrounding the restoration effort was complex. In the case of the Grand Canyon, the NPS held primary responsibility for the natural resource and administered some research, the U.S. Geological Survey (USGS) managed the largest share of the research, and the Bureau of Reclamation had facilities management responsibility and a primary role in the research centers. Additional powerful stakeholders included Native American tribes (Navajo, Hopi, and several others), regional power users, agricultural interests, environmental organizations, and cities that were water consumers (including San Diego and Phoenix). In the case of the greater Everglades, a similar context exists. The primary natural resource is on federal land, and the NPS conducts some of the scientific research while the USGS conducts a larger share. The SFWMD and the U.S. Army Corps of Engineers control the facilities, with additional powerful stakeholders including Native American tribes (Miccosukee and Seminole), agricultural interests, and cities that are water consumers or that demand flood control (Miami and others in southeast Florida).

The legal and management aspects of the Grand Canyon and Everglades cases are similar. In the Grand Canyon, concerns about national park landscapes and endangered species led to lawsuits designed to change water operations, with the objective of reversing environmental degradation. In 1992, the Grand Canyon Protection Act required the development of interim flow regulations on the operation of Glen Canyon Dam, operating rules that would be in effect until long-term solutions could be established. In the Everglades case, the 2002 Interim Operating Plan seeks to accomplish the same end in a different locale (USAGE, 2002a). Also, in both cases, adaptive management emerged as a long-term goal. Adaptive management cut its experimental teeth in the Grand Canyon case beginning in the late 1980s, so that by the early twenty-first century, adaptive management was a broadly accepted concept for South Florida restoration.

Management of science in both cases resulted in agreements for review by the National Research Council (NRC). In the case of the Grand Canyon, the NRC began its review in 1986 in response to a court order that the decisions of the Bureau of Reclamation in operating Glen Canyon Dam be guided by "good science." A series of reports have emerged from this process (NRC 1987, 1991, 1996, 1999b). Concerned about the public's investment in science for the greater Everglades ecosystem restoration, Congress mandated the present NRC review study.

The fundamental issues facing the support and conduct of research in the restoration efforts are the same in both cases, so that solutions used in the Grand Canyon case may be instructive examples for the greater Everglades case. The following points identify the issues common to both cases and identify the solution put in practice for the Grand Canyon case along with its correlative potential solution for the greater Everglades case

Inconsistent funding, loose agency agreements, and little competition for research contracts occurred in both projects. For the Grand Canyon, consistent funding for research was eventually drawn from power revenues, supplementing existing appropriations for science. Strengthened interagency agreements and a widened research contracting process also improved research. The emerging memorandum of understanding between NPS and USGS in the greater Everglades case offers some promise in this area, but improved solicitation of research proposals from a broader pool of workers is needed. Inconsistent research funding remains a problem in the Everglades.

Inadequate synthesis and integration plagued both the GOES and the CESI program. Synthesis and integration of diverse research projects are critical to restoration success, but they have been the weakest link in the GCES and the CESI program. In response to NRC recommendations, the GCES mounted a significant effort to integrate research results by establishing an integration team of scientists (not managers) and by establishing a position of senior scientist in the project to facilitate the integration process. South Florida science would benefit from similar approaches.

Inadequate coordination of ongoing science and inadequate usefulness of science research were issues in both cases. Scientists in some instances pursued their own research interests using GCES or CESI funding, without clear connections to the restoration objectives. This practice was curbed in the GCES by the installation of a senior scientist who improved coordination and acted as a "traffic police officer" for the projects that were funded. A similar approach might benefit the CESI program.

Insufficient science integration into decision making occurred in the Grand Canyon and in the greater Everglades. Before the GCES, science did not adequately advise Glen Canyon Dam operations. Once initiated, however, GCES research results were generated, peer reviewed, and then considered in decisions about dam operation. Scientific information is currently guiding a series of experimental releases designed to better understand the impact of flows on the ecosystem and improve conditions for endangered fish species (CREDA, 2002). In the greater Everglades case, construction and operational management decisions have often come before completion of the scientific process or with little scientific guidance.

Scientists do not make the management decisions in either the Grand Canyon or the Everglades case. In both examples, scientists do research and provide scientifically based advice in a general way, while operations managers make the decisions on how to operate the facilities. This arrangement, which is logical and is a legal necessity, implies that there is effective communication between researchers and decision makers so that managers can frame questions that are important to them while scientists can communicate their results in useful forms.

Communication of science results is effective in the Grand Canyon case, less so in the greater Everglades case. The early GCES was specifically under the jurisdiction of the Bureau of Reclamation, the agency also responsible for the management and operation of the facility. The GCMRC is now under direction of the USGS and the Adaptive Management Program in general. While researchers from many agencies accomplished the research in the Grand Canyon, the results were funneled to managers through a single “portal.” This connection allowed for the development of a clear line of communication within a single agency, and it provided a single group of science interpreters who (in theory at least) coordinated results. In the greater Everglades example, several agencies conduct research and report results, but heretofore there has been no centralized process whereby connective lines to managers can be clearly established, and the integrative function is difficult to accomplish.

In summary, the Glen Canyon Dam and the Everglades restoration cases have a number of important and revealing parallels. Although there are regional differences, the CESI program can benefit from lessons learned from the two decades of experience in the Grand Canyon. The importance of stable, adequate funding, the establishment of a science center led by a senior scientist, and an emphasis on integration of results are the most important transferable examples.

6

Conclusions and Recommendations

The Critical Ecosystem Studies Initiative (CESI) has been important to a number of the components of the greater Everglades ecosystem restoration. Although significant changes in the management and administration of the program must be made, the fundamental purposes and objectives should remain intact to provide science support for the Department of the Interior's (DOI) resource stewardship interests and restoration responsibilities, including its concurrence, consultation, and reporting requirements for the Comprehensive Everglades Restoration Plan (CERP). As the CERP is implemented over the next several decades, DOI will need an effective, coordinated, and strategic research program, including ongoing research on the ecological and biological impacts of the restoration projects, model development, comprehensive monitoring and assessment, and data integration and synthesis. Continued and substantially increased funding will be needed for the CESI program to adequately support DOI's interests in the restoration with the best possible peer-reviewed scientific information. Despite its importance, rigorous and comprehensive research alone is insufficient to assure strong contributions of science to inform restoration decision making. Effective synthesis and dissemination of research findings and the formal leadership role DOI is given in the restoration process may determine the impact of CESI science on the South Florida ecosystem restoration. Based on the review of the CESI program, the conclusions and recommendations of this study are summarized as follows:

1) Conclusion: The CESI program has been an important resource to help address the immense science information needs of the Everglades restoration. Achieving the goals of the South Florida ecosystem restoration will require a commitment to science throughout the process. The CESI program has funded many quality studies that have made important contributions to Everglades restoration. The federal investment has produced useful science, a rich database, and the starting point for acquiring a basic understanding of the dynamics of the Everglades ecosystem. The CESI program's support for research on the linkage between ecological and hydrological processes provides a strong scientific foundation for future decision making so that scientists and planners can respond to new and emerging concerns. The CESI program's gap-filling approach represents an effective strategy to meet complex and changing science needs in the midst of a large number of state and federal agencies with ongoing science programs. This scientific knowledge base, enhanced by quality research and ecosystem monitoring and assessment funded through the CESI program, will enable DOI to address its own resource management concerns and meet its restoration responsibilities for the CERP.

Recommendation: The fundamental purposes and objectives of the CESI's research program should remain intact, and the commitment to ecosystem research in addition to model development and environmental assessments needs to be continued.

2) Conclusion: Improvements are needed in CESI management. Narrow distribution of requests for proposals, an insufficient peer review process, limited involvement of expert advisors, and minimal accountability in interagency agreements are problems that need to be addressed in order to improve the effectiveness of the CESI program.

Recommendations:

- CESI managers should broaden the distribution of requests for proposals.
- The CESI program should develop a consistent and objective process for peer reviews of CESI proposals and a fast-track review process for critical research findings.
- CESI program managers should work closely with formal program advisory committees to incorporate diverse expert advice into the establishment of research priorities and to promote closer linkages with other South Florida monitoring and research activities.
- The ESI program must coordinate closely with the RECOVER[1] teams and other restoration science programs so that limited science resources are used wisely.
- The CESI program should expend funds in a timely fashion and should avoid the slow expenditure of appropriated funds that occurred in the early years of the program.
- The CESI manager and the CESI coordinator should have more direct responsibility for program funds allocated through interagency agreements.
- National Park Service (NPS) should remove the South Florida Natural Resource Center from the organizational and supervisory structure of Everglades National Park to improve application of CESI science funding over all DOI lands in South Florida.
- Future CESI management plans should involve sufficient scientific expertise and agency representation in the prioritization and management of the research. DOI should consider appointing a senior scientist within the pro

[1] REstoration, Coordination, and VERification

posed management structure to ensure proper emphasis and prioritization of research investments.

3) Conclusion: Funding is now inadequate to meet the current scientific information needs. Addressing critical unmet science needs is essential to inform restoration decision making and reduce the long-term costs of restoration. Original estimates of the requirements for DOI science were far larger than the amount of support that has been provided, and as a result many of the identified science gaps remain unaddressed. The CESI program has provided important initial research contributions at the intersections of ecology and hydrology; however, this research is still in its infancy and requires a strong and continued fundng commitment to maximize the likelihood of meeting the restoration goals. Notable gaps that the CESI program has not adequately addressed include social science, contaminants, and water-quality modeling. Meanwhile, enhancements are needed to maximize the usefulness of existing ecological and hydrological models.

Recommendations:

- Funding should be available to provide continued CESI support for ecosystem research and model development to meet DOI's scientific information needs for the restoration in addition to meeting the monitoring and assessment requirements of the CERP.
- The CESI program should continue to emphasize research on ecological processes because the linkage between ecological and hydrological attributes represents a critical foundation necessary to advise South Florida restoration planning.
- The CESI program should identify priority research topics in under-funded areas, such as those identified here (e.g., social sciences, water-quality modeling, and contaminants), and formulate effective research programs based on rigorous peer-review procedures. CESI managers should then develop budget estimates and seek additional funding to support these programs.
- Congress should increase CESI research funding to adequately address DOI's current restoration science needs including continued support for essential areas such as ecological process studies and model refinement, new support for additional research in priority science gaps, and significant improvements in review, dissemination, coordination, and synthesis.
- Continued and increased program funding should be contingent upon (1) adhering to and substantially improving the standards for proposal distribution and review and (2) broadening the involvement of expert advisors in the priority-setting and proposal-review processes.

4) Conclusion: Improvements are needed to enhance synthesis and integration efforts both within the CESI program and more broadly in the South Florida restoration. In the compressed timeframe of the South Florida restoration, an effective adaptive management process will be critical in order to incorporate new scientific information and guide project design. Barriers hinder the integration of research findings in all levels of the restoration planning process, and critical gaps exist in translating the available ecosystem data into knowledge over varying temporal and spatial scales. The CESI program, however, is only one component of a larger entity that includes many other science initiatives. The combined effect of these issues demand collaborative solutions to foster integration of research findings into South Florida restoration activities.

Recommendations:

- CESI management should place increased emphasis on the synthesis and dissemination of research results.
- A restoration-wide mechanism for science synthesis and integration should be developed, with appropriate staffing and resources. One approach to synthesis could include an entity with the capability to accumulate past and future research and monitoring results from a broad array of sources while serving as a locus for enhancing understanding of the restoration impacts on the whole ecosystem. The CESI program could serve a major role in such a coordinated initiative by providing data and by supporting the collaboration of investigators in restoration-wide synthesis efforts.
- South Florida restoration decision makers should increase up-front investments in critical science research that are likely to minimize total restoration costs. In addition to providing additional science funding support, restoration managers should also reevaluate the current restoration schedule in cases when critical science questions remain that could impact project design decisions beyond their inherent operational flexibility.
- Adequate funds should be made available to hire the staff needed to communicate both CESI and non-CESI science findings to restoration planners, decision makers, and the RECOVER teams.
- To support sound prioritization of research and monitoring activities for the South Florida restoration and provide leadership commensurate to DOI's interests and responsibilities in the restoration process, Congress should consider how best to formalize a significant role for DOI on the RECOVER while maintaining the broadest possible participation of other restoration stakeholders.

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Acronyms

ATLSS	Across Trophic Level System Simulation
BEST	Board on Environmental Studies and Toxicology
BNP	Biscayne National Park
C-111	Canal 111
C&SF	Central and Southern Florida Project
CERP	Comprehensive Everglades Restoration Plan
CESI	Critical Ecosystem Studies Initiative
COE	U.S. Army Corps of Engineers
CREDA	Colorado River Energy Distributors Association
CROGEE	Committee on Restoration of the Greater Everglades Ecosystem
CSOP	combined structural and operational plan
CSSS	Cape Sable seaside sparrow
DOI	U.S. Department of the Interior
EAA	Everglades Agricultural Area
ENP	Everglades National Park
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FCE-LTER	Florida Coastal Everglades Long Term Ecological Research
FCES	Florida Center for Environmental Studies
FDEP	Florida Department of Environmental Protection
FGFC	Florida Game and Fish Commission
FIU	Florida International University
FWS	U.S. Fish and Wildlife Service
FGDC	Federal Geographic Data Committee
FY	fiscal year
GAO	U.S. General Accounting Office
GCES	Glen Canyon Environmental Studies
GCMRC	Grand Canyon Monitoring and Research Center

GEE	greater Everglades ecosystem
KRR	Kissimmee River restoration
LTER	long term ecological research
MAP	Monitoring and Assessment Plan
ModWaters	Modified Water Deliveries Project
MOU	memorandum of understanding
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NPCA	National Parks and Conservation Association
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSM	Natural Systems Model
OMB	Office of Management and Budget
PDT	project delivery team
RECOVER	restoration, coordination, verification
SCC	Science Coordination Council
SFERTF	South Florida Ecosystem Restoration Task Force
SFNRC	South Florida Natural Resources Center
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model
SICS	Southern Inland Coastal System
SSG	Science Sub-Group
SCT	science coordination team
STA	stormwater treatment area
TIME	tide and inflows in the mangroves of the Everglades
USAGE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WCA	water conservation area
WRDA	Water Resources Development Act
WSTB	Water Science and Technology Board

Appendixes

Appendix A

CESI-Funded Projects, 1997–2001

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Coastal/ Estuary	32	Benthic Macrophyte and Invertebrate Distribution in the Mangrove Ecotone	NPS	1997	1	$63,914	Restudy; Modwaters
Coastal/ Estuary	33	Relationship of Sedimentary Sulfur, Iron, and Phosphorus Cycling to Water Quality in Florida Bay	NPS	1997	1	76,871	Restudy; Modwaters
Coastal/ Estuary	34	Paleoecological History of Pigeon Key, Florida Bay	NPS	1998	1	36,383	Restudy; Modwaters
Coastal/ Estuary	35	Diet of Red Drum and Snook in Florida Bay	NPS	1997	1	35,265	Restudy; Modwaters
Coastal/ Estuary	36	Relationships Among Inshore Pink Shrimp in Tortugas and Sanibel Fisheries	USGS	1997	1	75,800	Restudy; Modwaters
Coastal/ Estuary	37	Ecosystem Comparison of Florida Bay Communities Network Analysis	USGS	1997	1	84,200	Restudy; Modwaters
Coastal/ Estuary	38	*Thalassia testudinum* Resilience to Sulfide Stress in Florida Bay: An Experimental and Field Approach	NPS	1998	2	37,080	Restudy; Modwaters
Coastal/ Estuary	39	FATHOM: A Mass Balance Model for Salinity in Florida Bay	USGS	1997	2	118,300	C-111; Florida Bay Feasibility
Coastal/ Estuary	40	Fish Recruitment, Growth and Habitat Use in Florida Bay	USGS	1997	3	648,285	Modwaters; RECOVER

