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EXECUTIVE SUMMARY

The Florida Everglades is a complex ecosystem of diverse, interconnected subtropical habitats. Once comprised of over 4 million acres, today the historic Everglades have been reduced by half. The conflict of human versus natural elements in South Florida began in earnest in the early 1900s, when the control of water and the drainage of wetlands were first considered essential for commerce and human safety. Loss of life due to hurricane-related flooding in the 1920s accelerated drainage projects, culminating in the congressional authorization of the Central and Southern Florida (C&SF) Flood Control Project in 1948.

Over the course of the next 50 years, exponential population growth, urbanization, and agricultural practices significantly altered the South Florida ecosystem. Implementation of the C&SF Project hydrologically fragmented the Everglades, resulting in unnatural quantities and timing of freshwater flows to and through the remaining natural areas. These hydrologic changes resulted in severe ecosystem degradation, evidenced by a 90% decline in wading bird populations, declines in commercial and recreational fisheries, significant decreases in the number of Everglades tree islands, and widespread invasions of exotic plants and animals. Currently 68 species in the Greater Everglades are federally listed as threatened or endangered.

During the past two decades, the Florida Legislature and the U.S. Congress have enacted a series of laws to redress environmental harm to the South Florida ecosystem. Many of these laws provide the authorities under which the state and the federal governments operate and fund programs that collectively comprise the South Florida restoration effort. Most recently, the Congress authorized the implementation of the *Comprehensive Everglades Restoration Plan* (CERP), which will be implemented over the next four decades by the federal and state governments. The CERP will modify the C&SF Project to increase future water supplies for the environmental purpose of restoring the South Florida natural system, while also providing for other water-related needs in the region.

To support ongoing South Florida restoration efforts, the U.S. Department of the Interior and its bureaus, the U.S. Fish and Wildlife Service, the National Park Service, and the U.S. Geological Survey, developed this science plan to identify the science needed to support DOI managers in fulfilling their stewardship responsibilities for natural resources in South Florida. The science plan also supports DOI's efforts as a partner in South Florida restoration, including the implementation of the CERP.

Overall, DOI science will assist in the intergovernmental effort to answer three overarching restoration questions:

> *What actions will improve the quantity, timing, and distribution of clean fresh water needed to restore the South Florida ecosystem?*
>
> *What actions will restore, protect, and maintain natural resources on DOI lands in South Florida?*
>
> *What actions will recover South Florida's threatened and endangered species?*

Success in addressing these three overarching questions at ecological scales ranging from individual species and communities, to individual parks and refuges, to the entire South Florida ecosystem will require a well coordinated, collaborative, and integrated effort among participating agencies and stakeholders. None of these questions can be answered independently by any one agency or partner. Science must be synthesized and disseminated among the wide range of agencies and partners involved in this effort. Moreover, each of these questions raises more specific questions about the interrelated variables affecting the condition of the ecosystem, including hydropatterns (the quantity, timing, and

distribution of water), water quality, ecological responses of biological communities and species to changes in water quantity and quality, the role of fire, the effects of invasive exotic species, the effects of adjacent land uses on natural areas, and the effects of public use of parks and refuges. The major unanswered questions associated with particular projects are identified in this report and serve as the focal points for discussing what is known and what additional scientific information is needed to help ensure that each project produces the intended performance within the ecosystem.

This DOI science plan identifies the key projects and information needs for DOI managers as they fulfill their roles as stewards and partners in South Florida restoration efforts. Two DOI bureaus, the U.S. Fish and Wildlife Service (FWS) and the National Park Service (NPS), are responsible for the resource stewardship and public use of extensive public federal lands in the region, including Everglades National Park (the largest national park east of the Rockies), Biscayne and Dry Tortugas National Parks, Big Cypress National Preserve, and the Arthur R. Marshall Loxahatchee, Florida Panther, National Key Deer, and Ten Thousand Islands National Wildlife Refuges. The FWS has responsibilities for threatened and endangered species and other species of concern under such authorities as the Fish and Wildlife Coordination Act, the Endangered Species Act, and the Migratory Bird Treaty Act. The DOI also has a trust responsibility for American Indian reservation communities, including the Seminole and Miccosukee Indian Tribes. DOI's partnership role includes support for the Comprehensive Everglades Restoration Plan (CERP) including interim goals, performance measures, and support for various project components. Furthermore, it identifies a strategy for ensuring that the scientific information needed by managers is available at the appropriate time, when decisions are made. The coordination and prioritization of DOI science needs—based on managers' needs for information to support decision making — lays an important foundation for identifying gaps in scientific information and the management needs that must be addressed to achieve and maintain a restored Everglades.

This plan outlines the importance of developing and effectively synthesizing and communicating the best available science input into the decision making process in managing the DOI lands in South Florida. The USGS, in consultation with NPS and FWS, have developed a process for prioritizing the science needs relevant to the restoration and resource management projects identified in this science plan. This process utilizes a multi-tiered approach to assist in prioritizing critical science information needs. The prioritized list generated from this process will be the foundation for DOI's annual science funding strategy. Incorporated into this tiered approach are a number of factors:

- The relevance of the science effort to improving understanding of the ecological and hydrologic processes affecting DOI lands and resources
- The applicability of the science to multiple DOI restoration objectives or multiple projects
- Synthesis and sequencing to address the most urgent management information needs
- Maximization of cost-share opportunities and science coordination across bureaus or with DOI's CERP partners

The prioritization process outlined above emphasizes program integration and a primary goal of coordinating DOI investment in science to achieve economies of scale by effective integration of science programs from many different jurisdictions, including the private sector. The DOI bureaus are currently using this prioritization process to prioritize next year budget requests for science. In Addition, the NPS, FWS, and USGS will continue to proactively seek out partnerships and improve existing ones to maximize scientific inquiry

This plan strives to ensure that new information resulting from changed or unforeseen circumstances, new scientific or technical information, or information developed through the principles of adaptive management will be incorporated into the prioritization of DOI science efforts and land managers' decision making process. The DOI Science plan clearly identifies questions that managers have for the restoration process and the underlying scientific questions and information needed to address these questions. The plan also identifies timelines to get the information to managers when they need it. In order to answer these questions in a timely fashion, this plan specifically provides for development and use of improved predictive tools as well as a more comprehensive monitoring effort that will be the basis for new information that will be provided to the Department and partners' ecosystem restoration as adaptive management principles are implemented.

Three specific program areas, each with specific projects, are set forth in greater detail in the following pages. These program areas include (1) projects to improve the quantity, quality, timing and distribution of water; (2) habitat and species recovery projects; and (3) land and resource management projects. Implementation of this science plan will ensure that priority science needs are met for each of the projects identified and that DOI's science programs support the needs of the land-managing agencies involved in the South Florida restoration effort.

1. Plan Background and Purpose

The Greater Everglades Ecosystem

The Natural System

The southern Florida peninsula encompasses a mosaic of subtropical habitats connected and sustained by water. Before European settlement, this region of about 18,000 square miles was dominated by wetlands, which originated in the Kissimmee River drainage basin and flowed southward, through Lake Okeechobee and the Everglades, into highly productive estuaries and nearshore coastal waters, including Biscayne and Florida Bays.

South Florida receives between 40 and 65 inches of rainfall annually, most occurring during the wet season (June through October). The area is characterized by very low topographic relief. The nearly flat topography, proximity of thousands of miles of coastline, and high annual rainfall make much of the area susceptible to flooding.

Historically, water levels and flows in the wetland areas of the Everglades fluctuated seasonally in response to rainfall and runoff. During heavy rains, all but the tree islands were flooded. During the dry season, water levels generally were close to the land surface, but during droughts they often fell substantially below it. Major fires were a natural occurrence during droughts, and they swept over the land, burning vegetation and peat.

The freshwater marshes were characterized by extremely low levels of nutrients, creating the conditions conducive to extensive wetland sawgrass prairies—known as "the river of grass." These wetlands were punctuated with relatively low "uplands," which provided forested refuges for migratory species during times of flooding, as well as habitat for a diversity of year-round communities. In and around the estuaries, freshwater mingled with salt to create habitats supporting mangroves and nurseries for wading birds and fish. Beyond, nearshore islands and coral reefs provided shelter for an array of terrestrial and marine life.

The habitat in South Florida originally supported far-ranging animals, like the Florida panther, and super-colonies of wading birds, such as herons, egrets, roseate spoonbills, ibis, and wood storks.

Human Alterations to the Natural System

Some early land developers saw the potential for "improving" the Everglades wetlands through development and agriculture. However, efforts to reclaim the area for development and human habitation evolved slowly, as the marsh and sloughs were largely impenetrable and uninhabitable.

The conflict of human versus natural elements in South Florida began in earnest in the early 1900s, when the control of water and the drainage of wetlands were first considered essential for commerce and human safety. Loss of life due to hurricane-related flooding in the 1920s accelerated flood protection projects, culminating in the congressional authorization in 1948 of the Central and Southern Florida (C&SF) Flood Control Project. Over the course of the next 50 years, population growth, urbanization, and agricultural practices significantly altered the natural system.

Today South Florida encompasses significant remnants of the Everglades, including four national parks, thirteen national wildlife refuges, and numerous state parks and conservation areas, along with important urban centers, including Miami, and agricultural areas, including the Everglades Agricultural

Area (EAA). The C&SF Project, which provides for the diverse water-related needs of the region, consists of more than 1,400 miles of primary canals and more than a hundred water-control structures.

Providing for the diverse water-related needs of this area over many decades has resulted in unintended consequences for the Greater Everglades. Less than half the original wetland acreage of South Florida remains. Surface water flow within the Greater Everglades is fragmented and disrupted, changing the quantity and natural timing of water deliveries and negatively affecting the water quality and natural areas. Water flows from the Kissimmee River into Lake Okeechobee, and outflows from the lake, are through manmade canals. In the EAA, water is drained during wet periods and augmented during dry periods. Many wetlands that historically functioned as natural filters and water-retention areas are either severely impacted or entirely lost due to drainage changes or development. Compared to historic flows, canal discharges into Biscayne and Florida Bays are heavier during wet periods and lighter during dry periods, creating greater salinity fluctuations in the bays and affecting habitats along the gulf coast and within the reef tract from Key Biscayne to the Dry Tortugas. Additionally, the two bodies of water between Florida Bay and Biscayne Bay, Card and Barnes Sounds, have been essentially cut off from natural water deliveries.

The drainage system imposed by canals and other drainage features has impacted groundwater storage capacity. Aquifers provide municipal water supplies in the region. By 1990 about 872 million gallons of water per day (94% of it ground water) was being consumed by the nearly 6 million people living in or visiting the South Florida area. Another 2.7 million gallons per day (divided nearly evenly between ground water and surface water) was being used for agriculture.

Water quality is degraded in some areas by high levels of nutrients (such as phosphorus and nitrogen), pesticides, and other contaminants in agricultural and urban runoff. Nutrients and sulfur in major rivers (such as the Kissimmee and Caloosahatchee) and in canals draining the EAA affect Lake Okeechobee, the Everglades wetlands, and estuaries. These changes in water quality affect wetland vegetation. Replacement of the normal diversity of Everglades plants with cattails creates unsuitable habitat for Everglades animals, including fish and wading birds. Scientists have observed that the wetland area dominated by cattail is expanding, and if unchecked, could soon affect major portions of the remaining Everglades.

The evidence that the changes in surface and groundwater flows and water quality have had negative effects on habitats and organisms includes a 90% reduction in wading bird populations, 69 species on the federal endangered or threatened list, widespread invasion by exotic species, declines in commercial and recreational fisheries in Biscayne and Florida Bays, a significant decrease in the number of Everglades tree islands, the invasion of coastal sawgrass prairies by mangroves and compositional and structural changes in habitats throughout the region.

Addressing the Unintended Consequences of Growth

Overview of the Restoration Effort

By the 1970s and 80s the imbalance between natural system functioning and the growth of urban, agricultural, and other human uses had become a focus of decision making in Florida, as well as in Washington D.C. Since that time, a growing body of state, federal, tribal, and local programs and massive appropriations have been directed at restoring and protecting the natural environment of South Florida.

During the past two decades the Florida Legislature and the U.S. Congress have enacted a series of laws to redress environmental harm to the Everglades. Many of these laws provide the authorities under which the state and the federal governments operate and fund programs that collectively comprise the

South Florida restoration effort. In 1992 Congress directed the U.S. Army Corps of Engineers (USACE) to take steps to restore the Kissimmee River floodplain, which was disrupted when the river was channelized during the 1960s. In 1996 Congress established the intergovernmental South Florida Ecosystem Restoration Task Force (the Task Force) to coordinate the restoration efforts among the state, federal, tribal, and local agencies involved in the effort. At that time Congress also directed the USACE to submit a comprehensive review study of the C&SF Project for the purpose of modifying the project to restore, preserve, and protect the South Florida ecosystem. In 2000 Congress authorized the implementation of the $8 billion *Comprehensive Everglades Restoration Plan* (CERP), which will be implemented over the next four decades by the federal and state governments. The CERP will modify the C&SF Project to increase future water supplies for the purpose of restoring the Everglades to a more natural state, while also providing for other water-related needs in the region.

As public land managers of much of the Everglades, and with program responsibilities for fish and wildlife and Indian trust responsibilities, DOI plays a key role in the intergovernmental effort to restore and protect the natural resources located within the South Florida ecosystem. This is a collaborative effort, in which coordination among many agencies at all levels of government is critical to the successful restoration of the ecosystem. Within this collaborative work environment, DOI is both a steward, with specific mandates from Congress, and a partner, working with other agencies to achieve their own particular mandates in ways that are most advantageous to the ecosystem as a whole.

The Department of the Interior as Steward and Partner

Two DOI bureaus, the U.S. Fish and Wildlife Service (FWS) and the National Park Service (NPS), are responsible for the resource stewardship and public use of extensive public federal lands in the region, including Everglades National Park (the largest national park east of the Rockies), Biscayne and Dry Tortugas National Parks, Big Cypress National Preserve, and the Arthur R. Marshall Loxahatchee, Florida Panther, National Key Deer, and Ten Thousand Islands National Wildlife Refuges. The FWS has responsibilities for threatened and endangered species and other species of concern under such authorities as the Fish and Wildlife Coordination Act, the Endangered Species Act, and the Migratory Bird Treaty Act. DOI also has a trust responsibility for American Indian communities, including the Seminole and Miccosukee Indian Tribes.

DOI also chairs the Task Force, which provides a forum for sharing information, coordinating research, and facilitating the integration of the work efforts of the many agencies involved in ecosystem restoration. The Task Force has set three overarching goals for South Florida restoration:

1. Get the water right.
2. Restore, preserve, and protect natural habitats and species.
3. Foster compatibility between the built and natural systems.

The CERP is the foundation for Everglades restoration. The overarching goal of the CERP is "the restoration, preservation and protection of the South Florida ecosystem, while providing for other water-related needs of the region, such as flood protection and water supply." Led by the USACE and the South Florida Water Management District (SFWMD), the CERP is the blueprint for a significant portion of ecosystem restoration activities in South Florida. The CERP focuses on improving the quantity, timing, and deliveries of fresh water feeding the system. It also addresses improvements in water quality. These hydrologic improvements are anticipated to contribute to restoring natural terrestrial, estuarine, and marine habitats, which will promote the restoration of biological functions.

However, these improvements are insufficient, by themselves, to restore and sustain the ecosystem. Restoring habitats and biological function will require additional efforts, such as removing invasive

exotic species and reintroducing and recovering species. Ultimately restoration success will depend on implementing a reasonable balance between human needs and the needs of the ecosystem. South Florida's 'built environment' has experienced unprecedented accelerated growth over the past several years with increasing pressure on natural resources. Much of this developing landscape is sandwiched between Everglades and Biscayne National Parks. Restoration of the Greater Everglades requires sustainable compatibility of the built and natural systems; specifically, flood control, water supply and water quality.

The Role of Science in Ecosystem Restoration

The initiative to restore the South Florida ecosystem is unprecedented in its scope and complexity, and it will require innovative solutions and long-term commitments. The challenges faced by restoration managers are daunting: to understand the effects of nearly a century of wetland drainage and impoundment for water supply, flood protection, and development, and to acquire and utilize the information needed to restore the health of this unique ecosystem.

The Congress has directed that this complex restoration effort be guided by, and continuously adapted to reflect, the best science available. This will require an open and continuous dialog between scientists and managers. Two recent (2003) reviews of science programs—the Critical Ecosystems Study Initiative, conducted by the National Academy of Science (NAS), and the Science Coordination in South Florida report, conducted by the General Accounting Office (GAO)—identified the improvement of science coordination, the synthesis and integration of research data, and the communication of research findings to managers as high priority tasks for Everglades restoration. This strategy will guide how the Department of the Interior meets these priority tasks and will be the basis for integrating DOI science investment into the larger habitat restoration and management efforts.

The USACE has established a multi-agency Restoration Coordination and Verification Team (RECOVER) to support the implementation of the CERP with scientific and technical information. Science is being integrated into management of CERP components through an iterative process of research, modeling to identify targets and goals, project planning, project implementation, monitoring, assessment, and adaptive management. An ever-increasing body of knowledge and understanding of this complex system is providing new approaches to restore and protect the Everglades. DOI is a partner in developing and maintaining this scientific basis in support of RECOVER and the CERP. The science, which must continue to evolve, with the information synthesized into tools that can be used by managers to inform their decisions. In addition, DOI pursues science to support many non-CERP components of ecosystem restoration.

Ongoing Interior Science Efforts

In March 2002 the DOI Office of the Secretary, NPS, FWS, and USGS entered into a memorandum of understanding to coordinate all ongoing and future monitoring, research, planning, and interagency coordination activities supporting South Florida restoration. This coordination will facilitate the leveraging of resources and the development and use of the best available research products and monitoring and assessment tools responsive to the needs of NPS and FWS managers.

ES (CESI) and the USGS Priority Ecosystem Science (PES) program are DOI's primary science programs supporting South Florida management and restoration efforts. The USGS, the principal science arm of DOI, provides physical and biological sciences information, independent of the other bureaus. This science facilitates understanding of how the ecosystem functioned in the past, and assists in developing management tools, including landscape-scale models, to evaluate the impacts of proposed actions to restore the Everglades natural system. The purpose of the CESI and PES programs is to provide the

scientific information DOI managers need to fulfill their resource management and technical advisory responsibilities and to do a better job of targeting research to meet on-the-ground management needs. These programs have already provided a rich database of information about how the ecosystem functions and how the natural system has been altered. Information from the modeling, planning, and monitoring programs helps DOI managers understand the complex ecological and hydrologic linkages that affect DOI lands and other managed resources, set management priorities, and effectively participate in restoration decision processes.

More specifically, the scientific work accomplished over the past decades through CESI, PES, and other DOI efforts has

- contributed to the development of the Natural System Model, which simulates the predrainage hydrology of the Everglades
- clarified linkages between hydrologic conditions and ecosystem attributes
- produced tools to predict how the current system might respond to restoration of historic hydrologic conditions
- determined the background levels of nutrients needed to keep Everglades vegetation from converting to species tolerant of higher nutrient doses, such as cattail
- contributed to the understanding of the interactions of the Everglades surficial aquifer system and the canals, and of problems of seepage and seawater intrusion

DOI managers have focused early science efforts on restoration projects such as the Everglades Construction Project, the Modified Water Deliveries to Everglades National Park Project, and the C-111 Project, which directly impact DOI lands and are scheduled for completion within the next five years. Information derived from these early projects will inform larger scale restoration decisions and improve the design of future CERP projects.

Purposes of the Department of the Interior Science Plan

To support ongoing restoration efforts, DOI and its bureaus developed this science plan to identify the science needed to support DOI managers in fulfilling their stewardship responsibilities and to support DOI's efforts as a partner in implementing the CERP.

DOI science will assist in the intergovernmental effort to answer three overarching restoration questions:

What actions will improve the quantity, timing, and distribution of clean fresh water needed to restore the South Florida ecosystem?

What actions will restore, protect, and manage natural resources on DOI lands in South Florida?

What actions will recover South Florida's threatened and endangered species?

Success in addressing these three overarching questions at ecological scales ranging from individual species and communities, to individual parks and refuges, to the Greater Everglades requires a well-coordinated, collaborative, and integrated effort among all participating agencies. None of these questions can be answered independently. Furthermore, each of these questions raises more specific questions about all the interrelated variables affecting the condition of the ecosystem, including hydropatterns (the quantity, timing, and distribution of water), water quality, ecological responses of biological communities and species to changes in water quantity and quality, the role of fire, the effects of

invasive exotic species, the effects of adjacent land uses on natural areas, and the effects of public use of parks and refuges.

It is critical that science-based input synthesizing research, modeling, monitoring, and analysis be both timely and relevant to DOI managers' decision-making information needs. This DOI science plan identifies the key projects and information needs of DOI managers as they fulfill their roles as stewards and partners in South Florida. It describes what is known for each project and what science is needed to help ensure that the project results in intended consequences within the ecosystem. Finally, it identifies a strategy for coordinating and prioritizing DOI research or activities based on managers' needs for information to support decision making. By identifying the specific science needed by managers to make adequately informed and timely decisions, and by including the methods and tools needed to make this scientific information readily available to managers, this science plan provides the basis for ensuring that DOI investment in science is effectively integrated into the effort to restore the South Florida ecosystem.

The timetable for the CERP and other restoration projects is an important framework for ecosystem research. However, it will not be possible to resolve all scientific uncertainties before restoration projects are implemented. Managers will rely on an adaptive management approach to ensure that desired results are achieved through a process of monitoring, assessment, and refinement. This will require continuous collection of field data and scientific research to clarify an expanding understanding of the Greater Everglades ecosystem. The external reviews of South Florida ecosystem science coordination conducted by GAO and NAS identify needs for monitoring progress, additional research on ecological processes, model refinement, and improved tools for implementing adaptive management, including mathematical models. This science plan responds to those key findings of the GAO and NAS reviews.

Next Steps – Prioritizing Scientific Research and Synthesizing Results

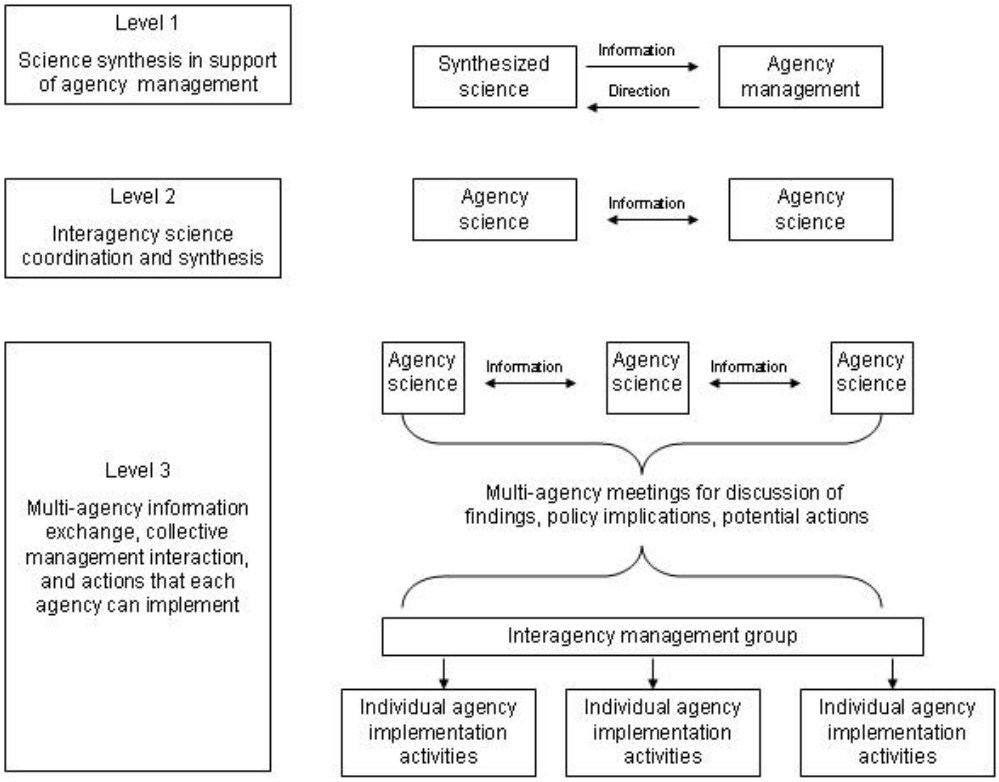
DOI managers will annually prioritize the science needs identified in this plan based on the need to inform land or water management decisions for DOI managed lands and resources, the time period for when scientific input is needed, and/or the extent to which the scientific needs may be unmet by other restoration partners. DOI intends to invest resources to synthesize and disseminate scientific results for managers as part of its responsibilities. The funds supporting the implementation of this science plan will come partly from the available DOI appropriations, such as the CESI (administered by the NPS) and the PES program (administered by the USGS). Other funding sources include DOI's CERP partners, the USACE and the SFWMD. The funding sources will be determined based on the role of each partner in restoration activities and their responsibility for producing the scientific results of interest.

The timetable for the CERP and other restoration projects is an important framework for ecosystem research. However, it will not be possible to resolve all scientific uncertainties before restoration projects are implemented. Managers will rely on an adaptive management approach to ensure that desired results are achieved through a process of monitoring, assessment, and refinement. This will require continuous collection of field data and scientific research to clarify an expanding understanding of the South Florida ecosystem.

Once the data are collected the next step is the synthesis of data into usable information. Currently, the development and utilization of scientific information generated by the Department's bureaus occur at three levels (see figure below). On level one, agency managers identify information needs and pass them to their agency scientists. In return, scientists synthesize the available information to inform the managers' decision-making process. Managers often provide feedback to the scientists during the reporting of the information, allowing for an exchange in information to better inform and accommodate

changing needs. This level one synthesis requires technical staff who are trained and experienced in synthesizing science in ways that best support the managers' needs.

On level two, scientists communicate research findings across agencies. This occurs informally by person-to-person contact or more formally at local and national meetings on a particular discipline or topic. The Department's Science Plan, which synthesizes the science needed to answer the major questions critical to the management of all of the Department's trust resources in South Florida, is an example of this level of synthesis. The plan is being used to gain consensus about the highest priority information gaps across all the Department's bureaus and to eliminate duplicative efforts in filling those gaps. Collaborative research by agencies and universities is another example. The Greater Everglades Ecosystem Restoration (GEER) conference is a regional meeting that strongly encourages this level of synthesis, with the added advantage of providing a forum for multidisciplinary exchanges. Other meetings to synthesize information are being considered for topics including the hydrologic impact on ecology; the role of ecosystem history in assessing/predicting historical, current, and future changes in the landscape; the influence of restoration on contaminants (including sulfur and mercury); and the mining of hydrologic flow and stage data to differentiate the influences of sea level rise, water management, and major climatic events on hydrologic dynamics in freshwater flows and coastal interactions.



Another important aspect of science synthesis is integration of activities that have a common theme. This integration can take many forms, such as periodic meetings among participants in related activities to share information about issues, successes, and failures and to coordinate methods and analyses to advance a collective understanding. A method of information synthesis that is often overlooked by the scientific community is the distillation of complex research findings into condensed, concise, well-

illustrated briefing-style publications. The USGS model for such publications is being adopted by other Department agencies for all new science activities.

In addition to the technical capabilities required at level one, level two synthesis requires protocols and communication processes to improve the quality of collaboration and information exchange among scientists.

The third level of synthesis occurs when information collected by various agency and university scientists is jointly presented with the goal of information exchange and informing a collective group of managers. The managers discuss the findings, examine management or policy implications, and set a course of action to incorporate the key insights derived from the scientific information exchange. The Task Force's plan to coordinate science and its Avian Ecology Workshops are examples of the third level of synthesis. In its plan to coordinate science, the Task Force has reviewed strategic science program areas and identified key gaps for further collaborative action. In the avian workshops, the Task Force assembled a panel of scientists who developed a synthesis report from numerous scientific presentations for consideration by the Task Force Working Group. The FWS is directing a substantial new research effort to fill the information gaps identified by the panel.

In addition to the technical capabilities, protocols, and processes required by levels one and two, level three synthesis requires collaborative policies and managers skilled in interagency cooperation and coordinated management.

A key component of the Department's synthesis activities is the effort to integrate its science into the CERP. In the authorization for the CERP (WRDA 2000), Congress asked the Corps to develop programmatic regulations that, among other things, "ensure that new information resulting from changed or unforeseen circumstances, new scientific or technical information or information that is developed through the principles of adaptive management contained in the CERP, or future authorized changes to the CERP are integrated into the Plan." Effective and informed adaptive management requires the synthesis of experimental research (understanding how the ecosystem operates), ecosystem monitoring (observing change), and forecast modeling (predicting change). Much of the earlier research on the South Florida ecosystem focused on establishing a basic understanding of ecosystem structure, processes, and functions. In addition, previous and current research on development of ecological, hydrologic, and chemical models provides a mechanism for synthesizing the data and information into a better understanding of integrative processes within the ecosystem. Although additional experimental/empirical research and model development are still needed, with the recent development of the CERP-related MAP, the opportunity is emerging for greatly improving the synthesis of experimental, monitoring, and modeling studies to effectively inform restoration planners and decision makers.

The Department's management bureaus identified the need for including ecological models in the evaluation of CERP project alternatives and the critical role that the Department needs to play in the IMC. Therefore, PES managers are increasing funding for ecological modeling studies and initiating a new study to implement ecological modeling at the IMC. They also are continuing to evaluate the Department's role at the IMC and will likely be stationing additional NPS personnel at the IMC in the near future.

2. PRIORITIZATION OF SCIENCE RESOURCE ALLOCATIONS

Prioritizing science needs for ongoing South Florida restoration is integral to the DOI mission as steward and partner with other federal and state agencies. With the enactment of the CERP it is important not only that appropriated funds be targeted at the highest priority research, planning, and interagency coordination needs of the restoration effort, but also that this prioritization be coordinated both within DOI and with state, federal, and other partners. This coordination leverages resources, maximizes the value of federal funds, and results in the best available research products and monitoring and assessment tools responsive to the needs of the NPS, the FWS, and DOI's CERP partners.

Prioritizing the science needed to support South Florida restoration begins by focusing on three key program areas benefiting DOI's resources and mission in South Florida:

1. Activities to improve the quantity, timing, and distribution of clean fresh water needed to restore the South Florida ecosystem
2. Activities to restore, protect, and manage natural resources on DOI lands in South Florida
3. Activities to recover South Florida's threatened and endangered species

The following chapters briefly describe key projects that support these program areas and summarize the remaining science needed to plan and adaptively manage these projects. Taken together, the restoration and resource management projects represent the high priority DOI science information needs critical for supporting restoration and management of the South Florida ecosystem.

The USGS, in consultation with the NPS and the FWS, is developing a process for prioritizing the science needs relevant to the restoration and resource management projects identified in this science plan. This process utilizes a multi-tiered approach to assist in prioritizing critical science information needs. The prioritized list generated from this process will be the foundation for DOI's annual science funding strategy. This tiered approach looks at a number of factors:

- The relevance of the science effort to improving understanding of the ecological and hydrologic processes affecting DOI lands and resources
- The applicability of the science to multiple DOI restoration objectives or multiple projects
- The applicability of the science to the development and refinement of performance measures and targets used to evaluate and assess restoration success
- Synthesis and sequencing to address the most urgent management information needs
- Maximization of cost-share opportunities and science coordination across bureaus or with DOI's CERP partners

Using this process, managers and scientists from the NPS, FWS, and USGS will annually review the benefits of DOI-funded science towards supporting DOI managed lands and resources, and the sequencing and timing requirements for that science. The NPS/FWS/USGS team will then recommend

an annual funding strategy and propose how available funds from the NPS CESI and USGS PES programs should be used to target scientific efforts yielding the greatest benefit related to DOI's responsibilities in South Florida. This strategy will take into account the ongoing research funded by other partners and stakeholders to avoid duplication and to maximize the use of other scientific efforts.

The prioritization process outlined above emphasizes a primary goal of achieving economies of scale by effectively integrating science programs from many different jurisdictions, including the private sector. The NPS, FWS, and USGS will continue to proactively seek out partnerships and improve existing ones to maximize scientific inquiry.

Finally, the prioritization process will emphasize coordination in developing annual funding proposals to implement DOI research, monitoring, and assessment programs supporting South Florida restoration activities

3. PROJECTS TO IMPROVE THE QUANTITY, QUALITY, TIMING, AND DISTRIBUTION OF WATER

Introduction

This chapter addresses DOI interests in individual water projects and the corresponding needs for scientific and technical information to help ensure that the projects achieve their intended purposes consistent with the legal mandates assigned to DOI agencies.

Overview of Water Management Activities and Authorities

Projects to increase environmental water supplies and restore more natural surface and groundwater flows are the core of the South Florida restoration initiative. The changes in the regional hydrology created by the C&SF Project have resulted in a sharp decline in the natural abundance and diversity of organisms in the Greater Everglades. Without corrective actions to restore the predrainage hydrology, natural ecosystem functions cannot be recovered.

Because half of the historical original Everglades has been drained and developed, it will be impossible to restore the entire ecosystem to predrainage conditions. However, managers and scientists believe that for the remaining Everglades it will be possible to achieve a healthy and functioning ecosystem that once again exhibits the essential characteristics of the predrainage system. These characteristics include more natural hydropatterns, including wet and dry season cycles, natural recession rates, natural surface water depths and patterns, and in coastal areas, natural salinity and mixing patterns. These characteristics are a precursor to achieving anticipated ecological benefits, which include improving native flora and fauna, restoring the presence of key species in historic habitats, and promoting natural patterns of plant communities ranging from aquatic communities to uplands.

The water engineering projects required for this initiative are coordinated primarily by the USACE and the SFWMD through the CERP and other project authorities. The water project managers are ultimately responsible for ensuring that the projects under their jurisdiction are producing the desired ecological improvements in the Greater Everglades. As a partner with specific authorities for the protection of fish, wildlife, and parks, DOI works cooperatively with the USACE, the SFWMD, and the Florida DEP to ensure that the improvements planned to restore a more natural hydrology to South Florida adequately consider the intended, anticipated, and actual responses within the ecological communities based on the best possible scientific information and analysis.

Restoring more natural surface and groundwater flows must address four interrelated factors: the quantity, quality, timing, and distribution of water. More water is not always better. Alternating periods of flooding and drying were vital to the historical functioning of the Everglades ecosystem. In general, the CERP and other water management projects include five kinds of engineering components for capturing and redirecting water to simulate a more natural system:

surface water storage reservoirs and water control structures

aquifer storage and recovery systems

projects to remove barriers to sheetflow

seepage management projects

operational changes in water delivery schedules

Together these components are planned to recapture much of the 1.7 billion gallons per day of water currently being discharged via canals into Biscayne and Florida Bays, the Straits of Florida, and the Gulf of Mexico. This water will be used to restore natural system functioning and to supplement urban and agricultural water supplies.

A major focus of DOI participation in the water engineering projects is on ensuring that the timing and distribution of water flows to wetlands, especially in the national parks and federal wildlife refuges, mimic natural flow patterns and preserve natural wetland functioning. Natural flows are driven by the seasonal rainfall patterns in the region, and the restoration project components must be designed and operated to mimic this natural variability. For example, the FWS is assisting the Corps and the South Florida Water Management District in revising the regulation schedule for Lake Okeechobee. Regulation of Lake Okeechobee is central to water management in the rest of the C&SF system. This provides an opportunity to not only improve habitat conditions within the littoral zone of Lake Okeechobee, but also influences conditions in connected areas, including the St. Lucie and Caloosahatchee estuaries and the Water Conservation Areas.

Another DOI concern is that the quality of the water used to rehydrate the landscape must be suitable for natural system functioning. The desired responses by plant and animal communities to the right amounts of water being available in the right places and at the right times will not occur unless the quality of the water meets the appropriate water quality standards. The CERP includes a number of construction projects, primarily reservoirs and stormwater treatment areas, specifically designed to ensure that water delivered into the Everglades meets appropriate standards. Because phosphorus enrichment was one of the earliest and most serious water quality issues identified in the Everglades, many of these projects concentrate on controlling phosphorus in runoff from urban and agricultural lands. Recognizing the critical importance of water quality to ecosystem restoration objectives, the CERP calls for a Comprehensive Integrated Water Quality Feasibility Study (CIWQFS), which will outline water quality issues, and a plan for linking water quality targets to hydrologic targets.

DOI is particularly concerned about the potential harm to fish and wildlife from contaminants that might be released as a result of CERP projects. The rehydration of lands previously used for agriculture, water stored in underground aquifers, or water diverted or reclaimed from urban areas may reintroduce contaminants from the soils. This issue is not addressed as part of the water quality targets for CERP projects but must be addressed as part of the stewardship responsibilities of DOI.

DOI is also interested in improving fish and wildlife habitat and recreational potential of water storage reservoirs and other constructed features in ways consistent with the water management functions of the project features.

DOI collaborates with the USACE and SFWMD on three primary activities:

> **Ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology.** The CERP and other restoration projects focus on hydrologic restoration in natural areas, with the assumption that ecologic restoration will follow. The SFWMD Natural System Model simulates predrainage Everglades hydrology as a basis for identifying hydrologic

targets. Ecological responses are inferred based upon conditions observed in the current ecosystem. As new information is gathered and modeling techniques are improved, understanding of the predrainage Everglades will increase, and targets and plans will be refined. Because natural flows are critical to DOI responsibilities in South Florida, participation in the development, refinement, and calibration of hydrologic models of the predrainage Everglades is an important component of DOI science plan.

Ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values. The CERP is a conceptual plan that is expected to be refined as science is applied to critical restoration questions and as details of the ecosystem are better understood. Modeling tools are continuously developed, improved, and used to create more detailed plans and to predict their impacts.

Each CERP project has or will have a project management plan that describes the general scope of the project. Based on these scoping plans, more detailed implementation plans, called *Project Implementation Reports* (PIRs), are prepared and submitted to Congress for approval. These reports require compliance with the National Environmental Policy Act (NEPA) and include consultations required under the Endangered Species Act and the Fish and Wildlife Coordination Act. As part of each PIR, the USACE identifies the appropriate quantity, timing, and distribution of water to be dedicated and managed for the natural system. The state will reserve that water for the natural system under the provisions of state water law.

As PIRs are formulated for individual projects, local models and other techniques are used to forecast and evaluate possible impacts of the projects and to formulate interim goals. Data from DOI field studies on the hydrologic requirements of individual species, communities, and ecosystems are essential to improving the models used to predict the impacts of project alternatives.

Assess the responses of ecological communities and species as a basis for adaptive management. Once projects are underway, DOI monitoring will focus on the responses of ecological communities and species to changes in hydrology and water quality. Such information will provide the basis for adaptive assessment and management to ensure that water management projects result in the desired ecological effects. For projects that are not meeting interim goals, managers can make science-based adaptations and better plan for achieving the longer term goals.

Overview of Science Support for DOI Managers

South Florida has one of the most extensive hydrologic and ecological data collection and analysis efforts in the country, with contributions from numerous federal and state agencies, including DOI. The collected field data support modeling efforts that convert large amounts of technical information into planning and evaluation tools. These tools directly support project design and adaptive management. In order to meet the modeling challenges of the CERP, DOI should be an active and important participant in the Interagency Modeling Center (IMC), which was established to provide an environment to conduct work in an open and collaborative technical environment.

Hydrologic Research and Modeling

Regional "landscape-scale" hydrologic models are guiding the early CERP projects. Landscape-scale modeling helps managers understand and plan for how multiple projects will interrelate across broad geographic areas under multiple jurisdictions. The Natural System Model (NSM) is the most widely applied quantitative hydrologic model to date. It provides regional scale estimates of South Florida's predrainage hydrology.

While the NSM provides a picture of the historic, predrainage Everglades, the South Florida Water Management Model (2 x 2 Model) provides a picture of how the regional water management system works. At a scale of 2 square miles, this landscape-scale model simulates regional predictions of the hydrologic conditions that would occur given changes in water management in South Florida. The 2 x 2 Model has been used for nearly two decades to evaluate the consequences of modifications to the C&SF Project. The acquisition of the basic data needed to support the model (evaporation, rainfall, geology, vegetation, water levels, topography, etc.) has been a priority for many years, and the model is "complete," although it is continuously updated. Groundwater flows have been added to improve some simulations of hydrologic conditions, but all the subsurface simulations end at the mainland shoreline rather than extending to the continental margin. The NSM Model is derived from the 2 x 2 Model and is continuously updated with that model to ensure that the inputs to each are the same.

A next generation hydrologic model that uses higher resolution in key areas, known as the South Florida Regional Simulation Model (RSM), is being developed by the SFWMD. Two higher resolution (500 x 500 meters) hydrologic models, known as the TIME and SICS, are available for the southern Everglades and are being used to predict salinity in the coastal wetlands. Additional models, particularly at local levels, and linkages among models are needed for the detailed design and adaptive management of individual projects.

Changes in the hydrology of the South Florida ecosystem will ultimately cause changes in downstream estuaries and embayments. Because hydrologic models used to design the CERP do not accurately represent groundwater and surface water flow without uncertainties, surface water and groundwater inputs into coastal estuaries such as Florida and Biscayne Bays, many questions remain regarding the link between changes in water management and the salinity and water quality in these estuaries. The Florida Bay Interagency Science Program is integrating the research, modeling, and monitoring projects needed to understand how the bay currently functions and how it will function in the future as part of the South Florida ecosystem. DOI interests in projects affecting Florida Bay and Biscayne Bay are addressed for each individual project.

Ecological Research and Modeling

The natural vegetation of the Everglades is a mosaic of dozens of different community types, each with its own hydrologic and nutrient requirements, many of which fluctuate widely over the course of a year. And just as vegetation patterns can be influenced by the presence or absence of water, vegetation patterns can also influence hydropatterns, thus affecting water flow and/or the transport of nutrients.

Computer models are used to project and evaluate how vegetation and wildlife in the South Florida ecosystem will respond to changes in hydrology and land use. These models combine detailed spatial information about elevation and current vegetation patterns with landscape-scale models of hydrology and include assumptions about ecological processes, such as nutrient transport and vegetative succession. It is important that the scale of models applied for ecological restoration match the scale of the problem being addressed.

During the development of the CERP, a set of ecological models were used to predict ecological responses to various water management scenarios in the Everglades ecosystem. These models were driven by the 2 x 2 Model and the higher resolution hydrologic models developed for the southern Everglades. New models are being developed that will output hydrologic data in different forms, which will enhance the compatibility between the hydrologic and the ecological models. While not yet as mature as the hydrologic models, the ecological models are useful for projecting the effects of hydrologic change on biotic communities and certain endangered species.

Three general kinds of ecological models are used to predict the ecological effects of the various CERP projects: Models of vegetative production, habitat suitability index (HSI) models, and faunal demographic models. HSI models produce maps indicating the spatial pattern of habitat suitability for particular species. Demographic models project how population size may change through time as a function of the changing environment. Such models are essential for performing population viability analyses to determine the risk of extinction.

As individual projects are designed and implemented, they will be based on the most up-to-date scientific knowledge currently available. As models are improved and additional models are developed, projects will be adaptively managed to increase the potential for restoration success.

Water Quality Research and Modeling

Degradation of water quality is pervasive throughout the Greater Everglades, particularly in agricultural and urban coastal areas. The past 20 years have seen extensive field and laboratory investigations used to determine the phosphorus standard that would protect the natural ecological conditions within the Everglades. These investigations are summarized in the SFWMD *Consolidated Reports*. The Environmental Protection Agency (EPA) and the USGS have worked on many other aspects of contaminants in the Everglades, and the EPA has summarized the available knowledge about water quality parameters such as mercury, nitrogen, and pesticides. In addition to the water quality study included in the CERP, which focuses on restoration targets for nutrients and bacteria, DOI is pursuing a science program to support the assessment and management of contaminants that could be introduced into the system as an indirect effect of water engineering projects.

Monitoring and Adaptive Management

WRDA 2000 authorizes the USACE to adaptively manage the ongoing CERP program to continuously incorporate new scientific and technical information into projects. This adaptive assessment and monitoring program will be used to refine and improve the design and operation of CERP projects and to determine whether the CERP is achieving its overarching objective of recovering healthy and sustainable ecosystems in South Florida. The adaptive management program is being carried out by "RECOVER," which is an interagency team of scientists and technical staff being led jointly by the USACE and the SFWMD. DOI scientists and technical staff serve on the RECOVER leadership group and co-chair some of the RECOVER subteams.

A RECOVER Adaptive Assessment Team (AAT) has developed a systemwide *Monitoring and Assessment Plan* (MAP), which establishes a framework for (1) measuring and understanding systemwide responses to CERP projects, (2) determining how well the CERP is meeting its goals and objectives, and (3) identifying opportunities for improving the performance of the CERP where needed. The MAP will provide a single, integrated plan for participating agencies, including DOI, to measure systemwide responses and the performance of the CERP.

Two key assumptions have been made that will be critical to the success of MAP implementation: (1) Existing monitoring will continue with existing funding sources (i.e., the MAP does not replace other agency efforts). (2) Partnering agencies will contribute funding and/or will participate in implementation of the MAP.

The MAP addresses only responses expected from implementation of CERP projects and does not include all of the components necessary to achieve long-term restoration of the South Florida ecosystem.

Examples of ongoing monitoring activities that are independent of the MAP include weather and water stage monitoring stations (USGS), salinity monitoring networks in Everglades and Biscayne Bay National Parks (NPS), and the American alligator survey network (CESI).

Organization of Water Projects

The remainder of this chapter discusses 21 projects designed to improve the quantity, quality, timing, and distribution of water flows in the region. The project-specific science needs are identified for each project. The projects are organized into the following six subdivisions:

Kissimmee-Okeechobee Watershed and the Everglades Agricultural Area

Upper East Coast

Loxahatchee

Water Preserve Areas and Seepage Management along the Marsh/Urban Interface

Lower West Coast

Everglades National Park, Biscayne Bay, and Florida Bay and Keys

In addition, a summary of the "Landscape-Scale Science Needed to Support Multiple CERP Projects" is provided at the end of this chapter. This science includes

Landscape-Scale Modeling

Comprehensive Integrated Water Quality Feasibility Study

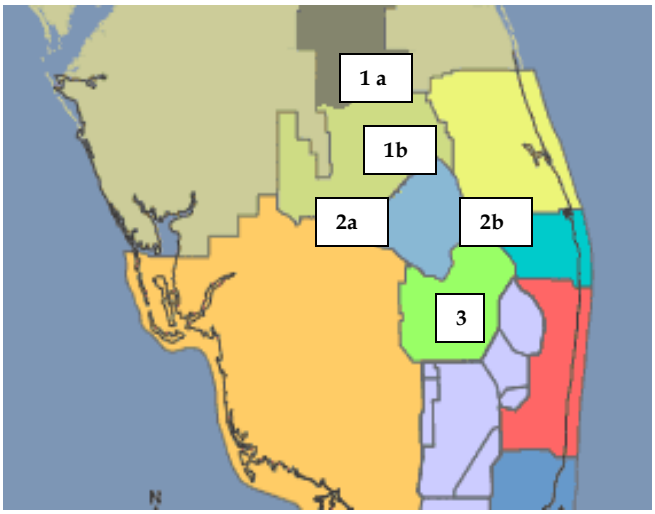
Studies to Support Fish and Wildlife Friendly Siting and Operation of Reservoirs, STAs, and ASR Structures

Risks to Fish and Wildlife from Contaminants

Landscape-Scale Monitoring and Assessment

Kissimmee-Okeechobee Watershed and the Everglades Agricultural Area

PROJECTS



1. Kissimmee-Okeechobee Watershed Projects: Kissimmee River Restoration and Lake Okeechobee Watershed
2. Aquifer Storage and Recovery
3. Everglades Agricultural Area Reservoirs

Overview

Historically, Lake Okeechobee served as the primary regulator of flows into the Everglades. Rainwater from the Kissimmee Valley flowed south to Lake Okeechobee. The lake would periodically overflow its banks, and water would continue its slow journey southward through a 60-mile-wide shallow river flowing over the flat and level grasslands of the Everglades.

The Kissimmee-Okeechobee watershed projects (#1 on the map) are proposed to restore natural flows and storage in the Kissimmee basin and to improve riverine and wetland habitats throughout the region. The CERP water storage projects around Lake Okeechobee (#2 and #3) are intended to provide the water management capability to restore a more natural hydrology to Lake Okeechobee and to release water in more natural patterns into the downstream Everglades.

The major DOI interests in these projects fall into three broad categories: the effects on habitats and species within the Kissimmee-Okeechobee watershed, the quality of the water captured for release into the downstream Everglades, and the timing of releases of stored water into the downstream Everglades.

The Kissimmee-Okeechobee watershed supports a great number of federally protected species, including many wide-ranging species such as the Florida panther, wood stork, bald eagle, and West Indian manatee. DOI is concerned about the loss of habitat that will result from the construction and operation of the large reservoirs (four included in the Lake Okeechobee Watershed Project, three in the Aquifer Storage and Recovery Pilot Project, and three in the Everglades Agricultural Area Reservoirs Project). Many of the project areas have important fish and wildlife habitats, including increasingly rare upland forest and prairie habitats and natural wetlands. In an effort to minimize impacts to these lands while planning for and constructing these facilities, the FWS has developed a GIS-based tool to incorporate data on rare habitats, biodiversity, and threatened and endangered species for the Lake Okeechobee Watershed Project. This GIS tool will be refined and used to consider fish and wildlife values when selecting sites for all the large storage reservoirs.

Additional studies of population distributions and abundance will fill gaps in the databases for federally protected species, along with research and monitoring to anticipate and track species' responses to habitat changes. Landscape-scale restoration in the Lake Okeechobee watershed will require decisions that balance the needs of one species or trophic level with another or that maximize biodiversity within the system. For example, the restoration of wetland habitat, while expected to benefit many communities and species, must be achieved in a way that minimizes the risk to threatened and endangered species, including Audubon's crested caracara and the Florida grasshopper sparrow, that have adapted to the drier conditions created by the C&SF Project drainage canals.

The timing and distribution of water deliveries from these water storage projects into the natural areas in the Kissimmee-Okeechobee watershed and also into the downstream Everglades is critical to the recovery of habitats and species. DOI needs to assist the USACE in developing rainfall-driven operating protocols that will mimic the natural timing and distribution of water to natural areas throughout the ecosystem.

The quality of the water captured in these storage projects could be affected by contaminated soils, in areas where former agricultural lands will be flooded to create reservoirs, and by unnatural levels of metals and other contaminants leached from geologic formations, where in-ground wells will be used to store water.

DOI managers can most effectively participate in CERP projects during three project stages: (1) NEPA scoping in the early stages of project design, to help ensure that hydrologic targets accurately reflect the natural predrainage conditions, (2) review of project alternatives, to ensure that fish and wildlife and parks are adequately considered in compliance with DOI mandates, and (3) monitoring and assessment of project results, to support project modification if needed to ensure that the intended conditions are achieved. The major questions that DOI managers need to answer at each stage to effectively fulfill their responsibilities as partner and steward are summarized below, along with the highest priority science needs for answering those questions. This information is discussed in greater detail for each individual project following this summary.

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN THE KISSIMMEE-OKEECHOBEE WATERSHED AND THE EVERGLADES AGRICULTURAL AREA

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	**Lake Okeechobee, Lake Okeechobee Watershed and Kissimmee River Restoration**		
	What operating protocols for these projects will mimic the natural predrainage hydrology in the Kissimmee-Okeechobee Watershed?	Research and possible model refinement to establish operating protocols	NEPA Scoping Lake Okeechobee Watershed Completed Kissimmee River Restoration
	Aquifer Storage and Recovery		
	Will recovered ASR waters be of adequate quality to discharge into natural areas?	Water quality studies	NEPA Scoping ASR Pilot Projects Completed Pilot Project Design Report (PPDR) Complete ASR Projects Currently scheduled to start directly following completion of the pilots in November 2009
	EAA Reservoirs		
	What hydrologic targets will mimic historic flows (including water depths, timing, and distribution) and water quality in the water conservation areas and Everglades National Park?	Research and modeling to refine hydrologic targets, including targets for water quality	NEPA Scoping Phase 1: 2001 Phase 2TBD
	What operating protocols for releases of reservoir waters will mimic the natural predrainage hydrology in the Everglades?	Research and possible model refinement to establish operating protocols	
	What water quality hazards are associated with storing water on former agricultural lands, and how can they be avoided?	Environmental risk assessments of water quality contaminants	
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	**Lake Okeechobee , Lake Okeechobee Watershed and Kissimmee River**		
	Where should treatment wetlands and reservoirs be sited to minimize negative impacts on flora and fauna in the basin and where possible to provide additional habitat benefits?	Studies of threatened/endangered species population distributions and abundance. GIS mapping of habitat	EIS Review, Section 7 Consultation, and CAR Lake Okeechobee Watershed Draft CAR: Feb 2006 Draft PIR/EIS May 2006 Final CAR: Jan 2007 Final PIR/EIS: April 2007 Kissimmee River Restoration Final CAR: 1992
	What are the potential benefits and adverse effects of the water treatment facilities and aboveground water storage reservoirs on watershed resources?	Research to evaluate effects on dry prairie species Research and modeling to evaluate effects on Everglade snail kites	
	Aquifer Storage and Recovery		
	What factors contribute to fish mortality at intake structures? What intake configurations will best reduce the potential for impacting aquatic organisms?	Studies of the effects of intake pumps and control structures	EIS Review, Section 7 Consultation, and CAR ASR Pilot Projects Draft: June 2004 Final: November 2004 ASR Projects Currently scheduled to start directly following completion of the pilots in November 2009
	What are the tolerances of plants and animals to the ranges of water quality likely to result from ASR?	Research to understand the tolerance of plants and animals to changes in water quality	
	EAA Reservoirs		
	Are there design and operational improvements that could enhance the	Research to support design and operational rules to enhance	EIS Review, Section 7 Consultation, and CAR

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN THE KISSIMMEE-OKEECHOBEE WATERSHED AND THE EVERGLADES AGRICULTURAL AREA

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	ecological value of the reservoirs without reducing the intended purpose?	fish and wildlife resources	Phase 1 Draft: October 2005 Final: December 2005 Phase 2: TBD
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	**Lake Okeechobee, Lake Okeechobee Watershed and Kissimmee River Restoration**		
	What are the project effects on Audubon's crested caracara, Florida grasshopper sparrow, and Everglade snail kite? (Lake Okeechobee Regulation Schedule review is included with CERP and other C&SF Projects.)	Monitoring and assessment to determine species responses to habitat changes: • Audubon's crested caracara • Florida grasshopper sparrow • Everglade snail kite(and its prey, Florida apple snail) •	Post-implementation monitoring and assessment For proposed revision to Lake Okeechobee Regulation Schedule, monitoring of apple snail abundance in the lake's littoral zone must start in FY 06 and continue indefinitely.
	Aquifer Storage and Recovery		
	What are the project effects on fish and wildlife in target ASR locations? What are the effects of water recovered from ASR projects on fish and wildlife in downstream wetlands and estuaries? Does the Upper Floridan contribute to subsurface flows into Biscayne and Florida Bays? How will the Implementation of ASR in CERP affect the water quality, geohydrology and/or ecology in Biscayne or Florida Bay?	Baseline studies and monitoring at ASR locations Baseline studies and monitoring in downstream wetlands Geological description of the Floridan aquifer under peninsular Florida, the continental margin, and Biscayne and Florida Bays. Research and modeling to determine the effects to the ecology of Biscayne or Florida Bay.	Post-implementation monitoring and assessment
	EAA Reservoirs		
	What are the effects of the reservoirs on fish and wildlife values? What are the effects of water recovered from EAA reservoirs on fish and wildlife in downstream wetlands and estuaries?	Monitoring and assessment to determine the effects of the reservoirs on the natural system	Post-implementation monitoring and assessment Part 1,Phase 1Completion: Dec 2009 Part 1,phase 2 Complete 2015 Part 2 Completion: 2020

Kissimmee-Okeechobee Watershed Projects

Project Purpose and Major DOI Interest

The Kissimmee-Okeechobee watershed originates in the Kissimmee Chain of Lakes near Orlando and terminates where the Kissimmee River enters Lake Okeechobee. The watershed provides both upland and wetland habitats for more than 30 federally listed species.

Two restoration projects, with separate authorizations, within this watershed are of particular interest to DOI: the Kissimmee River Restoration Project, which predates the CERP, and the CERP Lake Okeechobee Watershed Project.

The purpose of the Kissimmee River Restoration Project is to restore 40 square miles of native river and floodplain habitat. Seven miles of the river have been restored, and this project has a priority to be completed as soon as possible.

The CERP Lake Okeechobee Watershed Project includes four separable elements[1] that were combined to address the interdependencies and tradeoffs between the different components. The purposes of this project are to improve the water quality of Lake Okeechobee, provide for better management of lake water levels, and reduce damaging releases to the estuaries. Water from the watershed and the lake will be captured during wet periods for later use during dry periods. Aboveground reservoirs will increase the storage capacity and reduce the duration and frequency of both high and low water levels in the lake (which are stressful to its littoral zone ecosystems) and reduce large discharges from the lake (which are damaging to the downstream estuarine ecosystems). Water from upstream tributaries will be diverted to STAs to reduce nutrient loading into the lake. In addition, the project will restore the hydrology of isolated wetlands by plugging the connections to drainage ditches and diverting canal flows to adjacent wetlands.

The Kissimmee River Restoration and the Lake Okeechobee Watershed Projects have the potential to significantly affect threatened and endangered species habitat in the Kissimmee-Okeechobee watershed. Dry prairie is one of the characteristic communities in the Kissimmee-Okeechobee watershed that supports the endangered Florida grasshopper sparrow and the threatened Audubon's crested caracara. It is also one of Florida's most endangered upland ecological communities. DOI is concerned about the timing and distribution of water deliveries and how they will affect habitats and species. DOI is also concerned that the construction of the Lake Okeechobee Watershed Project will convert 54 square miles of mostly upland agricultural lands that support Audubon's crested caracaras and Florida grasshopper sparrows into water treatment facilities and aboveground water storage reservoirs. Large reservoirs and treatment wetlands will effectively eliminate the fish and wildlife habitat values of the sites selected for these facilities. They need to be sited in locations that avoid harm to federally protected species and designed to potentially provide additional habitat benefits wherever possible.

Also, the Kissimmee Chain of Lakes is one of the main wetlands supporting the endangered Everglade snail kite, particularly during times of drought in South Florida. The Kissimmee Chain of Lakes has been

[1] These four projects are the North of Lake Okeechobee Storage Reservoir, the Taylor Creek/Nubbin Slough Storage and Treatment Area, the Lake Okeechobee Watershed Water Quality Treatment Facilities, and Lake Okeechobee Tributary Sediment Dredging.

plagued by human-caused nutrient enrichment, proliferation of exotic and nuisance aquatic plants, and static lake levels under the present water management system. Current management techniques to maintain shoreline habitat include extreme lake drawdowns, aggressive herbicide programs, and muck removal. Extreme drawdowns have been shown to severely reduce the amount of prey (apple snails) available for snail kites. Extreme drawdowns, coupled with post-drawdown herbicide treatments, create shoreline vegetation communities that are less likely to support snail kite nesting and foraging.