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Coastal/ Estuary	41	Cooperative South Florida Estuarine Water Quality Monitoring Network	NPS	1997	5	226,118	Biscayne Bay Feasibility; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	42	Florida Bay Fish Habitat Assessment Program (FHAP)	USGS	1997	6	700,493	C-111; Rulemaking; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	43	Florida Bay Program Support	NPS	1998	5	449,110	All CERP-related projects
Coastal/ Estuary	44	Temporal and Spatial Variation in Seagrass Associated Fish and Invertebrates in Western Florida Bay	USGS	1997	5	464,758	Modwaters; RECOVER
Coastal/ Estuary	45	Florida Bay Program Support	USGS	1997	4	149,019	All CERP-related projects
Coastal/ Estuary	46	Issue of Journal "Estuaries" on Florida Bay	USGS	1998	1	23,500	Restudy; Modwaters
Coastal/ Estuary	47	Status of Ongoing Research in Biscayne Bay: A Workshop	USGS	1998	1	34,663	Restudy; Modwaters
Coastal/ Estuary	48	FATHOM: A Mass Balance Model for Salinity in Florida Bay	NPS	1998	2	297,764	C-111; Florida Bay Feasibility
Coastal/ Estuary	49	Mechanisms and Implications of *Thalassia* Die-Off on Florida Bay Mud Banks	NPS	1998	2	96,044	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	50	Flamingo Waste Water Study	NPS	1998	1	74,708	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	51	Distribution and Abundance of Jewfish in Everglades National Park as an Indicator of Ecosystem Restoration	NPS	1998	2	35,000	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	52	High Resolution Bathymetry of Florida Bay	USGS	1998	2	369,451	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	53	Seagrass Disease and Mortality in Florida Bay	NPS	1998	3	475,055	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	54	Estuarine Fish Community Structure - Patterns of Stability, Change and Succession in Relation to C-111	USGS	1998	3	231,766	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	55	Simulation Model of Seagrass Communities in Florida Bay	USGS	1999	3	486,937	Modwaters; RECOVER

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Coastal/ Estuary	56	Statistical Relationship Between Benthic Habitat and Water Quality	NPS	1999	1	28,942	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	57	Seagrass/Light Monitoring Network for Florida Bay	USGS	1999	1	191,007	Restudy; Modwaters; Fl Bay Feasibility
Coastal/ Estuary	58	PMC Support for the Interagency Florida Bay Program	NPS	1999	2	192,656	All CERP-related projects
Coastal/ Estuary	59	Analysis and Synthesis of Existing Information on Higher Trophic Levels in FL Bay	NPS	1999	2	107,404	C-111; Rulemaking; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	60	Baywatch - Nature Conservancy	NPS	1999	2	40,000	
Coastal/ Estuary	61	Development of a Landscape-scale Seagrass Model for Florida Bay	NPS	2000	3	105,164	Modwaters; RECOVER
Coastal/ Estuary	62	FATHOM/Salinity Predictions	NPS	1998	2	17,746	C-111; Florida Bay Feasibility
Coastal/ Estuary	119	Cooperative South Florida Estuarine Water Quality Monitoring Network	USGS	1997	1	62,000	All CERP-related projects
Coastal/ Estuary	153	Determining Nursery Areas for Red Drum, *Sciaenops ocellatus*, in Florida Bay	NPS	2001	1	21,000	Modwaters
Coastal/ Estuary	166	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida	USGS	1999	2	137,700	RECOVER; Modwaters; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	180	Water Flow Through Coastal Wetlands of Biscayne National Park	NPS	2001	1	90,000	
Coastal/ Estuary	181	Time Series Analysis and Statistical Modeling of Salinity, Canal Discharge, and Available Biological Data from Biscayne National Park	NPS	2001	1	45,000	Biscayne Bay Feasibility; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	182	Plankton Indicators of Ecological Change in South Biscayne Bay	NPS	2001	1	72,664	C-111; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	183	Mangrove-Fish Relationships in Biscayne Bay	NPS	2001	1	60,000	C-111; Bisc. Bay Coastal Wetlands
Coastal/ Estuary	184	Salinity Simulation Models for North Florida Bay	NPS	2001	1	35,833	Modwaters; RECOVER

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Coastal/ Estuary	185	N and P Limitation of Primary Productivity in Florida Bay	NPS	2001	3	225,000	Biscayne Bay Feasibility; Florida Bay Feasibility; Bisc. Bay Coastal Wetlands
Contaminants	156	Screening Level Risk Assessment to Determine Potential High Priority Contaminants and Natural Resources at Risk in Biscayne and Everglades Mangrove Modeling	NPS	2001	2	497,032	Reuse Pilot; CIWQP
Contaminants	174	Contaminants Program Support of Sample Collection Activities	NPS	2001	2	77,750	Reuse Pilot; CIWQP
Ecological Models	5	American Alligator Distribution, Thermoregulation, and Biotic Potential Relative to Hydroperiod	USGS	1997	3	80,840	Modwaters; C-111
Ecological Models	6	Effect of Everglades Prey on Crocodilian Growth, Development and Fertility	USGS	1997	3	77,590	Modwaters; C-111
Ecological Models	8	Parameterizing Individual Based Models of the Snail Kite	USGS	1997	1	33,510	Modwaters; C-111
Ecological Models	9	Development of Trophic Models for Amphibians and Reptiles	USGS	1997	2	131,395	Modwaters; C-111
Ecological Models	18	Individual-Based Spatially Explicit Model of Cape Sable Seaside Sparrow Population in the Florida Everglades	USGS	1998	2	71,606	Modwaters
Ecological Models	22	Effects of Hydrology on Wading Bird Parameters	USGS	1998	3	156,709	Modwaters
Ecological Models	23	Parameter Estimation and Population-Based Simulation Modeling of Alligator Populations	USGS	1998	3	254,383	Modwaters
Ecological Models	24	Development of an Internet-based GIS	USGS	1999	3	315,134	Modwaters
Ecological Models	25	Critical Model Development for Restudy: Additional Runs for DOI Restudy Needs and Alternatives Evaluation	USGS	1998	4	221,845	Restudy; Modwaters
Ecological Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes	USGS	1999	3	765,790	Modwaters; RECOVER

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Ecological Models	106	Development of Selected Components of an Across Trophic Level System Simulation (ATLSS) for the Wetland Ecosystems of South Florida	USGS	1997	5	1,724,433	RECOVER; All projects
Ecological Models	107	Computer Simulation Modeling of Intermediate Trophic Levels for ATLSS in the Everglades/Big Cypress Region	USGS	1997	5	279,784	Restudy; Modwaters
Ecological Models	108	Network Analysis of Trophic Dynamics of the Restoration of South Florida Wetlands	USGS	1997	4	304,212	Restudy; Modwaters
Ecological Models	109	Multimodeling Implementation Supporting ATLSS	USGS	1997	4	552,481	Restudy; Modwaters
Ecological Models	175	Estimation of Snail Kite Model Parameters	USGS	2001	2	95,525	Modwaters; RECOVER
Ecological Models	176	Vegetation Succession Modeling	USGS	2001	2	167,030	L-31N Pilot Project; C-111; Rulemaking; WCA 3A Decomp
Ecological Models	177	Influence of Hydrology and Habitat on apple snail Abundance	USGS	2001	3	135,000	Modwaters; RECOVER
Ecological Models	178	Everglades Crayfish Response to Everglades Restoration	USGS	2001	2	74,000	Modwaters; RECOVER
Ecological Processes / Ind. Species	63	Spatial and Temporal Changes in Tree Islands in Response to Altered Hydrologies in the Aurthur R. Marshall Loxahatchee National Wildlife Refuge	USGS	1997	1	55,600	Modwaters
Ecological Processes / Ind. Species	64	Modeling Spatial and Temporal Dynamics of White-tailed Deer in the Florida Everglades, Everglades National Park	NPS	1997	1	17,000	Restudy; Modwaters
Ecological Processes / Ind. Species	65	Statistical Analysis of American Alligator Nesting Data in Everglades National Park in Relation to Geographic, Hydrologic, and Temporal Variation	NPS	1997	1	37,000	Restudy; Modwaters
Ecological Processes / Ind. Species	66	Monitoring Program for the American Crocodile, Everglades National Park	NPS	1997	1	5,500	Modwaters; WCA 3A; C-111

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Ecological Processes / Ind. Species	67	Multiple Regression Analysis of Environmental Factors Influencing Temporal and Spatial Patterns of Foraging Wading Birds in the Florida Everglades	NPS	1997	1	21,374	C-111; WCA 3A Decomp; NW 3A
Ecological Processes / Ind. Species	68	Dry Down Tolerance of the Florida apple snail: Effects of Age and Season	USGS	1997	2	147,600	WCA 3A Decomp; Rulemaking
Ecological Processes / Ind. Species	69	Assessment of Marsh Vegetation in Response to Hydrological Restoration in Shark Slough	NPS	1997	5	110,000	C-111; WCA 3A Decomp; Rulemaking;
Ecological Processes / Ind. Species	70	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration	NPS	1997	5	354,725	C-111; WCA 3A Decomp; Rulemaking;
Ecological Processes / Ind. Species	72	Long-Term Study of Fire Regimes in Pinelands, and Associated Wetland Community Vegetation	USGS	1997	4	423,000	Restudy
Ecological Processes / Ind. Species	73	Population Structure and Spatial Distribution of Aquatic Consumers Communities in Everglades National Park	USGS	1997	6	456,059	Modwaters; RECOVER
Ecological Processes / Ind. Species	74	Experimental Studies of Population Growth and Predator Prey Interactions of Fishes in Everglades National Park	USGS	1997	4	230,981	Modwaters; RECOVER
Ecological Processes / Ind. Species	75	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration	USGS	1997	3	263,646	Restudy; Modwaters
Ecological Processes / Ind. Species	76	Vegetation Dynamics of Land-Margin Ecosystems: Mangroves in the Gulf Coast of South Florida	USGS	1997	4	425,025	Restudy; Modwaters
Ecological Processes / Ind. Species	77	Population Ecology of the Cape Sable Seaside Sparrow	NPS	1997	5	406,599	C-111; WCA 3A Decomp; Rulemaking
Ecological Processes / Ind. Species	78	American Alligator Distribution, Thermoregulation and Biotic Potential Relative to Hydroperiod in the Everglades	USGS	1997	3	452,915	Restudy; Modwaters; C-111
Ecological Processes / Ind. Species	79	The Effects of Everglades Food Items (Prey) on Crocodilian Growth, Development and Fertility	USGS	1998	2	149,115	Restudy; Modwaters

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Ecological Processes / Ind. Species	80	Monitoring Freshwater Fish and Invertebrate Communities	NPS	1998	4	506,094	Rulemaking; C-111; WCA 3A Decomp; Modwaters
Ecological Processes / Ind. Species	81	Fish and Invertebrate Communities of Short Hydroperiod Wetlands in the Rocky Glades	NPS	1997	5	686,536	Rulemaking; C-111; WCA 3A Decomp; Modwaters
Ecological Processes / Ind. Species	82	Fish Communities and Swamp Eel Populations of South Florida Canal and Stream Ecosystems as Indicators of Ecosystem Restoration	USGS	1998	3	140,300	
Ecological Processes / Ind. Species	83	Role of Aquatic Refuges in Wetland Complex of the Greater Everglades in Relation to Ecosystem Restoration	USGS	1999	3	371,862	Rulemaking; C-111; WCA 3A Decomp; Modwaters
Ecological Processes / Ind. Species	84	Compilation of Alligator Data Sets in South Florida	USGS	1999	1	209,611	WCA 3A Decomp; Modwaters
Ecological Processes / Ind. Species	85	Avian Restoration in Everglades National Park	NPS	1998	4	314,283	
Ecological Processes / Ind. Species	86	Inventory of Tree Islands in WCA 2 and 3	USFWS	1999	3	70,000	WCA 3A Decomp; Modwaters
Ecological Processes / Ind. Species	87	Assessment of Selected T&E Wildlife in the Pine Rocklands and Hammocks of Dade County	USFWS	1999	3	29,100	
Ecological Processes / Ind. Species	88	Dispersal, Habitat Selection, and Survivorship of Juvenile Florida Grasshopper Sparrows in Winter	USFWS	1999	3	229,028	
Ecological Processes / Ind. Species	89	Status, Distribution, and Habitat of the American Crocodile in Florida	USFWS	1999	3	194,213	Modwaters; WCA 3A Decomp; Rulemaking; RECOVER
Ecological Processes / Ind. Species	90	Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem	USFWS	1999	3	237,998	
Ecological Processes / Ind. Species	91	Wood Stork Nesting Surveys in Big Cypress National Preserve	USFWS	1999	3	5,000	
Ecological Processes / Ind. Species	92	Wildlife Monitoring Support	NPS	1999	3	48,000	Modwaters; WCA 3A Decomp; Rulemaking; RECOVER

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Ecological Processes / Ind. Speciesv	93	Composition and Structure of Groundcover Plant Communities in the Long Pine Key Region of Everglades National Park	NPS	1999	3	343,568	Restudy
Ecological Processes / Ind. Species	94	Cape Sable Seaside Sparrow Population Survey Support	NPS	2000	1	50,000	Modwaters; WCA 3A Decomp; Rulemaking; RECOVER
Ecological Processes / Ind. Species	95	Breeding Biology of Cape Sable Seaside Sparrow	NPS	2000	2	100,724	Modwaters; Rulemaking; RECOVER
Ecological Processes / Ind. Species	123	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida	USGS	1997	4	75,900	Restudy; Modwaters
Ecological Processes / Ind. Species	124	Potential of the Endangered American Crocodile to Provide a Quantifiable Measure of Restoration Success in the Greater Everglades/South Florida Ecosystem	NPS	1998	1	20,700	Restudy; Modwaters
Ecological Processes / Ind. Species	125	Wading Birds in South Florida	NPS	1997	1	67,911	Restudy; Modwaters
Ecological Processes / Ind. Species	126	Analyzing Historical Data to Set Restoration Targets for Wading Bird Nesting in South Florida	NPS	1999	1	100,083	Modwaters; RECOVER
Ecological Processes / Ind. Species	128	Eagle and Osprey Monitoring	NPS	1997	3	35,000	Modwaters; WCA 3A Decomp; Rulemaking; RECOVER
Ecological Processes / Ind. Species	129	Everglades National Park Tree Islands: Interactions of Hydrology, Vegetation, and Soils	NPS	2000	2	333,245	Rulemaking; C-111; WCA 3A Decomp; Modwaters
Ecological Processes / Ind. Species	133	Analysis of Relationships of Everglades Fish with Hydrology Using Long-term Databases from Everglades National Park	NPS	1998	2	10,837	Restudy; Modwaters
Ecological Processes / Ind. Species	146	Avian Restoration Studies	NPS	1997	4	74,779	Restudy; Modwaters
Ecological Processes / Ind. Species	187	Spatial Variability and Modeling of Soil Accretion in Shark River Slough	NPS	2001	3	398,986	Modwaters; C-111; RECOVER

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Ecological Processes / Ind. Species	188	Relative Distribution, Abundance, and Demographic Structure of the American Alligator in Relation to Habitat, Water Levels, and Salinities	NPS	2001	1	75,000	RECOVER; All projects
Ecological Processes / Ind. Species	189	Genetic Analysis of Cape Sable Seaside Sparrow Populations	NPS	2001	1	52,503	RECOVER; All projects
Hydrological Models	14	Southern Inland Coastal Systems Model Development	USGS	1997	3	678,722	Modwaters; RECOVER
Hydrological Models	15	Flow Velocity and Water Level Transects in SICS Model Area: Model Support	USGS	1997	2	553,905	Modwaters
Hydrological Models	16	Geology & Ecological History of the Buttonwood Ridge	USGS	1997	2	296,503	Modwaters
Hydrological Models	17	Geochemical Determinations of Groundwater Flow in Everglades National Park	NPS	1999	1	64,500	Modwaters
Hydrological Models	19	Land Characteristics from Remote Sensing	USGS	1998	2	156,600	Modwaters
Hydrological Models	20	Groundwater-Surface Water Hydrologic Exchange Fluxes and Relation to Mercury in the Northern Everglades	USGS	1998	3	287,945	Modwaters
Hydrological Models	21	Canal and Wetland Flow/Transport Interaction	USGS	1998	2	67,568	Modwaters
Hydrological Models	26	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida	USGS	1997	4	371,862	C-111; Rulemaking; Bisc. Bay Coastal Wetlands
Hydrological Models	27	Freshwater Discharges into Northeastern Florida Bay	USGS	1999	2	461,813	
Hydrological Models	28	Vegetative Resistance to Flow in the Everglades	USGS	1999	2	191,120	Restudy; Modwaters
Hydrological Models	30	Interrelation of Everglades Hydrology and Florida Bay Dynamics to Ecosystem Processes	USGS	1999	3	30,000	Modwaters; RECOVER
Hydrological Models	31	Effect of Wind on Surface Water Flows in the Everglades	USGS	1999	2	228,724	Restudy; Modwaters
Hydrological Models	162	Water Flows and Nutrient Fluxes to the SW Coast of Everglades National Park	USGS	2000	1	200,000	
Hydrological Models	179	Documenting the importance of water flow to Everglades landscape structure and sediment transport in Everglades National Park	NPS	2001	2	559,574	WCA 3A Decomp; NW 3A