What Is Known

Only 16% of remaining dry prairie habitat in Florida is in conservation lands. The majority of loss of dry prairie habitat in this watershed has resulted from conversion to agricultural lands. According to the Central Florida Planning Council, counties within the watershed are likely to experience population growth rates above the South Florida average, making additional impacts on dry prairie habitats likely. If appropriately managed, existing agricultural lands, such as improved pasture, unimproved pasture, and rangeland may provide suitable habitat for Florida grasshopper sparrows and Audubon's crested caracaras.

The heart of the Audubon's crested caracara species distribution falls within the Kissimmee-Okeechobee watershed; however knowledge of the current distribution of Audubon's crested caracaras in this area is incomplete.

Six populations of Florida grasshopper sparrows are found on four tracts of land, one of which is in private ownership, all within the Kissimmee-Okeechobee watershed. Maintenance of the hydrologic and ecologic regime of dry prairies is required for Florida grasshopper sparrow feeding and breeding. With appropriate management, existing protected dry prairie lands can support existing populations of endangered Florida grasshopper sparrows. Recovery of the species will require restoring additional habitat to allow the species to occupy its historic range and increase its population size.

What Is Needed

Studies of threatened/endangered species population distributions and abundance. DOI needs better information on the distributions and abundance of Audubon's crested caracara, Florida grasshopper sparrow, and Everglade snail kite in the Kissimmee-Okeechobee watershed to make recommendations to the USACE regarding site selections and designs for the Lake Okeechobee Watershed Project. Once current distribution and habitat use have been characterized, restoration alternatives can be evaluated to minimize their impacts on these species' habitats and to maximize the enhancement of potential future habitats.

GIS mapping of habitat. In an effort to minimize impacts to the existing habitat where large reservoirs and treatment wetlands, that are part of the CERP, are being constructed, the FWS is refining a GIS-based tool to incorporate data on rare habitats, biodiversity, and threatened and endangered species for the Lake Okeechobee Watershed Project. This project will provide the data needed to maximize potential habitat improvements and minimize the negative impacts in the planning and construction of these management features.

Research and possible model refinement to establish operating protocols. DOI needs to provide recommendations to the USACE regarding the design and operation of water storage and treatment facilities to ensure that they do not have impacts on existing fish and wildlife and to maximize potential habitat benefits for species in the area. These recommendations need to be developed on a timeline that will allow input into alternative selection for each component of the project based on the most current knowledge available to support protection of fish and wildlife values.

Research to evaluate effects on dry prairie species. Research into the effects of alternative water management scenarios is necessary to define the best management for dry prairie species.

Research and modeling to evaluate effects on Everglade snail kites. Additional research and information is needed to support development of water regulation schedules in the Kissimmee Chain of Lakes and Lake Okeechobee that maintain and improve Everglade snail kite prey availability, nesting habitat, and foraging habitat in these regions (see "Avian Species Recovery," page). Detailed information about the effects of various drawdown scenarios on apple snail abundance, distribution, and recovery will allow the development of operating protocols to foster healthy apple snail populations, which are critical to Everglade snail kite recovery. Research will evaluate the effects of extreme drawdowns on snail kite foraging efficiency. A model will be developed to evaluate the cumulative effects on kite habitat due to lake drawdowns in the Kissimmee Chain of Lakes and other CERP projects. This information will also be applicable to an evaluation of potential effects on the population on a wider regional scale.

Monitoring and assessment to determine species responses to habitat changes. Information about the impacts of habitat changes on Audubon's crested caracara, Florida grasshopper sparrows, and Everglade snail kites will assist DOI in providing input into the adaptive management phases of these projects.

Aquifer Storage and Recovery Pilots and Regional Study

Project Purpose and Major DOI Interest

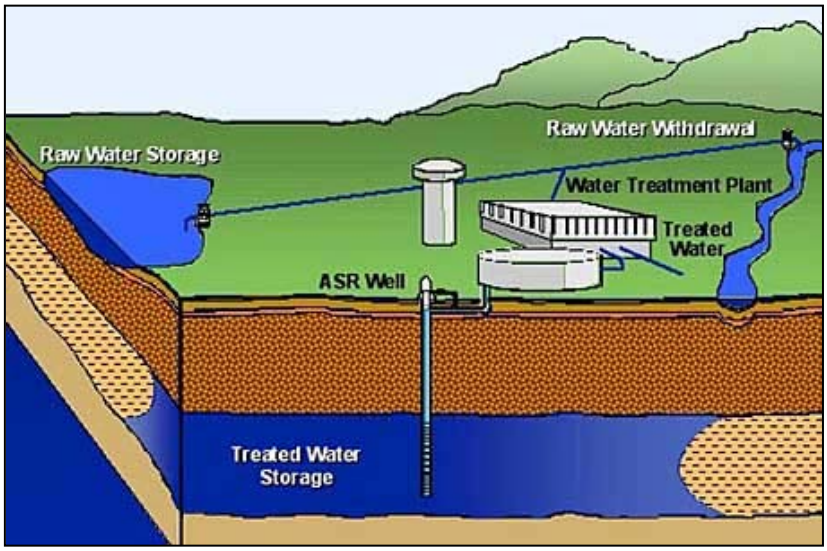
Aquifer storage and recovery (ASR) involves the construction of underground storage wells, often as companions to reservoirs or other surface water bodies, to provide additional water storage capability. Water is stored in a suitable aquifer during times when water is available and recovered from the well during times when it is needed. The CERP proposes to use ASR at an unprecedented scale to temporarily store up to 1.6 billion gallons of treated freshwater per day in the underlying brackish Floridan aquifer system. The storage from regional ASR implementation is expected to help reduce the degree and frequency of damaging high and low water stages on Lake Okeechobee and high and low water flow events in downstream estuaries and wetlands. ASR is also expected to support agricultural and other consumptive water supply needs. The advantages of ASR wells over traditional surface water storage systems include less need to remove land from current uses (such as agriculture), reduced land acquisition costs, reduced evaporation losses, the possibility of locating ASR wells in areas of greatest need (thereby reducing water distribution costs), and the potential to recover large volumes of water during severe droughts. About 330 ASR wells have been proposed, each with an assumed capacity of 5 million gallons per day during recharge or recovery. These wells will store water approximately 1,000 feet underground in a brackish aquifer.

Three ASR pilot projects will be located near Lake Okeechobee, adjacent to the Hillsboro Canal, and near the Caloosahatchee River. These projects will identify the most suitable sites for ASR wells in the vicinities of these surface water bodies and the optimum configurations of those wells. The pilot projects will provide information regarding the characteristics of the aquifer system within the proposed basins, including the hydrogeological and geotechnical characteristics of the aquifer. By addressing technical uncertainties about many aspects of well construction and operation, the pilot projects will provide the information needed to properly design the rest of these facilities.

An *ASR Regional Study* will address regional issues that are beyond the scope of the ASR Pilot Projects, including potential effects of the full-scale CERP ASR Program on the environment and on economically disadvantaged communities and existing users of the Floridan aquifer system.

The results from the ASR Pilot Projects and the *ASR Regional Study* will be utilized to determine the feasibility of large-scale ASR and its potential effects on water levels, water quality within the aquifer, surface water quality, biota, and ecosystem processes.

ASR has the potential to affect ecosystem processes and fish and both positively and negatively wildlife habitats, largely depending on the quality of the recovered water. Another concern is the effect of intake structures on aquatic organisms at the intake sites. High numbers of operating ASR wells will pump significant volumes of water, which may contain concentrations of aquatic organisms including larval, juvenile, and adult fish. Fish mortality caused by ASR intakes may reduce recreational stocks.



A successful ASR program will benefit fish and wildlife resources by providing a significant part of the additional water supply needed to achieve CERP restoration goals and other benefits. DOI is particularly concerned that careful attention to the lessons learned in the pilots and regional ASR studies be applied to minimize the potential for direct, indirect and/or cumulative effects on managed resources through habitat modifications and/or contaminant introduction.

The ultimate success of the ASR program will require understanding which geological environments are capable of serving as storage zones while minimizing the potential for adversely affecting the physical and chemical properties (temperature, pH, metals, and radionuclides) of the stored water. The efficacy of ASR at the scale proposed needs to be verified. If the initial assumptions concerning the application of ASR prove to be inaccurate, understanding the relationships between the geological, chemical, and biological processes will be critical to understanding the potential tradeoffs among benefits or impacts to the natural system, and/or to determining the extent to which ASR will be used and what, if any, other water storage contingencies will be necessary. Much information will be garnered from the proposed pilot studies, although individual well characteristics may be highly site specific.

Given the current uncertainty of the projected 70% recovery rates from 330 proposed wells, storage contingency planning is being undertaken by the federal and state partners to evaluate alternatives to replace any realized deficits in storage capacities that are essential to the success of the CERP.

What Is Known

Of the three major aquifer systems underlying the Everglades area (the *surficial*, *intermediate*, and *Floridan* systems), the upper 250 feet of the surficial aquifer system, which includes the highly permeable Biscayne aquifer, is the principal source of freshwater for the more than 6 million people in southeastern Florida.

The intermediate aquifer system, which underlies the shallow surficial aquifer, is a source of freshwater mostly along the gulf coast. The Floridan aquifer, which is the principal source of fresh ground water in many parts of Florida, is the deepest aquifer in the region; however, south of Lake Okeechobee, water in the Floridan aquifer is too mineralized for most uses. Subtle changes in land elevation or slight rises in

sea level can increase the potential for coastal flooding and also can reverse the hydraulic head and allow saltwater intrusion into aquifers.

The physiography and hydrology of the intermediate aquifer system (upper Floridan) and its confining units are partially described for the area under the Florida mainland. However, as this formation extends out under the continental margin, the physiographic and hydrologic descriptions decreases dramatically. The area of discharge for this aquifer, if there is one, is poorly understood but presumed to be located in the deeper regions of the western Straits of Florida, or possibly further east.

ASR water storage technology has been used by drinking water suppliers in the United States since 1969. A recent USGS report indicates that 22 active ASR wells utilize the targeted Upper Floridan aquifer in the CERP study area. The aquifer is brackish to saline in southern Florida, which can greatly affect the recovery of stored freshwater. The success of storage and recovery depends on maintenance of a "freshwater bubble" in this saline environment. Many site-specific factors may affect the integrity of this bubble, including ambient salinity and structural features that may allow the freshwater to migrate.

While most of the few large-capacity, large-diameter (greater than 20-inch) ASR wells in southern Florida are operated at rates of 1 to 2 million gallons per day (mg/d), the CERP-proposed 5 mg/d recharge and production rates per well remain unverified. CERP assumes a recovery efficiency of 70% of the injected volume. The USGS reports highly varying rates of recovery ranging from as low as 2% to as high as 84%, with ten sites achieving a recovery efficiency above 30% during at least one cycle. Recovery rates of 4 to 5 mg/d achieved during recent ASR cycle testing at the Miami-Dade West Well Field, however, offer evidence that the desired recharge rates are possible.

What Is Needed

Water quality studies. The areas of study related to ASR include the specific water quality characteristics of waters to be injected, the water quality characteristics of water recovered, and the water quality characteristics of water within the receiving surface and ground waters.

Hydrogeologic studies. Knowledge of the hydrologic framework and hydrology of the intermediate aquifer system (upper Floridan) and its confining units needs to be improved with further geotechnical and hydrologic studies in areas underlying the Florida mainland and especially between the internal greater Everglades, Biscayne Bay and Florida Bay. In addition, descriptions of the physiography and hydrology of the Floridan aquifer needs to be developed for areas that extend out under the continental margin and into the Biscayne Bay. If any discharge areas are identified additional research and modeling will be needed to determine effects on the ecology in Biscayne or Florida Bay as ASR is implemented.

Research to understand the tolerance of plants and animals to changes in water quality. Understanding the tolerances of plants and animals to the ranges of water quality conditions likely to result from ASR operation will be critical to minimizing the potential for unanticipated adverse impacts on fish and wildlife resources. The *ASR Regional Study* incorporates a myriad of proposed studies that include geotechnical, microbiological, water quality, biological, and ecological elements. They will investigate, among other things, the potential environmental effects of recovered waters, by testing their toxicological properties and exposure pathways. The pilot projects will afford the opportunity to perform some of these studies during the two years of proposed cycle testing. If the pilot projects do not produce the anticipated results, additional data will be needed to support analysis of alternatives.

Baseline analysis and monitoring in downstream wetlands. DOI needs to support baseline analyses and continued monitoring to ensure that the waters from these facilities are of appropriate quality and thus do not pose any threat to fish and wildlife resources.

Baseline studies and monitoring at ASR locations. An ecological characterization baseline study will establish biotic community conditions in the vicinity of proposed ASR well concentrations. The proposed five-year duration of this baseline study should incorporate sufficient natural variability to enable monitoring and adaptive management during full ASR operations in the future. This information will help improve site selection and facility design in targeted ASR locations.

Studies of the effects of intake pumps and control structures. In order to reduce impacts to fish species in the region, studies will identify better designs for intake pumps and control structures that will minimize impingement (trapping organisms against intake screens) and entrainment (passage of organisms through a pump) of aquatic organisms at intake sites.

Everglades Agricultural Area Reservoirs

Project Purpose and Major DOI Interest

The purposes of this project are to reduce damaging flood releases from the Everglades Agricultural Area (EAA) to the water conservation areas, to reduce Lake Okeechobee regulatory releases to the estuaries, to meet supplemental agricultural irrigation demands, and to increase flood protection within the Everglades Agricultural Area.

The EAA, located between Lake Okeechobee and the water conservation areas, encompasses an area totaling approximately 718,400 acres (1,122 square miles) of highly productive organic peat or muck soils, making it one of Florida's most important agricultural regions. Approximately 77% of the EAA is in agricultural production for crops including sugar cane, vegetables, sod, rice, and citrus. Flooded and cultivated agricultural fields attract foraging birds, including wading birds. The southern rim of the EAA (the Holey Land, Rotenberg, and Browns Farm tracts) contains wildlife management areas that support populations of wading birds, deer, wild hogs, and waterfowl.

Agriculture in the EAA is highly dependent on the current system of canals running through the region to drain excess water during the wet season and supplement water supplies for irrigation during the dry season. Water quality concerns, soil subsidence, and encroachment of urbanization are all ecosystem stressors related to maintaining agriculture in this area. Water quality, particularly phosphorus loading, is being addressed through improved farming practices and stormwater treatment.

Hydrologic improvements will be accomplished through improved storage and canal conveyance capacity. This two-phase project will construct three aboveground reservoirs of approximately 20,000 acres each and restore more natural timing of deliveries to the water conservation areas.

Changes in the hydrology and water quality in the water conservation areas from implementation of these projects will affect the Loxahatchee National Wildlife Refuge, located in WCA-1, and downstream areas, such as Taylor Slough, the mangrove communities, and northeast Florida Bay, inside Everglades National Park. DOI has a strong interest in ensuring that the waters introduced into the natural system mimic the natural predrainage hydrology in terms of quantity, quality, timing, and distribution patterns. DOI is also interested in the potential habitat and recreational values of the water storage reservoirs themselves and in ensuring that wildlife attracted to the reservoirs are not harmed by the quality of the water impounded on former agricultural lands.

What Is Known

The southern rim of Lake Okeechobee was historically a dense swamp of pond apple, willow, and elderberry. Areas farther to the south were dominated by sawgrass mashes, part of the "river of grass" that flowed south through the Everglades into Florida Bay. Significant changes in the hydrology of this area have had wide reaching effects far outside the boundaries of the EAA.

What is Needed

Research and modeling to refine hydrologic targets, including targets for water quality. Additional research and modeling are needed to help DOI managers better understand the natural quantity, timing, and distribution of water in the park and how to restore those conditions.

The water quality performance targets for this project will initially be based on water quality targets for the Everglades Construction Project and other designated uses of the EAA waters. Additional research will help refine these targets to ensure that the quality of the water from potential sources throughout the watershed is suitable for ecosystem restoration.

Research and possible model refinement to establish operating protocols. DOI needs to provide the operating protocols to the USACE that will allow operators to replicate natural system functioning in the marshes and the surficial Biscayne aquifer. These protocols should provide water managers more flexibility, based on actual rainfall (real-time conditions) rather than on projections of annual averages, in order to avoid engineering the wetlands into an unnatural state. These protocols will help ensure that the quantity, timing, and distribution of water into the park mimics the hydropatterns of natural flows through Taylor Slough and the mangrove communities to the coastal estuaries: northeast Florida Bay, Manatee Bay, and the landlocked areas, Barnes and Card Sounds.

The operating protocols should include a drought management plan that addresses the onset, progression, recession, and termination of drought stages, based on rainfall data, soil moisture, and reservoir level indicators.

Restoration partners need more information about how to mimic natural hydrologic patterns simultaneously with other CERP goals and objectives.

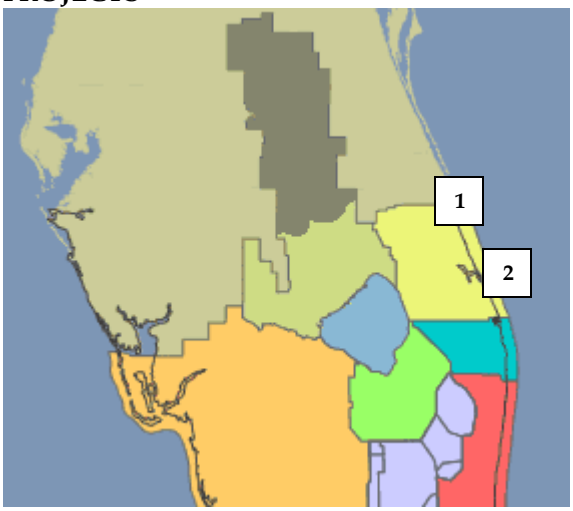
Environmental risk assessments of water quality contaminants. Water quality investigations will assess the environmental risks from storing water on former agricultural lands.

Research to support design and operational rules to enhance fish and wildlife resources. FWS needs to identify ways in which the EAA reservoirs can be managed and operated to provide favorable habitat for fish and wildlife while maintaining the water management functions.

Monitoring and assessment to determine the effects of the reservoirs on the natural system. As phase one of this project comes on line, DOI scientists need to focus on assessing how the increased water and canal flow capacity and changes in water quality affect the natural system and on how to improve these outcomes during the second phase of this project.

Upper East Coast

PROJECTS



1. Wetland Restoration on the Allapattah Ranch Natural Area
2. Ten-Mile Creek Reservoir Assisted Stormwater Treatment Area

Overview

The CERP upper east coast region is separated from the Kissimmee-Okeechobee watershed by the eastern coastal ridge. This watershed drains to the east, into the Indian River Lagoon, considered the most biodiverse estuarine system in all of North America, and the Saint Lucie Estuary, a major tributary at the southern end of the lagoon. Unnaturally high and low freshwater discharges from the C&SF Project canals are changing the salinity and water quality in the lagoon and estuary. The Wetland Restoration on the Allapattah Ranch Natural Area Project will serve as a pilot for the development of methods to reduce the damaging effects of watershed runoff and high peak freshwater discharges into the lagoon and estuary. The Ten-Mile Creek Reservoir Assisted Stormwater Treatment Area is a prototype for several such reservoir-assisted STAs intended to reduce sediment loads in waters delivered downstream. The technologies developed through these projects will have wide application in similar CERP projects, particularly in other components of the Indian River Lagoon project. DOI is interested in ensuring that the projects are designed to provide the greatest possible benefits to fish and wildlife values and to avoid inadvertent adverse effects on federally protected species. Additional research to understand the linkages between hydrology, fire, and ecology in the Allapattah wetlands will help refine management scenarios and may have broader application elsewhere. Site-specific monitoring of habitats and species at both project areas will support adaptive management to enhance fish and wildlife values.

DOI managers can most effectively participate in CERP projects during three project stages: (1) NEPA scoping in the early stages of project design, to help ensure that hydrologic targets accurately reflect the natural predrainage conditions, (2) review of project alternatives, to ensure that fish and wildlife and parks are adequately considered in compliance with DOI mandates, and (3) monitoring and assessment of project results, to support project modification if needed to ensure that the intended conditions are achieved. The major questions that DOI managers need to answer at each stage to effectively fulfill their responsibilities as partner and steward are summarized below, along with the highest priority science needs for answering those questions. This information is discussed in greater detail for each individual project following this summary.

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN UPPER EAST COAST

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	**Restoration on the Allapattah Ranch Natural Area**		
	What are the hydrologic targets in the Allapattah Ranch area?	Modeling to determine the natural hydrology	NEPA Scoping Completed
	What are the water quality concerns for rehydration of this formerly agricultural land?	Environmental risk assessments of water quality contaminants	
	Ten Mile Creek Reservoir-Assisted Stormwater Treatment Area		
	What hydrologic targets will achieve more natural flows in Ten Mile Creek?	Modeling to determine natural flows in Ten Mile Creek	NEPA Scoping Completed
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	**Restoration on the Allapattah Ranch Natural Area**		
	Will the proposed hydrologic changes affect the flora and fauna in the area, in particular Audubon's crested caracara?	Research to understand linkages between hydrology and ecology in the Allapattah Ranch Natural Area	EIS Review, Section 7 Consultation, and CAR Final CAR: Feb 2002 Final PIR/EIS: March 2004
	Ten Mile Creek Reservoir-Assisted Stormwater Treatment Area		
	What are the links between hydrology, water quality, and ecology in the Ten Mile Creek area?	Studies of species' responses to fluctuating water levels	EIS Review, Section 7 Consultation, and CAR September 1999
	What are the potential effects on native fisheries, and particularly on the opossum pipefish?	Studies of the effects of intake structures	
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	**Restoration on the Allapattah Ranch Natural Area**		
	What are the indicators of the desired ecological response?	Site-specific monitoring and adaptive assessment	Post-implementation monitoring and assessment Project Completion: 2010
	What monitoring and assessment program can best use the ranch to learn about the restoration of these wetland habitats?	New indicator species and bioassessment approaches (such as, midge communities) are needed to more precisely quantify biotic changes due to changes in the hydroperiod and water quality from restoration efforts.	
	Ten Mile Creek Reservoir-Assisted Stormwater Treatment Area		
	What are the key indicators of the desired ecological responses?	Biological monitoring to identify indicator species	Post-implementation monitoring and assessment Project Completion: December 2005

Restoration on the Allapattah Ranch Natural Area

One of Six Components in the C-23/24 Basin of Indian River Lagoon South (IRLS) Feasibility Study

Overview of the Indian River Lagoon Feasibility Study

The *Indian River Lagoon - South Feasibility Study* is the second feasibility study initiated under the C&SF Project *Comprehensive Review Study* (Restudy) authorized by Congress in 1996. The purpose of the study is to investigate making structural and operational modifications to the C&SF Project to improve the quality of the environment, to protect the Floridan aquifer, to ensure the integrity, capability, and conservation of

urban and agricultural water supplies, and to achieve other water-related purposes in the upper east coast area. The *Final Feasibility Study* for this project recommends a plan that will improve water quality within the St. Lucie Estuary and the Indian River Lagoon by reducing the damaging effects of watershed runoff, reducing high peak freshwater discharges to control salinity levels, and reducing nutrient loads, pesticides, and other pollutants. The plan also includes water supply for agriculture to offset reliance on the Floridan aquifer.

The plan involves the purchase of approximately 90,000 acres of wetland/upland habitats and their conservation (if in a natural state) or enhancement (if impacted). Natural areas include pine flatwoods, forested wetlands, scrub, wet prairies, and marshes. Impacted areas include agricultural lands such as citrus, row crops, and improved and unimproved pasture. Water management projects include 170,000 acre-feet of storage reservoirs (C-44 West, C-23 and C-24 North and South, and C-25) and stormwater treatment areas (C-44 West, C-44 East, C-23, C-24, C-25 and C-23/C-44 Canal/STA), storage in 90,000 acres of natural storage areas (Allapattah, Palmar, and Cypress Creek), and removal of 5,500,000 cubic yards of muck from the St. Lucie River and Estuary.

The restored wetlands will provide large tracts of contiguous, high-quality fish and wildlife habitat in an otherwise highly agricultural watershed. The St. Lucie Estuary and Indian River Lagoon will benefit from more natural hydrology in the upper reaches of the watershed. Other, less severely drained adjacent areas (remnant pine flatwoods and forested wetlands) should also benefit from the increased hydroperiod, better management of cattle and exotics, and promotion of a more natural fire regime.

Animals expected to benefit the most from habitat conservation and enhancement are wading birds, other waterfowl, amphibians, and aquatic reptiles and invertebrates. Threatened or endangered species include Everglade snail kite, wood stork, bald eagle, Audubon's crested caracara, and whooping crane. Forested upland species, including the federally endangered red-cockaded woodpecker and threatened Florida scrub-jay, could also benefit. The conservation of large tracks of forested land, especially in the western portion of the study area, is expected to provide potential habitat for the recovery of the endangered Florida panther.

Project Purpose and Major DOI Interest

The Allapattah Natural Area is the first large tract of land in the IRLS to be restored. A monitoring plan is needed to guide additional restoration plans for the remaining IRLS natural areas.

The 20,000-acre Allapattah Ranch Natural Area was historically a mosaic of pine flatwoods, wet prairie, and freshwater marsh. Today, the land consists primarily of improved pasture, degraded wetlands, and impacted native upland habitat. The land has been extensively drained for cattle grazing and other farming practices. Contaminated stormwater quickly drains through the network of ditches into the C-23 Canal, and then to the middle part of the St. Lucie Estuary.

The St. Lucie Estuary watershed covers an area of approximately 775 square miles. Three of its major drainage basins are now linked to the estuary by the C-23, C-24, and C-44 project canals. The canals convey stormwater runoff from within these basins to the St. Lucie River and Estuary. In addition, the C-44 canal conveys flood control discharges from Lake Okeechobee to the South Fork of the St. Lucie River. The C-25 canal, located in northern St. Lucie County, discharges runoff directly into the Indian River Lagoon near Ft. Pierce Inlet.

These drainage modifications coupled with land use changes in the St. Lucie Estuary watershed have dramatically increased wet season flows to the estuary and significantly reduced dry season inflows. The reduction in dry season base flows has affected habitats and organisms dependent on brackish or fresh water wetlands during their life cycles. High-volume stormwater discharges produce rapid fluctuations

of salinity, and also sedimentation. The increase in nutrient and sediment loading has contributed to the build-up of fine-grained, nutrient-rich muck in the estuary. The resultant change in aquatic communities within the estuary consists of increases in pollutant-tolerant benthic organisms and decreases in seagrass and oyster communities.

The ecology of the Indian River Lagoon has also been affected by these fresh water discharges from the C&SF Project canals. The existing seagrass beds may be threatened by the increased nutrient loading, high turbidity, and introduction of colored water, which diminishes light penetration needed to support submerged aquatic vegetation. Habitat diversity and species diversity in the lagoon system are believed to be affected by the decline in water and sediment quality.

Restoration will entail filling ditches and canals on former agricultural lands to create a more natural hydroperiod. Approximately half of the ranch is on drained and partially drained hydric (high-moisture) soils, which provide an excellent opportunity for restoration. By backfilling the drainage ditches the land can be rehydrated and large volumes of stormwater will be contained on site.

DOI is most interested in evaluating the success of efforts to enhance wetland and adjacent upland habitats in the Allapattah Ranch Natural Area. The project will serve as a pilot for the development of methods that may be implemented on the remaining 70,000 acres of natural areas for the Indian River Lagoon South Project. The FWS has predicted that the Allapattah Ranch has the potential to provide habitat for 32 out of the 43 indicator species in the Indian River Lagoon-South project area. These include three threatened or endangered species, including Audubon's crested caracara, known to occur in the project area and six others that are likely to occur. It is anticipated that both habitat and species richness will increase significantly as a result of restoration activities at Allapattah Ranch.

What Is Known

Although comprehensive biological surveys have not been conducted on the Allapattah Ranch, sandhill cranes, wading birds, raptors, white-tailed deer, and turkeys are known to occupy the site. Recent investigations have indicated high usage by Audubon's crested caracara, including one active nest located in February 2003. Incidental observations conducted during these surveys have identified 67 additional bird species. The state-listed Florida tree fern and Florida peperomia have been found within the forested wetland along the parcel's western boundary. Numerous native plant species occupy the remnant wetlands throughout the property.

What Is Needed

Modeling to determine the natural hydrology

Research to understand linkages between hydrology and ecology in the Allapattah Ranch Natural Area. The linkages between the restoration of the historic hydroperiod, concurrent management of exotics and fire, and the responses of the various ecological communities must be understood in order to define the best management scenarios for the mosaic of wetland and upland communities that are, or will be, present on the property. This knowledge will assist DOI in providing input into the adaptive management phase as the effects of restoring wetland habitats on native species are understood.

Surveys using Wetland Rapid Bioassessment Protocols are costly and have not been sensitive enough for quantifying marsh system biotic responses to restoration projects in the upper east coast region. Research

is needed to identify sensitive and reliable invertebrate indicators of changes in water quality and hydroperiod. Chironomid and Ceratopogonid midges are abundant and diverse in wetland systems, and have proven to be particularly sensitive to changes in environmental conditions in south Florida marsh systems. Methods, such as pupal exuviae sampling, that sample these important invertebrates efficiently may be particularly effective and efficient in identifying indicator species, and in monitoring water quality and hydroperiod changes through changes in midge community composition during restoration.

Environmental risk assessments of water quality contaminants. Water quality investigations will assess the environmental risks from storing water on former agricultural lands.

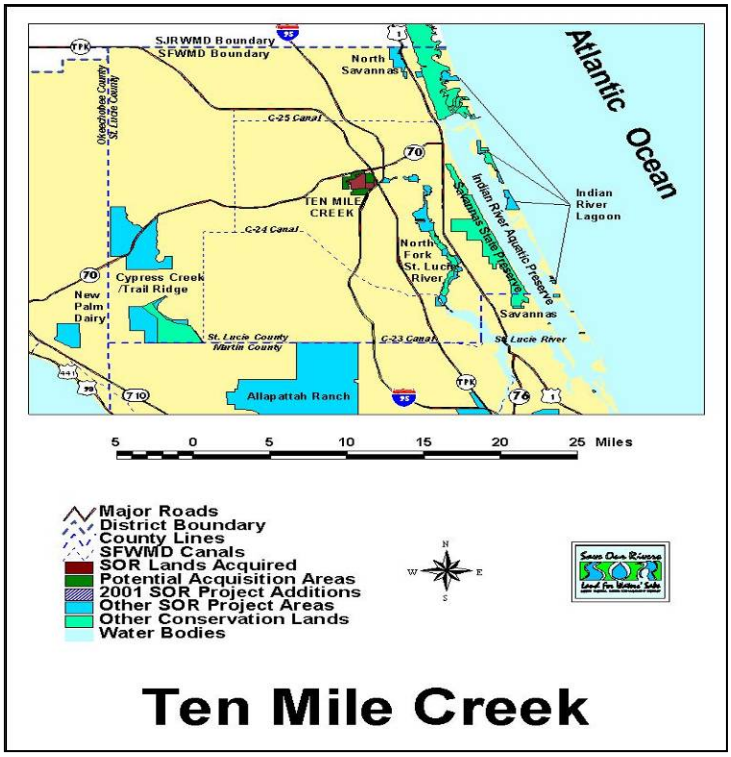
Site-specific monitoring and adaptive assessment. Hydrologic and ecological monitoring will provide the information needed to assess project benefits and to avoid or minimize impacts to the federally listed species utilizing this habitat and other important fish and wildlife values.

Surveys using the Wetland Rapid Bioassessment Protocol are underway to measure existing conditions for comparison to post-hydroperiod-restoration responses. However, this methodology is not sensitive enough to precisely quantify changes in the hydroperiod and water quality or the resulting responses of the biologic communities. A site-specific monitoring and adaptive assessment plan will augment the CERP MAP. The SFWMD will be monitoring hydrologic restoration (increases in spatial extent, depth, and duration of wetlands). DOI has developed an ecological monitoring plan for evaluating ecological conditions during and following restoration. The methodology will be capable of gauging expanded and intensified wildlife utilization through an increase in the spatial extent of wetlands, improvements in habitat functional quality, and improvements in native plant and animal species diversity and abundance.

Ten Mile Creek Reservoir-Assisted Stormwater Treatment Area

Project Purpose and Major DOI Interest

The purpose of this project is to provide seasonal or temporary storage of stormwater from the Ten Mile Creek basin to attenuate and treat wet-season stormwater flows originating in the basin prior to release into the North Fork of the St. Lucie Estuary. It involves the construction of an aboveground reservoir with a pump station, a gated water level control structure, and a stormwater treatment area for water quality. Settling of suspended solids within the 526-acre storage reservoir is expected to reduce sediment loads delivered downstream. This is the first of several such CERP projects being designed for aboveground water storage and treatment. Scheduled for completion in 2004, it will be the first test of this technology in South Florida, and will provide information for the design, operation, and maintenance of future similar facilities.



DOI is interested in ensuring that the design of this feature does not pose threats to the fishery community of the basin, and especially to a candidate species for federal listing, the opossum pipefish. The current design includes a large intake pump to draw water from Ten Mile Creek. Design alternatives to reduce mortality of aquatic organisms have not been incorporated. Current hydrologic modeling indicates that the reservoir will fluctuate annually from 10 feet deep to completely dry, which will prevent the establishment of high-quality habitat for native fish and wildlife.

This project is termed a Critical Restoration Project and was authorized under Section 528 of WRDA 1996. Under this authority, the Secretary of the Army, in cooperation with the SFWMD (the nonfederal project sponsor) and the Task Force, provided the determination that this project will produce independent, immediate, and substantial restoration, preservation, and protection benefits and will be generally consistent with the conceptual framework specified in the Governors Commission for a Sustainable South Florida's *Conceptual Plan*.

What Is Known

The fishery data for Ten Mile Creek are scant, and only a partial species list is available from angler interviews and a 1994 Florida DEP fish-kill investigation. Several important recreational gamefish, such as largemouth bass and snook, inhabit the creek, and several native fishes occur in the St Lucie River and may be present in Ten Mile Creek. Native tropical species include opossum pipefish (a candidate species for federal protection), bigmouth sleeper, spinycheek sleeper, mountain mullet, river goby, and slashcheek goby.

Wildlife utilization data for the project area are also limited. A five-day wildlife survey of the Ten Mile Creek citrus grove, the area proposed for the reservoir, found 36 wildlife species, including great egret, great blue heron, red-tailed hawk, merlin, wild turkey, blue jay, downy and hairy woodpeckers, ovenbird, European starling, bobcat, white-tailed deer, butterflies, Cuban anole, and the eastern indigo snake (federally listed as threatened). Thirty-three understory plant species were also identified between the citrus rows. An additional 20 animal and 65 plant species were sighted in the unimproved pasture and wetlands, the area proposed for the stormwater treatments area, adjacent to the citrus grove.

What Is Needed

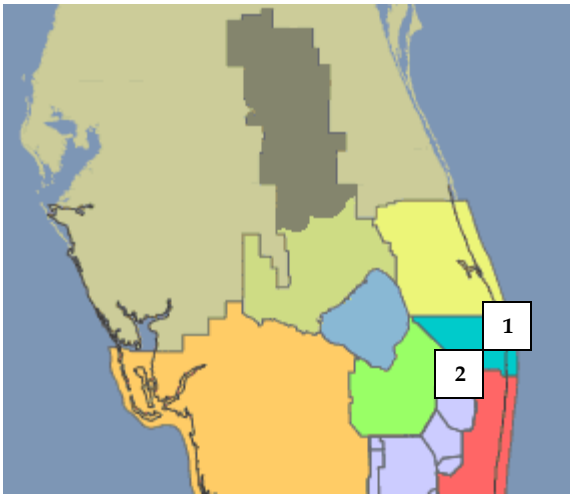
Modeling to determine natural flows in Ten Mile Creek

Biological monitoring. Biological monitoring of the Ten Mile Creek Project will provide valuable information about species diversity and relative abundance, and it should guide selection of an indicator species for gathering current population data and long-term monitoring. Additional information about length, weight, age (gamefish only), and sex will help managers understand the fishery and provide the demographic information for possible modeling analyses. For the first year, the sampling will be conducted six to ten times in order to best delineate variability in population structure and to identify potential spawning times and species. This information will allow investigators to more efficiently conduct subsequent sampling at a reduced frequency (two or three times a year). Field water quality parameters such as water temperature, dissolved oxygen, pH, and conductivity will also be measured and correlated with species diversity and abundance.

Studies of the effects of intake structures (alternative designs). DOI is concerned about the impacts of high-velocity pumps on fish and wildlife communities. The FWS needs to work with the USACE to find alternative designs and locations for these pumps that minimize impacts on fish and wildlife resources.

Study of species' responses to fluctuating water levels. DOI needs to understand how reservoir-assisted STAs can be operated to provide adequate wet refugia (such as tree islands) and dry refugia (such as alligator holes). Determining the effects of fluctuating water levels in the reservoirs and the stormwater treatment areas on native fish and wildlife communities will support adaptive management to optimize benefits to fisheries and wildlife while maintaining the management functions of the reservoir-assisted STAs.

Loxahatchee



PROJECTS

1. North Palm Beach County
2. Arthur R. Marshall Loxahatchee Internal Canal Structures

Overview

Projects to improve water deliveries to the Loxahatchee River and Slough and the ARM Loxahatchee National Wildlife Refuge (which includes WCA-1) have the potential to improve habitat values in these areas. DOI has a great interest in ensuring that the quality, timing, and distribution of the additional water dedicated to these natural systems is suitable for natural system restoration. New local basin hydrologic and ecological models, to be integrated with the CERP models, will aid in understanding the effects of hydrologic change on habitats and species in this area. The use of water from stormwater treatment areas to augment flows to the wildlife refuge raises concerns about phosphorus and other contaminants The ecological responses to hydrologic change will be monitored to help ensure the desired responses and to avoid inadvertent impacts to fish and wildlife. Species of special concern include the eastern indigo snake and Everglade snail kite.

DOI managers can most effectively participate in CERP projects during three project stages: (1) NEPA scoping in the early stages of project design, to help ensure that hydrologic targets accurately reflect the natural predrainage conditions, (2) review of project alternatives, to ensure that fish and wildlife and parks are adequately considered in compliance with DOI mandates, and (3) monitoring and assessment of project results, to support project modification if needed to ensure that the intended conditions are achieved. The major questions that DOI managers need to answer at each stage to effectively fulfill their responsibilities as partner and steward are summarized below, along with the highest priority science needs for answering those questions. This information is discussed in greater detail for each individual project following this summary.

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN THE LOXAHATCHEE AREA

Major DOI Responsibilities and Interests	**Major Unanswered Questions**	**Needed Science**	Timeline
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	North Palm Beach County Part 1		
	What are the links between hydrology and ecology in the Loxahatchee Slough and River and the Lake Worth Lagoon?	Regional integration of water transport and ecological models	NEPA Scoping Completed
	Arthur R. Marshall Loxahatchee NWR Internal Canal Structures		
	What hydrologic targets will restore the natural predrainage hydrology? What water quality criteria must be achieved for the agricultural and urban waters diverted into the refuge?	Synthesis and integration of data about historic hydrologic and ecological conditions on the refuge Development of an integrated hydrodynamic and water quality model.	NEPA Scoping 2020
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	North Palm Beach County Part 1		
	What is the distribution of protected species throughout the project area? What are the anticipated effects on the eastern indigo snake and Everglade snail kite?	Population and habitat utilization data about threatened eastern indigo snake and endangered Everglade snail kite	EIS Review, Section 7 Consultation, and CAR Draft: Aug 2006 Final: Aug 2007
	Arthur R. Marshall Loxahatchee NWR Internal Canal Structures		
	What are the links between hydrology, water quality, and ecology in the refuge?	Research to understand the ecological effects of hydrology and water quality on refuge resources	EIS Review, Section 7 Consultation, and CAR 2020
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	North Palm Beach County Part 1		
	What are the effects on endangered species?	Inventory and monitoring of all federally listed species	Post-implementation monitoring and assessment Project Completion: 2008
	Arthur R. Marshall Loxahatchee NWR Internal Canal Structures		
	What is the ecological response to hydrologic change?	Monitoring and assessment of responses: • water quality (including phosphorus and conductivity) • hydrology • periphyton • aquatic communities and habitats • invertebrate and plant communities	Post-implementation monitoring and assessment Project Completion:

North Palm Beach County Part 1

Project Purpose and Major DOI Interest. The North Palm Beach County Part 1 Project is a complex set of interrelated but separable components of the CERP[2] covering about 40,000 acres in northern Palm Beach and southern Martin Counties. The purposes of the project are to increase water supplies to the municipalities of northern Palm Beach County, provide increased flows to enhance hydroperiods in the Loxahatchee Slough, increase base flows to the Northwest Fork of the Loxahatchee River, and reduce high freshwater discharges to the Lake Worth Lagoon. When completed in 2014, this 12-year project will provide environmental, urban, and agricultural water supplies, flood attenuation, and water quality improvement for north Palm Beach County.

The water dedicated to the natural system will help restore wetlands in Loxahatchee Slough and restore more natural flows to the Northwest Fork of the Loxahatchee River, which is Florida's only designated wild and scenic river. An almost contiguous greenbelt extends from the state-owned DuPuis Reserve in the west, to the Jonathan Dickenson State Park in the northeast, and southward to the Grassy Waters Preserve. Eighteen federally listed plant and wildlife species occur within the project area, two of which, the Everglade snail kite and the eastern indigo snake, are species of special concern because little is known about their life histories within this project region. Proposed alterations to water flow, water depth, inundation period, flood frequency, and water quality will affect the snail kite's primary prey, the apple snail, resulting in impacts to the bird's foraging strategy and ultimately to its nesting success.

What Is Known

Several local-basin water-transport models are under development and will be used to inform the project design. The two primary water-transport models under consideration for this project are the RSM and the Lower East Coast Regional (LECR) Model. The Corps and SFWMD are currently combining these two models with watershed-specific models developed for this region to accurately predict the hydrologic effects on the natural system from alterations to the existing water delivery system.

Numerous ecological databases are available for the north Palm Beach County area, although incorporating this data and new information into a more comprehensive habitat map is part of what is needed in order to plan effectively for protection of species in this area. Snail Kite and Indigo snakes either occur or are likely to occur in this area given the knowledge base on these species habitat needs and preferences. Long- term snail kite monitoring occurs in the Grassy Waters Preserve, where nest success within the preserve is being documented.

What Is Needed

Regional integration of water transport and ecological models. DOI scientists will use the best available information to predict the ecological responses to the project performance targets during project design. Regional integration of the local hydrologic models and creation of ecological models that describe the effects of water allocations on fish and wildlife are longer term science needs. Although ecological models will not be available during the project design phase, through modification from incorporation of new information currently being collected they will eventually provide improved information to be used by the project managers to better predict the ecological benefits or adverse affects of adaptive management strategies. The integration of hydrologic and ecological models on a regional level will provide a critical tool necessary to ensure consistent decision making by the many federal management agencies in the region working to restore ecological sustainability.

[2] The North Palm Beach County project is composed of six separable elements including Pal-Mar and J.W. Corbett Wildlife Management Area Hydropattern Restoration (including Loxahatchee River Restoration), L-8 Basin Modifications, C-51 and L-8 Reservoir, Lake Worth Lagoon Restoration, C-17 Back-pumping and Treatment, and C-51 Back-pumping and Treatment.

Population and habitat utilization data about threatened eastern indigo snake and endangered Everglade snail kite. Studies to document the presence, abundance, population size, breeding potential and other life history characteristics of these species throughout the project area will fill these gaps in existing databases and provide improved baselines for considering impacts on these species.

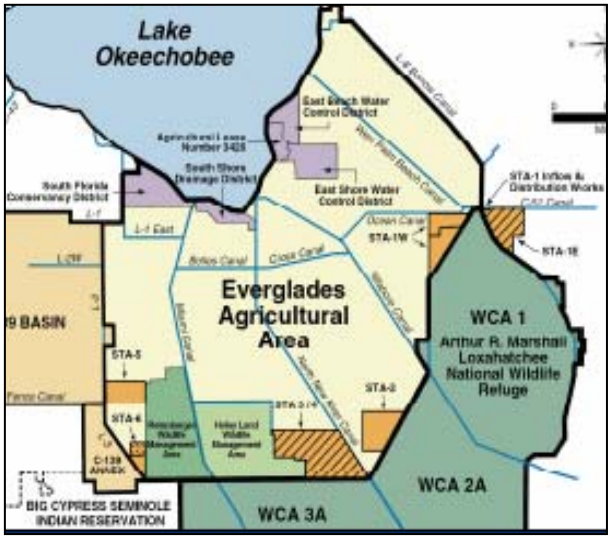
Inventory and monitoring of all federally listed species. A complete inventory of all federally listed species in the project area will allow managers to adequately consider the multi-species effects of this restoration project. GIS map layers and databases for each species' occurrence, range, and abundance will be compiled in a centralized location for multiagency use.

DOI will track the effects of changes in hydrology, specifically hydration of upland or transitional communities, on the federally listed species in the project area. DOI will provide this information to the RECOVER team during the evaluation and adaptive management phase of this project.

Flows into the Arthur R. Marshall Loxahatchee NWR Including Internal Canal Structures and STAs

Project Purpose and Major DOI Interest

The purpose of the CERP project, Internal Canal Structures, is to improve the timing, depth, and distribution of water delivered to the Arthur R. Marshal Loxahatchee National Wildlife Refuge from Stormwater Treatment Areas (STAs) 1 East and 1 West. The CERP plan currently assumes that the canal structures will remain closed except to pass outflows and water supply deliveries from the STAs to the coastal canals.



The refuge, located in Palm Beach County, represents one of the last vestiges of the historic soft-water Everglades. Much of the Everglades developed as a rainfall-driven system with surface waters low in nutrients (such as phosphorus and nitrogen) and ions (such as sodium and calcium). This low-conductivity, or soft-water, condition was a major determinant of the historic ecosystem structure and function. The base of much of the refuge food chain is a unique, diverse periphyton assemblage that has developed under these soft-water conditions. The low conductivity waters are also associated with lower rates of key ecosystem processes, such as decomposition, than what occur in areas of the Everglades with higher conductivity waters (e.g., areas impacted by canal discharges).

The STAs will discharge water in new locations in the refuge and the DOI is concerned about the quality of the water from the STAs that will occur at these new locations. Because the Internal Canal Structures also will change how water moves from the canals into the interior of the refuge, that restoration project have the potential to change refuge water quality and subsequently refuge flora and fauna. Although the ecological impacts associated with increased surface water phosphorus concentrations in the Everglades are well recognized, the ecological impacts associated with an increased conductivity are not understood. However, information from other wetlands indicates that increases in conductivity may elicit undesirable ecological changes. Potential impacts in the refuge include changes to the periphyton community, which

in turn may result in changes in populations and communities of primary consumers, such as apple snails, and subsequently of species such as the Everglade snail kite, which feeds on the snails.

A secondary related concern is how the water will be distributed in terms of depths and duration of depths, since changes in the depth of water and the amount of time an area is flooded can affect plant communities and critical habitats such as tree islands, wet prairies, and sloughs. . The current water regulation schedule has been in place since 1995. Current operational issues, development of STAs, and water quality constraints were not foreseen when the schedule was developed. The current schedule needs to be reviewed in the context of current and projected future constraints and operational issues in order to insure that the appropriate quantity, timing, and distribution of clean water are provided to the refuge.

Refuge managers need to understand how water quality and quantity affect refuge resources in order to provide appropriate operational targets to the USACE prior to project design and suggested modifications to the refuge regulation schedule if appropriate. The appropriate targets need to address the management goal of restoring and conserving the natural diversity, abundance, and ecological function of refuge flora and fauna, as outlined in the refuge's 2000 *Comprehensive Conservation Plan* and agreed to in the terms of the current license agreement with the SFWMD. An important DOI role in this project is to provide technical input during project planning and design to ensure that the project is designed and implemented in a way that will not harm existing resources while accomplishing the objectives of improving water delivery in other parts of the refuge.

What Is Known

Information about the current hydrologic conditions in the refuge is well documented and provides a good baseline for analysis of any changes related to implementation of this project.

It has long been known that the fringes of the refuge are affected by high conductivity canal water. More recent evidence indicates a trend towards increased intrusion of this water into the refuge interior with noticeable impacts on water chemistry and sensitive biota. DOI managers and scientists have expressed concern over the spread of such impacts and their relationship to water management activities including operation of the STAs and meeting the requirements in the current water regulation schedule.

What Is Needed

Synthesis and integration of data about historic hydrologic and ecological conditions on the refuge. Data about historic hydrologic, water quality, and ecological conditions will be needed to develop the specific hydrologic targets for the project.

Research to understand the ecological effects of hydrology and water quality on refuge resources. CERP project managers and refuge managers will need information that relates conductivity and the pattern and duration of water depths within the refuge to changes that will occur with the project and other changes in water management as a basis for project design and adaptive management. Both a synthesis of past data and collection of current data are needed.

Gradient studies that focus on community change (invertebrate and plant communities especially) are needed for identifying reliable indicators of water quality in this soft water system and monitoring to detect undesirable changes in the NWR marsh system.

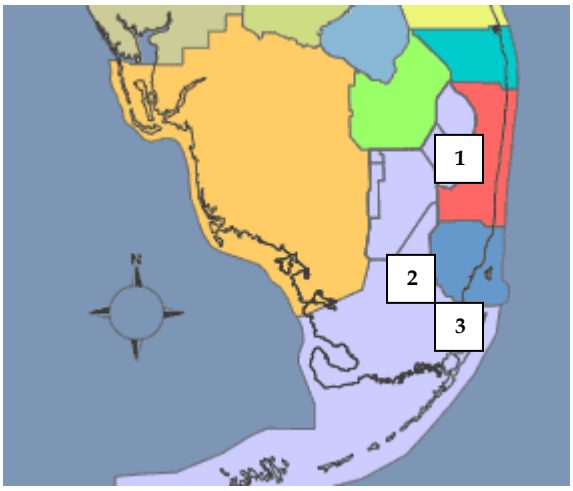
Development of an integrated hydrodynamic and water quality model. The most appropriate tool for making evaluations that have both water quality and water quantity components is an integrated hydrodynamic and water quality model. The development and refinement of this model will require

additional information about the spatial patterns of conductivity within the refuge and the relationship of those conductivity patterns to periphyton, aquatic communities, and endangered species.

Monitoring and assessment of responses. Establishment of pre- and post-project monitoring protocols for hydrology, water quality including phosphorus and conductivity, periphyton, aquatic communities, and habitats will provide data that can be used to assess whether the project is having the desired effect. Coupled with mesocosm experiments, these data can be used to understand how changes in water quality and quantity, due to water management actions, affect refuge resources.

Water Preserve Areas and Seepage Management along the Marsh/Urban Interface

PROJECTS



1. Water Preserve Areas
2. Lake Belt In-Ground Reservoir Technology Pilot Project
3. L-31N Seepage Management Pilot and Everglades National Park Seepage Management

Overview

These projects focus on the control and management of the large volumes of water currently lost from the natural Everglades to the lower east coast. The water preserve areas, an interconnected series of marshlands, reservoirs, and aquifer recharge basins between the Everglades Water Conservation Area and the coast, will reduce seepage, manage the quantity and the quality of the water returned to the Everglades, and provide other benefits, such as urban water supply. Seepage management technologies will be investigated through a number of pilot projects. The L-31N Seepage Management Pilot, Everglades National Park Seepage Management, and Lake Belt In-Ground Reservoir Technology Pilot Project are closely related. The L-31 N pilot will provide the technology needed to support seepage management for Everglades National Park. The in-ground reservoir pilot will address remaining uncertainties related to in-ground storage that are not addressed by the L-31N pilot.

DOI is particularly interested in the success of the water preserve projects as a means of attaining the natural hydrologic targets in the Everglades marshes. The water preserve areas will prove critical in ensuring improvements to the Arthur R. Marshall Loxahatchee National Wildlife Refuge and Everglades National Park, and the habitats of numerous threatened and endangered species. DOI is also concerned about preserving the quality and critical water deliveries to coastal estuaries and offshore areas north and east of Barnes Sound.

Determining the best technology for managing seepage from the water preserve areas involves a number of issues of concern to DOI, including the potential for impeding the recharge of wellfields to the east of any barriers and the potential for disrupting groundwater flows into natural areas to the east and south.

The effects of these projects on water quality are important concerns of DOI. The quality of the water captured in the water preserve areas could be affected by contaminated soils, in areas where former agricultural lands will be flooded, and by unnatural levels of metals and other pollutants leached from geologic formations, where in-ground reservoirs are used.

DOI managers can most effectively participate in CERP projects during three project stages: (1) NEPA scoping in the early stages of project design, to help ensure that hydrologic targets accurately reflect the natural predrainage conditions, (2) review of project alternatives, to ensure that fish and wildlife and parks are adequately considered in compliance with DOI mandates, and (3) monitoring and assessment of project results, to support project modification if needed to ensure that the intended conditions are

achieved. The major questions that DOI managers need to answer at each stage to effectively fulfill their responsibilities as partner and steward are summarized below, along with the highest priority science needs for answering those questions. This information is discussed in greater detail for each individual project following this summary.

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN WATER PRESERVE AREAS AND SEEPAGE MANAGEMENT ALONG THE MARSH/URBAN INTERFACE

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	**Water Preserve Areas**		
	What operating protocols for the WPAs will ensure that outflows support marsh-driven hydrologic targets? How do we develop protocols that are also compatible with the urban supply and flood protection protocols?	Research and possible model refinement to establish operating protocols	NEPA Scoping Schedules for the nine separate WPA projects are revised. C-9, C-11 and WCA 3A/3B seepage Aug 2005 The dates for the other components are expected by September 2004
	How can seepage from the WPAs best be managed?	Seepage measurements	
	How can the design and operation of WPAs ensure that water contaminants are avoided?	Environmental risk assessment of water quality contaminants	
	Lakebelt In-Ground Reservoir Technology Pilot Project		
	How can seepage from the WPAs best be managed?	Information about the effectiveness of seepage barriers in Lake Belt reservoirs	NEPA Scoping Completed
	Will the outflow from the Lakebelt reservoirs be of adequate quality to discharge into natural areas?	Research into biochemical processes that occur in deep lakes and how they will affect outflow.	
	L-31N Seepage Management Pilot and Everglades National Park Seepage Management		
	How will the proposed seasonal operation of the seepage control projects affect hydropatterns and water levels in Northeast Shark Slough?	Determination of the source of flow	NEPA Scoping L-31july 2006
	How can predicted natural hydropatterns for Northeast Shark Slough be translated into operating rules for seepage control structures?	Research and possible model refinement to establish operating protocols	
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	**Water Preserve Areas**		
	What design and operational improvements could enhance ecological benefits of the water preserve areas while meeting water management goals?	Research to support design and operating rules to enhance fish and wildlife resources	EIS Review, Section 7 Consultation, and CAR C-9, C-11 and WCA 3A/3B seepage draft Nov 2005 Final Jan 2006
	Lakebelt In-Ground Reservoir Technology Pilot Project		
	What design and operational improvements could enhance the ecological value of the reservoirs without reducing the intended purpose?	Research to determine the ecological function of deep lakes	EIS Review, Section 7 Consultation, and CAR Draft: May 2015-2020 Final: May 2015-2020
	How will construction of the Lakebelt reservoirs affect the hydrology of the surficial aquifer south of the Lakebelt	Model of the dynamics within the surficial aquifer	
	L-31N Seepage Management Pilot and Everglades National Park Seepage Management		

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN WATER PRESERVE AREAS AND SEEPAGE MANAGEMENT ALONG THE MARSH/URBAN INTERFACE

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	How will the proposed seasonal operations of the seepage control works affect ecological responses in Northeast Shark Slough? What methods of seepage control are the most ecologically desirable?	Monitoring and assessment of pilot project information	EIS Review, Section 7 Consultation, and CAR L-31N Seepage Management Draft: March 2006 Final: March 2007 ENP Seepage Management Revised PMP September 2005
	How does water management East of the Coastal Ridge affect recharge and flow within the Biscayne aquifer?	Additional research and modeling are needed to determine how seepage control actions will affect groundwater flows and recharge within the surficial aquifer and delivery of groundwater between the Everglades and Biscayne Bay.	
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	Water Preserve Areas		
	What treatment and monitoring program will ensure adequate quality of water being put into the park?	Baseline surveys for long-term monitoring comparison	Post-implementation monitoring and assessment Project Completion: TBD
	Lakebelt In-Ground Reservoir Technology Pilot Project		
	What parameters and locations should be monitored to determine the water quality?	Groundwater assessments of water quality inside and outside seepage barriers of deep lakes	Post-implementation monitoring and assessment Project Completion: September 2011
	L-31N Seepage Management Pilot and Everglades National Park Seepage Management		
	What monitoring projects are required to assess the long-term effects of the seepage control structures?	Monitoring and assessment of pilot project information and biomonitoring	Post-implementation monitoring and assessment L-31N Seepage Management Original Completion Date: June 2006 - Delayed ENP Seepage Management Project Completion: September 2013

Water Preserve Areas

Project Purpose and Major DOI Interest

The Water Preserve Area (WPA) Projects consist of nine components[3] encompassing 190,000 acres. The shared purposes of these projects are (1) to retain more water in the natural system by reducing seepage losses from the Everglades, (2) to capture, store, and if necessary treat stormwater currently discharged to tide for other uses, such as recharging wellfields, and (3) to provide fish and wildlife benefits where possible while meeting water management goals.

[3] The WPA components are Acme Basin B Stormwater Treatment Area (STA) and Impoundment; Strazzula Wetlands; Agricultural Reserve Reservoir; Hillsboro Impoundment; Broward County WPA; WCA 3A/3B Flows to Central Lake Belt; WPA Conveyance; Bird Drive Recharge; and Eastern C-4 Structure and WCA-2B Flows to Everglades National Park.

Conceptually, the projects incorporate an interconnected series of marshlands, reservoirs, and aquifer recharge basins east of the Everglades Water Conservation Area. The resulting mosaic of wetlands, buffers, and reservoirs will make possible and complement several CERP water storage projects planned for the future (2010-2020). The WPAs will contribute to natural system water quantity through storage and seepage management. Other benefits include increased aquifer recharge and surface water storage capacity. Together these projects will enhance regional water supplies for urban and agricultural uses and increase the spatial extent of wetlands, providing vital habitat connectivity for species that require large unfragmented tracts of land for survival.

Water preserve areas have the potential to affect nearly all areas within the Everglades Protection Area, which comprises the WCAs 1, 2, and 3, Everglades National Park, and the Arthur R. Marshall Loxahatchee National Wildlife Refuge. DOI has a great interest both in the quantity, timing, and distribution of water deliveries to these areas and in the quality of the water delivered. The primary water quality concerns are the risk of contaminants associated with the rehydration of former agricultural lands. Water soluble contaminants, such as methyl mercury, phosphorus, and nitrogen, are expected to be found in WPA project areas. Initial inundation may lead to water quality issues, as contaminants in the soil are liberated or mobilized.