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Landscape Patterns	101	Investigation of Mercury Contamination in the Everglades and South Florida Ecosystem	USEPA	1999	1	200,000	EAA Reservoir; C-111; CIWQP; NW 3A
Landscape Patterns	102	Program Support: Lab Rehab	NPS	1999	1	26,800	All restoration-related science
Landscape Patterns	103	Assessment of Marsh Vegetation in Response to Hydrologic Restoration in Shark Slough	NPS	1997	4	50,000	L-31N Pilot Project; C-111; Rulemaking; WCA 3A Decomp
Landscape Patterns	104	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration	NPS	1997	4	278,000	L-31N Pilot Project; C-111; Rulemaking; WCA 3A Decomp
Landscape Patterns	148	A Multispecies/Habitat Evaluation of Everglades Restoration Plans	USFWS	1999	2	228,638	RECOVER; All Projects
Landscape Patterns	190	Habitat-Based GIS Query Tools for Everglades Restoration	NPS	2001	2	225,000	RECOVER; All Projects
Landscape Patterns	191	Methodologies and Tools to Support Decision Making in Everglades Restoration	NPS	2001	2	189,411	RECOVER; All Projects
Landscape Patterns	192	Development of a Simulation Model Relating Hydrology, Topography, and Edaphic Factors to Plant Community Structure in Marshes	NPS	2001	2	295,797	L-31N Pilot Project; C-111; Rulemaking; WCA 3A Decomp
Landscape Patterns	195	Effects of Public Land Use on T&E Species Populations and Habitats in Big Cypress National Preserve	NPS	2001	2	270,000	SW Florida Feasibility
Landscape Patterns	196	Mapping and Characterization of Aquatic Refugia in Loxahatchee National Wildlife Refuge and Everglades National Park	NPS	2001	2	105,800	MWD; WCA 3A Decomp; Rulemaking; RECOVER
Phosphorous Threshold	171	Various Supplemental Water Quality Projects	NPS	1998	2	84,437	
Planning	110	Committee on Restoration of the Everglades Ecosystem	SFERTF	1999	5	350,000	All restoration-related science
Planning	114	Invasive Species Control Strategy Development	SFERTF	1998	5	560,950	All CERP-related projects
Planning	170	Various Coop Science and Planning Studies	SFERTF	1997	10	650,000	All CERP-related projects
Planning	172	Science Program Review: CROGEE	SFERTF	1999	10	809,100	All restoration-related science
Planning	173	Ecosystem Restoration Planning	SFERTF	1998		1,863,100	

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Science Information	149	Development of a South Florida Ecosystem Thesaurus	USGS	2001	1	59,950	
Science Information	150	Development of a National Biological Information Infrastructure (NBII) Node for the South Florida Ecosystem	USGS	2001	1	74,688	RECOVER; All Projects
Science Information	154	Hydrologic Data Collection & Analysis In and Near Everglades National Park	NPS	2001	1	66,352	RECOVER; All Projects
Science Information	158	CESI Project Information Sheets and WWW Planning	USGS	2001	1	80,000	
Science Information	165	NPS Biological and Physical Data Management and Dissemination	NPS	2001	1	480,400	RECOVER; All Projects
Science Information	186	Hydrologic Data Collection and Analysis in and near Everglades National Park	NPS	2001	1	75,504	RECOVER; All Projects
Social Science	193	Water Demands, Economic Growth, and Economic Impacts of the CERP Projects	NPS	2001	1	191,600	All relevant projects
Social Science	194	Handbook for Community Involvement	NPS	2001	1	79,854	All relevant projects
High Density Topography	3	Topographic Surveys of the Everglades	USGS	1997	5	3,934,083	L-31N Pilot Project; WCA 3A Decomp; NW 3A
High Density Topography	4	Leveling Data for Levee 4-Hwy 41	USGS	1999	1	138,000	Modwaters; C-111
High Density Topography	161	Critical Topographic Data for Completion of a Vertical Control Network	NPS		1	112,880	L-31N Pilot Project; WCA3A Decomp; NW 3A
Water Quality Technology	152	Stability and Bioavailability of Recently Accreted Phosphorus from Advanced Treatment Technologies	NPS	2001	1	65,187	EAA Reservoir; CIWQP; NW 3A
Water Quality Technology	160	Expansion of Field-scale PSTA Research	NPS	2001	1	195,525	EAA Reservoir; C-111; CIWQP; NW 3A
Water Quality Treatment	96	Incorporating Advanced Water Quality Treatment Technologies into STA Design	NPS	1997	2	23,600	EAA Reservoir; C-111; CIWQP; NW 3A
Water Quality Treatment	97	Evaluation of Environmentally Friendly Plant Production Systems for Use in or Adjacent to Everglades	NPS	1998	3	146,625	

Program	Proj. ID	Project Title	Agency	FY Start	CESI Project Length (years)	Total Project Cost to Date	Restoration Projects: High Priority Info Needs
Water Quality Treatment	98	Using Transect Sampling to Relate a Phosphorus Addition Flume Study to Long-term Water Quality Impacts	NPS	1999	2	100,000	Modwaters; Rulemaking; RECOVER
Water Quality Treatment	99	Evaluation of Periphyton Treatment Area for Removal of Phosphorous	NPS	2000	2	474,996	Modwaters; Rulemaking; RECOVER
Water Quality Treatment	100	Water Quality Evaluations	NPS	1997	3	25,004	EAA Reservoir; C-111; CIWQP; NW 3A
Water Quality Treatment	136	Analysis of Historical Water Quality Data	NPS	2001	1	115,000	CIWQP
Water Quality Treatment	137	Effect of Flow Rate on Phosphorus Uptake by Periphyton	NPS	2001	2	121,764	Modwaters; C-111
Water Quality Treatment	138	Nematoceran Community Relationships with Hydroperiod and Water Quality in Shark and Taylor Sloughs	NPS	2000	1	45,393	Modwaters
Water Quality Tribes	1	WQ Studies on Seminole Lands	SFERTF	1997	4	2,408,175	
Water Quality Tribes	2	WQ Studies on Miccosukee Lands	SFERTF	1999	3	641,125	
CERP	147, 163, 164	CERP Implementation Reallocation	NPS	2001	1	1,697,000	All relevant projects
ENP Admin		Administrative Overhead Cost, NPS (5%)	NPS			2,482,650	
ENP Admin		Additional Information Support Costs	NPS			15,060	

SOURCE: William Perry, NPS, written communication 2002.

Appendix B

CESI-funded Research Projects and Their Relationship to the Science Subgroup Science Objectives

The following table shows the CESI-funded projects (also detailed in Appendix A) according to relevant science objectives that were identified in the Science Subgroup (1996) report on Scientific Information Needs. This information was provided upon request by the CESI coordinator with assistance from several program managers. The specific scientific objectives are highlighted below and include the entire South Florida region (SF region) and region-wide objectives for models, exotics, mercury, threatened and endangered species (T&E), and contaminants. The table also includes objectives for the following subregions: the southern Everglades, the southern coastal areas (S.Coast), the lower east coast urban area (LEG), and the Water Conservation Areas (WCA). CESI projects that partially address the objectives are also listed.

Program	Project ID	Project Title
Science Objective 1: Determine the Relationships Between Hydrologic Regime and Ecosystem Structure and Function. (SF Region)		
Hydro Models	26	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Eco Proc/Ind Sp	129	Everglades National Park Tree Islands: Interactions of Hydrology, Vegetation, and Soils
Eco Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes
Landscape	192	Development of a Simulation Model Relating Hydrology, Topography, and Edaphic Factors to Plant Community Structure in Marshes
Eco Proc/Ind Sp	187	Spatial Variability and Modeling of Soil Accretion in Shark River Slough
Projects partially addressing this objective:		
Eco Models	5	American Alligator Distribution, Thermoregulation, and Biotic Potential Relative to Hydroperiod
Coastal	37	Ecosystem Comparison of Florida Bay Communities Network Analysis
Eco Proc/Ind Sp	73	Population Structure and Spatial Distribution of Aquatic Consumers Communities in Everglades National Park
Eco Proc/Ind Sp	74	Experimental Studies of Population Growth and Predator Prey Interactions of Fishes in Everglades National Park
Eco Proc/Ind Sp	83	Role of Aquatic Refuges in Wetland Complex of the Greater Everglades in Relation to Ecosystem Restoration

Program	Project ID	Project Title
Eco Models	106	Development of Selected Components of an Across Trophic Level System Simulation (ATLSS) for the Wetland Ecosystems of South Florida
Eco Proc/Ind Sp	169	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration
Eco Models	175	Estimation of Snail Kite Model Parameters
Eco Proc/Ind Sp	188	Relative Distribution, Abundance, and Demographic Structure of the American Alligator in Relation to Habitat, Water Levels, and Salinities
Eco Proc/Ind Sp	70	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Science Objective 2: Develop a Science Methodology to Restore Characteristic Salinity and Circulation Patterns to Estuaries. (SF Region)		
Hydro Models	14	Southern Inland Coastal Systems Model Development
Hydro Models	15	Flow Velocity and Water Level Transects in SICS Model Area: Model Support
Hydro Models	16	Geology & Ecological History of the Buttonwood Ridge
Hydro Models	17	Geochemical Determinations of Groundwater Flow in Everglades National Park
Hydro Models	19	Land Characteristics from Remote Sensing
Hydro Models	21	Canal and Wetland Flow/Transport Interaction
Hydro Models	26	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Hydro Models	27	Freshwater Discharges into Northeastern Florida Bay
Hydro Models	28	Vegetative Resistance to Flow in the Everglades
Hydro Models	30	Interrelation of Everglades Hydrology and FL Bay Dynamics to Ecosystem Processes
Hydro Models	31	Effect of Wind on Surface Water Flows in the Everglades
Coastal	32	Benthic Macrophyte and Invertebrate Distribution in the Mangrove Ecotone
Coastal	33	Relationship of Sedimentary Sulfur, Iron, and Phosphorus Cycling to Water Quality in Florida Bay
Coastal	34	Paleoecological History of Pigeon Key, Florida Bay
Coastal	39	FATHOM: A Mass Balance Model for Salinity in Florida Bay
Coastal	40	Fish Recruitment, Growth and Habitat Use in Florida Bay
Coastal	41	Cooperative South Florida Estuarine Water Quality Monitoring Network
Coastal	42	Florida Bay Fish Habitat Assessment Program (FHAP)
Coastal	44	Temporal and Spatial Variation in Seagrass Associated Fish and Invertebrates in Western Florida Bay
Coastal	48	FATHOM: Mass Balance Model for Salinity in Florida Bay
Coastal	52	High Resolution Bathymetry of Florida Bay
Coastal	55	Simulation Model of Seagrass Communities in Florida Bay
Coastal	59	Analysis and Synthesis of Existing Information on Higher Trophic Levels in Florida Bay
Coastal	62	FATHOM/Salinity Predictions
Eco Proc/Ind Sp	82	Fish Communities and Swamp Eel Populations of South Florida Canal and Stream Ecosystems as Indicators of Ecosystem Restoration
Coastal	181	Time Series Analysis and Statistical Modeling of Salinity, Canal Discharge, and Available Biological Data from Biscayne National Park
Coastal	182	Plankton Indicators of Ecological Change in South Biscayne Bay
Coastal	183	Mangrove/Fish Relationships in Biscayne Bay
Coastal	185	N and P Limitation of Primary Productivity in Florida Bay
Projects partially addressing this objective:		

Program	Project ID	Project Title
Coastal	38	*Thalassis testudinum* Resilience to Sulfide Stress in Florida Bay: An Experimental and Field Approach
Coastal	49	Mechanisms and Implications of Thalassia Die-Off on Florida Bay Mud Banks
Coastal	51	Distribution and Abundance of Jewfish in Everglades National Park as an Indicator of Ecosystem Restoration
Coastal	56	Statistical Relationship Between Benthic Habitat and Water Quality
Coastal	57	'Seagrass/Light Monitoring Network for Florida Bay
Coastal	61	Development of a Landscape-scale Seagrass Model for Florida Bay
Coastal	153	Determining Nursery Areas for Red Drum, *Scienceaenops ocellatus,* in Florida Bay
Coastal	53	Seagrass Disease and Mortality in Florida Bay
Coastal	62	FATHOM/Salinity Predictions
Science Objective 3: Develop Technically Sound Site-specific and Landscape-level Wetland Functionality Assessment Methods. (SF Region)		
Topography	3	Topographic Surveys of the Everglades
Eco Models	5	American Alligator Distribution, Thermoregulation, and Biotic Potential Relative to Hydroperiod
Eco Models	6	Effect of Everglades Prey on Crocodilian Growth, Development and Fertility
Eco Models	8	Parameterizing Individual Based Models of the Snail Kite
Eco Models	9	Development of Trophic Models for Amphibians and Reptiles
Eco Models	18	Individual-Based Spatially Explicit Model of Cape Sable Seaside Sparrow Population in the Florida Everglades
Eco Models	22	Effects of Hydrology on Wading Bird Parameters
Eco Models	23	Parameter Estimation and Population-based Simulation Modeling of Alligator Populations
Eco Proc/Ind Sp	64	Modeling Spatial and Temporal Dynamics of White-tailed Deer in the Florida Everglades, Everglades National Park
Eco Proc/Ind Sp	68	Dry Down Tolerance of the Florida Apple Snail: Effects of Age and Season
Eco Proc/Ind Sp	69	Assessment of Marsh Vegetation in Response to Hydrological Restoration in Shark Slough
Eco Proc/Ind Sp	70	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Eco Proc/Ind Sp	75	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration
Eco Proc/Ind Sp	78	American Alligator Distribution, Thermoregulation and Biotic Potential Relative to Hydroperiod in the Everglades
Eco Proc/Ind Sp	79	The Effects of Everglades Food Items (Prey) on Crocodilian Growth, Development and Fertility
Eco Proc/Ind Sp	93	Composition and Structure of Groundcover Plant Communities in the Long Pine Key Region of Everglades National Park
Eco Proc/Ind Sp	124	Potential of the Endangered American Crocodile to Provide a Quantifiable Measure of Restoration Success in the Greater Everglades/SF Ecosystem
Eco Proc/Ind Sp	125	Wading Birds in South Florida
Eco Proc/Ind Sp	126	Analyzing Historical Data to Set Restoration Targets for Wading Bird Nesting in South Florida
Eco Proc/Ind Sp	129	Everglades National Park Tree Islands: Interactions of Hydrology, Vegetation, and Soils
Eco Proc/Ind Sp	133	Analysis of Relationships of Everglades Fish with Hydrology Using Long-term Databases from Everglades National Park

Program	Project ID	Project Title
WQ Treat	138	Nematoceran Community Relationships with Hydroperiod and Water Quality in Shark and Taylor Sloughs
Eco Models	177	Influence of Hydrology and Habitat on Apple Snail Abundance
Eco Models	178	Everglades Crayfish Response to Everglades Restoration
Hydro Models	179	Documenting the Importance of Water Flow to Everglades Landscape Structure and Sediment Transport in Everglades National Park
Projects partially addressing this objective:		
Topography	4	Leveling Data for Levee 4-Hwy 41
Eco Proc/Ind Sp	80	Monitoring Freshwater Fish and Invertebrate Communities
Eco Proc/Ind Sp	81	Fish and Invertebrate Communities of Short Hydroperiod Wetlands in the Rocky Glades
Eco Models	108	Network Analysis of Trophic Dynamics of the Restoration of South Florida Wetlands
Topography	161	Critical Topo Data for Completion of a Vertical Control Network
Landscape	196	Mapping and Characterization of Aquatic Refugia in Loxahatchee National Wildlife Refuge and Everglades National Park
Science Objective 4: Describe and Quantify Linkages Between Nutrient and Contaminant Loads and Storages and Ecosystem Structure and Function. (SF Region)		
WQ Treat	96	Incorporating Advanced Water Quality Treatment Technologies into STA Design
WQ Treat	98	Using Transect Sampling to Relate a Phosphorus Addition Flume Study to Long-term Water Quality Impacts
WQ Treat	99	Evaluation of Periphyton Treatment Area for Removal of P
WQ Treat	100	Water Quality Evaluations
Landscape	101	Investigation of Mercury Contamination in the Everglades and SF Ecosystem
WQ Treat	136	Analysis of Historical Water Quality Data
WQ Treat	137	Effect of Flow Rate on Phosphorus Uptake by Periphyton
Water Qual Tech	152	Stability and Bioavailability of Recently Accreted Phosphorus from Advanced Treatment Technologies
Water Qual Tech	160	Expansion of Field-scale PSTA Research
Hydro Models	162	Water Flows and Nutrient Fluxes to the SW Coast of Everglades National Park
Phos Thresh	171	Various Supplemental Water Quality Projects
Projects partially addressing this objective:		
Coastal	41	Cooperative South Florida Estuarine Water Quality Monitoring Network
Science Objective 5: Develop Control Methods on Exotics at Entry, Distribution, and Landscape Levels. (SF Region)		
Exotics	114	Invasive Species Control Strategy Development
Science Objective 6: Develop Scientifically Based Methods to Restore Plant Communities and Wildlife Habitat. (SF Region)		
Eco Proc/Ind Sp	63	Spatial and Temporal Changes in Tree Islands in Response to Altered Hydrologies in the Arthur R. Marshall Loxahatchee National Wildlife Refuge
Coastal	71	Hydrologic Variation and Ecological Processes in the Mangrove Forests in South Florida
Eco Proc/Ind Sp	76	Vegetation Dynamics of Land-Margin Ecosystems: Mangroves in the Gulf Coast of South Florida
Eco Proc/Ind Sp	86	Inventory of Tree Islands in WCA 2 and 3
Landscape	103	Assessment of Marsh Vegetation in Response to Hydrologic Restoration in Shark ! Slough