Five federally listed species are present in the project area: West Indian manatee, wood stork, Everglade snail kite, eastern indigo snake, and Cape Sable seaside sparrow.

DOI will recommend improvements in the design and operation of the aboveground reservoirs to provide ancillary benefits to fish and wildlife wherever possible.

What Is Known

Water quality in South Florida has been the target of extensive field and laboratory investigation over the past two decades, but only recently has there been considerable scientific and technical investigation of large water storage areas (WPAs and STAs) and their use in improving water quality. The SFWMD's 2002 *Consolidated Everglades Report* summarizes the current scientific knowledge about the water quality effects of nutrients and mercury in the Everglades.

What Is Needed

Baseline surveys for long-term monitoring comparison. Surveys will measure baseline conditions (water quality, flora, and fauna) as a reference for future evaluations of post-restoration response to hydrologic change. Long-term monitoring of plant and animal communities and biomonitoring within the WPAs should be initiated to generate data sets to be used for adaptive management of hydrologic restoration targets. Baseline, mid-project, and post-project monitoring will determine the effects of WPAs on migratory and federally listed species. Post-project vegetation studies will be conducted on target plant communities to monitor the success of hydrologic restoration of wetlands and to provide information for effective adaptive management.

Environmental risk assessments of water-quality contaminants. This is another project with potential for ecological effects associated with increases in toxic contaminant loads in stored waters. Studies will be conducted to assist the USACE in designing techniques to minimize water quality degradation during the conversion of agricultural land to water storage areas. Other studies will focus on improving water quality within the conveyance and seepage canals during operation.

Research and possible model refinement to establish operating protocols. Many studies have documented the importance to fish and wildlife of maintaining plant diversity, providing horizontal and vertical vegetative structure, tree islands, snags, underwater substrate, and deep water zones within artificial water bodies such as aboveground reservoirs. The hydrologic requirements of some species are

well documented; however, an integrated approach will be needed to address the needs of multiple species.

DOI needs to identify operating protocols to achieve desired hydrologic targets appropriate for each of the WPAs. These operating protocols will have a specific target or range and will be used to indicate how well, or poorly, each WPA alternative meets project objectives for restoration.

These operating protocols will help determine how to best manage the fringes of the marsh to achieve water storage, reduced seepage, maintain aquifer recharge, and other project objectives. The hydrologic targets need to address appropriate timing, cleanliness, and distribution to replicate natural function in the marsh. The operational protocols should provide water managers more flexible management techniques based on actual rainfall (real-time conditions) rather than projection of annual averages, in order to avoid engineering the wetlands into an unnatural state. Monitoring and assessment will continue to provide information that will help evaluate the response of the system to the new operating parameters.

Research to support design and operational rules to enhance fish and wildlife resources. FWS needs to identify ways in which the WPA projects can be managed and operated to provide favorable habitat for fish and wildlife while maintaining the water management functions. An important design consideration will be to ensure that there are adequate dry season refugia, such as alligator holes, to accommodate species during dry seasons.

Seepage measurements. Research regarding the design, implementation, and management of water storage areas of this magnitude does not currently exist. The seepage management pilot projects need to be completed and analyzed to provide the information needed to fully implement this program. [4]

Lakebelt In-Ground Reservoir Technology Pilot Project

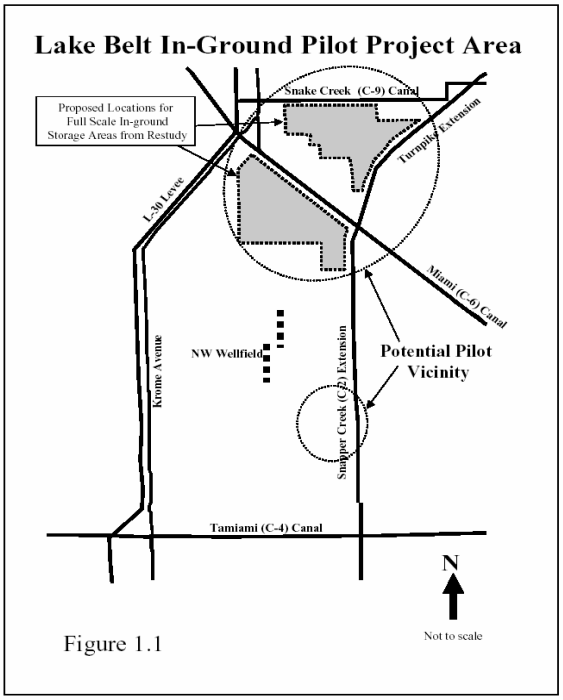


Figure 1.1

Project Purpose and Major DOI Interest

In Palm Beach and Broward Counties, the water preserve areas will be implemented as aboveground impoundments, but in Miami-Dade County the highly permeable aquifer precludes the use of aboveground impoundments and requires in-ground reservoirs. Rock mining in Northwest Miami-Dade County has created many large rock quarries at depths up to 80 feet. These quarries are proposed for use as deep water lakes that will provide water storage capacity in southwest Miami-Dade. The in-ground reservoirs will be designed to store stormwater runoff or WCA water during the wet season when levels are too high in the WCAs and to deliver water during the dry season.

Due to the porous nature of these pits, water storage without a seepage barrier around them would cause the water to enter the surficial groundwater aquifer system, raising the water table and causing flooding. Drawing water from these areas without a seepage barrier would impact

[4]See "L31N Seepage Management Pilot Project," page 54.

wellfields, drain adjacent wetlands, and increase seepage from the water conservation areas to the west.

The Lake Belt In-Ground Reservoir Technology Pilot Project was initiated to address uncertainties with using seepage barriers in four CERP components: Central Lake Belt Storage Area; North Lake Belt Storage Area; L-31N Levee Seepage Management; and L-8 / C-51 Reservoir. The uncertainties include appropriate construction technologies, storage efficiencies, impacts on local hydrology, and water quality effects. Water quality assessments will include a determination as to whether the in-ground reservoirs and seepage barriers will allow for storage of untreated waters without concern for groundwater contamination. Upon completion of the pilot, the USACE will be able to better design the in-ground water storage projects listed above.

The proposed design of the full-scale in-ground reservoirs will enclose approximately 15 square miles of existing rock mines and areas permitted for future excavation with seepage barriers. The Lake Belt Pilot Project will involve installing a seepage barrier around an existing smaller rock-mined area with geology similar to the geology at the proposed locations for the full-scale in-ground reservoirs.

The in-ground reservoir projects are of particular interest to DOI because they will provide important flows into Everglades and Biscayne Bay National Parks that are needed to achieve restoration. The overall purpose of the North and Central Lake Belt Storage Projects will be to store excess water and provide environmental water supply deliveries to Northeast Shark River Slough, WCA-3B, and Biscayne Bay. In addition to concerns about how the water will be delivered into the wetlands,[5] DOI is concerned with the quality of water discharged from the in-ground reservoirs. The depth of these lakes and their method of construction ensure connection with deep groundwater strata typically containing high concentrations of dissolved solids, whose potential effects on the ecosystem are unknown. One of the signature features of un-impacted Everglades waters is relatively low concentrations of dissolved solids, especially as compared to ground water. Increases in dissolved solids due to the connection of deep groundwater strata to surface water could be problematic.

DOI is also interested in the potential to design these projects to be as compatible as possible with wildlife use without interfering with their primary purposes and to ensure that the barriers used to confine the reservoirs will not adversely effect groundwater flow into the natural areas further south Deep water lakes exhibit characteristics that would be very different from those typically experienced by Everglades plants and animals. DOI managers need to understand the management issues raised by these differences so that they can recommend design improvements to the USACE that will benefit fish and wildlife and mitigate any potential impacts on vegetation.

What Is Known

Dissolved solids concentrations in the Everglades have increased over decades as the result of agricultural and urban development. The ecological impacts of these increases are currently being investigated.

What Is Needed

Information about the effectiveness of seepage barriers in Lake Belt reservoirs. Construction of seepage barriers around the rock pits may alleviate the concerns associated with storing and removing water from these in-ground reservoirs; however, seepage barrier technology of this magnitude has not been used in South Florida, which creates uncertainties regarding constructability, storage effectiveness, groundwater impacts, and water quality effects.

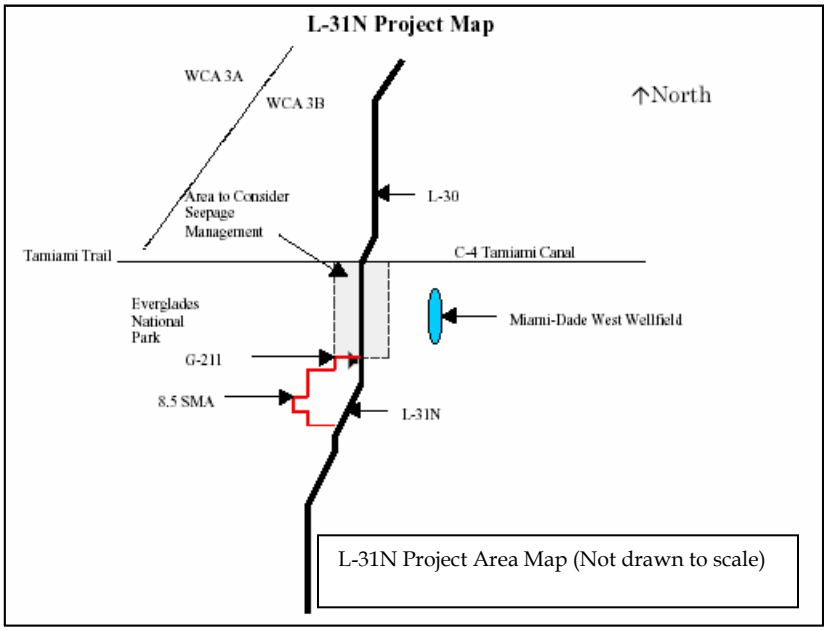
Research to determine the ecological function of deep lakes. From an ecological standpoint, there are no similar deep water habitats in the Everglades, so the ecological value and function of large acreages of such habitats are unknown.

[5] Water deliveries are addressed under the DECOMP and CSOP Projects, pages 67 and 71.

Research into biochemical processes that occur in deep lakes and how they will affect outflow. Research into the biogeochemical processes that will occur in these very deep lakes, and how those processes will affect the water quality of the outflow, will be needed to determine the extent of necessary treatment, so that the outflow will be of adequate quality to discharge into natural areas.

Groundwater assessments of water quality inside and outside seepage barriers of deep lakes. Assessments of water quality at various locations will aid in determining the locations to be monitored over time to assess effects on water quality .

L-31N Seepage Management Pilot and Everglades National Park Seepage Management



Project Purpose and Major DOI Interest

Urban and agricultural development of Miami-Dade County has substantially reduced the area of the Northeast Shark Slough (NESS) drainage basin. This in turn has substantially reduced the amount of flow through the marsh and into downstream estuaries. In addition, large seepage losses occur to the east as a result of an extremely permeable groundwater flow system and large water level differences between the slough and the developed areas to the east. These two factors have caused reduced hydroperiods and water depths in the slough. Most of the seepage water is intercepted by the L-31N canal and is routed into south Dade, where it frequently causes other water-related problems.

The CERP plan contains several components to control seepage out of natural areas. The most complex seepage management projects are the L-31N Seepage Management Pilot Project and the Everglades National Park Seepage Management Project, which together are intended to investigate then apply the most appropriate and effective technology to control and manage the large volumes of water currently lost from Northeast Shark Slough to the urbanized lower east coast. The two projects are considered together because the science needs are similar.

The purpose of the pilot project is to investigate seepage management technologies and to determine the appropriate amount of wet season groundwater flow to return to Everglades National Park while minimizing the impacts to downstream water users such as Miami-Dade County and Biscayne National Park. This pilot is expected to provide the technology needed to reduce levee seepage flow across L-31N adjacent to Everglades National Park and to reduce groundwater flows during the wet season by capturing groundwater flows with a series of groundwater wells adjacent to L-31N then backpumping those flows to Everglades National Park.

The purposes of the Everglades National Park Seepage Management Project are to improve water deliveries to Northeast Shark River Slough and to restore wetland hydropatterns in Everglades National Park by reducing levee and groundwater seepage and increasing sheetflow. This project will reduce levee seepage flow across L-31N adjacent to Everglades National Park. Groundwater flows during the wet season will be captured and pumped back to the park. Water from upstream natural areas will be diverted into a buffer area adjacent to the park, where sheetflow will be reestablished. Further, this project includes relocation of the Modified Water Deliveries Project structure S-356 to provide more effective water deliveries to Everglades National Park. The increased flows into Northeast Shark Slough resulting from the Modified Water Deliveries Project will increase the potential for seepage from the slough, and pump station S356 is intended to return this additional seepage flow back to the slough.

New discharges to the park will be designed to meet applicable water quality criteria. Scheduled to begin at the conclusion of the pilot study, the project is slated for completion in 2013.

Improved water deliveries are expected to improve the ecological conditions in Northeast Shark River Slough and in the downstream estuaries. Reduced hydroperiods in the slough resulting from seepage losses have caused negative ecological impacts such as invasions of non-wetland species, and have the potential to disrupt nesting of alligators and wading birds, including wood storks. Evidence suggests that flow volumes and/or velocities are also important to maintaining the ridge and slough landscape.

What Is Known

Northeast Shark Slough has been the focus of numerous hydrologic investigations in recent years, and a reasonable hydrologic database is available. Extensive water level monitoring is currently being conducted by the NPS and the USGS. Outside of Everglades National Park, flow in L-31N, a direct indicator of seepage, is measured, and the SFWMD keeps detailed records of water levels and estimated flows at all of the C&SF structures. A relatively long database related to fish communities in Northeast Shark Slough is available and has been used in conjunction with hydrologic data to develop linkages between the hydrology and the response of aquatic communities. Wading birds and American alligators are among the keystone species that are routinely monitored in this area. Water quality is also monitored at several structures in the footprint of this project, and the monitoring data could be used as baseline water quality information.

A number of studies conducted by the USGS and others document the geology and hydrologic characteristics of the surficial aquifer. Additional studies provide more focused information about the subsurface characteristics of the West Dade Wellfield, located just 2 miles east of L-31N, and the rock-mining area located adjacent to L-31N.

Several hydrologic models are available for use in this area. The USGS has calibrated and verified MODBRANCH, which combines a widely used groundwater model (MODFLOW) with a one-dimensional model for canals and structures (BRANCH). This model has seen wide use in South Florida and is a viable candidate for use in evaluating alternatives for seepage management. The SFWMD has nearly completed development of the RSM, which also could have applications in these projects.

What Is Needed

Monitoring and assessment of pilot project information. Monitoring and analysis of the pilot project information will address most of the management questions. Hydrologic monitoring and assessment will evaluate the physical response of the system and any impacts to downstream water supply. Ecological monitoring and assessment of vegetation changes and impacts on American alligators and wading birds will address the ecological response to the physical changes in the system. In addition, water quality monitoring and biomonitoring will assess potential impacts to the system from introduction of water from other sources.

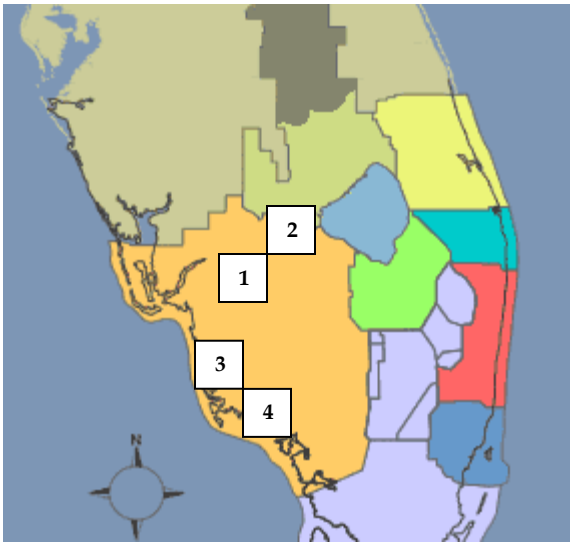
Determination of the source of flow. An additional flow gauge in the canal at the L29 intersection will support a determination of the source of flow measured by the other gauges.

Research and possible model refinement to establish operating protocols. Research will be conducted to determine the appropriate hydrologic response to rainfall and to translate that information into appropriate performance targets for input into the design and operating rules to manage water levels and flow volumes.

Research to define how back pumping and groundwater hydraulic gradients affect the flow of water and groundwater recharge in the surficial aquifer. Further research to assess the origin and the amount of water delivered to the coastal estuaries, Biscayne Bay, Card Sound and Barnes Sound via freshwater and groundwater flows.

Additional research and modeling are needed to determine how extensive seepage control actions will affect groundwater flows and recharge within the surficial aquifer and ultimate delivery of groundwater between the Everglades and Biscayne Bay. Modeling is needed to quantify the amount of water east of the Coastal Ridge that is entering the coastal estuaries. Better definition of the hydrologic framework and geohydrology of the Biscayne aquifer and overlying confining soils and sediments are needed. Baseline high-resolution groundwater level monitoring is needed between WPAs, Everglades National Park, and groundwater connection to Biscayne Bay. Further, research is needed to understand how changing water levels will affect groundwater flow within the surficial aquifer and how changing water levels, increase in flood duration in the natural system, and seepage management will affect the recharge of this aquifer, and, ultimately, groundwater flows to Biscayne Bay.

Lower West Coast



PROJECTS

1. Southwest Florida Feasibility Study
2. C-43 Basin Storage Reservoir
3. Picayune Strand Hydrologic Restoration
4. Henderson Creek/Belle Meade Restoration

Overview

Florida lies beyond the range of most CERP projects and models. The C&SF Project *Comprehensive Review Study* recommended a feasibility study to identify southwest Florida water resource conditions and to develop potential solutions to any problems that might be identified. DOI has a great interest in this area, which covers approximately 4,300 square miles and includes two major drainage basins and the largest subtropical mangrove estuarine ecosystem in the United States. Lands under DOI stewardship include the J.N. "Ding" Darling and Florida Panther /Ten Thousand Islands National Wildlife Refuges, Big Cypress National Preserve, and Everglades National Park.

Drainage to support intensive urbanization has significantly decreased coastal wetlands and altered the freshwater inflows and salinity in the southwest coastal estuaries and bays. A principal goal for all of the southwest Florida hydrologic restoration projects is the reestablishment of natural freshwater flows and salinity in these areas. The Henderson Creek/Belle Meade Restoration Project and the Picayune Strand Hydrologic Restoration Project are similar projects that propose to meet this goal through a combination of rehydrating wetlands, removing barriers to sheetflow, and reducing canal point discharges.

Because the 2 x 2 Model does not have a database that includes southwest Florida, the SFWMD has created a regional hydrologic model, the MIKE-SHE, to fill this gap, and it is being used to predict how water will change under different alternatives. A fully verified regional physical model needs to be developed and integrated with ecological models to more accurately predict salinity patterns and the responses of biological communities and species to hydrologic changes.

Landscape level restoration in southwest Florida may require decisions that favor one species or trophic level over another or that maximize biodiversity within an ecological system. Assessment tools to support this level of decision making are a critical priority of long-term regional resource planning. Species of particular concern in southwest Florida include such far-ranging species as the Florida panther, West Indian manatee, wood stork, and migratory birds.

DOI managers can most effectively participate in CERP projects during three project stages: (1) NEPA scoping in the early stages of project design, to help ensure that hydrologic targets accurately reflect the natural pre drainage conditions, (2) review of project alternatives, to ensure that fish and wildlife and

parks are adequately considered in compliance with DOI mandates, and (3) monitoring and assessment of project results, to support project modification if needed to ensure that the intended conditions are achieved. The major questions that DOI managers need to answer at each stage to effectively fulfill their responsibilities as partner and steward are summarized below, along with the highest priority science needs for answering those questions. This information is discussed in greater detail for each individual project following this summary.

SUMMARY OF DOI SCIENCE NEEDS RELATED TO THE LOWER WEST COAST

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	**Southwest Florida Feasibility Study**		
	What hydrologic targets will support the restoration of predrainage ecological conditions, including short hydroperiod (ephemeral) wetland habitats, in this area? What are the critical links between hydrology, water quality, and ecological responses in southwest Florida?	Modeling to predict temporal and spatial variations in hydrologic conditions Modeling to predict temporal and spatial salinity patterns in estuaries	NEPA Scoping Completed
	C-43 Basin Storage Reservoir		
	What hydrologic targets will achieve natural flows in the Caloosahatchee River?	Modeling to determine natural flows in the Caloosahatchee River	NEPA Scoping May 2004
	Henderson Creek / Belle Meade Restoration		
	What are the hydrologic targets for freshwater inflows into the mangrove estuaries and Rookery Bay? What are the operating protocols needed to establish rainfall-driven operations?	Additional analysis of Henderson Creek/Rookery Bay hydrology Research and possible model refinement to establish operating protocols	NEPA Scoping TBD
	Picayune Strand Hydrologic Restoration		
	What are the hydrologic targets for freshwater inflows?	Refinement of the MIKE-SHE Model	NEPA Scoping Completed
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	**Southwest Florida Feasibility Study**		
	How do hydrologic and water quality targets relate to the landscape-scale assemblage of habitats needed to support the area's fish and wildlife resources and particularly the wide-ranging species, such as the Florida panther, West Indian manatee, Florida black bear, wood stork, and other migratory and wading birds?	Modeling to predict trophic- or species-level responses to habitat changes	EIS Review, Section 7 Consultation, and CAR Draft: March 2008 Final: May 2009
	C-43 Basin Storage Reservoir		
	How will hydrologic restoration contribute to the recovery of listed species particularly the West Indian manatee, and to the protection and enhancement of fish and wildlife values?	Geographic information system (GIS) mapping for habitat database Modeling of West Indian manatee responses to habitat changes	EIS Review, Section 7 Consultation, and CAR Draft: May 2006 Final: Dec 2006

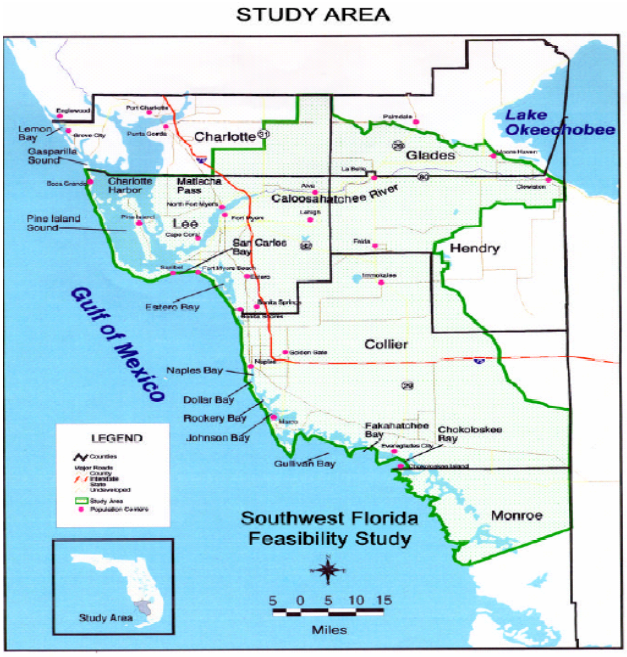
SUMMARY OF DOI SCIENCE NEEDS RELATED TO THE LOWER WEST COAST

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	**Henderson Creek / Belle Meade Restoration**		
	What are the links between freshwater flows and ecological responses in the upland areas and the receiving water bodies of Rookery Bay?	Modeling to predict the relative abundance and spatial distributions of estuarine fish and macroinvertebrates	EIS Review, Section 7 Consultation, and CAR TBD
	Picayune Strand Hydrologic Restoration		
	What are the anticipated effects on the threatened and endangered species in the project area, and particularly the West Indian manatee, Florida panther, and wood stork?	Synthesis and study of the impacts of altered hydrology on the Florida Panther NWR	EIS Review, Section 7 Consultation, and CAR Complete
	What alternative will provide the most benefits for fish and wildlife resources?	Modeling to predict changes in hydrology and ecology in the Ten Thousand Islands NWR	
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	**Southwest Florida Feasibility Study**		
	What are the key indicators of the desired ecological responses?	Identification and monitoring of key indicators and communities is needed for assessing hydrological restoration efforts and accompanying water quality concerns	Post-implementation monitoring and assessment Project Completion: TBD
	C-43 Basin Storage Reservoir		
	What are the effects on threatened and endangered species?	Monitoring of bird species: • bald eagle • Audubon's crested caracara • Everglade snail kite • wood stork Monitoring of West Indian manatee responses to habitat changes	Post-implementation monitoring and assessment Project Completion: April 2011
	Henderson Creek / Belle Meade Restoration		
	What are the key ecological indicators and how will they respond to the desired flow regime?	Identification and monitoring of indicator species: • euryhaline and stenohaline crabs eastern oyster	Post-implementation monitoring and assessment Project Completion: TBD
	Picayune Strand Hydrologic Restoration		
	What are the effects on wildlife within the Ten Thousand Islands NWR?	Baseline data and monitoring of effects on wildlife within the Ten Thousand Islands NWR	Post-implementation monitoring and assessment Project Completion: TBD
	What are the hydrologic effects on receiving waters south of the project area?	Monitoring of water flows and water quality in receiving waters south of the project area	
	What are the effects on threatened and endangered species?	Monitoring of effects on federally listed species affected by the project: • West Indian manatee • Florida panther • wood stork	
	What is the ecological response to hydrologic change?	Monitoring of ecological responses to hydrologic change: • amphibians • aquatic invertebrates and fishes • wading birds • crab, oyster, fish, and marine invertebrates in estuaries	

Southwest Florida Feasibility Study

Project Purpose and Major DOI Interest

The C&SF Project *Comprehensive Review Study* recommended a feasibility study to identify southwest Florida water resource conditions and to develop potential solutions to any problems that may be identified. Although most of southwest Florida lies outside the area covered by the CERP models, it is known that dredging, filling, and channelization have altered the hydrology of this region, resulting in significant adverse effects on native habitats and wildlife. Lee County alone has lost 19% of its original mangrove forests.



The project area includes the Caloosahatchee and Big Cypress watersheds. Historically, the Caloosahatchee River was a shallow, meandering 50-mile-long drainage. This watershed includes a pristine mangrove-dominated estuary, a habitat unique in the continental United States. Mangroves support fish and macroinvertebrate communities by providing protected nursery areas and food for a multitude of important commercial and recreational marine species.

As a result of dredging and channelization beginning in 1884, the river now extends 71 miles from Lake Okeechobee to San Carlos Bay. The river is managed by three locks, the most downstream of which also serves as a barrier to salinity and tide within the 26-mile-long estuarine portion of the Caloosahatchee River. Water releases from Lake Okeechobee occur through a series of locks when lake levels exceed the USACE criteria for flood protection.

The Big Cypress watershed of the region drains to the coastal marshes and mangrove swamps of Estero Bay, Rookery Bay, and the Ten Thousand Islands. This area includes extensive urban and agricultural development as well as public land holdings and has historically been one of the most rapidly developing areas in the nation. There are a significant number of canals and structures in the watershed, the operation of which affect interior wetlands and receiving waters.

The *Southwest Florida Feasibility Study* will address the health of upland and aquatic ecosystems in this 4,300 square mile area and consider a variety of parameters, including water flow, water quality, water supply, maintenance of existing flood protection, wildlife, biological diversity, and natural habitat. Given the large amount of public land in the study area, a major goal is to define the hydrologic linkages among nearly 30 federal, state, or county-managed areas and to coordinate the management and stewardship of these areas. DOI needs to continue its technical support role with the USACE through alternative development and subsequent project design and implementation.

The study area contains a number of wetland communities of significant concern to DOI, particularly short-hydroperiod freshwater marshes and wet prairies, seagrass beds, and mangrove forests. Up to 20 federally listed species and their critical habitat or experimental populations may occur within the study

area. Southwest Florida likely represents the most important region of Florida in supporting wide-ranging listed species, such as the Florida panther, Florida black bear, and wood stork. Okaloacoochee Slough encompasses approximately 140,000 acres of primary habitat for Florida panthers. Area wetlands support the nation's largest historical wood stork rookery, the remnant of which is protected in Audubon's Corkscrew Swamp Sanctuary. Forty-three species of migratory nongame birds of management concern are supported by the southwest Florida ecosystem. Seagrass beds off the southwest Florida coast provide habitat and nursery grounds for many fish and invertebrate communities and are especially important in benthic-based primary productivity. West Indian manatees, waterfowl, fish, and wading birds rely heavily on seagrass systems as forage areas.

What Is Known

Studies have been completed on the function of ephemeral wetlands (seasonal ponds, freshwater marshes, isolated wet prairies, and hydric flatwoods) to establish those environmental characteristics critical to the survival and health of the numerous species adapted to the wet-dry annual seasonal regimes of South Florida. The wetland communities with the largest loss in the study area are short-hydroperiod freshwater marshes and wet prairies. Many species have life history cycles that are especially adapted to take advantage of the temporal nature of these habitats. These habitats also serve as seasonal refuges for species that are unable to survive or adapt to the altered hydrological cycles resulting from development. As water tables are lowered, the viability of these isolated ephemeral wetlands is reduced.

Background research and modeling, including a predevelopment vegetation map, a conceptual ecological model, and a regional simulation hydrological model (RSM), have been completed.

What Is Needed

Modeling to predict temporal and spatial variations in hydrologic conditions. Models that integrate sheetflow and groundwater conditions are needed to predict the temporal and spatial variations in hydrologic conditions that will occur with simulated depths of inundation in freshwater wetlands.

Modeling to predict temporal and spatial salinity patterns in estuaries. A principal goal for all of southwest Florida's hydrological restoration projects is the reestablishment of the minimum freshwater flows, and the elimination of freshwater point-source discharges, needed to restore more natural hydrology—and particularly salinity patterns—in estuaries. To have meaningful input into project targets, DOI managers will need to (1) understand how the hydrologic conditions in the estuaries are expected to change in response to hydrologic changes in the watershed and other restoration efforts, and (2) make assumptions about how the expected changes relate to the natural, predrainage hydrologic conditions in the estuary. The best tool for providing this information would be a fully calibrated and verified regional salinity model supported by continuous monitoring and other data acquisition.

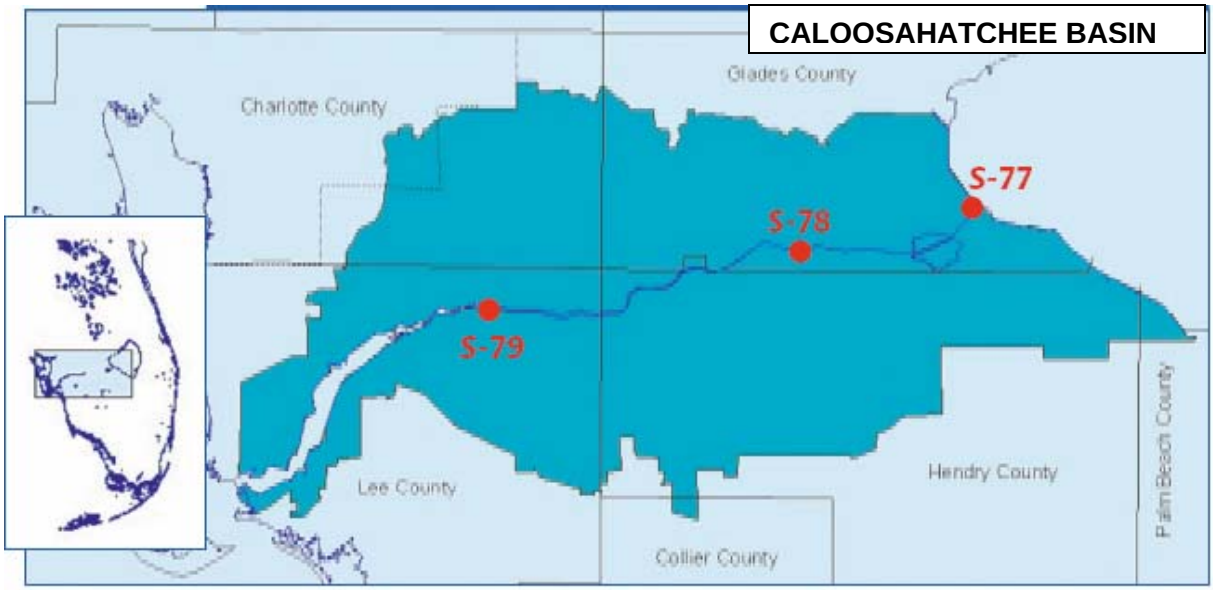
This will require the development and calibration of estuarine mixing/circulation models. In order to predict the spatial and temporal salinity patterns in estuaries following upstream restoration, the dynamics of tidal and freshwater mixing must be understood. Hydrological modeling techniques now exist to allow development of these models. Once modeled, the effectiveness of estuarine restoration can be tested by comparing predicted salinity patterns with those empirically measured. Existing models such as the 2 x2 Model and the NSM do not cover the feasibility study area. The hydrological model developed for the feasibility study area does not extend to the estuaries.

Modeling to predict trophic- or species-level responses to habitat changes. Development of evaluation tools to support landscape-level decision making is a critical priority for long-term regional resource planning. Ecological models needed for southwest Florida include (1) Florida panther response to habitat quality and quantity and changes in these habitats, (2) West Indian manatee response to changes in

freshwater outflow and changes in seagrass distribution in estuaries due to watershed restoration activities, (3) migratory bird response to losses of forested ecosystems, and (4) wood stork response to alterations in wetland hydrology.

Identification and monitoring of key indicators. Research is needed to **identify** plant, invertebrate and vertebrate species that are diagnostic of particular hydrological conditions and that are responsive to hydrologic and water quality changes in the region.

C-43 Basin Storage Reservoir



Project Purpose and Major DOI Interest

The Caloosahatchee River once had an undistinguishable connection to Lake Okeechobee and probably received overflow from the lake only in abnormally wet years. The river was shallow and had numerous oxbows. Flooding was common. Water development activities, including the direct connection of the river through the C-43 canal to Lake Okeechobee, has highly altered the hydrology of the river and basin.

The purpose of this project is to capture Caloosahatchee River Watershed (C-43 basin) runoff and releases from Lake Okeechobee. The reservoir will be designed for environmental, urban, and agricultural uses, water supply benefits, flood attenuation, and water quality benefits in terms of reduced salinity and nutrients in the Caloosahatchee Estuary.
Although WRDA 2000 did not specifically authorize construction of the C-43 Basin Storage Reservoir Project, WRDA authorized its inclusion in the development of a *Project Implementation Report* as part of the CERP.

This project is the first part of the C-43 Basin Storage Reservoir and ASR component. The project includes an aboveground reservoir with a total storage capacity of approximately 160,000 acre-feet located in the C-43 basin in Hendry, Glades, or Lee Counties. The initial design of the reservoir assumes 20,000 acres with water levels fluctuating up to 8 feet above grade. The final size, depth and configuration of this facility will be determined through more detailed planning and design. The C-43 reservoir will also be operated in conjunction with the Caloosahatchee Backpumping Project, which includes a stormwater treatment area for water quality treatment. If the level of water in the reservoir exceeds 6.5 feet and Lake Okeechobee is below a predetermined level, then water is released and sent to the backpumping facility.

In order to restore the downstream estuaries, the proposed reservoir and STA must be located within the watershed.

The Caloosahatchee River basin contains both wetland habitats (freshwater swamps, sloughs, marshes, and estuaries) and upland habitats (pine flatwoods, temperate oak/palmetto hammocks, tropical hammocks, dry prairie, and xeric scrub communities). Although classified as distinct habitats, these systems form an interdependent mosaic, particularly for wide-ranging, imperiled species such as the bald eagle, Audubon's crested caracara, Everglade snail kite, and wood stork. The Caloosahatchee basin is also an important area for panther recovery. Also, a vital portion of the regional West Indian manatee population resides seasonally and/or year-round in the Caloosahatchee River and estuary.

The FWS is in the process of providing site and design recommendations to the USACE to reduce the direct and indirect impacts of the reservoir and STA on the habitat of threatened and endangered species in the project area. Even if large man-made reservoirs and STAs are sited in agricultural areas of relatively low habitat value, their long-term presence and operation in the Caloosahatchee watershed will modify the habitat quality for the four federally listed bird species (bald eagle, Audubon's crested caracara, Everglade snail kite, and wood stork) and perhaps other species, as well.

The flows from the Caloosahatchee River into the estuary directly affect the J. N. Ding Darling National Wildlife Refuge and also habitat on other public and private lands. A comprehensive conservation plan to comply with the National Wildlife Refuge System Improvement Act of 1997 is currently in preparation. The FWS is in the process of providing recommendations to reduce the direct and indirect impacts of this project on habitats throughout the watershed. As part of its analysis, the FWS will estimate the incidental take for all of the listed species when the preferred alternative is identified by the USACE.

What Is Known

A great deal of information on the manatee population in the Caloosahatchee River basin and the connecting C-43 basin has been collected and analyzed. Periodic surges of freshwater discharged into the Caloosahatchee River and its estuary during high rainfall events negatively impact the salinity level and habitat needs of the estuary. In addition to rapid salinity changes, these freshwater inflows affect nutrient loads and water transparency, which also control seagrass survival and distribution. Seagrasses support the estuarine food web and affect the distribution and movement patterns of manatees. The geographic distribution of food, warm-water refugia, freshwater sources, and the risk of boat-caused injury and mortality in the Caloosahatchee basin are factors that affect the recovery of the endangered manatee in this area.

What Is Needed

Modeling to determine natural flows in the Caloosahatchee River

Monitoring of bird species. Once sites are selected for these facilities, DOI will need to assess the type and degree of project impacts on federally protected species in the project area (bald eagle, Audubon's crested caracara, Everglade snail kite, and wood stork). DOI must use time and resources efficiently and quickly to collect and analyze baseline data and to synthesize it into recommendations that will assist the USACE in the design and construction of these facilities in ways that will minimize negative impacts on species and maximize potential benefits. After construction, habitat use at the facilities and in adjacent areas will be monitored, and the data analyzed to provide input into the adaptive management phase of the project. Indirect impacts related to the operation of the water management structures cannot be accurately predicted until operational plans are refined after construction and testing, at which time the FWS will need to reassess the indirect take these facilities will cause within the watershed.

Geographic information system (GIS) mapping for habitat database. The GIS-based tool the FWS has developed to map habitats for consideration in siting structures for the Lake Okeechobee Watershed Project will be refined and expanded with additional data for use in site selection that considers fish and wildlife values in the Caloosahatchee basin. [6]

Modeling and monitoring of West Indian manatee responses to habitat changes. DOI will use the current database and best available science to provide input to the USACE to reduce impacts on manatees. As more information is collected and analyzed, predictions of how manatee behavior will be affected by anticipated changes in their habitat will be linked to modeling and empirical studies of estuarine water circulation, salinity, water clarity, and seagrass distribution conducted by the SFWMD. Comparison of baseline data with post-construction conditions will be used in an adaptive assessment process to recommend changes in project operation or design to most benefit recovery of the manatee in this essential portion of its range. The operation of the water-storage and treatment facilities as an integrated system will be evaluated as part of an adaptive assessment program, and their effects on seagrasses and manatees will be part of this assessment.

Henderson Creek / Belle Meade Restoration

Project Purpose and Major DOI Interest

The Henderson Creek/Belle Meade Restoration Project is located about 5 miles south of Naples in southwestern Florida. The area known locally as the Belle Meade is the primary watershed for Henderson Creek, which drains into the Rookery Bay estuary. Collier County is currently facing unprecedented urban growth. Canals, roads, planned unit developments, commercial projects, and agriculture have greatly altered the volume, timing, and quality of freshwater entering the fragile estuarine ecosystems and severely restricted the ability of the associated wetlands to filter pollutants. While channelization and development have disrupted this system, acquisition and restoration of the undeveloped lands surrounding Henderson Creek, which link the watershed and estuary, can stop further hydrologic and habitat disturbance.

The primary DOI concern is to ensure that flows are managed to avoid unnatural surges of freshwater into one of the largest expanses of mangrove estuary in North America, part of which is protected inside the Ten Thousand Islands National Wildlife Refuge near Rookery Bay. The Rookery Bay National Estuarine Research Reserve and Ten Thousand Islands Aquatic Preserve, under the stewardship of the National Marine Fisheries Service and the Florida Department of Environmental Protection, are adjacent to the wildlife refuge. This region provides habitat for 14 federally listed threatened or endangered animal species, including the West Indian manatee. The bay also provides critical nursery habitat for commercially and recreationally important finfish and shellfish.

A weir situated north of Highway 41 is the main water control structure on Henderson Creek, controlling flows into Rookery Bay. Until recently, the weir could not be adjusted to mimic natural freshwater inflow patterns. Stream-gauging equipment was installed during the spring of 2001 to help regulate flow through the weir. The appropriate timing and amount of freshwater inflow through the weir on Henderson Creek need to be determined in order to conserve and protect listed species dependent upon the estuarine habitat in Rookery Bay.

What Is Known

Water circulation in Rookery Bay is a complex function of freshwater flows, tidal and wind forces, and local depths. Freshwater enters the bay through surface and groundwater flows and intense seasonal and

[6] See the discussion of this topic for the Kissimmee basin, page 27.

episodic rains. Historically, surface freshwater percolated through wetland flowways before entering Henderson Creek and the bay.

Hydrologic manipulations and land use changes in the area over the past few decades have significantly affected the amount of freshwater entering Rookery Bay. Historically, the estuary received freshwater at about 2,500 cubic feet per second per month (cfs/month), but during the early 1990s the inflows regularly exceeded 10,000 cfs/month, a fourfold increase. Very high flows from Henderson Creek have occasionally resulted in rapid drops in salinity in the mid-region of the estuary, with significant impacts on water quality and biota.

What Is Needed

Additional analysis of Henderson Creek/Rookery Bay hydrology. Restoring this part of the ecosystem will require greater understanding of the spatial and temporal salinity patterns and the dynamics of tidal and freshwater mixing in the predrainage estuary and bay. To have meaningful input into project targets, DOI managers will need to (1) understand how the hydrologic conditions in the estuary will be expected to change in response to upland hydrologic changes and other restoration efforts, and (2) make assumptions about how the expected changes relate to the natural, predrainage hydrologic conditions in the estuary. The best tool for providing this information would be a fully verified regional physical model supported by continuous monitoring and other data acquisition. If it is not feasible to develop such a model before the project design phase, less sophisticated models can be used, and assumptions can be validated or refined during project assessment and adaptive management.

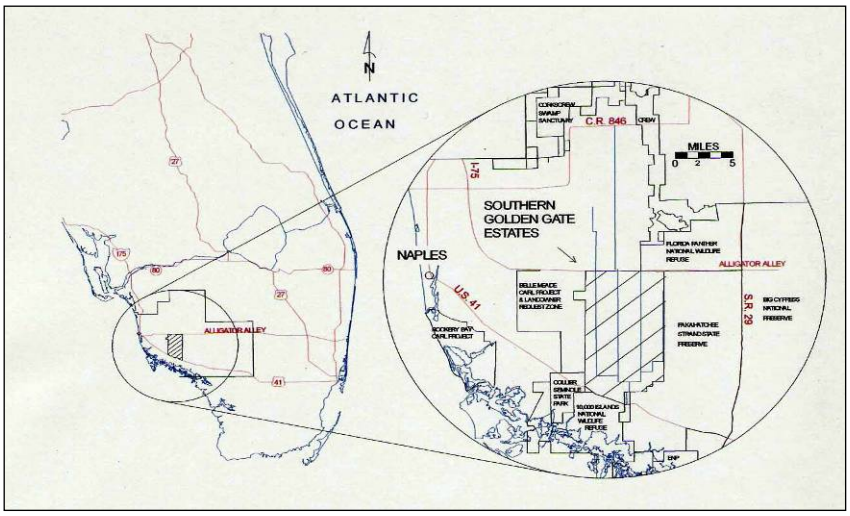
Four major tasks are necessary for this project: (1) understand the estuarine circulation patterns (and if possible determine salinity distribution under various freshwater inflow regimes), (2) gather temperature and salinity data across Rookery Bay and Henderson Creek associated with seasonal inflow regimes for four seasons, (3) map depths and bottom type within Rookery Bay using sonar, and (4) refine and validate information used to support decisions.

Research and possible model refinement to establish operating protocols

Modeling to predict the relative abundance and spatial distributions of estuarine fish and macroinvertebrates. Hydrologic and ecological model outputs will be needed to fully evaluate and predict the potential impacts of restoration alternatives. The Florida Fish and Wildlife Conservation Commission's Florida Marine Research Institute has been developing habitat suitability models that could be linked to the estuarine water circulation models. The modeling can be used to predict how changes in salinity/temperature patterns could influence the relative abundance and spatial distributions of important species of estuarine fish and macroinvertebrates.

Identification and monitoring of indicator species. Baseline information about the seasonal distribution of keystone species during both dry and wet seasons needs to be gathered and correlated with baseline hydrologic conditions. Modeling and verification of changes in species distribution as the project is implemented will improve the understanding of the linkages between potential freshwater inflow regimes from the Henderson Creek weir and the resulting ecological responses.

Picayune Strand Hydrologic Restoration



Project Purpose and Major DOI Interest

The Faka Union Canal System, completed in 1968, includes approximately 48 miles of canals intended to drain the proposed Southern Golden Gate Estates residential development project. The resulting hydrologic effect of these large canals is severe overdrainage of the area and large point-source freshwater discharges to downstream estuarine systems.

The purpose of the project is to restore and enhance the fish and wildlife habitat, particularly wetlands, in Picayune Strand Hydrologic Restoration and on adjacent public lands by reducing overdrainage. A combination of spreader channels, canal plugs, road removal, and pump stations will reestablish more natural overland flows and improve the quality of the coastal estuaries by spreading the freshwater discharges more evenly among the bays and moderating the large salinity fluctuations currently caused by point discharges from the Faka Union Canal.

The project is located in the Big Cypress watershed of the Everglades region, in an area of approximately 94 square miles in southwestern Collier County. It is surrounded by a number of environmentally sensitive public lands, including the Florida Panther National Wildlife Refuge, the Ten Thousand Islands National Wildlife Refuge/National Estuarine Research Reserve/ Aquatic Preserve, the Belle Meade tract of the Picayune Strand State Forest, and the Fakahatchee Strand State Preserve. Changes in this region of the Everglades will also affect other parts of the Everglades, including Everglades National Park.

Fifteen federally listed animal species and one candidate fish species are present or potentially present in the project area. These include the Florida panther, West Indian manatee, wood stork, American crocodile, Everglade snail kite, red-cockaded woodpecker, piping plover, eastern indigo snake, and bald eagle. Five listed sea turtle species, one listed fish, and three candidate fish under the jurisdiction of the National Marine Fisheries Service may be affected by the project.

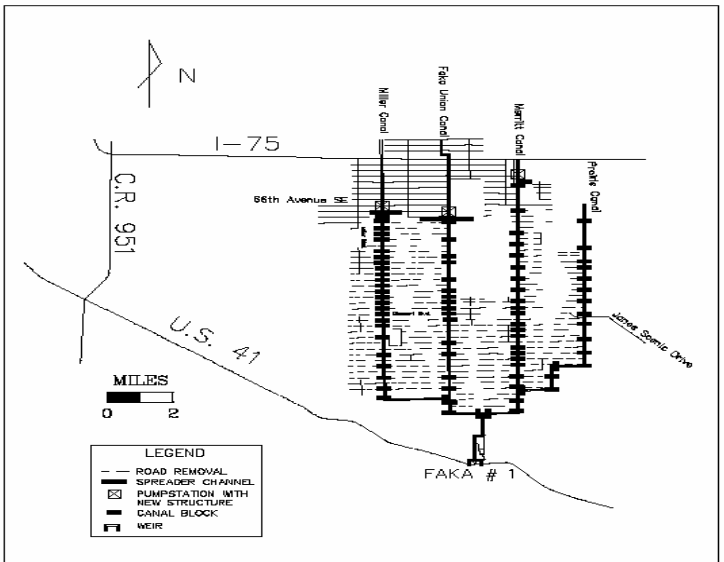


FIGURE 1. Recommended Plan Southern Golden Gate Estates Hydrologic Restoration

What Is Known

It is estimated that the Faka Union Canal System has increased drainage by 16 times faster than historic conditions, lowered water tables by 2 to 4 feet, and reduced the hydroperiod by 2 to 4 months, resulting in a dramatic increase in forest fires and annual runoff.

Wetlands in the project area have experienced significant historic losses through land use changes. Pine forest and freshwater marsh habitats have had the greatest losses in this area since 1900, with 88% of the pine forests and 59% of the freshwater marshes converted to other uses. The *Southwest Florida Environmental Impact Statement* indicates that an average of 508 acres per year of wetland fill was permitted in parts of Lee and Collier Counties from 1991 to 1998, and incremental losses are projected to continue. Remaining undeveloped areas are severely stressed by invasions of exotic vegetation, such as Brazilian pepper and melaleuca

The downstream estuarine systems are also adversely affected. Point-source freshwater discharges into Faka Union Bay are thought to be five times greater than those that historically occurred, while adjacent bays now receive less water. Four of the canals in this project flow into one major canal and then into Faka Union Bay, causing negative impacts to the estuary from freshwater pulses. Biological studies suggest that the canals have changed the salinity regime of the Faka Union Estuary, which has resulted in a reduction in submerged aquatic vegetation and a decrease in the estuary's value to fish and shellfish as nursery habitat. Species composition and standing stocks of submerged aquatic vegetation and macroalgae are sensitive to salinity variation. A comparison of information in several studies shows that seagrass cover in Faka Union Bay and other nearby bays has declined substantially since at least 1970. Oyster reefs, another critically important estuarine habitat, have been displaced seaward, where they are more subject to parasitic disease infestations.

What Is Needed

Refinement of the MIKE-SHE Model. Because this model will also be used to support the design of the project's structural components, it is important that it accurately predict the hydrologic conditions during local precipitation events. Further work will update topographic data, predict ground-surface water interactions, and develop reasonable precipitation amount/pattern assumptions for the project area.

Modeling to predict changes in hydrology and ecology in the Ten Thousand Islands NWR. A high-resolution hydrologic model is needed to predict the amounts, locations, and timing of flows through the Ten Thousand Islands refuge expected to result from this project. This model will be linked to a vegetation succession model to project ecological conditions and impacts on protected species and habitats under different water management regimes. Needed investigations will address the relationships between hydrology and factors such as fire, exotic plants, and aquatic prey species to determine how changes in hydrology will be expected to affect the distribution and viability of species such as wood storks, wading birds, and manatees.

Synthesis and study of the impacts of altered hydrology on the Florida Panther NWR. A study is needed to address how water levels have been altered and the affects of altered water levels and flows on terrestrial and freshwater wildlife habitats on the Florida Panther NWR, particularly how they have affected the spread of exotic plants, wading bird feeding and nesting success, and native plant communities.

Monitoring of water flows and water quality in receiving waters south of the project area. The extensive fresh and saltwater wetland habitats that exist south of U.S. 41 on the Ten Thousand Islands NWR and Fakahatchee Strand State Preserve are influenced by freshwater flows and water quality that have been altered by the Southern Golden Gate development project. A study to obtain baseline water flow and water quality data prior to Southern Golden Gate Estates restoration, and monitoring of water flows and water quality after the restoration, will determine what impacts the restoration has on water quality and quantity entering the wetland habitats south of U.S. 41.

Monitoring of effects on federally listed species affected by the project. Baseline, mid-project, and post-project studies will be conducted to monitor and determine the direct, indirect, and cumulative effects of this project on several federally listed species. Monitoring will cover three different habitat zones

(estuarine, upland, and wetland) that provide habitat for the endangered species such as West Indian manatee, Florida panther, and wood stork. Baseline data and analysis will provide DOI with the most current information to aid in developing recommendations to the USACE on siting and design of the project components. Mid- and post- project monitoring will provide information on the effects of this project on the different habitat zones and the threatened and endangered species that inhabit them, as a basis for adaptive management of this project.

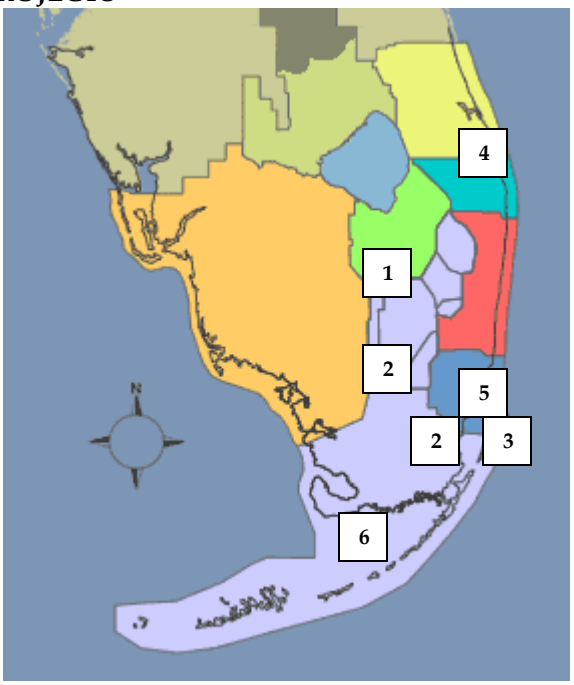
Monitoring of effects on wildlife within the Ten Thousand Islands NWR. A synoptic survey needs to be conducted of the current conditions of key habitats within the Ten Thousand Islands NWR, including hardwood hammocks, coastal islands, and emergent marsh. Key species including sea turtles, American crocodile, West Indian manatee, and water birds will be monitored to assess the effects of the project and guide adaptive management.

Monitoring of ecological responses to hydrologic change. State and federal agencies have begun baseline monitoring of fish and wildlife in the study area. This information will provide the basis for post-project analysis to determine if and to what extent hydrological restoration efforts benefit terrestrial and aquatic species. These studies need to be expanded to include larval sampling for amphibians, expanded sampling of aquatic invertebrates (including crayfish) and fishes, and standardized breeding bird survey protocols. Post-project vegetation studies will monitor wetland responses to hydrologic restoration efforts and provide information needed for adaptive management.

It is important that biological indicator studies be done to determine the effects of changes in freshwater flows on downstream estuarine communities and to verify the progress of coastal habitat restoration. These studies should include information on crab, oyster, fish, and marine invertebrate abundance and distribution in affected estuaries.

Everglades and Biscayne National Parks, Biscayne Bay, and the Florida Keys

PROJECTS



1. Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement, Part 1 (DECOMP)
2. Combined Structural and Operations Plan (CSOP), Including the C-111 Spreader Canal
3. Biscayne Bay Coastal Wetlands
4. Additional Water for Everglades National Park and Biscayne Bay
5. Wastewater Reuse Pilot
6. Florida Bay and Florida Keys Feasibility Study

Overview

A number of CERP and other hydrologic restoration projects are intended to reintroduce flows from water storage components into the broad expanse of the northern, middle, and southern Everglades, with the intent of restoring natural hydropatterns and the sheetflows that historically moved from north to south through the Everglades into the Gulf of Mexico, Florida Bay, and the other nearshore estuaries. The CSOP project will develop an integrated structural and operational plan for two other projects: the Modified Water Deliveries Project, which will improve water deliveries from WCA-3A and WCA-3B into Everglades National Park, and the C-111 Project, which will create a buffer area between the park and the urban and agricultural lands to the east. The hydrologic improvements in Everglades National Park are to occur concurrently with reducing flood damage on the lower east coast. The CSOP project is expected to restore natural hydrology to Taylor Slough and to improve the hydrology in Shark Slough. The natural hydrology of Shark Slough will be restored by the DECOMP project, which will remove impediments to sheetflow in WCA-3A, restoring natural flow paths into WCA-3B and the southern Everglades. The Biscayne Bay Coastal Wetlands Project will restore these wetlands, recreating an estuarine zone and more natural freshwater flows into Biscayne Bay.

The CERP recognizes that these interrelated projects cannot, by themselves, provide water in sufficient quantities to fully achieve the goals of restoring the natural hydrology and ecology of the Everglades and Biscayne Bay. The *Comprehensive Review Study* identifies potential sources of additional water, which will be assessed in the Additional Water for Everglades National Park and Biscayne Bay Feasibility Study. The Water Reuse Project addresses the possible use of reclaimed water to support natural system restoration.

The Florida Bay and Florida Keys Feasibility Study will determine the additional modifications (in addition to the restoration of more natural flows through the southern Everglades).needed to restore natural water quality and ecological conditions to Florida Bay.

These projects raise a number of issues of critical concern to DOI. First, reintroducing the volume of sheetflow necessary to mimic the historic hydrology in the southern Everglades will significantly affect the hydrology in the middle and northern Everglades, where remnant communities and species have either adapted to the changed hydrology or are so stressed that drastic changes in hydrology during a transition period may precipitate their decline before a more naturally functioning system can be established. For example, the restoration of the southern Everglades, which is essential to certain species, such as the Cape Sable seaside sparrow and Everglade snail kite, raises questions about the protection of tree islands in the water conservation areas, which is a major DOI priority.

The timing and distribution of water deliveries are critical to Everglades communities. Because these plant and animal communities evolved under ecological conditions marked by alternating periods of intensive rainfall and drought, any hydrologic targets based on "average annual" rainfall (the outputs from the current models) will not adequately reflect the conditions needed to sustain these communities. The model target levels need to be translated into estimates of water distributions and levels during wet, dry, and transitional seasons, and during a particular week/day of a particular year. DOI needs to assist the USACE in developing "rainfall-driven" operating protocols that will mimic the natural timing and distribution of water into the natural system.

Another concern is the quality of the water being introduced into the natural system from storage reservoirs on agricultural lands and from deep wells.

Additional research to improve the understanding of linkages between hydrology and ecology in the Everglades and in Biscayne and Florida Bays, along with the identification and monitoring of indicators of desired ecological responses, will be critical to enhancing fish and wildlife values and to avoiding inadvertent impacts to federally protected species.

DOI managers can most effectively participate in CERP projects during three project stages: (1) NEPA scoping in the early stages of project design, to help ensure that hydrologic targets accurately reflect the natural predrainage conditions, (2) review of project alternatives, to ensure that fish and wildlife and parks are adequately considered in compliance with DOI mandates, and (3) monitoring and assessment of project results, to support project modification if needed to ensure that the intended conditions are achieved. The major questions that DOI managers need to answer at each stage to effectively fulfill their responsibilities as partner and steward are summarized below, along with the highest priority science needs for answering those questions. This information is discussed in greater detail for each individual project following this summary.