Program	Project ID	Project Title
Landscape	104	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Eco Proc/Ind Sp	123	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Coastal	166	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Eco Models	176	Vegetation Succession Modeling
Landscape	192	Development of a Simulation Model Relating Hydrology, Topography, and Edaphic Factors to Plant Community Structure in Marshes
Projects partially addressing this objective:		
Topography	3	Topographic Surveys of the Everglades
Eco Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes
Eco Proc/Ind Sp	93	Composition and Structure of Groundcover Plant Communities in the Long Pine Key Region of Everglades National Park
Eco Proc/Ind Sp	129	Everglades National Park Tree Islands: Interactions of Hydrology, Vegetation, and Soils
Hydro Models	26	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Coastal	35	Diet of Red Drum and Snook in Florida Bay
Coastal	36	Relationships Among Inshore Pink Shrimp in Tortugas and Sanibel Fisheries
Coastal	39	FATHOM: a Mass Balance Model for Salinity in Florida Bay
Coastal	48	FATHOM: Mass Balance Model for Salinity in Florida Bay
Science Objective 7: Provide the Scientific Base for Reestablishing Sustainable Native Wildlife Populations. (SF Region)		
Eco Proc/Ind Sp	72	Long-Term Study of Fire Regimes in Pinelands, and Associated Wetland Community Vegetation
Eco Proc/Ind Sp	73	Population Structure and Spatial Distribution of Aquatic Consumers Communities in Everglades National Park
Eco Proc/Ind Sp	74	Experimental Studies of Population Growth and Predator Prey Interactions of Fishes in Everglades National Park
Eco Proc/Ind Sp	85	Avian Restoration in Everglades National Park !
Eco Proc/Ind Sp	94	Cape Sable Seaside Sparrow Population Survey Support
Eco Proc/Ind Sp	128	Eagle and Osprey Monitoring
Eco Proc/Ind Sp	146	Avian Restoration Studies
Eco Proc/Ind Sp	169	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration
Eco Models	175	Estimation of Snail Kite Model Parameters
Eco Proc/Ind Sp	188	Relative Distribution, Abundance, and Demographic Structure of the American Alligator in Relation to Habitat, Water Levels, and Salinities
Eco Proc/Ind Sp	189	Genetic Analysis of Cape Sable Seaside Sparrow Populations
Projects partially addressing this objective:		
Eco Models	5	American Alligator Distribution, Thermoregulation, and Biotic Potential Relative to Hydroperiod
Eco Models	6	Effect of Everglades Prey on Crocodilian Growth, Development and Fertility
Eco Models	8	Parameterizing Individual Based Models of the Snail Kite
Eco Models	9	Development of Trophic Models for Amphibians and Reptiles
Eco Models	18	Individual-Based Spatially Explicit Model of Cape Sable Seaside Sparrow Population in the Florida Everglades

Program	Project ID	Project Title
Eco Models	22	Effects of Hydrology on Wading Bird Parameters
Eco Models	23	Parameter Estimation and Population-based Simulation Modeling of Alligator Populations
Eco Proc/Ind Sp	64	Modeling Spatial and Temporal Dynamics of White-tailed Deer in the Florida Everglades, Everglades National Park
Eco Proc/Ind Sp	68	Dry Down Tolerance of the Florida Apple Snail: Effects of Age and Season
Eco Proc/Ind Sp	78	American Alligator Distribution, Thermoregulation and Biotic Potential Relative to Hydroperiod in the Everglades
Eco Proc/Ind Sp	79	The Effects of Everglades Food Items (Prey) on Crocodilian Growth, Development land Fertility
Eco Proc/Ind Sp	82	Fish Communities and Swamp Eel Populations of South Florida Canal and Stream Ecosystems as Indicators of Ecosystem Restoration
Eco Proc/Ind Sp	83	Role of Aquatic Refuges in Wetland Complex of the Greater Everglades in Relation to Ecosystem Restoration
Eco Proc/Ind Sp	89	Status, Distribution, and Habitat of the American Crocodile in Florida
Eco Models	107	Computer Simulation Modeling of Intermediate Trophic Levels for ATLSS in the Everglades/Big Cypress Region
Eco Models	177	Influence of Hydrology and Habitat on Apple Snail Abundance
Eco Models	178	Everglades Crayfish Response to Everglades Restoration
Hydro Models	179	Documenting the Importance of Water Flow to Everglades Landscape Structure and Sediment Transport in Everglades National Park
Coastal	38	*Thalassis testudinum* Resilience to Sulfide Stress in Florida Bay: An Experimental and Field Approach
Eco Proc/Ind Sp	67	Multiple Regression Analysis of Environmental Factors Influencing Temporal and Spatial Patterns of Foraging Wading Birds in the Florida Everglades
Eco Models	108	Network Analysis of Trophic Dynamics of the Restoration of S FL Wetlands
Science Objective 8: Provide Direct Scientific Support for Restoration Projects. (SF Region)		
Eco Models	25	Critical Model Development for Restudy: Additional Runs for DOI Restudy Needs and Alternatives Evaluation
Eco Proc/Ind Sp	85	Avian Restoration in Everglades National Park
Eco Proc/Ind Sp	90	Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem
Eco Proc/Ind Sp	88	Dispersal, Habitat Selection, and Survivorship of Juvenile Florida Grasshopper Sparrows in Winter
Science Objective 9: Develop Scientific Foundation for Sustainable Agriculture. (SF Region)		
WQ Treat	97	Evaluation of Environmentally Friendly Plant Production Systems for Use in or Adjacent to Everglades
Projects partially addressing this objective:		
Soc Science	193	Water Demands, Economic Growth, and Economic Impacts of the CERP Projects
WQ Tribes	1	WQ Studies on Seminole Lands
WQ Tribes	2	WQ Studies on Miccosukee Lands
Science Objective 10: Determine Linkage Between Water Management and Rainfall with Meteorological Model Linked to Hydrologic Model (SFARPS). (Regional: Models)		
Science Objective 11: Determine Targets and Strategy to Re-create Natural Quantity, Timing, and Distribution of Water Using Natural and Water Management Hydrologic Models (NSM, SFWMM). (Regional: Models)		

Program	Project ID	Project Title
Science Objective 12: Quantify Water Management Effects on Salinities, Water Depths, and Water Flow in Mangrove Zone Using Hydrologic Salinity Models. (Regional: Models)		
Hydro Models	26	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Hydro Models	30	Interrelation of Everglades Hydrology and Florida Bay Dynamics to Ecosystem Processes
Eco Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes
Projects partially addressing this objective:		
Coastal	54	Estuarine Fish Community Structure—Patterns of Stability, Change and Succession in Relation to C-111
Coastal	56	Statistical Relationship Between Benthic Habitat and Water Quality
Coastal	57	Seagrass/Light Monitoring Network for Florida Bay
Coastal	153	Determining Nursery Areas for Red Drum, *Scienceaenops ocellatus,* in Florida Bay
Coastal	180	Water Flow Through Coastal Wetlands of Biscayne National Park
Science Objective 13: Evaluate Ecosystem Impacts of Alternative Water Management Strategies Using Linked Trophic-level Models. (Regional: Models)		
Eco Models	24	Development of an Internet-based GIS
Coastal	37	Ecosystem Comparison of Florida Bay Communities Network Analysis
Eco Models	106	Development of Selected Components of an Across Trophic Level System Simulation (ATLSS) for the Wetland Ecosystems of South Florida
Eco Models	107	Computer Simulation Modeling of Intermediate Trophic Levels for ATLSS in the Everglades/Big Cypress Region
Eco Models	109	Multimodeling Implementation Supporting ATLSS
Projects partially addressing this objective:		
Eco Models	25	Critical Model Development for Restudy: Additional Runs for DOI Restudy Needs and Alternatives Evaluation
Eco Models	108	Network Analysis of Trophic Dynamics of the Restoration of South Florida Wetlands
Science Objective 14: Determine Effects of Alternative Water Management Strategies on Landscape Structure and Function Using Landscape Models. (Regional: Models)		
Eco Models	109	Multimodeling Implementation Supporting ATLSS
Eco Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes
Eco Models	25	Critical Model Development for Restudy: Additional Runs for DOI Restudy Needs and Alternatives Evaluation
Eco Models	106	Development of Selected Components of an Across Trophic Level System Simulation (ATLSS) for the Wetland Ecosystems of South Florida
Projects partially addressing this objective:		
Eco Proc/Ind Sp	63	Spatial and Temporal Changes in Tree Islands in Response to Altered Hydrologies in the Arthur R.Marshall Loxahatchee National Wildlife Refuge
Eco Proc/Ind Sp	69	Assessment of Marsh Vegetation in Response to Hydrological Restoration in Shark Slough
Eco Proc/Ind Sp	76	Vegetation Dynamics of Land-Margin Ecosystems: Mangroves in the Gulf Coast of South Florida
Landscape	103	Assessment of Marsh Vegetation in Response to Hydrologic Restoration in Shark Slough
Landscape	104	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Coastal	166	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida

Program	Project ID	Project Title
Landscape	192	Development of a Simulation Model Relating Hydrology, Topography, and Edaphic Factors to Plant Community Structure in Marshes
Eco Proc/Ind Sp	123	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Eco Proc/Ind Sp	187	Spatial Variability and Modeling of Soil Accretion in Shark River Slough
Eco Models	108	Network Analysis of Trophic Dynamics of the Restoration of South Florida Wetlands
Science Objective 15: Determine Abundance and Diversity of Native Flora and Fauna on the Basis of Available Habitat Using GAP. (Regional: Models)		
Eco Proc/Ind Sp	127	A Multispecies/Habitat Evaluation of Everglades Restoration Plans
Science Objective 16: Determine Acreage of Favorable Estuarine Habitat in Terms of Salinity and Bottom Features Using a Seascape Model Linked to Hydrologic Models. (Regional: Models)		
Projects partially addressing this objective:		
Coastal	41	Cooperative South Florida Estuarine Water Quality Monitoring Network
Coastal	182	Plankton Indicators of Ecological Change in South Biscayne Bay
Coastal	184	Salinity Simulation Models for North Florida Bay
Eco Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes
Hydro Models	14	Southern Inland Coastal Systems Model Development
Hydro Models	30	Interrelation of Everglades Hydrology and Florida Bay Dynamics to Ecosystem Processes
Science Objective 17: Determine How Water Management Affects Salinity and Circulation in Florida Bay Using Hydrodynamic Models. (Regional: Models)		
Projects partially addressing this objective:		
Coastal	39	FATHOM: a Mass Balance Model for Salinity in Florida Bay
Coastal	48	FATHOM: Mass Balance Model for Salinity in Florida Bay
Coastal	52	High Resolution Bathymetry of Florida Bay
Coastal	62	FATHOM/Salinity Predictions
Science Objective 18: Develop Effective Restoration Methods That Discourage Re-invasion By Exotics. (Regional: Exotics)		
Exotics	114	Invasive Species Control Strategy Development
Science Objective 19: Determine and Enhance Natural Controls. (Regional: Exotics)		
Projects partially addressing this objective:		
Eco Proc/Ind Sp	70	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Science Objective 20: Develop Biological Controls. (Regional: Exotics)		
Science Objective 21: Develop Multispecies Monitoring Plan. (Regional: Exitics)		
Science Objective 22: Develop Multispecies Management Plan. (Regional: Exotics)		
Science Objective 23: Develop Screening and Risk Assessment Methods. (Regional: Exotics)		
Science Objective 24: Develop Sterile Cultivars of Popular Exotics that Regenerate Readily in South Florida. (Regional: Exotics)		

Program	Project ID	Project Title
Science Objective 25: Inventory and Characterize Potential Sources. (Regional: Mercury)		
Science and Objective 26: Determine contributions of External and Internal Sources to Present Hg Contamination Problems. (Regional: Mercury)		
Science Objective 27: Understand Role of Water and Nutrients In Hg Transport and Mobilization. (Regional: Mercury)		
Science Objective 28: Understand Impacts Mercury on Health of Everglades Biota. (Regional: Mercury)		
Science Objective 29: Build Risk Characterization and Forecasting Capability. (Regional: Mercury)		
Science Objective 30: Monitor and Evaluate Mercury Risks in Response to Ecosystem Management Source Control. (Regional: Mercury)		
Science Objective 31: Determine the Relationships Between Hydrologic Regime and Ecosystem Structure and Function. (Regional: T&E)		
Eco Proc/Ind Sp	67	Multiple Regression Analysis of Environmental Factors Influencing Temporal and Spatial Patterns of Foraging Wading Birds in the Florida Everglades
Eco Proc/Ind Sp	89	Status, Distribution, and Habitat of the American Crocodile in Florida
Projects partially addressing this objective:		
Eco Proc/Ind Sp	78	American Alligator Distribution, Thermoregulation and Biotic Potential Relative to Hydroperiod in the Everglades
Eco Proc/Ind Sp	83	Role of Aquatic Refuges in Wetland Complex of the Greater Everglades in Relation to Ecosystem Restoration
Eco Proc/Ind Sp	84	Compilation of Alligator Data Sets in South Florida
Eco Proc/Ind Sp	86	Inventory of Tree Islands in WCA 2 and 3
Landscape	196	Mapping and Characterization of Aquatic Refugia in Loxahatchee National Wildlife Refuge and Everglades National Park
Eco Proc/Ind Sp	77	Population Ecology of the Cape Sable Seaside Sparrow
Science Objective 32: Conduct Ecological Studies for Listed Species to Answer Critical Management Questions. (Regional: T&E)		
Coastal	51	Distribution and Abundance of Jewfish in Everglades National Park as an Indicator of Ecosystem Restoration
Eco Proc/Ind Sp	65	Statistical Analysis of American Alligator Nesting Data in Everglades National Park in Relation to Geographic, Hydrologic, and Temporal Variation
Eco Proc/Ind Sp	66	Monitoring Program for the American Crocodile, Everglades National Park
Eco Proc/Ind Sp	77	Population Ecology of the Cape Sable Seaside Sparrow
Eco Proc/Ind Sp	84	Compilation of Alligator Data Sets in South Florida
Eco Proc/Ind Sp	87	Assessment of Selected T&E Wildlife in the Pine Rocklands and Hammocks of Dade County
Eco Proc/Ind Sp	88	Dispersal, Habitat Selection, and Survivorship of Juvenile Florida Grasshopper Sparrows in Winter
Eco Proc/Ind Sp	90	Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem
Eco Proc/Ind Sp	91	Wood Stork Nesting Surveys in Big Cypress National Preserve