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN EVERGLADES NATIONAL PARK, BISCAYNE BAY, AND THE FLORIDA KEYS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement		
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	What were the physical and ecological conditions in the Greater Everglades prior to drainage and modification, including • Current and historic hydrologic, geologic, ecological, and water quality conditions • physical, chemical, and biological processes responsible for development and persistence of soils and geomorphological patterns in the historical Everglades landscape What are the hydrologic targets needed to mimic historic flows, including water depths, timing, and distribution?	Additional research to understand the linkages among the geologic, hydrologic, chemical, climatologically, and biological processes that shaped the predrainage Everglades	NEPA Scoping Phase 1: TBD Phase 2: 2010 (NOTE – schedule under revision)
	Combined Structural and Operational Plan (CSOP), Including the C-111 Spreader Canal		
	What are the operating protocols needed to mimic natural flows through Everglades National Park? What impact will increased freshwater flows have on coastal communities? What water quality hazards are associated with using water derived from agricultural basins to augment flows into natural areas?	Research and possible model refinement to support the refinement of hydrologic targets and operating protocols Information on evapotranspiration (ET) and how it is regulated in the Greater Everglades is necessary to determine overall hydrologic budgets and to predict how hydrologic changes will affect the natural systems. Modeling to predict salinity in the mangrove community and northeast Florida Bay Environmental risk assessments of water quality contaminants	NEPA Scoping CSOP March 2004 *C-111 Spreader Canal* August 2004
	Biscayne Bay Coastal Wetlands		
	How much freshwater, and in what seasonal patterns, was delivered historically to Biscayne Bay? What are the water quality performance targets for estuarine systems?	Additional research to understand predrainage hydrology Biscayne Bay hydrologic model Research to determine the sensitivity of marine organisms and potential - biomagnification	NEPA Scoping June 2006
	Additional Water for Everglades National Park and Biscayne Bay Feasibility Study		
	The science needs listed above under Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement and Combined Structural and Operational Plan (CSOP), Including the C111 Spreader Canal also meet needs for this project. Therefore any unanswered questions would have to be timed to meet the needs of the first of these 3 projects that come on line.(reference the 2 project above) . What were the physical and ecological conditions in Shark River and Taylor Sloughs and Biscayne Bay prior to drainage and modification, including • historic hydrologic, geologic, ecological, and water quality conditions • physical, chemical, and biological processes responsible for development and persistence of soils and geomorphological patterns in the historic landscape • what were the historic salinity patterns in Biscayne Bay	Analysis of historic conditions in Everglades National Park and southern Biscayne Bay	NEPA Scoping TBD

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN EVERGLADES NATIONAL PARK, BISCAYNE BAY, AND THE FLORIDA KEYS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	What are the hydrologic targets needed to mimic historic flows, including water depths, timing, and distribution, in the Everglades and the Biscayne Bay coastal wetlands?		
	How will natural flows in Taylor Slough change the quantity, quality, timing, and distribution of flows into Barnes and Card Sounds?		
	How much additional water is needed to mimic the predrainage hydrology in Everglades and Biscayne Bay National Parks?		
	What are the water quality hazards and how can they be avoided?	Environmental risk assessment of water quality contaminants	
	Wastewater Reuse Pilot Project		
	What constituents of wastewater pose a potentially significant risk to the ecosystems in which they are introduced?	Environmental risk assessments of water quality contaminants	NEPA Scoping TBD
		Criteria for site selection of pilot.	
	What is the risk of these constituents to downstream ecosystems?		
	Florida Bay and Florida Keys Feasibility Study		
	What are the links between the impediment to circulation created by the causeway and the ecology of Florida Bay, and particularly the coral reefs that have grown up around the causeway?	Models to simulate how restoration projects will alter the hydrology of Florida Bay	NEPA Scoping Completed
	What are the water quality hazards associated with wastewater disposal in the bay and how can they be avoided?	Water quality studies	
	What are the sources of nitrogen to Florida Bay and what are the impacts of elevated nitrogen levels?		
	Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement		

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN EVERGLADES NATIONAL PARK, BISCAYNE BAY, AND THE FLORIDA KEYS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	How are hydrologic changes expected to affect tree islands, ridge and slough habitats, and marl prairies?	Research to understand the critical factors for sustaining tree islands, ridge and slough habitats, and marl prairies	EIS Review, Section 7 Consultation, and CAR Phase 1 Draft: TBD Final: TBD Phase 2:–TBD (Schedule under revision)
		Methods to evaluate sheetflow patterns and volumes are necessary in ridge and slough communities and near tree islands in areas likely to be impacted by restoration projects.	
	What are the effects of hydrologic barriers on nutrient cycling and transport, and on the movement of invasive and exotic species?	Research to understand and reduce the effects of hydrologic barriers on ecological connectivity	
		Research to understand and reduce the effects of roads, levees, and canals on the spread of exotic species	
	How will hydrologic changes affect the variety of wildlife species that depend on the Everglades marshes?	Additional research to understand the effects of different hydrologic regimes and ecological processes on restoring and maintaining ecosystem composition and function.	
		Process-level investigations on the mechanisms controlling the interaction between biological and hydrological indicators are necessary.	
		Identification of current stressors that are affecting the system	
	Combined Structural and Operational Plan (CSOP), Including the C111 Spreader Canal		
	For a given set of hydrologic targets for the CSOP, what floral and faunal responses can be expected? How close are they to the predrainage ecology?	Improvement of ecological models to make them more suitable for application and analysis	EIS Review, Section 7 Consultation, and CAR CSOP Draft: December 2006 Final: July 2007 C-111 Spreader Canal Draft: Julyl 2006 FinalFeb2007
	Biscayne Bay Coastal Wetlands		
	What are the links between hydrology and ecology in the Biscayne Bay coastal wetlands?	Additional research to understand the links between hydrology, coastal salinity, and ecology	EIS Review, Section 7 Consultation, and CAR Draft: Dec 2005 Final: May 2006
	What are the critical factors that contribute to suitable habitat for manatees, crocodiles, smalltooth sawfish, sea turtles, wood storks, bald eagles, and eastern indigo snakes?	Research of critical habitat factors for threatened and endangered species	
	How will the project alternatives affect habitat for threatened and endangered species?		
	What is the "pollution clearing" capacity of the wetlands and what is the potential for biomagnification	Research to determine the clearing and saturation capacities of sawgrass and mangrove habitats	

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN EVERGLADES NATIONAL PARK, BISCAYNE BAY, AND THE FLORIDA KEYS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Additional Water for Everglades National Park and Biscayne Bay Feasibility Study		
	The science needs listed above under Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement and Combined Structural and Operational Plan (CSOP), Including the C111 Spreader Canal also meet needs for this project. Therefore any unanswered questions would have to be timed to meet the needs of the first of these 3 projects that come on line.(reference the 2 project above) .		TBD
	Wastewater Reuse Pilot Project		
	What are the effects of Waste Water Reuse on fish and wildlife?	An inventory of Waste Water Reuse constituents and their biotic tolerances	
	Florida Bay and Florida Keys Feasibility Study		
	What are the links between freshwater inflows to Florida Bay and the ecology of the bay? What are the links between the impediment to circulation created by the causeway and the coral reefs that have grown up around the causeway?	Modeling of ecological responses to hydrologic change. Indicator groups that should be represented in these evaluations include • coral reef species • estuarine fish (coastal marshes and streams) • wading birds (e.g., spoonbills, egrets), • marine fish (e.g. spotted sea trout, mangrove snapper) • submerged aquatic vegetation (sea grasses) • mangrove forest species • federally listed species (American crocodiles)	EIS Review, Section 7 Consultation, and CAR Draft : July 2008 Final: March 2009
	Will the increased flow of fresh water flowing through the Everglades into Florida Bay have any measurable chemical effect on off shore waters?	Dilution studies combined with hydrodynamic models for Florida Bay that extend onto the offshore platform	
	Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement		
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	What are the effects of hydrologic changes on the Everglades natural system?	Baseline studies and monitoring: MAP components: • plant community species composition, cover, and density in marl prairie and ridge and slough habitats in the southern Everglades • wading bird nesting colony location, size, and timing in freshwater marshes • American alligator population recovery and the role of alligator holes as aquatic refugia in major Everglades slough habitats • fish and invertebrate sampling studies • wood stork nesting and population monitoring • American crocodile population monitoring • habitat conditions on tree islands and conditions for	Post-implementation monitoring and assessment Phase 1 Completion: October 2010 Phase 2 Completion: April 2015

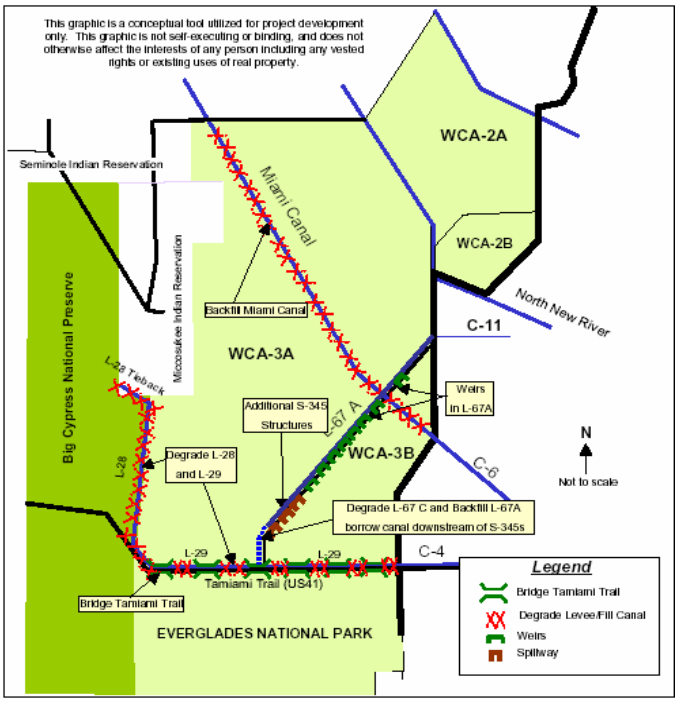
SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN EVERGLADES NATIONAL PARK, BISCAYNE BAY, AND THE FLORIDA KEYS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
		restoration of historic tree island distribution and abundance Additional DOI monitoring needs: • species composition, cover, and density in tree islands • eastern indigo snakes • West Indian manatee use of canals • migratory bird occurrence and abundance • exotic fish species • snail kite habitat condition, nesting, and productivity • Cape Sable seaside sparrow population monitoring • wood stork habitat use, productivity, and survival • processes affecting soil accretion, tree island restoration, and maintenance of the ridge and slough landscape pattern • response of coastal communities to simultaneous effects of increased freshwater flows and sea-level rise • Vegetation community monitoring in Taylor Slough and the Rocky Glades • Freshwater marsh fish and invertebrate monitoring in the southern Everglades • Mangrove landbirds	
	Combined Structural and Operational Plan (CSOP), Including the C111 Spreader Canal		
	Is the CSOP achieving the anticipated results? What are the effects on the Cape Sable seaside sparrow and Everglade snail kite? How will alterations in water deliveries through the C-111 and Model Lands affect the macro and micro biotic communities in Barnes and Card Sounds?	Development of methodology to quantify ecological connectivity especially across major potential barriers of flow such as Tamiami Trail and Alligator Alley Monitoring of ecological communities and threatened and endangered species: • vegetation, periphyton, and aquatic communities in the vicinity of the proposed C-111 buffers • Everglade snail kite • Cape Sable seaside sparrow Detailed community descriptions for Barnes And Card Sounds	Post-implementation monitoring and assessment CSOP Project Completion: February 2008 C-111 Spreader Canal Project Completion: March 2009
	Biscayne Bay Coastal Wetlands		
	What are the key indicators of a natural ecological response in the Biscayne Bay coastal wetlands? What are the baseline conditions of the indicators?	Baseline ecological data: • vegetation coverage • West Indian manatee • American crocodile • roseate spoonbill	Post-implementation monitoring and assessment Project Completion: December 2015
	Additional Water for Everglades National Park and Biscayne Bay Feasibility Study		

SUMMARY OF DOI RESPONSIBILITIES AND SCIENCE NEEDS RELATED TO WATER PROJECTS IN EVERGLADES NATIONAL PARK, BISCAYNE BAY, AND THE FLORIDA KEYS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Refer to the questions and science needs listed above under Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement and Combined Structural and Operational Plan (CSOP), Including the C111 Spreader Canal		
	Wastewater Reuse Pilot Project		
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	What concentrations of known and EPOC's start to affect the primary trophic levels of marine and estuarine communities	Research to document the sensitivity of marine organisms and quantify the potential magnitude of biomagnifications that might occur in juvenile and nursery habitats	
	Florida Bay and Florida Keys Feasibility Study		
	What is the ecological response to hydrologic change?	Monitoring to assess ecological responses to hydrologic change: • estuarine fish (coastal marshes and streams) • wading birds (e.g., spoonbills, egrets) • marine fish (e.g. spotted sea trout, mangrove snapper) • submerged aquatic vegetation (sea grasses) • mangrove forest species • federally listed species (American crocodiles)	Post-implementation monitoring and assessment Project completion: TBD

Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement



Project Purpose and Major DOI Interest

One of the central projects in CERP is Decompartmentalization of Water Conservation Area 3 (Decomp). The compartmentalization of the water conservation areas has contributed to the loss of historic overland flows through the central Everglades slough system. This alteration of flows has resulted in temporal changes in hydropatterns and hydroperiods in the historic deepwater, central axis of the Shark River Slough system.

The purpose of this project is to restore sheetflow and reestablish the ecological and hydrological connections between WCAs- 3A and -3B, Everglades National Park, and Big Cypress National Preserve. The project includes raising and bridging portions of the Tamiami Trail and filling in portions of the Miami Canal within WCA-3. Due to the dependencies of project components, this project will be implemented with the Water Preserve Areas Project, which will create a bypass for water supply deliveries to the Miami Canal using the North New River Canal.

This project, which is planned to be implemented in two parts, is expected to deliver significant environmental benefits to WCAs-3A and -3B and to Everglades National Park by removing the Miami Canal, plugging and/or backfilling the L-67 A and C and the L-68 canals, degrading the L-28 tieback levee and the L-29 levee, and eliminating the deep pool in the southern end of the conservation area. It is expected to benefit Everglades National Park by restoring the natural flow paths through Shark Slough toward the west coast estuaries. Restoring historical sheetflow distributions, depth patterns, hydroperiods, and hydrologic connectivity in the southern Everglades will improve the health of habitats important to this ecosystem, including ridge and slough, marl prairie, and rocky glades landscapes.

At the same time that it anticipates these hydrologic improvements in the southern Everglades, DOI is concerned that increased stages through the northern and central Everglades will further stress the surviving tree islands in those areas. In working to restore the natural hydrology, with the assumption that natural ecosystem responses will eventually restore the mosaic of ecological communities indigenous to this region, DOI remains committed to protecting the tree island ecological community from adverse effects.

Threatened and endangered species affected by the project include wood stork, Everglade snail kite, Florida panther, Cape Sable seaside sparrow, eastern indigo snake, and West Indian manatee. The Cape Sable seaside sparrow and American crocodile will also be affected downstream from the Decomp project area.

DOI is interested in the ecological, as well as the hydrologic, dimensions of connectivity and flow, such as nutrient cycling and transport and wildlife migration. Consequently, evaluating these ecological aspects

of connectivity will be an integral part of analyzing the potential outcomes of decompartmentalization scenarios. As the project is implemented and flow is improved, additional actions might be needed to ensure that the ecological response mimics the natural predrainage ecology.

What is Known

Extensive research has been conducted to conclude that the best way to restore the ecological function to the system is to restore more natural hydrology to the Everglades. Investigations have provided a number of useful performance measures relating hydrologic change and ecological response. Information on the attributes of the many keystone species and most endangered species in this area are well documented, and monitoring and research continue to expand the understanding of the needs of these species in the different habitats of this system.

Community structure and vegetation composition have changed markedly as a result of the C&SF Project within the water conservation areas and Everglades National Park. The Decomp *Project Management Plan* notes that the current system, the result of many years of compartmentalization, is considerably more complex than the original landscape. The presence of levees, roadways, canals, and structures to control water flow has created a patchwork of unnaturally varied landscape units.

Some overdrained areas, such as those in northern WCA-3, have been impacted not only by drought but also by frequent fires, which have damaged the organic soils that previously underlaid the area. Tree islands have been reduced in number and size, and marsh vegetation has shifted to that characteristic of shorter hydroperiods.

Other portions, such as those in southern WCA-3A, have been subjected to wetter conditions, and more stabilized water levels. In these areas, the local diversity of vegetation structure and composition has been reduced, resulting in a relatively homogenous composition. Tree islands have also been impacted in these areas, but as a result of long-term inundation and water stress instead of overdrying. Ridge and slough communities and marl prairies have also been significantly reduced.

Maybe the most marked change is the juxtaposition of the different conditions within the landscape. While the historic Everglades consisted of a long, continuous, interconnected marsh that varied very gradually, the placement of levees, canals, and roads leads to conditions where some of the wettest conditions occur immediately adjacent to some of the driest, with only a levee in between. The resulting patchwork of habitat types and conditions has disrupted the continuity that characterized the predrainage system. These habitat changes have caused significant reductions in populations of birds and other animals.

What Is Needed

Additional research to understand the linkages among the geologic, hydrologic, chemical, climatological, and biological processes that shaped the predrainage Everglades. Additional research will identify the range of water depths, hydroperiods, spatial distributions of water, flow characteristics, and water quality that existed in the project area prior to drainage. Information about the physical, chemical, and biological processes responsible for development and persistence of soils and geomorphological patterns in the historic Everglades landscape, such as the soil-forming processes in the ridge and slough habitats, will help managers of DOI lands and resources in the WCAs and Everglades National Park manage for a historic diversity and productive array of fish, wildlife, and plants.

Process-level investigations on the mechanisms controlling the interaction between biological and hydrological indicators are necessary. Information on the seasonal and annual controls on productivity rates, ecosystem water use, nutrient dynamics and limitations, competition, seedling germination, and mortality will provide the basis for simulation models and for predictions of how the natural systems will

react to altered hydrologic and climatological regimes. A detailed understanding of the mechanisms controlling ecosystem productivity and dynamics is the only reliable way to predict how these systems will react to altered stressors.

Studies are needed for key invertebrate groups used for monitoring sheetflow restoration. It is important to know how their ecology is related to sheetflow, or more importantly, how they are adversely affected by unnatural flow conditions produced by present day structures.

Research to understand the critical factors for sustaining tree islands, ridge and slough habitats, and marl prairies. Additional research will help scientists describe a hydrologic regime that will allow the restoration of tree islands, ridge and slough habitats, and marl prairies in an expanse and configuration that will be sustainable. The restoration of these communities will depend on restoring ecosystem function, which includes the processes of flow, soil accretion and transport, and an appropriate disturbance regime that includes fires, floods, and droughts occurring with a more natural frequency Development of GIS-based databases that can map many hydrologic and biologic indicators will help researchers notice potential linkages between hydrology and ecology in this area, and allow them to evaluate the overall ecological response to project implementation. Another research project, the Loxahatchee Impoundment Landscape Assessment Study, being conducted on the Loxahatchee wildlife refuge, is a controlled experiment to determine the interrelationships among a number of hydrologic and ecological variables, including water levels, water flow, fish species, and vegetation types.

Research to understand and reduce the effects of hydrologic barriers on ecological connectivity. Research to understand sheet flow in key aquatic communities, and to understand interactions of hydrologic flow with nutrient and carbon cycling and transport, will help identify and reduce barriers to these critical processes.

Research to understand and reduce the effects of roads, levees, and canals on the spread of exotic species. Improved understanding of how linear features such as roads, levees, and canals may act to speed the spread of exotic species will allow development of measures to control or minimize this effect and the impacts of exotic species.

Understanding the effects of sea-level rise. The formation and sustainability of coastal communities is a result of the interaction between upland freshwater and tidal inputs. Both of these hydrologic processes are likely to change in the future with restoration projects and with sea level rise. Resource management and restoration efforts will require a thorough understanding of the biological and physical controls on the formation and maintenance of these coastal communities. Research is necessary to assess the current and historic relationships between sea level, salinity, overland freshwater flows, tidal regimes, water budgets, and climate on mangrove and oligohaline communities. This information will be used to develop and validate process-based models useful for simulating hydrologic fluxes, soil dynamics, productivity, carbon balance, and spatial variability in the mangrove and oligohaline zones in coastal areas.

Additional research to understand the effects of different hydrologic regimes and ecological processes on restoring and maintaining ecosystem function

Identification of current stressors that are affecting the system

Baseline studies and monitoring. The MAP includes a number of components that are relevant for the decompartmentalization of WCA-3A and particularly important to DOI:

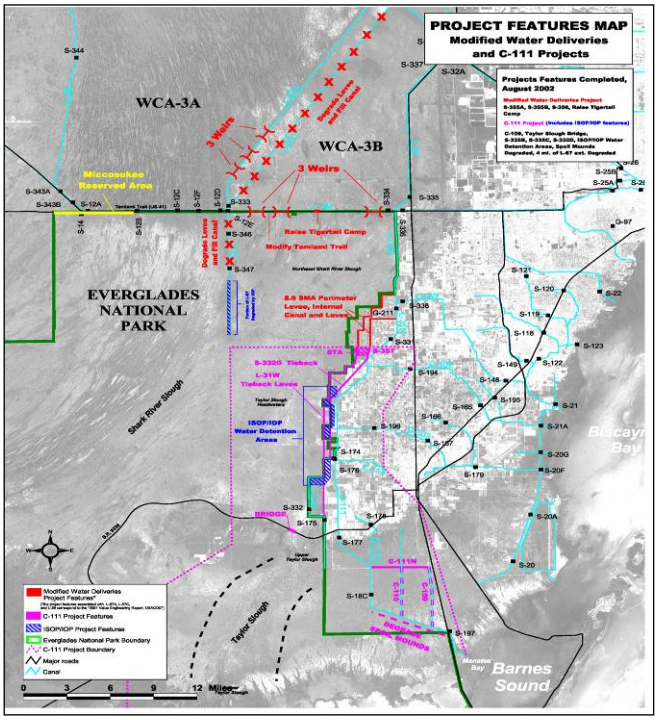
- plant community species composition, cover, and density in marl prairie and ridge and slough habitats in the southern Everglades
- wading bird nesting colony location, size, and timing in freshwater marshes
- American alligator population recovery and the role of alligator holes as aquatic refugia in major Everglades slough habitats
- fish and invertebrate sampling studies
- wood stork nesting and population monitoring
- American crocodile population monitoring
- habitat conditions on tree islands and conditions for restoration of historic tree island distribution and abundance

Additionally, DOI needs to fill gaps in baseline information and monitor the following:

- species composition, cover, and density in tree islands
- eastern indigo snakes
- West Indian manatee use of canals
- migratory bird occurrence and abundance
- exotic fish species
- snail kite habitat condition, nesting, and productivity
- Cape Sable seaside sparrow population monitoring
- wood stork habitat use, productivity, and survival
- processes affecting soil accretion, tree island restoration, and maintenance of the ridge and slough landscape pattern
- response of coastal communities to simultaneous effects of increased freshwater flows and sea-level rise
- Vegetation community monitoring in Taylor Slough and the Rocky Glades
- Freshwater marsh fish and invertebrate monitoring in the southern Everglades
- Mangrove land birds

Combined Structural and Operational Plan (CSOP), Including the C111 Spreader Canal

Project Purpose and Major DOI Interest



The Combined Structural and Operational Plan (CSOP) is an integrated structural and operational plan for two modifications of the C&SF Project known as the Modified Water Deliveries to Everglades National Park (MWD) Project and the C-111 Project. The purpose of the CSOP is to define the operations for the C-111 and MWD Projects that will be consistent with their respective project purposes.

The MWD Project is authorized by the Everglades National Park Protection and Expansion Act of 1989. Its purpose is to modify the CS&F Project to improve water deliveries into the park and restore the natural hydrologic conditions within the park.

The *C-111 General Reevaluation Report* recommended additional modifications to the C&SF Project to provide for the restoration of the ecosystem in Taylor Slough and the eastern panhandle of the park while maintaining flood damage reduction within the C-111 basin. These modifications include the construction of buffer areas to provide a hydrologic separation between urban areas, where flood damage reduction is a priority, and natural areas, where restoration of the natural hydrology is a priority.

A CERP-related project is the C-111 Spreader Canal. The purposes of this project are to enhance the C-111 Canal to rehydrate the Model Lands, establish sheet flow and hydropatterns that will sustain native ecosystems in the Southern Glades and Model Lands, provide more natural sheet flow to Florida Bay by eliminating point sources of freshwater discharges through C-111 to the estuarine systems of Manatee Bay and Barnes Sound, and maintain some level of flood protection for agricultural and urban areas in the project area.

The primary DOI interests in the CSOP include improving water deliveries into both the Everglades and Florida Bay portions of Everglades National Park and the Model Lands, restoring the historic hydrologic conditions in the park as well as, Barnes Sound through Manatee Bay, protecting the natural values associated with the park and headwater of Biscayne National Park, and exploring opportunities for enhancing the recovery of threatened and endangered species that will be affected by the project, notably the Cape Sable seaside sparrow and Everglade snail kite.

Additionally, DOI is concerned with the operating rules and water quality in the C-111 buffer component of the CSOP. Because of the porous nature of the soil in this area it is important that the buffer areas be designed and operated to avoid interference with natural flows in the park. Operation of the buffers using "marsh-driven criteria" will ensure that the adjacent natural marsh is not flooded in an unnatural pattern by water leaking out of the buffer areas. Some of the water used in the buffer areas will likely

come from urban and agricultural basins and could be introduced into wetlands. DOI has a strong interest in ensuring that this water is clean enough for introduction into the park.

What Is Known

Both the modeling and the field observations needed to predict and monitor changes in hydrology are currently in place, and no additional work in those areas is contemplated.

DOI agencies, as well as the USACE, SFWMD, and EPA, conduct extensive and continuous monitoring in the CSOP footprint. The parameters collected range from observations of rainfall and water levels to across-the-landscape monitoring of wading birds and American alligators. Federal and state agencies monitor Everglade snail kites, Cape Sable seaside sparrows, wood storks, and American crocodiles. Population models of snail kite and sparrow are used in project evaluations. Because CSOP is a project that is in its final design stages, it will be necessary to use available information to evaluate alternatives.

A network for monitoring water quality, aquatic communities, and vegetation is in place to detect changes in native flora and fauna related to operation of the CSOP. The report *A Synthesis of Research on Florida Bay* compiles the current knowledge of the ecosystem history, structure, and function and of the ecological effects of human activities in Florida Bay.

What Is Needed

Research and possible model refinement to support the refinement of hydrologic targets and operating protocols. Additional research will support refinements to the hydrologic targets needed to achieve fully natural flows in Taylor Slough and Shark Slough. The targets need to address appropriate timing, cleanliness, distribution of flow, and ecological connectivity to replicate natural function in the marsh. The operating protocols developed from the refined targets should allow water managers more flexibility to manage the marsh based on actual rainfall rather than on projections of annual averages, in order to avoid engineering the wetlands into an unnatural state. The NSM target levels need to be translated into real-time estimates of "natural" targets for the marshes, mangrove zone, and the northeast Florida Bay. These predictions can then provide the basis for operational rules for the new structures. In the short tem DOI must provide input based on what is known today to improve the operating program being developed for this project. Information on the volume, timing and distribution of overland flows and the relationships with nearby structure and canal operations is necessary. Flow measurements should be used to validate large-scale hydrologic models such as the SFWMD 2x2, since these models are used to simulate the pre-drainage and current systems to design restoration alternatives, and to set restoration targets.

Rainfall and evapotranspiration are the two major components of hydrologic balance in south Florida. While rainfall is measured regularly throughout the system, ET is not. ET is of primary importance in all the hydrologic models used to simulate south Florida ecosystems. To date, only a very limited dataset exists with which to calibrate and validate these models. Moreover, there currently is only very limited understanding of the variability in evapotranspiration rates across community types occurring in ENP. As communities shift with increasing freshwater flows, spatial patterns of ET and water budgets will also change with implications for regional water management.

Sheetflow is the defining characteristic of the Everglades. The restoration of historic sheetflow patterns is therefore a primary goal of CERP and CSOP, yet there currently exists no widely accepted method for evaluating sheetflow volumes, velocities, or spatial patterns with respect to nutrient dynamics, landscape, or community type. Understanding the current relationships between large scale sheetflow patterns and nutrient fluxes, water quality, sediment transport and microtopography, and the sustainability of ridge and slough and tree island habitat is necessary to develop operating protocols, restoration targets and to monitor the success of these projects.

Environmental risk assessments of water-quality contaminants. The C-111 project raises many water quality issues for Everglades and Biscayne National Parks. Water quality investigations will assess the environmental risks from using water derived from agricultural basins to augment ground and surface water flows into natural areas. Current information does not resolve the nutrient uptake capacity of the limestone aquifer and the effectiveness of periphyton stormwater treatment areas. The potential for increases in toxic contaminant loads, such as pesticides, and their ecological effects require further study.

Improvement of ecological models to make them more suitable for applications and analysis. Considerable information is available about the interrelated responses of salinity levels, vegetation, fish and macroinvertabrates, and wading birds to hydroperiod and flow. Improved understanding about the linkages among these variables will be possible once the ecological models, particularly ATLSS, are refined and linked to the more detailed hydrologic models, with suitable user interfaces provided.

Development of methodology to quantify ecological connectivity especially across major potential barriers of flow such as Tamiami Trail and Alligator Alley

Modeling to predict salinity in the mangrove community, northeast Florida Bay, Manatee Bay and Barnes Sound. Local models that couple with the regional 2 x 2 Model are needed.

Monitoring of ecological communities and threatened and endangered species. Continued monitoring of hydrology, ecology, and water quality in the Everglades and Florida Bay will determine whether actual changes are consistent with predictions, improve the predictive capability of models, and detect unforeseen adverse impacts in time to correct them through adaptive management. In addition to ongoing systemwide monitoring, monitoring of key parameters in the footprint of the CSOP needs to focus on the vegetation, periphyton, and aquatic communities in the vicinity of the proposed C-111 buffers and on Everglade snail kite and Cape Sable seaside sparrow habitats and populations.