Program	Project ID	Project Title
Eco Proc/Ind Sp	92	Wildlife Monitoring Support
Eco Proc/Ind Sp	95	Breeding Biology of Cape Sable Seaside Sparrow
Coastal	184	Salinity Simulation Models for North Florida Bay
Projects partially addressing its objective:		
Eco Proc/Ind Sp	124	Potential of the Endangered American Crocodile to Provide a Quantifiable Measure of Restoration Success in the Greater Everglades/SF Ecosystem
Eco Proc/Ind Sp	127	A Multispecies/Habitat Evaluation of Everglades Restoration Plans
Eco Proc/Ind Sp	128	Eagle and Osprey Monitoring
Eco Proc/Ind Sp	79	The Effects of Everglades Food Items (Prey) on Crocodilian Growth, Development and Fertility
Eco Proc/Ind Sp	94	Cape Sable Seaside Sparrow Population Survey Support
Eco Proc/Ind Sp	188	Relative Distribution, Abundance, and Demographic Structure of the American Alligator in Relation to Habitat, Water Levels, and Salinities
Eco Proc/Ind Sp	189	Genetic Analysis of Cape Sable Seaside Sparrow Populations
Eco Proc/Ind Sp	84	Compilation of Alligator Data Sets in South Florida
Eco Proc/Ind Sp	87	Assessment of Selected T&E Wildlife in the Pine Rocklands and Hammocks of Dade County
Eco Proc/Ind Sp	88	Dispersal, Habitat Selection, and Survivorship of Juvenile Florida Grasshopper Sparrows in Winter
Eco Proc/Ind Sp	90	Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem
Eco Proc/Ind Sp	91	Wood Stork Nesting Surveys in Big Cypress National Preserve
Eco Proc/Ind Sp	92	Wildlife Monitoring Support
Eco Proc/Ind Sp	95	Breeding Biology of Cape Sable Seaside Sparrow
Science Objective 35: Develop Information for the Multispecies Recovery Plan to Maximize Benefits to a Variety of Listed Species. (Regional: T&E)		
Eco Proc/Ind Sp	87	Assessment of Selected T&E Wildlife in the Pine Rocklands and Hammocks of Dade County
Eco Proc/Ind Sp	88	Dispersal, Habitat Selection, and Survivorship of Juvenile Florida Grasshopper Sparrows in Winter
Eco Proc/Ind Sp	90	Restoration of *Jacquemontia reclinata* to the South Florida Ecosystem
Eco Proc/Ind Sp	87	Assessment of Selected T&E Wildlife in the Pine Rocklands and Hammocks of Dade County
Eco Proc/Ind Sp	188	Relative Distribution, Abundance, and Demographic Structure of the American Alligator in Relation to Habitat, Water Levels, and Salinities
Science Objective 36: Determine Regional Usage Patterns Regarding Pesticides and Other Contaminants. (Regional: Contaminants)		
Contam	156	Screening Level Risk Assessment to Determine Potential High Priority Contaminants and Natural Resources at Risk In Biscayne and Everglades
Science Objective 37: Review and Synthesize Results of Previous and Ongoing Contaminants Monitoring Studies. (Regional: Contaminants)		
Projects partially addressing this objective:		
Contam	156	Screening Level Risk Assessment to Determine Potential High Priority Contaminants and Natural Resources at Risk In Biscayne and Everglades
Science Objective 38: Assess Chronic Toxicity Risks to Aquatic Organisms Under Existing Ambient and Episodic Concentrations. (Regional: Contaminants)		

Program	Project ID	Project Title
Science Objective 39: Assess Lethal and Sub-lethal Effects of Contaminants Found in the South Florida Ecosystem. (Regional: Contaminants)		
Science Objective 40: Assess Surface Microlayers of Coastal Waters for Importance in Community Exposure to Contaminants. (Regional: Contaminants)		
Science Objective 41: Conduct Detailed Monitoring of Contaminants in Water Sediments, Atmosphere, and Biota. (Regional: Contaminants)		
Projects partially addressing this objective:		
Hydro Models	20	Groundwater-Surface Water Hydrologic Exchange Fluxes and Relation to Mercury in the Northern Everglades
Science Objective 42: Determine Loads and Concentrations Associated with Storm Events in Comparison to Everyday Conditions. (Regional: Contaminants)		
Science Objective 43: Construct Linked Land Use/Runoff Model to Determine Potential Transport of Organic Contaminants. (Regional: Contaminants)		
Science Objective 44: Quantify and Model Flows and Water Levels Within and Between Drainage Basins. (Subregion: S Everglades)		
Science Objective 45: Determine Role of Rainfall, Climate, Soils, Vegetation, and Water Management. (Subregion: S Everglades)		
Eco Proc/Ind Sp	187	Spatial Variability and Modeling of Soil Accretion in Shark River Slough
Science Objective 46: Quantify and Model Factors Controlling Ambient Water Quality. (Subregion: S Everglades)		
Projects partially addressing this objective:		
Hydro Models	162	Water Flows and Nutrient Fluxes to the SW Coast of Everglades National Park
Water Qual Tech	152	Stability and Bioavailability of Recently Accreted Phosphorus from Advanced Treatment Technologies
Water Qual Tech	160	Expansion of Field-scale PSTA Research
WQ Treat	96	Incorporating Advanced Water Quality Treatment Technologies into STA Design
WQ Treat	99	Evaluation of Periphyton Treatment Area for Removal of P
WQ Treat	100	Water Quality Evaluations
WQ Treat	98	Using Transect Sampling to Relate a Phosphorus Addition Flume Study to Long-term Water Quality Impacts
WQ Treat	137	Effect of Flow Rate on Phosphorus Uptake by Periphyton
Science Objective 47: Define Nutrient Thresholds for Major Wetland Communities. (Subregion: S Everglades)		
Projects partially addressing this objective:		
Coastal	41	Cooperative South Florida Estuarine Water Quality Monitoring Network
Coastal	182	Plankton Indicators of Ecological Change in South Biscayne Bay
Landscape	101	Investigation of Mercury Contamination in the Everglades and South Florida Ecosystem
Phos Thresh	171	Various Supplemental Water Quality Projects
WQ Treat	98	Using Transect Sampling to Relate a Phosphorus Addition Flume Study to Long-term Water Quality Impacts

Program	Project ID	Project Title
Science Objective 48: Define Contaminant Thresholds for Major Wetland Communities. (Subregion: S Everglades)		
Science Objective 49: Determine Historic and Current Patterns in Soils and Vegetation Distribution and Productivity (Including Periphyton). (Subregion: S Everglades)		
Projects partially addressing this objective:		
Eco Proc/Ind Sp	69	Assessment of Marsh Vegetation in Response to Hydrological Restoration in Shark Slough I
Eco Proc/Ind Sp	70	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Eco Proc/Ind Sp	129	Everglades National Park Tree Islands: Interactions of Hydrology, Vegetation, and Soils
Eco Proc/Ind Sp	187	Spatial Variability and Modeling of Soil Accretion in Shark River Slough
Science Objective 50: Determine Processes Controlling Soil Formation and Vegetation Community Development. (Subregion: S Everglades)		
Projects partially addressing this objective:		
Eco Models	176	Vegetation Succession Modeling
Eco Proc/Ind Sp	69	Assessment of Marsh Vegetation in Response to Hydrological Restoration in Shark Slough
Eco Proc/Ind Sp	70	Temporal and Spatial Patterns in Taylor Slough Vegetation Due to Hydrologic Restoration
Eco Proc/Ind Sp	187	Spatial Variability and Modeling of Soil Accretion in Shark River Slough
Landscape	195	Effects of Public Land Use on T&E Species Populations and Habitats in Big Cypress National Preserve
Science Objective 51: Quantify and Model Dynamics of Productivity and Composition of Fish and Invertebrate Communities Across Landscapes and Within Wetland Types. (Subregion: S Everglades)		
Eco Proc/Ind Sp	73	Population Structure and Spatial Distribution of Aquatic Consumers Communities in Everglades National Park
Eco Proc/Ind Sp	80	Monitoring Freshwater Fish and Invertebrate Communities
Eco Proc/Ind Sp	81	Fish and Invertebrate Communities of Short Hydroperiod Wetlands in the Rocky Glades
Projects partially addressing this objective:		
Eco Proc/Ind Sp	75	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration
Eco Proc/Ind Sp	133	Analysis of Relationships of Everglades Fish with Hydrology Using Long-term Databases from Everglades National Park
Eco Proc/Ind Sp	73	Population Structure and Spatial Distribution of Aquatic Consumers Communities in Everglades National Park
Eco Proc/Ind Sp	74	Experimental Studies of Population Growth and Predator Prey Interactions of Fishes in Everglades National Park
Eco Proc/Ind Sp	169	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration
Eco Models	175	Estimation of Snail Kite Model Parameters
WQ Treat	138	Nematoceran Community Relationships with Hydroperiod and Water Quality in Shark and Taylor Sloughs
Eco Proc/Ind Sp	82	Fish Communities and Swamp Eel Populations of South Florida Canal and Stream Ecosystems as Indicators of Ecosystem Restoration
Science Objective 52: Determine Factors Controlling Foraging Behavior, Reproductive Success, Survival, and Population Size of Key Species. (Subregion: S Everglades)		

Program	Project ID	Project Title
Coastal	153	Determining Nursery Areas for Red Drum, *Scienceaenops ocellatus,* in Florida Bay
Projects partially addressing this objective:		
Eco Proc/Ind Sp	125	Wading Birds in South Florida
Coastal	59	Analysis and Synthesis of Existing Information on Higher Trophic Levels in Florida Bay
Eco Proc/Ind Sp	66	Monitoring Program for the American Crocodile, Everglades National Park
Eco Proc/Ind Sp	80	Monitoring Freshwater Fish and Invertebrate Communities
Eco Proc/Ind Sp	81	Fish and Invertebrate Communities of Short Hydroperiod Wetlands in the Rocky Glades
Eco Proc/Ind Sp	89	Status, Distribution, and Habitat of the American Crocodile in Florida
Coastal	183	Mangrove/Fish relationships in Biscayne Bay
Eco Proc/Ind Sp	83	Role of Aquatic Refuges in Wetland Complex of the Greater Everglades in Relation to Ecosystem Restoration
Landscape	196	Mapping and Characterization of Aquatic Refugia in Loxahatchee National Wildlife Refuge and Everglades National Park
Coastal	180	Water Flow Through Coastal Wetlands of Biscayne National Park
Science Objective 53: Model Relationships Between Changing Landscape Patterns and the Loss of Species, Communities, and Ecological Heterogeneity. (Subregion: S Everglades)		
Projects partially addressing this objective:		
Landscape	195	Effects of Public Land Use on T&E Species Populations and Habitats in Big Cypress National Preserve
Eco Proc/Ind Sp	73	Population Structure and Spatial Distribution of Aquatic Consumers Communities in Everglades National Park
Eco Proc/Ind Sp	74	Experimental Studies of Population Growth and Predator Prey Interactions of Fishes in Everglades National Park
Eco Proc/Ind Sp	169	Life History Ecology and Interactions of Everglades Crayfishes in Response to Hydrological Restoration
Eco Models	175	Estimation of Snail Kite Model Parameters
Science Objective 54: Develop Information on Factors that Influence Salinity, Currents, and Exchange Rates. (Subregion: S Coast)		
Projects partially addressing this objective:		
Coastal	34	Paleoecological History of Pigeon Key, Florida Bay
Coastal	181	Time Series Analysis and Statistical Modeling of Salinity, Canal Discharge, and Available Biological Data from Biscayne National Park
Coastal	184	Salinity Simulation Models for North Florida Bay
Coastal	180	Water Flow Through Coastal Wetlands of Biscayne National Park
Science Objective 55: Determine Sources, Sinks, Quantities, Qualities, and Effects of 'External' Inputs. (Subregion: S Coast)		
Projects partially addressing this objective:		
WQ Treat	136	Analysis of Historical Water Quality Data
WQ Tribes	1	WQ Studies on Seminole Lands
WQ Tribes	2	WQ Studies on Miccosukee Lands
WQ Treat	96	Incorporating Advanced Water Quality Treatment Technologies into STA Design
WQ Treat	100	Water Quality Evaluations
Landscape	101	Investigation of Mercury Contamination in the Everglades and SF Ecosystem
Coastal	119	Cooperative South Florida Estuarine Water Quality Monitoring Network
Water Qual Tech	152	Stability and Bioavailability of Recently Accreted Phosphorus from Advanced Treatment Technologies

Program	Project ID	Project Title
Contam	156	Screening Level Risk Assessment To Determine Potential High Priority Contaminants and Natural Resources at Risk In Biscayne And Everglades
Water Qual Tech	160	Expansion of Field-scale PSTA Research
Hydro Models	162	Water Flows and Nutrient Fluxes to the SW Coast of Everglades National Park
Phos Thresh	171	Various Supplemental Water Quality Projects
Coastal	50	Flamingo Waste Water Study
Science Objective 56: Determine Environmental Variables that Dictate Distribution and Condition of Seagrass, Mangrove, Sponge, and Coral Habitats. (Subregion: S Coast)		
Coastal	33	Relationship of Sedimentary Sulfur, Iron, and Phosphorus Cycling to Water Quality in Florida Bay
Coastal	38	*Thalassis testudinum* Resilience to Sulfide Stress in Florida Bay: An Experimental and Field Approach
Coastal	49	Mechanisms and Implications of Thalassia Die-Off on Florida Bay Mud Banks
Coastal	53	Seagrass Disease and Mortality in Florida Bay
Coastal	54	Estuarine Fish Community Structure—Patterns of Stability, Change and Succession in Relation to C-111
Coastal	56	Statistical Relationship Between Benthic Habitat and Water Quality
Coastal	57	Seagrass/Light Monitoring Network for Florida Bay
Coastal	55	Simulation Model of Seagrass Communities in Florida Bay
Coastal	61	Development of a Landscape-scale Seagrass Model for Florida Bay
Coastal	185	N and P Limitation of Primary Productivity in Florida Bay
Projects partially addressing this objective:		
Coastal	59	Analysis and Synthesis of Existing Information on Higher Trophic Levels in Florida Bay
Coastal	62	FATHCM/Salinity Predictions
Eco Proc/Ind Sp	123	Hydrologic Variation & Ecological Processes in the Mangrove Forests in South Florida
Eco Models	29	Mangrove Modeling of Landscape, Stand Level, and Soil-Nutrient Processes
Coastal	32	Benthic Macrophyte and Invertebrate Distribution in the Mangrove Ecotone
Coastal	40	Fish Recruitment, Growth and Habitat Use in Florida Bay
Coastal	42	Florida Bay Fish Habitat Assessment Program (FHAP)
Coastal	44	Temporal and Spatial Variation in Seagrass Associated Fish and Invertebrates in Western Florida Bay
Coastal	71	Hydrologic Variation and Ecological Processes in the Mangrove Forests in South Florida
Eco Proc/Ind Sp	76	Vegetation Dynamics of Land-Margin Ecosystems: Mangroves in the Gulf Coast of South Florida
Eco Models	176	Vegetation Succession Modeling
Coastal	181	Time Series Analysis and Statistical Modeling of Salinity, Canal Discharge, and Available Biological Data from Biscayne National Park
Science Objective 57: Protect Natural Areas: Expand Wildlife Corridors, Flyways, and Greenways. (Subregion: S Coast)		
Science Objective 58: Increase Populations of Protected and Other Native Species. (Subregion: S Coast)		
Projects partially addressing this objective:		
Eco Proc/Ind Sp	146	Avian Restoration Studies
Eco Proc/Ind Sp	68	Dry Down Tolerance of the Florida Apple Snail: Effects of Age and Season

Program	Project ID	Project Title
Eco Proc/Ind Sp	77	Population Ecology of the Cape Sable Seaside Sparrow
Eco Proc/Ind Sp	85	Avian Restoration in Everglades National Park
Eco Proc/Ind Sp	126	Analyzing Historical Data to Set Restoration Targets for Wading Bird Nesting in South Florida
Eco Models	177	Influence of Hydrology and Habitat on Apple Snail Abundance
Eco Proc/Ind Sp	67	Multiple Regression Analysis of Environmental Factors Influencing Temporal and Spatial Patterns of Foraging Wading Birds in the Florida Everglades
Science Objective 59: Determine Impacts of Changes in Habitat and Environmental Conditions on Recruitment, Growth, and Survival. (Subregion: S Coast)		
Coastal	35	Diet of Red Drum and Snook in Florida Bay
Coastal	36	Relationships Among Inshore Pink Shrimp in Tortugas and Sanibel Fisheries
Projects partially addressing this objective:		
Coastal	44	Temporal and Spatial Variation in Seagrass Associated Fish and Invertebrates in Western Florida Bay
Coastal	35	Diet of Red Drum and Snook in Florida Bay
Coastal	36	Relationships Among Inshore Pink Shrimp in Tortugas and Sanibel Fisheries
Eco Proc/Ind Sp	67	Multiple Regression Analysis of Environmental Factors Influencing Temporal and Spatial Patterns of Foraging Wading Birds in the Florida Everglades
Eco Proc/Ind Sp	126	Analyzing Historical Data to Set Restoration Targets for Wading Bird Nesting in South Florida
Eco Proc/Ind Sp	124	Potential of the Endangered American Crocodile to Provide a Quantifiable Measure of Restoration Success in the Greater Everglades/SF Ecosystem
Eco Proc/Ind Sp	125	Wading Birds in South Florida
Coastal	32	Benthic Macrophyte and Invertebrate Distribution in the Mangrove Ecotone
Coastal	38	*Thalassis testudinum* Resilience to Sulfide Stress in Florida Bay: An Experimental and Field Approach
Coastal	40	Fish Recruitment, Growth and Habitat Use in Florida Bay
Coastal	42	Florida Bay Fish Habitat Assessment Program (FHAP)
Coastal	59	Analysis and Synthesis of Existing Information on Higher Trophic Levels in Florida Bay
Eco Proc/Ind Sp	66	Monitoring Program for the American Crocodile, Everglades National Park
Eco Proc/Ind Sp	89	Status, Distribution, and Habitat of the American Crocodile in Florida
Eco Proc/Ind Sp	94	Cape Sable Seaside Sparrow Population Survey Support
Eco Proc/Ind Sp	128	Eagle and Osprey Monitoring
Coastal	183	Mangrove/Fish Relationships in Biscayne Bay
Eco Proc/Ind Sp	188	Relative Distribution, Abundance, and Demographic Structure of the American Alligator in Relation to Habitat, Water Levels, and Salinities
Eco Proc/Ind Sp	189	Genetic Analysis of Cape Sable Seaside Sparrow Populations
Science Objective 60: Develop Water Budgets that Mutually Benefit Natural and Developed Areas. (Subregion: LEC)		
Science Objective 61: Conserve and Improve Quality of Runoff. (Subregion: LEC)		
Science Objective 62: Reduce Dry-season Recession Rate. (Subregion: LEC)		
Science Objective 63: Improve Hydroperiods of Overdrained Wetlands (Subregion: LEC)		

Program	Project ID	Project Title
Science Objective 64: Maintain Safe, Uncontaminated Drinking Water. (Subregion: LEC)		
Science Objective 65: Expand Ecotone/Buffer Areas (Subregion: LEC)		
Projects partially addressing this objective:		
Soc Science	193	Water Demands, Economic Growth, and Economic Impacts of the CERP Projects
Science Objective 66: Develop Control Methods. (Subregion: LEC)		
Subregion: LEC		
Science Objective 67: Protect or Restore Natural Areas. (Subregion: LEC)		
Science Objective 68: Expand Wildlife Corridors, Greenways, Flyways, and Mitigation Banks. (Subregion: LEC)		
Science Objective 69: Restore Quality of Estuarine/Coastal Waters. (Subregion: LEC)		
Projects partially addressing this objective:		
Contam	156	Screening Level Risk Assessment To Determine Potential High Priority Contaminants and Natural Resources at Risk In Biscayne And Everglades
Coastal	185	N and P Limitation of Primary Productivity in Florida Bay
Science Objective 70: Restore Volume, Timing, and Distribution of Freshwater Flow to Estuaries. (Subregion: LEC)		
Projects partially addressing this objective:		
Hydro Models	14	Southern Inland Coastal Systems Model Development
Hydro Models	15	Flow Velocity and Water Level Transects in SICS Model Area: Model Support
Hydro Models	16	Geology & Ecological History of the Buttonwood Ridge
Hydro Models	17	Geochemical Determinations of Groundwater Flow in Everglades National Park
Hydro Models	19	Land Characteristics from Remote Sensing
Hydro Models	21	Canal and Wetland Flow/Transport Interaction
Hydro Models	27	Freshwater Discharges into Northeastern Florida Bay
Hydro Models	28	Vegetative Resistance to Flow in the Everglades
Hydro Models	31	Effect of Wind on Surface Water Flows in the Everglades
Coastal	181	Time Series Analysis and Statistical Modeling of Salinity, Canal Discharge, and Available Biological Data from Biscayne National Park
Coastal	182	Plankton Indicators of Ecological Change in South Biscayne Bay
Coastal	183	Mangrove/Fish Relationships in Biscayne Bay
Eco Models	176	Vegetation Succession Modeling
Coastal	180	Water Flow Through Coastal Wetlands of Biscayne National Park
Landscape	192	Development of a Simulation Model Relating Hydrology, Topography, and Edaphic Factors to Plant Community Structure in Marshes
Science Objective 71: Develop System-wide Water Budget and Future Projections Under Growth and Restoration Scenarios. (Subregion: WCA)		
Science Objective 72: Examine Hydropattern Variability on Various Spatial/Temporal Scales Annually and Continuously. (Subregion: WCA)		

Program	Project ID	Project Title
Science Objective 73: Determine Landscape Response to Climatic Extremes, Fire, and Storms. (Subregion: WCA)		
Science Objective 74: Detemine Compatibility of Estuarine Inflow Requirements and Upstream Restoration Objectives. (Subregion: WCA)		
Science Objective 75: Determine Mechanisms Regulating Community Populations of Native Flora, Fauna. (Subregion: WCA)		
Eco Proc/Ind Sp	67	Multiple Regression Analysis of Environmental Factors Influencing Temporal and Spatial Patterns of Foraging Wading Birds in the Florida Everglades
Eco Proc/Ind Sp	126	Analyzing Historical Data to Set Restoration Targets for Wading Bird Nesting in South Florida
Science Objective 76: Relate Landscape Pattern and Function to Degree of Connectivity. (Subregion: WCA)		
Science Objective 77: Determine Feasibility of Restoring Predrainage Landscape. (Subregion: WCA)		
Science Objective 78: Determine Ecological Impacts of Nutrient Concentrations, Loadings, and Storages. (Subregion: WCA)		
Science Objective 79: Determine Extent and Impacts of Exotic Invasions. (Subregion: WCA)		
Science Objective 80: Determine Pre-drainage Fire Extent and Frequency. (Subregion: WCA)		
Support Development and Management of Databases, Information Transfer Systems, and Decision Support Tools that Will Facilitate Technically Sound Assessment Methods.		
Coastal	46	Issue of Journal "Estuaries" on Florida Bay
Coastal	47	Status of Ongoing Research in Biscayne Bay: A Workshop
Coastal	60	Baywatch—Nature Conservancy
Eco Proc/Ind Sp	127	A Multispecies/Habitat Evaluation of Everglades Restoration Plans
Eco Proc/Ind Sp	144	Information System Support
Science Info	149	Development of a South Florida Ecosystem Thesaurus
Science Info	150	Development of a National Biological Information Infrastructure (NBII) Node for the South Florida Ecosystem
Science Info	154	Hydrologic Data Collection & Analysis in and near Everglades National Park
Science Info	158	CESI Project Information Sheets and WWW Planning
Science Info	165	NPS Biological and Physical Data Management and Dissemination
Science Info	186	Hydrologic Data Collection and Analysis in and near Everglades National Park
Landscape	190	Habitat-based GIS Query Tools for Everglades Restoration
Landscape	191	Methodologies and Tools to Support Decision Making in Everglades Restoration
Soc Science	193	Water Demands, Economic Growth, and Economic Impacts of the CERP Projects
Soc Science	194	Handbook for Community Involvement
Landscape	195	Effects of Public Land Use on T&E Species Populations and Habitats in Big Cypress National Preserve

Program	Project ID	Project Title
Projects partially addressing this objective:		
Eco Models	24	Development of an Internet-based GIS
Coastal	47	Status of Ongoing Research in Biscayne Bay: A Workshop
Coastal	60	Baywatch—Nature Conservancy
Eco Models	106	Development of Selected Components of an Across Trophic Level System Simulation (ATLSS) for the Wetland Ecosystems of South Florida
Eco Proc/Ind Sp	144	Information System Support
Science Info	149	Development of a South Florida Ecosystem Thesaurus
Science Info	150	Development of a National Biological Information Infrastructure (NBII) Node for the South Florida Ecosystem
Science Info	154	Hydrologic Data Collection & Analysis in and near Everglades National Park
Science Info	158	CESI Project Information Sheets and WWW Planning
Science Info	165	NPS Biological and Physical Data Management and Dissemination
Science Info	186	Hydrologic Data Collection and Analysis in and near Everglades National Park
Landscape	190	Habitat-based GIS Query Tools for Everglades Restoration
Landscape	191	Methodologies and Tools to Support Decision Making in Everglades Restoration
Eco Models	109	Multimodeling Implementation Supporting ATLSS
Science Objective 82: Restoration Science Support: Review.		
Eco Plan Review	172	Science Program Review: CROGEE
Science Objective 83: Restoration Planning Support.		
Coop Studies	170	Various Coop Science and Planning Studies

SOURCE: William Perry, NPS, written communication 2002.

Appendix C

Future CESI Science Objectives

Examples of remaining south Florida research needs and science objectives, identified by current CESI staff and program managers, are listed below (William Perry, NPS, written communication, 2002).

Hydrological and Ecological Modeling:

- Continue to work to define hydrological performance targets
- Add transport functions to hydrological models to assess contaminant transport
- Refine the Natural Systems Model
- Develop hydrodynamic models for Florida and Biscayne bays, with linkages to upstream inflow modeling to evaluate impact of CERP projects on bay salinities
- Improve elevation data in critical areas for improved hydrological modeling
- Refine ecological models
- Develop simulation models to evaluate changes in critical habitat factors (e.g., tree islands, marl prairie)

Ecological Processes:

- Develop predictive relationships between hydrology and key indicator species (e.g., snail kite, apple snails)
- Define the relationships between salinity and indicator species in Florida and Biscayne bays (e.g., pink shrimp, mangroves, submerged aquatic vegetation)
- Develop aquatic insects and zooplankton as indices of hydrological or water-quality changes based on existing data
- Develop habitat suitability indices for critical species

Landscape Patterns:

- Develop a landscape-scale simulation model to link hydrology to plant community structure
- Define the relationship between water quality and benthic communities in Florida and Biscayne Bays

- Refine the relationships between abiotic processes (e.g., hydroperiod, flow, fire) and biotic responses (e.g., tree island maintenance and composition)
- Evaluate the impacts of public land use on threatened and endangered species

Water Quality:

- Evaluate treatment technologies for improvement of water quality in the Everglades
- Determine the effects of flow on phosphorous uptake to evaluate water-treatment techniques
- Define the relationship between biological indicators and water quality at Everglades reference sites
- Develop nutrient-loading models for Florida and Biscayne bays
- Develop best management practices for agricultural areas near restored Everglades habitats
- Assess potential ecotoxicological impacts of operation of critical CERP projects

Science Information:

- Develop and maintain a database of historical and current biological and physical data with agency and public access
- Organize existing ecological data (habitat and population data) for South Florida into Geographic Information Systems for analysis of hydrological scenarios
- Create a system among key agencies to facilitate transfer of South Florida restoration science data for CERP implementation
- Develop and implement methodologies and decision support tools that will permit effective and timely assessment of CERP projects on DOI natural resources

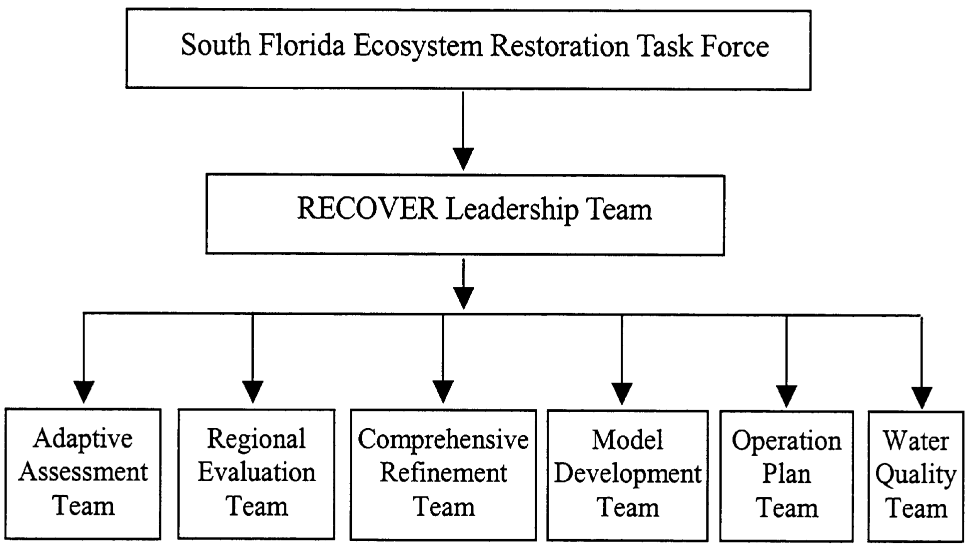
Social Science:

- Evaluate the economic and social effects of the Everglades restoration

Appendix D

Structure of RECOVER

The role of REstoration, Coordination, and VERification (RECOVER) is to organize and apply scientific and technical information in ways that are most effective in supporting the objectives of the Comprehensive Everglades Restoration Plan (CERP). RECOVER links science and the tools of science to a set of system-wide planning, evaluation, and assessment tasks. These links provide RECOVER with the scientific basis for meeting its overall objectives of evaluating and assessing CERP performance, refining and improving the plan during the implementation period, and ensuring that a system-wide perspective is maintained throughout the restoration program.



RECOVER LEADERSHIP TEAM

The RECOVER Leadership Team is responsible for coordinating and integrating the activities of the other six RECOVER teams and ensuring that the overall focus and direction of the implementation process remain consistent with the goals of system-wide restoration. Specifically, the leadership team's tasks include:

- setting the overall priorities for RECOVER
- issuing the annual report card
- refining the overall vision of success for the CERP

RECOVER TEAMS

Adaptive Assessment Team (AAT)

Objectives:

- Create, refine, and provide documentation for a set of conceptual ecological models for the total system and for each of the major physiographic regions of south Florida
- Create and refine a set of attribute-based biological performance measures for the CERP
- Design and review the system-wide monitoring and data management program needed to support the CERP
- Use the information coming from the system-wide monitoring program to assess actual system responses as components of the CERP and produce an annual assessment report describing and interpreting these responses
- Coordinate all scientific peer reviews of RECOVER documents

Regional Evaluation Team (RET)

Objectives:

- Review and revise the set of system-wide stressor-based performance measures
- Review and revise restoration targets
- Resolve technical issues pertaining to the performance measures
- Coordinate with the Comprehensive Refinement Team and project delivery teams during the plan formulation and design phases of the projects, and evaluate the effects of these plans on the system as a whole
- Analyze and compare the regional effects of refinements to the CERP
- Refine the existing and future plan without project condition

- Conduct system-wide analyses of the CERP using the latest refinements in predictive tools (e.g., South Florida Water Management Model, Everglades Landscape Model)

Comprehensive Refinement Team (CRT)

Objectives:

- Recommend refinements and improvements to the CERP throughout the implementation period, as new information that identifies where, how, and why these improvements should be made becomes available
- With the other five RECOVER teams, identify needed plan refinements and a means for incorporating these refinements into the design
- Serve as the "keeper" of information on the most current version of the CERP and "without project" conditions
- Address system-wide performance issues

Model Development Team (MDT)

Objectives:

- Ensure that the predictive tools used to conduct the evaluations of CERP components are consistent with the scales and targets set by the performance measures for each component
- Oversee the quality of physical, water-quality, and ecological models
- Coordinate the resolution of technical issues pertaining to the models, including any necessary refinement or enhancement of system-wide tools (e.g., the South Florida Water Management Model)

Operation Plan Team (OPT)

Objectives:

- Coordinate and resolve system-wide operational issues associated with the implementation of the CERP
- Support the project delivery teams in the design of operational criteria and water-control plans for each of the CERP components
- Work with the Adaptive Assessment Team in reviewing hydrologic responses during the implementation period
- Coordinate or recommend interim operational criteria wherever these changes may provide enhancements in the performance of the plan before all components of the plan are in place

Water Quality Team (WQT)

Objectives:

- Develop and review water-quality performance measures
- Develop the water-quality components of the CERP system-wide monitoring plan
- Provide input into the annual assessment of system responses, particularly as they relate to water quality
- Serve as a link between RECOVER and project delivery teams to ensure local water quality for projects is appropriately addressed and is coordinated with system-wide water quality performance measures and targets
- Work with CERP environmental compliance coordinators to develop a system-wide strategy for permit-related water-quality monitoring
- Coordinate with efforts underway to develop the South Florida Water Quality Protection Program and the CERP Water Quality Feasibility Study

SOURCE: SFWMD, 2002b

Appendix E

Memorandum of Understanding for Integration of Research, Planning and Interagency Coordination

MEMORANDUM OF UNDERSTANDING

Among

THE UNITED STATES DEPARTMENT OF THE INTERIOR

And

NATIONAL PARK SERVICE

And

FISH AND WILDLIFE SERVICE

And

UNITED STATES GEOLOGICAL SURVEY

For

INTEGRATION OF RESEARCH, PLANNING AND INTERAGENCY COORDINATION SUPPORTING EVERGLADES RESTORATION ACTIVITIES

This Memorandum of Understanding (MOU) is made and entered into among the Department of the Interior, Office of the Secretary (DOI), the National Park Service (NPS), the United States Fish and Wildlife Service (FWS), and the United States Geological Survey (USGS), collectively referred to as the "Parties."

I. Authorities

National Park System Organic Act, 16 U.S.C. § 1 *et seq.*

Wilderness Act of 1964, 16 U.S.C. § 1131 *et seq.*

Fish and Wildlife Coordination Act, 16 U.S.C. § 661

Endangered Species Act of 1973, 16 U.S.C. § 1531 *et seq.*

National Wildlife Refuge System Improvement Act of 1997, 16 U.S.C. § 668dd–668ee, P.L. 105–57

Water Resources Development Act of 1996, Pub. L. No. 104–303, § 528, 110 Stat 3767 (1996)

Water Resources Development Act of 2000, Pub. L. No. 106–541, § 601, 114 Stat. 2572 (2000)

U.S. Geological Survey Organic Act, 43 U.S.C. 31 (a) *et seq.*

Economy Act, 31 U.S.C. § 1535

II. Purpose and Joint Objectives

The purpose of this MOU is to integrate and facilitate coordination among the Parties for all ongoing and future monitoring, research, planning, and interagency coordination activities supporting Everglades restoration. With the enactment of the Comprehensive Everglades Restoration Plan (CERP), it is important that appropriated funds target not only the highest priority research, planning, and interagency coordinating needs of the restoration effort, but are coordinated both within the Department of the Interior, and with related on-going efforts of state and other Federal partners. This integration will facilitate the leveraging of resources, maximize the value of Federal funds, and ensure that the best available research products and monitoring and assessment tools, responsive to the needs of NPS and FWS, are obtained.

Both NPS and FWS are responsible for the stewardship of one-half the remaining Everglades ecosystem and have responsibilities to provide technical expertise to the Army Corps of Engineers (Corps) as it implements, with the State of Florida, one of the largest watershed restoration programs in the world. As the Department's premier research organization, the USGS is uniquely situated to provide quality research products responsive to the needs of the NPS and FWS, and other Federal and state partners, as Everglades restoration efforts proceed.

The MOU will ensure: (1) ongoing and future research and related products are determined collaboratively by the Parties to support Everglades restoration activities and the needs of the NPS and FWS; (2) the continuation of ongoing monitoring and assessment activities of the NPS and FWS to assess the effects of Everglades restoration projects on Interior managed lands and resources for which Interior plays a key stewardship role, including Endangered Species; and (3) the continuation of critical planning and interagency coordination activities being implemented by the Office of the Executive Director, South Florida Ecosystem Restoration Task Force (SFERTF). These efforts include: ecosystem restoration planning activities, required reports for the Congress, high priority coordination efforts of the Task Force and the Department's on-going partnership with the Army Corps of Engineers including ecosystem science peer review.

This MOU will apply to programs proposed for funding in FY 2003 and beyond, wherever funds may be appropriated which support an integrated monitoring, research, planning, and interagency coordination program for ecosystem restoration initiatives in South Florida.

III. Responsibilities of the Parties

A. Principle Points of Contact

To provide for consistent and effective communication among the Parties, each Party shall appoint a principal representative, located in South Florida, to serve as its central point of contact on matters related to this MOU.

B. Determination and Funding of Requirements for Monitoring, Research, Planning and Interagency Coordination:

FWS, NPS, and USGS shall have primary responsibility, working collaboratively with other state and Federal partners, including the Department's Office of the Executive Director, SFERTF, the Seminole and Miccosukee Tribes, and the Army Corps of Engineers, to determine and rank the research requirements to be funded and implemented as part of this integrated program. Additionally, FWS and NPS, in collaboration with the USGS, shall be responsible for determining an appropriate amount of funds required to sustain critically important monitoring and assessment activities on lands and trust resources managed by the Department. Data collected through these activities must meet Federal Geographic Data Committee (FGDC) standards as applicable.

The USGS will develop, in collaboration with NPS and FWS, a consolidated, external peer-reviewed research program that integrates FWS and NPS requirements, and which includes a detailed list of research tasks and timelines to support critical decision points associated with the restoration effort. Each research task should have an estimate of funds needed for each year, as well as a list of deliverables and set of milestones. USGS is responsible for reviewing NPS and FWS monitoring and assessment data standards and data base programs as agreed to by the Parties.

The Executive Director, SFERTF shall be responsible for proposing the annual amount of funding necessary to implement planning and interagency coordination responsibilities and activities as well as other related functions in support of the Departments monitoring, assessment, and research programs.

Annual funding proposals shall be collaboratively developed with the Parties and shall be submitted to the Department as part of the annual DOI budget process.

Upon Congressional appropriation of funding for research projects covered by the MOU, funds will be transferred to the most appropriate source as collaboratively agreed to among NPS, FWS and USGS. The USGS will provide to NPS and FWS collaboratively agreed upon study plans that include appro priate peer-reviews of the plans and products being funded. The appropriated funds for peer-reviewed monitoring and assessment activities shall be transferred to the FWS and NPS, consistent with the amounts approved for such expenditure. Similarly, appropriated funds for interagency coordination and planning activities shall be transferred to the Office of the Executive Director, SFERTF consistent with the amounts approved for such expenditure.

USGS agrees to tailor its administrative overhead associated with the implementation of this program to an appropriate level. For funds that are transferred to another DOI entity for implementation, this overhead will be no more than 3 % with a goal of reducing or eliminating such costs.

C. Reporting Requirements

Any Party receiving funds for research or monitoring and assessment activities, or planning and interagency coordination projects through this integrated program agrees to report to the lead Everglades policy official as designated by the Secretary of the Interior to summarize the annual progress and results of the projects and programs covered by this MOU.

IV. Interagency Coordination and Dispute Resolution

The Parties shall work collaboratively to plan, seek funding and execute an integrated research, monitoring and assessment, planning and interagency coordination effort. In the event a dispute is identified by any of the Parties, the Parties agree to resolve the dispute at the lowest organizational level within 30 days. If the dispute is not resolved within that time frame, the Parties agree to elevate the dispute to the next organization level for resolution. Ultimate resolution of disputes related to this MOU shall reside with the lead Everglades policy official as designated by the Secretary of the Interior.

V. Term of MOU

This MOU shall become effective on the last date of signature below and shall terminate upon the mutual agreement of the parties. This MOU may be modified or amended as appropriate by mutual consent in writing of the Parties. No modification shall be binding on any Party unless such modification or amendment is in writing and is executed by all the Parties. This MOU may be executed in one or more counterparts, each of which shall be deemed an original, but which together shall constitute one and the same instrument. A facsimile copy of this MOU and any signatures hereon shall be considered for all purposes as originals.

The following information describes the proposed framework for implementing the above MOU:

Implementing DOI's Everglades MOU

Preface: At a meeting of the DOI South Florida Everglades Managers [Salt (SFERTF, OED), Finnerty (NPS), Slack (FWS), Musaus (FWS), Jodrey (DOI HQ via phone), Best (USGS)] on April 30, 2002, we discussed a recommended format for implementing the MOU. Specifically, we discussed the format for Science Advisory to USGS as per the intent of the Everglades MOU. We agreed on the following general format.

Science Advisory Council:

1. RESPONSIBILITY: The Science Advisory Council will be responsible for helping to define the broad-scale, programmatic-level science information needs; and, assist with defining DOI-level funding requests. Specifically, by abstracting information from the MOU, the “charge” to the Science Advisory Council is defined as follows:

a. “…integrate and facilitate coordination among all Parties for the ongoing and future monitoring, research, planning and interagency coordination activities supporting Everglades restoration…
b. “…facilitate the leveraging of resources, maximize the value of Federal funds, and ensure that the best available research products and monitoring and assessment tools...are obtained.
c. “…determine and rank the research requirements to be funded and implemented….”

2. MEMBERSHIP: Following the guidelines in the MOU, “FWS, NPS, and USGS shall have primary responsibility, working collaboratively with each other, state and Federal partners, including the Department's Office of the Executive Director, SFERTF, the Seminole and Miccosukee Tribes, and the Army Corps of Engineers….” Therefore, this Council will consist of Senior Level Managers for GEER and CERP including DOI, COE, SFWMD, EPA, and advisors from the Seminole and Miccosukee Tribes as per the following:

DOI Partners:

a. Two representatives from the NPS

- ENP Superintendent—Maureen Finnerty
- Big Cypress Superintendent—John Donahue

b. Two representatives from the FWS

- Field Supervisor—Jay Slack
- Refuge Manager (and SF coordinator)—Mark Musaus

c. Two representatives from USGS [TBD] and the USGS Greater Everglades Science Coordinator serving to facilitate the Council
d. One representative from OED SFERTF—Rock Salt

Other Everglades Restoration Collaborators:

e. One advisor from US COE—Dennis Duke
f. One advisor from US EPA—Richard Harvey
g. One advisor from South Florida Water Management District—TBD
h. One advisor from the Seminole Tribe—Craig Tepper (TBC)
i. One advisor from the Miccosukee Tribe—Terry Rice

3. MEETINGS: It is anticipated that the Council will meet at least twice annually.

Science Implementation Committee (SIC):

1. RESPONSIBILITY: The Science Implementation Committee will be responsible for ensuring that the recommendations of the Science Advisory Council are implemented within both budget and time-line constraints [i.e., the Science Implementation Committee will turn the broad-scale science information needs into projects with clearly defined objectives, time lines, deliverables, and budgets]. The SIC will develop through the USGS "…a consolidated, externally peer-reviewed research program that integrates the FWS and NPS requirements, and which includes a detailed list of research tasks and timelines to support critical decision points associated with the restoration effort." The USGS, through the SIC, will ensure that "…data collected through these activities… meet Federal Geographic Data Committee (FGDC) standards as applicable." {{Once the SIC meets, this section will be expanded with more detailed duties and time lines.}}
2. MEMBERSHIP: This Committee will consist of senior science managers for each of the four USGS disciplines, the USGS Greater Everglades Science Program Coordinator, plus a member from the FWS and NPS. The FWS and NPS South Florida Everglades Principals will appoint their members to this Committee. The USGS Greater Everglades Science Program Coordinator will chair this Committee.
3. MEETINGS: It is anticipated that the Committee will meet no less than quarterly, and more often during the process of soliciting and evaluating proposals.

SOURCE: James Tate, DOI, personal communication, 2002.

Appendix F

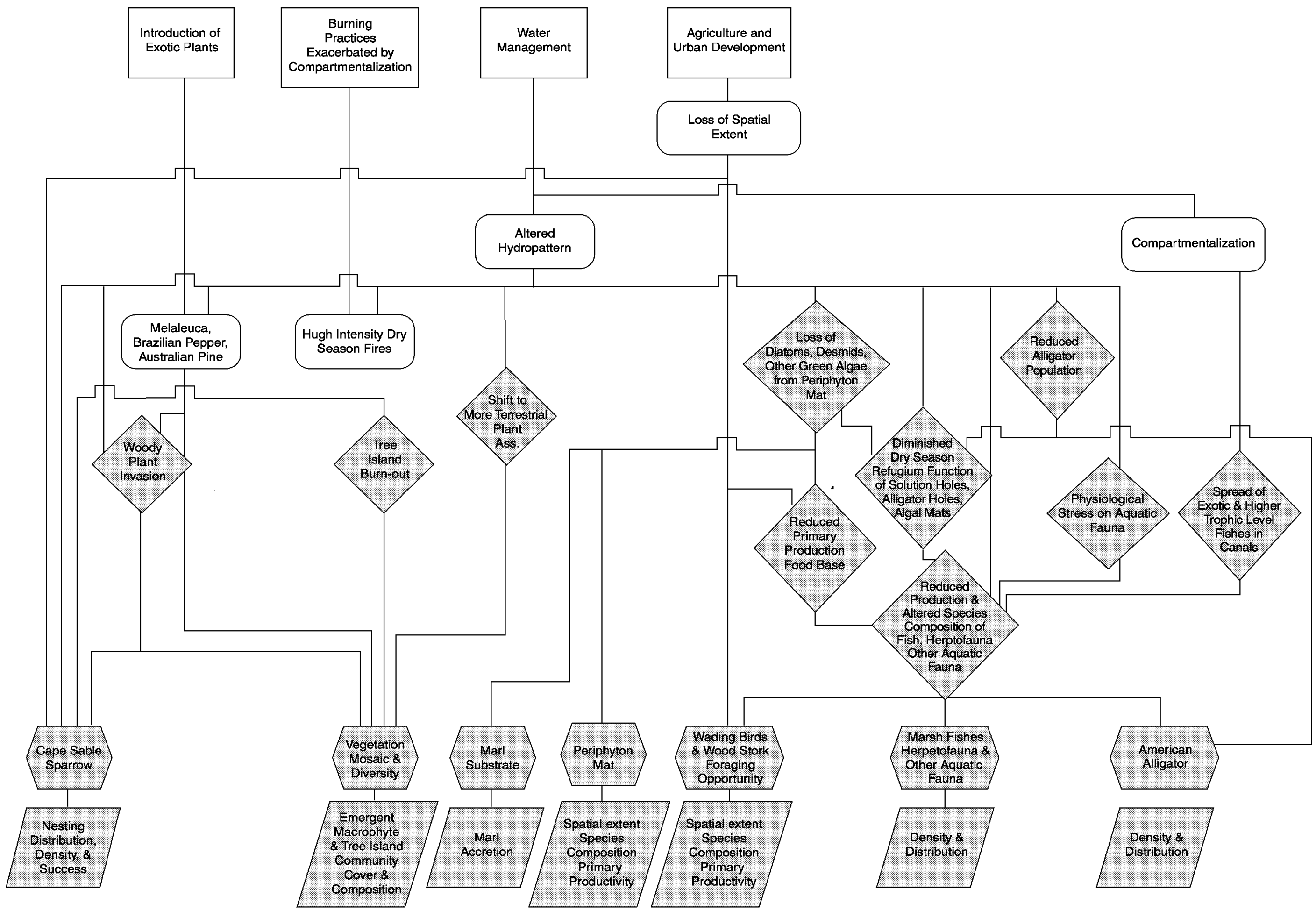
Monitoring and Assessment Plan Conceptual Model

The Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP) is based on nine regional conceptual models and an eco-system-wide model. The nine regional models are fully developed, while the ecosystem-wide model is in the early stages of development. Although the conceptual models form the basis for the MAP, these models have wider application in the broader restoration because they are a representation of the current state of understanding of ecosystem function based on the best science available. These simple, nonquantitative models were used to develop a set of causal hypotheses that explain the impact anthropogenic drivers and stressors have on the natural system. Each of the models details the linkages between drivers, stressors, and ecosystem attributes. The models also identify the most appropriate measures of each attribute. The conceptual models include five major components:

1. **Drivers** are the major external forces, either natural (e.g., sea-level rise) or anthropogenic (e.g., regional land-use programs) that have large-scale influences on natural systems
2. **Stressors** are the physical or chemical changes that occur within the ecosystem that are brought about by the drivers. Stressors cause significant changes in the biological components, patterns, and relationships in the natural system
3. **Ecological effects** are the biological responses to the stressors
4. **Attributes,** or indicators, are typically populations (e.g., number of roseate spoonbills), species (e.g., American alligator), guilds (e.g., number of nesting birds), communities (e.g., tree islands), or processes (e.g., primary production)

5. **Measures** are the specific feature(s) of each attribute that must be monitored to determine the attribute response to changes in the stressors

Each of the models includes documentation that describes (1) the dynamics and problems of the specific physiographic region, (2) descriptions of the external drivers, ecological stressors, and attributes, (3) description of the expected ecological response to changes in drivers and stressors expressed as hypotheses, with the degree of associated uncertainty, and (4) preliminary restoration targets for the attributes. The Critical Ecosystem Studies Initiative has funded a number of projects that have contributed to the Marl Prairie and Rocky Glades conceptual model included here to illustrate model structure.



Marl Praire and Rocky Glades conceptual model. Drivers are shown as rectangles, stressors as ovals, ecological effects as diamonds, attributes as hexagons, and measures as parallelograms. SOURCES: Adapted from USACE, 2001.

Appendix G

Conflict Resolution in the Florida Everglades

At the beginning of January 2001, the Jacksonville District of the U.S. Army Corps of Engineers contacted the U.S. Institute for Environmental Conflict Resolution (the Institute) to request neutral assistance in resolving a long-standing interagency conflict related to the protection of the endangered Cape Sable seaside sparrow (CSSS). The request came at the suggestion of the Council on Environmental Quality in the Executive Office of the President. The Corps had completed a draft environmental impact statement (EIS) on an interim plan for protection of the CSSS, until the long-delayed ModWaters and C-111 projects could be completed. With the Institute's assistance, the EIS was completed in May 2002 (USAGE, 2002a).

The Institute's assistance was requested because of its unique role, as established by the U.S. Congress in 1998, to assist in the resolution of interagency, intergovernmental, and multistakeholder environmental, natural resource, and public lands conflicts. The Institute is part of the Morris K.Udall Foundation, an independent agency of the executive branch. The Institute serves as an impartial, nonpartisan institution providing professional neutral expertise, services, and resources to all parties involved in environmental disputes, regardless of who initiates or pays for the assistance.

With the concurrence of the Corps and the three other agencies involved— Everglades National Park, the Fish and Wildlife Service, and the South Florida Water Management District—the Institute has taken a phased approach to the conflict-resolution effort, beginning with an assessment of the conflict situation followed by an initial meeting with the leadership of the four agencies. This initial interagency meeting was used to assess the agencies' individual and collective interests in pursuing a collaborative conflict-resolution effort and to determine appropriate next steps if there was sufficient mutual commitment to proceed. One of the options proposed was consideration of a multistakeholder collaborative EIS process for the upcoming Combined Structural and Operational Plan (CSOP) for the ModWaters and C-111 projects, which have been delayed for approximately a decade. The inability to resolve differences and build broad consensus with other interested and affected stakeholders has been a major reason for this delay.

In accordance with the National Environmental Policy Act (NEPA) of 1969, the Corps must complete an EIS for CSOP. Although an EIS is commonly viewed as a set of required procedural steps that federal agencies must follow, it can also serve as a framework for collaboration and consensus building with other federal, state, and local agencies and tribal governments, as well as with stakeholders and nongovernmental organizations. In CSOP, the four agencies have four common goals they hope to achieve through the collaborative EIS process:

1. reaching an interagency agreement on CSOP
2. building a broad consensus for a CSOP solution
3. avoiding litigation
4. building trust among the stakeholders

Thus far, collaborative efforts among the four agencies have generated agreements on

- a memorandum of understanding (MOU) that clarifies the roles of the four agencies in the CSOP EIS process and affirms their commitment to complete the EIS using a collaborative approach
- CSOP's purpose and objectives
- the base condition to which CSOP alternatives will be compared
- the need for a new hydrologic model to assist in evaluating impacts of various CSOP alternatives (the agencies have jointly developed the scope of work, they have agreed to share the cost of development of the new model, and they will sit together as an interagency selection committee to review and evaluate proposals)
- the sequence of modeling activities for the CSOP process

Each step in the NEPA process, from identification and evaluation of alternatives through selection of a preferred alternative, will be addressed through the collaborative process. Although the agencies' proposed ground rules provide that they will make decisions by consensus, the MOU makes it clear that the Corps is the lead agency in the EIS process and retains responsibility and authority for the final record of decision in the CSOP EIS.

SOURCE: Analee Mayes, Consensus Builders, Inc., personal communication, 2002.

Appendix H

Rosters of the Water Science and Technology Board and the Board on Environmental Studies and Toxicology

WATER SCIENCE AND TECHNOLOGY BOARD

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PETER GLEICK, Pacific Institute for Studies in Development, Environment, and Security, Oakland, California
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ROBERT PERCIASEPE, National Audubon Society, Washington, D.C.
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STEPHANIE E.JOHNSON, Staff Officer

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ELLEN A.DE GUZMAN, Research Associate
PATRICIA JONES KERSHAW, Study/Research Associate
ANITA A.HALL, Administrative Assistant
JON Q.SANDERS, Senior Project Assistant
ANIKE L.JOHNSON, Project Assistant

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ROBERTA M.WEDGE, Program Director for Risk Analysis
K.JOHN HOLMES, Senior Staff Officer
SUSAN N.J.MARTEL, Senior Staff Officer
SUZANNE VAN DRUNICK, Senior Staff Officer
RUTH E.CROSSGROVE, Managing Editor

Appendix I

Biographical Information of the Critical Ecosystem Studies Initiative Panel Members and NRC Staff

Linda K.Blum is a research associate professor in the Department of Environmental Sciences at the University of Virginia (UVA). Dr. Blum began her career at UVA in 1986 as a research assistant professor. Prior to arriving at UVA, she was a consultant to the South Florida Water Management District, Sitler, Inc., and Hydrosystems, Inc., in Charlottesville, Virginia. She was also a professor of biology at the State University of New York College at Buffalo. She was awarded the NASA Summer Faculty Fellowship in 1998 and 1999 and is a member of the Estuarine Research Federation, Atlantic Estuarine Research Society, American Society of Limnology and Oceanography, American Society for Microbiology, American Phytopathology Society, Society of Sigma Xi, and the American Association for the Advancement of Science. She holds a B.S. and M.S. in forestry from Michigan Technological University and a Ph.D. in soil science from Cornell University. Dr. Blum has been a member of the National Research Council's Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) since its inception in September 1999.

John A.'Jeb' Barzen is the director of field ecology at the International Crane Foundation. His research experience is in prairie, savanna, and wetland restoration in southern Wisconsin, southern Vietnam, and southwest China. He received his M.S. in biology from the University of North Dakota (1989), and his B.S. in wildlife biology from the University of Minnesota (1982) and he is an honorary fellow in the Department of Zoology, the Institute of Environmental Studies, and the College of Natural Resources (Stevens Point) at the University of Wisconsin. His main research interests are prairie/savanna wetland restoration in Wisconsin and Asia, linking poverty alleviation with conservation, and implementing conservation on private lands.

Lauren J.Chapman is an associate professor in the Department of Zoology at the University of Florida. She also holds the title of Honorary Lecturer, Makerere University, Kampala, Uganda, and associate scientist, Wildlife Conservation Society. Dr. Chapman combines ecological and physiological approaches in her research in order to understand the evolution of tropical freshwater fishes. Her current work in East Africa focuses on the role of wetlands in the maintenance of fish faunal structure and diversity. She is also involved in the conservation and management of tropical waters with an emphasis on patterns of species loss and resurgence in the Lake Victoria basin. She received her Ph.D. from McGill University in 1990.

Peter L.deFur is president of a consulting firm, Environmental Stewardship Concepts, and is an affiliate associate professor at the Center for Environmental Studies at Virginia Commonwealth University. He has extensive experience in risk assessment and ecological risk assessment regulations, guidance, and policy. Dr. deFur also worked as a visiting investigator at the Smithsonian Environmental Research Center in Edgewater, Maryland. He was a member of the NRC Board on Environmental Studies and Toxicology (BEST). He serves on the Board of the Science and Environmental Health Network, and he serves as president of the Association for Science in the Public Interest. In 1994–1996 Dr. deFur served on the National Research Council's Committee on Risk Characterization. He received his B.S. and M.S. degrees in biology (1972 and 1977, respectively) from the College of William and Mary, and his Ph.D. in biology (1980) from the University of Calgary, Alberta, Canada.

F.Dominic Dottavio has served as the dean and director of the Ohio State University at Marion since 1993, where he also holds an appointment as a professor of natural resources. Prior to arriving at Ohio State, he was the chief scientist and assistant regional director of the National Park Service in Atlanta. In this position, Dr. Dottavio was responsible for the Park Service's scientific and natural resource management activities in 58 parks and 5 universities throughout the southeastern United States, Puerto Rico and the Virgin Islands. He also has served as director of the Center for Natural Areas in Washington, D.C., and was a policy analyst with the Heritage Conservation/Recreation Service. Dr. Dottavio has authored over 100 publications on tourism, outdoor recreation, and Natural Parks Service resource management issues and has served on the boards and advisory councils of a number of professional organizations, including the Renewable Natural Resources Foundation, Archbold Tropical Research Center, Southern Appalachians Man and the Biosphere Program, Virgin Islands Research and Resource Management Cooperative, and Oak Studies Board. He earned a B.S. in natural resource management in 1973 from the Ohio State University, an M.S. from Yale University in 1975, and a Ph.D. from Purdue University in 1979.

William L.Graf is the Education Foundation University Professor and professor of geography at the University of South Carolina. His specialties include fluvial geomorphology and hydrology, as well as policy for public land and water. His research and teaching have focused on river-channel change, human impacts on river processes, morphology, and ecology, along with contaminant transport and storage in river systems. In the arena of public policy, he has emphasized the interaction of science and decision making, and the resolution of conflicts among economic development, historical preservation, and environmental restoration for rivers. He has authored or edited 7 books and more than 120 scientific papers, book chapters, and reports, and he has given more than 90 public presentations. He is past president of the Association of American Geographers and has been an officer in the Geological Society of America. President Clinton appointed him to the Presidential Commission on American Heritage Rivers. His NRC service includes membership on the Water Science and Technology Board and the Board on Earth Sciences and Resources. He has served on many NRC committees and has chaired NRC committees on innovative watershed management and research priorities of the U.S. Geological Survey. He is a National Associate of the National Academies. His Ph.D. is from the University of Wisconsin, Madison, with a major in physical geography and a minor in water resources management.

James P.Heaney is a professor at the University of Colorado in the Department of Civil, Environmental, and Architectural Engineering. He was a professor of environmental engineering sciences at the University of Florida for 23 years and served as director of the Florida Water Resources Research Center from 1979 to 1991. Dr. Heaney's current research interests focus on developing simulation and optimization techniques to evaluate innovative urban water infrastructure systems including water supply, wastewater, and stormwater. He has served as vice-chair on the American Society of Civil Engineers' Urban Water Resources Research Council from 1999 until the present. Dr. Heaney has over 170 publications and serves as a diplomat for the American Academy of Environmental Engineers. Dr. Heaney has served the National Academies as a member of the Committee on Watershed Management, the Panel on Sources, and the Water Science and Technology Board. He earned his BSCE from Illinois Institute of Technology in 1962, his MSCE from Northwestern University in 1965, and his Ph.D. in civil engineering from Northwestern University in 1968.

Stephen R.Humphrey is dean of the College of Natural Resources and Environment at the University of Florida, where he also serves as affiliate professor of Latin American studies, wildlife ecology, and zoology. Prior to his appointment as dean, he served as interim dean from 1993 to 1997 and as interim chair of the Department of Wildlife Ecology and Conservation from 1996 to 1997. He was the commissioner and chair of the Environmental Regulation Commission, Florida Department of Environmental Protection, from 1991 to 1999. He served as a member of the Florida Panther Technical Advisory Council, Florida Game and Fresh Water Fish Commission, from 1992 to 1997. For the past 12 years, he has served as the chief financial officer for the Society for Conservation Biology. In addition, he sat as chairman of the Board of Trustees for the Florida Chapter of The Nature Conservancy from 1987 to 1989, and he continues his service as a trustee. Dr. Humphrey has been a member of the National Research Council's Committee on Restoration of the Greater Everglades Ecosystem (CROGEE) since its inception in September 1999.

Stephen S.Light is director of the Center for Working Landscapes at the Institute for Agricultural and Trade Policy in Minneapolis, Minnesota. As a policy director with the South Florida Water Management District in the early 1980s, Dr. Light helped introduce the concept of adaptive management to the management of the Florida Everglades, and he helped develop an iterative testing process for reintroducing flows into the Shark River slough in Everglades National Park. Dr. Light was a coeditor of the widely cited 1995 volume on *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. He received his B.S. degree from Thiel College, his M.S. degree from Pennsylvania State University, and his Ph.D. degree in natural resources policy and management from the University of Michigan.

Charles R.O'Melia is the Abel Wolman Professor of Environmental Engineering in the Department of Geography and Environmental Engineering at the Johns Hopkins University in Baltimore, Maryland. After receiving his master's degree in environmental engineering, Dr. O'Melia worked for Hazen and Sawyer, Engineers (1956–1957). He then returned to Michigan to study for his doctorate, working on the filtration of algal suspensions. From 1961 to 1964, he served as assistant professor of sanitary engineering at the Georgia Institute of Technology. In 1964–1966 he was a postdoctoral fellow and lecturer in water chemistry at Harvard University. He joined the University of North Carolina (UNC) at Chapel Hill in 1966 as associate professor and became professor in 1970. From 1977 to 1980, he served as deputy chair of the Department of Environmental Sciences and Engineering at UNC. He assumed the position of professor of environmental engineering at Johns Hopkins in 1980 and served as department chair from 1990 to 1995. In 1998, he was appointed as Abel Wolman Chair in Environmental Engineering at Johns Hopkins. He is a member of the National Academy of Engineering, the American Society of Civil Engineers, the American Chemistry Society, the American Academy of Environmental Engineers, the American Water Works Association, the American Society of Limnology and Oceanography, the Association of Environmental Engineering Professors, Tau Beta Pi, Chi Epsilon, and Sigma Xi. He has served as director, vice president, and president of the Association of Environmental Engineering Professors. He is a past member of the Water Science and Technology Board and the Board on Environmental Studies and Toxicology, and has served on many NRC committees.

Carol M.Wicks is associate professor of geological sciences at the University of Missouri-Columbia. Her expertise is in karst hydrology and geochemistry, including numerical modeling of groundwater flow and contaminant transport, the response of basins to recharge events, and disturbance to stygobitic species due to recharge events. She received a B.S. in chemical engineering from Clarkson University, a M.E. in chemical engineering from the University of Virginia, and an M.S. and Ph.D. in environmental sciences from the University of Virginia. She also completed a post-doctoral fellowship at the U.S. Geological Survey. She is the President of the Karst Waters Institute and a member of the Geological Society of America and the American Geophysical Union. She has served as associate editor of the journals Groundwater and Water Resources Research and is currently an editor of the virtual international journal “Speleogenesis and Evolution of Karst Aquifers.”

Daniel E.Willard is professor emeritus of the Indiana University's Department of Biology and School of Public and Environmental Affairs. He taught zoology at the University of Texas from 1966 to 1970, and he then taught at the University of Wisconsin through 1977. In 1986, he won Indiana University's Distin-guished Teaching Award. From 1986 to 1992, he served as the director of Envi-ronmental Science and Policy Programs. Dr. Willard's research interests are wetland ecology, natural resources management, and aquatic biology. Dr. Willard has served the National Academies as a member of the Committee on the Resto ration of Aquatic Ecosystems: Science, Technology, and Public Policy (1989– 1991), and on the Committee on Irrigation Induced Water Quality Problems (1985–1990). Dr. Willard has served the Congressional Office of Technology Assessment, the Department of Justice, and the Environmental Protection Agency's Wetland Committee among others. He earned his Ph.D. in zoology from the University of California, Davis, in 1966, and his A.B. in biology from Stanford University in 1959. He retired in 1998. He is currently the president of the Sycamore Land Trust.

National Research Council Staff

Stephanie Johnson is a project officer with the Water Science and Technology Board. She received her B.A. from Vanderbilt University in chemistry and geology, and her M.S. in environmental sciences from the University of Virginia. She is currently finishing her Ph.D. in Environmental Sciences at the University of Virginia on the subject of pesticide transport and microbial bioavailability in soils. Her research interests include contaminant transport, aqueous geochemistry, and hydrogeology. She joined the National Research Council in 2002.

Jon Q.Sanders is a senior project assistant with the Water Science and Technology Board. He holds a B.A. in anthropology (1998) from Trinity University. He is a member of the American Anthropological Association, the Society for Applied Anthropology, the Washington Association of Professional Anthropologists, and the American Indian Science and Engineering Society. He is coauthor of “Sitting Down at the Table: Mediation and Resolution of Water Conflicts” (2001). Jon's research interests include organizational culture, political ecology, and environmental decision making.