Detailed community descriptions for Barnes and Card Sounds. The ecology of the two coastal estuaries Barnes and Card Sound could be dramatically affected by changes in water deliveries via the C-111, the placement of culvert across US1 roadway and the rehydration of the Model Lands. Intensive documentation of the biotic structure in these basins to ensure that we do not alter these two estuarian basins to something other that natural function

Biscayne Bay Coastal Wetlands

New Picture Here

Project Purpose and Major DOI Interest

The Biscayne Bay Coastal Wetlands (BBCW) Project, scheduled for completion in 2015, is intended to correct the effects of diverting overland freshwater flows into canals, a process that has drained wetlands, caused unnatural surface discharges of freshwater into Biscayne Bay, and reduced groundwater inflows into the bay. The purposes of this project are to rehydrate and reconnect freshwater and estuarine wetlands, to reestablish a more natural estuarine zone along the western side of Biscayne Bay, and to reduce point source discharges into Biscayne Bay. The project will replace lost overland flow and partially compensate for the reduction in groundwater seepage by redistributing the available surface water entering the area from regional canals.

The proposed redistribution of freshwater flow across a broad front is expected to restore or enhance freshwater wetland, tidal wetland, and nearshore bay habitats, including habitats in Biscayne National

Park. The project is expected to result in sustained lower-than-seawater salinities in the tidal wetlands and the nearshore bay and be conducive to the reestablishment of oyster bars and other components of the oyster reef community. Achieving these results is dependent on the project being designed to provide additional freshwater to these areas. If only the existing water volume is redistributed, then salinities would actually increase. Diversion of canal discharges into coastal wetlands is expected not only to reestablish productive estuarine nursery habitat all along the shoreline but also to reduce the abrupt discharges of freshwater into the bay near canal outlets, which are physiologically stressful to fish and benthic invertebrates.

Threatened or endangered species within the project area include manatees, crocodiles, smalltooth sawfish, sea turtles, wood storks, bald eagles, and eastern indigo snakes. Changes in timing, distribution, and volume of freshwater delivery could potentially affect the existing or potential habitats of these species.

What Is Known

Historically, a significant amount of freshwater flowed into Biscayne Bay through a system of sloughs, which originated in the Everglades via rivers and creeks, transverse glades, and sheetflow through coastal wetlands. Some work has been done to estimate surface flow through the transverse glades. Groundwater inputs are known to have been significant and large enough to create coastal and offshore springs.

The scientific understanding of the historic conditions of the bay is increasing. Based on recent paleoecological studies, which partially document historic salinity patterns, scientists have established that the historic pattern of freshwater inflows from surface and ground sources resulted in fewer high and low salinity extremes than what occur under current conditions. Today's seasonal, high-volume freshwater canal discharges cause high-magnitude, rapid salinity fluctuations near canal outlets. The nearshore bay experiences seasonal periods of low salinity during the wet season, when canal discharges are high, and periods of high salinity during the dry season, in the absence of freshwater inputs. While some fluctuation is expected, the nearshore bay salinity regime is now much less stable than it was historically.

Historic estuarine conditions sustained extensive sawgrass prairies, mangrove communities, seagrass beds, and oyster bars and provided productive nursery habitats for a spectrum of fish, shellfish, crocodiles, manatees, and other animals. Recent studies have defined the importance of mangrove and seagrass communities to the ecology of the bay. The paleoecological studies mentioned above draw some conclusions about the historical salinity patterns and ecology of the bay and work to refine this history is ongoing. These studies have also provided information about the contemporary use of habitats in and near the bay by migratory birds and many endangered species, such as the West Indian manatee.

What Is Needed

Additional research to understand predrainage hydrology. Additional research will identify the range of water depths, hydroperiods, spatial distributions of water, and flow characteristics that existed in the Biscayne Bay coastal wetlands prior to drainage. Information about the physical, chemical, and biological processes responsible for the development and persistence of soils and geomorphological patterns in the historic wetlands will help DOI managers better understand the historic hydrologic regime.

Biscayne Bay hydrologic model. Hydrologic targets for the coastal wetlands must be established. In order to establish these targets, a clear understanding of the relationship between hydrology, salinity, and ecology/biological response is required. A local model of Biscayne Bay capable of simulating coastal surface and groundwater hydrology and associated nearshore salinities will then be required in order to determine whether or not these targets are met. The NSM and 2 x 2 Models do not simulate these

variables and the BBCW project area lies at the fringe of the models' domain. However, two local models are being developed that can be coupled with the regional model used by the USACE and SFWMD to make NSM-linked predictions of salinity in Biscayne Bay. Information about how much freshwater was delivered historically to the Bay, and in what seasonal patterns, will provide a basis for establishing and adjusting hydrologic targets. The ensuing ecological responses and desired future ecological conditions, along with the relationship between historical, current, and desired future condition should also be factored into target adjustments Research is needed to characterize and evaluate the importance of groundwater and karstlike flows to the coastal estuaries.

Water Quality Performance Targets. There are no water quality standards for estuarine systems. There is sufficient documentation in the scientific literature to indicate that marine, and possibly estuarine, systems are far more sensitive to low level contamination than more robust terrestrial ecosystems. Research is needed to document the sensitivity of marine organisms and quantify the potential magnitude of biomagnification that might occur in juvenile and nursery habitats characteristic of the south Florida estuaries. Water quality performance targets for coastal marine and estuarine systems need to be established.

Research to determine the clearing and saturation capacities of sawgrass and mangrove habitats Research through a pilot project is needed to help identify what the "pollution clearing" capacity of the wetlands and the potential for biomagnification is as water enters Biscayne Bay

Additional research to understand the links between hydrology and ecology. Output from the hydrologic model will be analyzed. Ongoing paleoecological studies will continue, and proposed studies of the historic types and distributions of habitats, flora, and fauna will be used to draw conclusions about the relationships that existed historically between hydrologic and ecological factors in the nearshore, estuarine, and freshwater areas of western Biscayne Bay. These historic conditions and relationships must then be used to develop desired future conditions and thus, project targets. Projections can then be made about how close various project alternatives might come to approximating these desired targets and conditions and to restoring habitat features such as creeks, glades, and wetlands. This effort should include ecologic models for Coastal Estuaries, which are key assessment tools for these areas.

Research of critical habitat factors for threatened and endangered species. Additional research into the critical factors that contribute to suitable habitat for West Indian manatees, American crocodiles, smalltooth sawfish, sea turtles, wood storks, bald eagles, and eastern indigo snakes will inform the analysis of potential impacts and help avoid adverse effects.

Baseline ecological data. An important gap in the science needed to plan and monitor this project is baseline ecological data, particularly about the existing vegetation coverage, including, but limited to, West Indian manatee, American crocodile, and roseate spoonbill. Baseline conditions will provide the basis for identifying changes in key species and understanding the relationships between those changes and the environmental factors that affect species' habitat and sustainability.

Additional Water for Everglades National Park and Biscayne Bay Feasibility Study

Project Purpose and Major DOI Interest

This project addresses the additional water needed to achieve the ecological goals for both Everglades and Biscayne Bay National Parks. During the development of the CERP it was determined that additional water could be captured to meet predrainage hydrologic targets for Everglades National Park and Biscayne Bay. This project assesses the options for achieving those targets. If successful this project will reduce extreme events like regulatory releases to estuaries, excessive flooding in the water conservation

areas, and severe damaging dryouts in the marsh. Urban and agricultural areas will benefit from the extra water storage and be less dependent on the natural areas to meet their needs.

The USACE completed a final reconnaissance study report in June 2003 that investigated and confirmed the need for providing additional water to the park and the bay, in addition to the amount that will be provided upon implementation of the CERP. The reconnaissance study confirmed that federal participation is warranted to proceed to a feasibility-level study; however, a nonfederal sponsor for the feasibility phase has not yet been identified. The report also recommends deferral of the feasibility phase until completion of the technical documentation report to be prepared for the Initial CERP Update Project currently underway by RECOVER. It is anticipated that once RECOVER updates the CERP, a nonfederal partner will be identified.

Generally, the feasibility study considers design configurations for routing water from Palm Beach and Broward Counties to Everglades and Biscayne Bay National Parks. DOI is interested in understanding (1) how water can be redirected from the water conservation areas in the upper part of the system into the park without adversely affecting the desired ecological response in the water conservation areas, (2) the feasibility of establishing and achieving the hydrological targets expected to improve ecological conditions in the parks, and (3) the risks related to the introduction of urban runoff into the Everglades Protection Area and Biscayne Bay.

What Is Known

The reconnaissance study confirmed the need for additional water to Everglades National Park and Biscayne Bay in addition to the amount that will be provided upon implementation of the CERP. The Modified Waters, Decompartmentalization, and CSOP Projects all contribute additional water, but not enough to achieve predrainage hydrologic targets and the improved ecology that is expected to result from improved hydrology. The reconnaissance report outlines a number of alternatives for capturing water in urban areas, which need additional investigation in the feasibility study.

Predictions based on the NSM can be used to provide restoration targets for water depths in the southern Everglades. New information is being added to better reflect current understanding of the predrainage system.

Several approaches are being used to estimate the historical surface and groundwater flows to Biscayne Bay and Florida Bay. A suite of potential models has been developed for use in predicting salinity in Florida Bay.

What Is Needed

Analysis of historic conditions in Everglades National Park and southern estuaries: Biscayne Bay, Card Sound and Barnes Sound Dated soil cores in Taylor Slough will help DOI managers understand the predrainage vegetation and hydrology in that region of the park. Paleoecological investigations will provide a historical profile of salinities in Biscayne and Florida Bays and the basins between them. Vegetation, topography, soils, and hydrologic surveys along tree island and ridge and slough transects in WCA-2, WCA-3, Northeast Shark River Slough, Taylor Slough, and southern Shark Slough will provide information needed to understand spatial variability and to assess hydrologic needs based on site-specific physical and ecological conditions. By measuring flow, water depth, and vegetation characteristics along a topographic and vegetation gradient, response curves can be generated to estimate the predrainage vegetation distribution and the vegetation distribution expected from restoration alternatives. These response curves are required to establish the need for additional water and to assess the ecological integrity of restoration alternatives.

Research quantifying the linkages of freshwater flows to the eastern coastal estuaries, Barnes and Card Sounds through central Biscayne Bay, on the flow of water through the Taylor Slough and the Model Lands.
Both Barnes and Card sound are the headwater of central and lower Biscayne Bay and any modification to the ecological function and character within those basins will be reflected in the ecological function of Biscayne Bay.

Environmental risk assessments of water quality contaminants. Water quality investigations will assess the environmental risks from rerouting urban and agricultural runoff and from reusing wastewater, both of which are under consideration as a source of water for this project. These investigations will include source water characterization, ecosystem response to contaminants, and models of contaminant fate and transport. This work will require field studies of body burden in indicator species, field studies of biogeochemical cycling, and development of tools for water quality modeling.

Wastewater Reuse Pilot Project

Project Purpose and Major DOI Interest

The main goals of this pilot project are to address uncertainties, including water quality, costs, and timing, associated with the possible use of reclaimed water in environmentally sensitive areas including Everglades and Biscayne National Parks. If the pilot project concludes that the use of reclaimed water is not practicable in this regard, a full-scale project will not be initiated.

DOI has a great interest in the quality of the water delivered into Everglades and Biscayne Bay National Parks. Because urban wastewater has been identified as a possible source of the additional water needed to meet predrainage hydrologic targets in the parks, DOI is interested in the wastewater treatment technology and whether it will be adequate to meet the goals of resource protection and ecosystem restoration. Currently, two CERP projects propose reuse of wastewater.

This pilot project is one of four pilot projects authorized in CERP. It will address water quality issues associated with discharging reclaimed water into natural areas, such as the West Palm Beach water catchment area, Biscayne National Park, and the Bird Drive basin. The pilot facility will be constructed in south Miami-Dade to determine the ecological effects of using superior, advanced treated reuse water to replace and augment freshwater flows to Biscayne Bay and to determine the level of superior, advanced treatment required to prevent degradation of freshwater and estuarine wetlands and nearshore waters. The constituents of concern in wastewater will be identified, and the ability of superior, advanced treatment to remove those constituents will be determined. The City of West Palm Beach is constructing a pilot facility to treat wastewater from the East Central Regional Wastewater Treatment Facility using advanced and superior wastewater treatment processes to remove nitrogen and phosphorus.

What Is Known

The impacts of stormwater and municipal, industrial, and agricultural wastewater on water quality variables are well documented. Many different treatment technologies are available, and the resulting wastewater varies significantly depending on the technology used. Some treatment processes, such as chemical additions and filtration, can add or remove essential water constituents that can impact water-receiving ecosystems. Also, treated wastewater, even though it may have very low concentrations of nutrients, pharmaceuticals, endocrine disrupters, and heavy metals, can discharge significant loads of these pollutants into receiving waters because of the large flow volumes. This added load of pollutants often has detrimental effects on the natural ecosystem, causing imbalances of the natural flora and fauna.

What Is Needed

Environmental risk assessments of water quality contaminants. DOI needs to understand the potential ecological effects and human health effects of discharging reclaimed water into natural systems, including freshwater wetlands, estuarine wetlands, and Biscayne Bay. A detailed comparison of wastewater constituents versus constituents of the receiving waters and downstream ecosystems will determine if the reuse water contains constituents that have potential to affect downstream ecosystems. If so, a risk analysis will determine the concentrations and loads of these constituents as they move through the surface and ground water and sediments in downstream ecosystems. If adequate information on the impacts of these constituents on native flora and fauna is not available, bioassay experiments need to be performed on native species to provide this information for the risk assessment.

Research evaluating the potential for natural system biological "scrubbing" of treated waste water are needed.

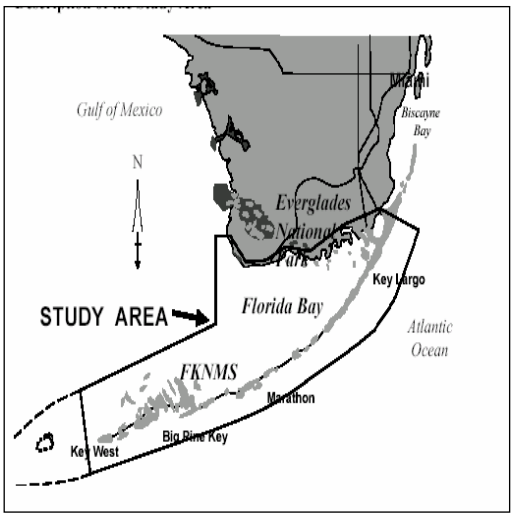
Research is needed to document the sensitivity of marine organisms and quantify the potential magnitude of biomagnification that might occur in juvenile and nursery habitats characteristic of the south Florida estuaries. Much of the water produced by treating waste water will be use to make up water delivery short falls to the coastal estuaries. It is well documented in the literature that the coastal systems are more sensitive to low levels of pollutants and biomagnification of low pollution levels is greater in marine systems. Research is needed to document the sensitivity of marine organisms and quantify the potential magnitude of biomagnification that might occur in juvenile and nursery habitats characteristic of the south Florida estuaries. This research needs to include the developing list of environmental pollutants of concern, or EPOC's. Controlled dosing experiments on the Phytoplankton and smaller zooplankton assemblages could be used to better understand issues of sensitivity and biomagnification.

Criteria for site selection of pilot. DOI needs to provide input into the development of criteria for selection of an appropriate wetland test area that replicates the southern section of the Everglades. The limited data on capturing, treating, and reusing water comes from a recent project in the northern part of the system. The water treatment technologies constructed and tested through this project will provide important input into a DOI analysis of whether the water derived from the pilot is of marsh quality and if the process can be replicated to deliver water to the natural system at the right times and in the right amounts.

Florida Bay and Florida Keys Feasibility Study

Project Purpose and Major DOI Interest

The Florida Bay and Florida Keys Feasibility Study is designed to evaluate Florida Bay and its connections to the Everglades, the Gulf of Mexico, and the Florida Keys marine ecosystem to determine the modifications needed to successfully restore the water quality and the ecological conditions of the bay.



Florida Bay is a large, shallow, coastal saline ecosystem. Between 1987 and the early 1990s it experienced rapid and extensive ecological degradation. During the summer of 1987 approximately 100,000 acres of seagrass "died off" in western Florida Bay. This die-off was followed by phytoplankton blooms and sponge die-offs. These ecological changes came at the end of a multiyear

drought. Salinity, especially in the eastern basins, is highly dependent on local rainfall. During the drought, bay salinity levels greatly increased and made the bay resemble more of a marine rather than an estuarine ecology. Conditions within Florida Bay have continued to visibly decline, including losses of seagrass habitat, diminished water clarity, micro-algal blooms of increasing intensity and duration, and population reductions in economically significant species such as pink shrimp, sponges, lobster, and recreational gamefish. Wading birds, forage fish, juveniles of game fish species, and other species that historically utilized the bay and adjacent estuarine wetlands have relocated, often at greatly reduced population levels, as their habitats have changed.

This project is of critical interest to DOI, which has management responsibilities in the project area including the Florida Bay portion of Everglades National Park, Dry Tortugas National Park, four national wildlife refuges (Crocodile Lake, National Key Deer, Great White Heron, and Key West), and critical habitat for a number of federally protected species. This region also encompasses the Florida Keys National Marine Sanctuary, an area of submerged lands administered by the National Marine Fisheries Service. The sanctuary contains part of Florida Bay and the entire Florida Reef Tract, the largest reef system in the continental United States.

Florida Bay will be the eventual recipient of increased sheet flows through Taylor Slough and Shark Slough, both within Everglades National Park. It is therefore important to consider the hydrology of the coastal estuaries as well as the historic hydrology of the southern Everglades region, including the now isolated Model Lands, when setting targets for water entering the park. The restoration of more natural flows through the southern Everglades is expected to also restore more natural flows into Florida Bay, restoring more natural salinity patterns. However, DOI remains concerned about the quality of the water to be introduced into the coastal estuaries. For example, increasing freshwater flow to the bay could increase nutrient (particularly nitrogen) loading, which might induce more frequent and more extensive phytoplankton blooms. High nitrogen levels may reflect the historic quality of water within the Everglades, but it may not reflect the historic quality of water in the coastal estuaries. These adjacent ecological systems may have different requirements and different problems that will require balancing their conflicting needs.

DOI managers also need to understand how a related project, the Florida Keys Tidal Restoration Project, will affect the circulation of water in the bay and Keys. This project uses bridges or culverts to restore some tidal connections between Florida Bay and the Straits of Florida in a section of the Middle Keys where this tidal flow was eliminated in the early 1900s during the construction of Flagler's railroad. Altered tidal flows between Florida Bay and the Straits of Florida have resulted in adverse water quality and fish and wildlife habitat impacts. However, changing water circulation patterns through the Keys by changing the configuration of the Keys passes could affect water quality conditions and the health of the coral reefs in the Florida Keys National Marine Sanctuary and Biscayne National Park that have adapted to the current circulation patterns. Increasing the water flow could also increase trace contaminant loading, depending on sources and flow pathways.

At least 22 commercially and/or recreationally important aquatic species are known to use the coastal estuaries Florida Bay and Biscayne Bay as nursery grounds. A guideboat industry operates within Florida Bay and Biscayne Bay. Target species of the recreational fishing industry include snook, redfish, tarpon, permit, bonefish, spotted seatrout, and mangrove snapper. Target species of the commercial fishing industry include Penaeid shrimp, stone crabs, and blue crabs (all in Biscayne Bay). The coastal estuaries are nurseries for many species, including young spiny lobsters and several species of snappers, grunts, and sparids. Florida Bay and nearby coastal estuaries and embayments are the principal nursery habitat for pink shrimp, which is the basis of a multimillion dollar fishery in the Tortugas. Pink shrimp are an important species commercially and form a prey base for higher trophic level organisms.

What Is Known

Although scientists disagree about the basic causes of problems within Florida Bay, most agree that they are probably symptomatic of disruptions of natural processes within the bay. Scientists and engineers from state and federal agencies as well as the academic community are working together for the purpose of identifying the problems and potential corrective measures to solve or at least minimize the causes of Florida Bay's problems.

Ecologically and hydrologically Florida Bay may be divided into three basins: eastern, central, and western. Overland freshwater flows through Taylor Slough and direct rainfall are the sources of freshwater for the eastern zone, which currently has extreme variations in salinity and high levels of dissolved organic matter. High methyl mercury levels occur in eastern Florida Bay and its biota. Health advisories are posted, warning of elevated mercury levels in some fishes.

Although such extremes have not been observed in the costal estuaries northeast of Florida Bay, in the basins from Barnes Sound and north, salinities have increased steadily since the 1960's, and possibly as far back as the 1910, the period of construction for the extensive Central and South Florida (C&SF) drainage system. Both Card and Barnes Sounds are typically hyper saline to saline and some areas of Biscayne Bay become hypersaline during the warmer summer months. Isohaline marine species of fish are now commonly observed along the western and northern shorelines of Biscayne Bay and Card Sound. Five canals drain directly into Biscayne Bay so salinities along the shoreline vary widely, closely following rainfall patterns. Salinity condition are more stable in Card and Barnes Sounds because only one canal, C-111, drains into Barnes Sound. Card Sound essentially receives no water except though rainfall "sheet flowing" to the basin across isolated landward wedge known as Model Lands

The central zone is hypersaline and has unnaturally high nitrogen and phosphorus levels and high levels of dissolved organic matter. The western zone, which is open to the Gulf of Mexico, has fairly stable marine conditions. Shark Slough indirectly provides freshwater inputs via tidal and current flows along Florida's west coast.

What Is Needed

Models to simulate how restoration projects will alter the hydrology of Florida Bay. More freshwater alone will not return Florida Bay to more natural conditions. The quantity, timing, distribution, and quality of freshwater released to Florida Bay must be considered separately and holistically. A significant amount of research has been conducted on how the Florida Bay system functioned historically, how it functions currently, and how the recent changes relate to hydrologic management of the upstream system. However, because distinguishing between the numerous possible natural and man-caused changes in an ecosystem is difficult at best, particularly when they are superimposed spatially and temporally, a number of information gaps need to be addressed before critical decisions can be made about upstream water management that affects Florida Bay.

The complexity of the system and the impacts of restoration and management scenarios can only be evaluated through modeling. The USGS Water Resources Division is adapting a coastal hydrological model that will simulate how restoration projects will alter the physical environment in terms of water elevation and salinity in coastal wetlands, lakes, and streams. An additional model will be needed to link to the coastal hydrological model and translate the output from that model into corresponding changes in Florida Bay. Several such models are under development and should be able to be tested and become operational within three years. The USACE is developing a hydrodynamic model to simulate water circulation patterns in the bay. Among other things this model will support predictions of salinity resulting from varying temporal and spatial freshwater inflows. For example, the model will accept output from surface and groundwater hydrologic models to predict the impacts that C&SF Project restoration alternatives will have on Florida Bay. DOI needs to complete the models it is developing and

actively participate in the development of models by other agencies to ensure that this work is carried out efficiently with no overlap.

Water quality studies. Nutrient, toxic contaminant levels, and emergent pollutants of concern and how they relate to inputs from freshwater inflow, run-off from the developed areas of the Upper Keys, and inputs from the Gulf of Mexico are key water quality issues.

Regarding inputs from freshwater inflow, the water entering Florida Bay through the Taylor Slough is derived from agricultural runoff and urban flood control operations. The establishment of water quality targets and recommendations for management will require additional studies of the role of plant nutrients, their sources, and amounts arriving in Florida Bay. Measures to address pollution specific to the Everglades may not be adequate to protect Florida Bay. Nitrogen levels, which may have been relatively high in the historic Everglades, are thought to be elevated above natural background levels in parts of Florida Bay and may be contributing to phytoplankton blooms. Because upstream water management activities may affect nitrogen inputs (even from natural sources) into the bay, it is important that nitrogen levels within Florida Bay, their sources, and the ramifications for the bay be studied and understood. Increased freshwater inflow from the agriculturally dominated C-111 basin could result in increased pesticide loads into Florida Bay.

Other potential sources of contaminates, such as the Florida Keys and the Gulf of Mexico, will also need to be assessed to determine their potential for affecting the water quality of Florida Bay.

Modeling of ecological responses to hydrologic change. It is anticipated that, but not completely understood how, restoring historic circulation patterns to waters that have been impeded and stagnant for decades will significantly improve water quality, benthic floral and faunal communities, and larval distribution of both recreational and commercial species (e.g. spiny lobster) in the nearshore waters in the vicinity of these restoration sites. Simulations of ecological responses to proposed project design and operation will be evaluated first on the basis of anticipated changes in the quality and quantity of habitat for important indicator species, and second (where feasible and appropriate) on anticipated changes in the population sizes of those species. Information on the life history requirements of indicator species, including their responses to hydropattern change, will be needed to address anticipated changes in species populations. Indicator groups that should be represented in these evaluations include estuarine fish (coastal marshes and streams), wading birds (e.g., spoonbills, egrets), marine fish (e.g. spotted sea trout, mangrove snapper), submerged aquatic vegetation (sea grasses), mangrove forest species, and federally listed species (American crocodiles). Dilution studies combined with hydrodynamic models for Florida Bay that extend onto the offshore platform are needed.

Monitoring of ecological responses. Monitoring will ensure the accuracy of predictions and measure the success of restoration projects. For each of the indicator species or biological communities selected for simulation-based project evaluation, a monitoring program will be initiated as part of the model refinement and adaptive management process. Monitoring will be an essential part of the long-term management of the bay and will provide continuous data observations of the restoration/management changes to the upstream system that will help improve the value and calibration of the models.

Understanding the effects of sea-level rise. The formation and sustainability of coastal communities is a result of the interaction between upland freshwater and tidal inputs. Both of these hydrologic processes are likely to change in the future with restoration projects and with sea level rise. Resource management and restoration efforts will require a thorough understanding of the biological and physical controls on the formation and maintenance of these coastal communities. Research is necessary to assess the current and historic relationships between sea level, salinity, overland freshwater flows, tidal regimes, water budgets, and climate on mangrove and oligohaline communities. This information will be used to develop and validate process-based models useful for simulating hydrologic fluxes, soil dynamics,

productivity, carbon balance, and spatial variability in the mangrove and oligohaline zones in coastal areas. Large salinity corrections that are to be achieved in Florida Bay will have a similar, although admittedly smaller effect on the physiochemical conditions in coastal water immediately seaward of the string of Key bounding and defining the coastal estuaries from Florida Bay to northern Biscayne Bay. The coral reef ecosystem within this coastal zone is highly stressed and, some predict, near collapse.

Landscape-Scale Science Needed to Support Multiple CERP Projects

Overview

This section addresses the needs for science that looks at the different regions of the South Florida ecosystem as one contiguous landscape. Understanding the linkages between hydrology and ecology at this landscape scale is critical to the successful accomplishment of ecosystem restoration. Landscape-scale science--which includes broad regional hydrologic and ecological modeling(including flow projections), comprehensive water quality programs, and a comprehensive monitoring program—is contributing to the design and management of CERP projects. Planning and implementation efforts for the *South Florida Multi-Species Recovery Plan* (see chapter 4) and other ecosystem recovery projects also require the application of landscape-scale science, thus reinforcing the need to focus scientific endeavors in this field.

An important goal of this effort is to coordinate the collection of field data with model calibration and verification. In addition, tools need to be developed that will allow managers to more readily interpret model output. The scope, complexity--and potential ramifications—of these overarching models and programs requires effective interagency participation to ensure the best possible mix of resources are available and the work and funding are coordinated and cost-effective.

SUMMARY OF HIGH PRIORITY LANDSCAPE-LEVEL SCIENCE NEEDS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Landscape-Scale Modeling		
Help ensure that hydrologic performance targets accurately reflect the natural predrainage hydrology and ecology (DOI CERP partnership responsibility)	What are the physical conditions in the Greater Everglades prior to drainage and how will the existing conditions respond to water management? What is the influence of regional CERP activities (EAA water reservoirs, ASR, barrier walls, etc.) on groundwater recharges to Everglades National Park, Florida Bay and Biscayne Bay and how do they affect seepage into the surficial aquifer? What monitoring programs and research projects need to be implemented that will provide appropriate data for verification and calibration of existing models?	Develop tools to describe the hydrology in the predrainage ecosystem. A groundwater model is needed to address historical, current and projected groundwater flows between Everglades and Biscayne and Florida Bays Model and monitoring of the surficial aquifer Collection and synthesis of model calibration and verification data Sensitivity and uncertainty analyses Continuous calibration, validation, testing, and peer review Improved accessibility of modeling data and analysis results through the development of decision support tools and graphical user interfaces Improved accessibility of model code and associated metadata	The landscape-level science needs relate to multiple projects with multiple timelines.
	Comprehensive Integrated Water Quality Feasibility Study		
	What were the water quality parameters in the pre-drainage Everglades?	Research to determine the natural water quality parameters for the estuaries.	

SUMMARY OF HIGH PRIORITY LANDSCAPE-LEVEL SCIENCE NEEDS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Landscape-Scale Modeling		
Help ensure that hydrologic performance targets protect threatened and endangered species and promote fish, wildlife, and park values (consultations on project design related to DOI stewardship responsibilities)	What simulation models need to be developed that will predict the ecological response of key indicator species and landscape level communities to proposed changes in water management? What decision support tools, including graphical user interfaces, need to be developed so that model output can be easily interpreted for assessment purposes? What are the ways to increase sustainable compatibility of the built environment with natural system needs of national parks and refuges – especially, relevant to water-related challenges? Can linking together existing models of the ecological response of individual species provide insight into the predictive response of multiple species to changes in water management or do additional models need to be developed? Which hydrologic models are available to cover coastal areas where the SFWMM is less accurate, and how might the input into those models be improved? How can ecological performance measures be incorporated into decision support tools that have reasonably simple output formats? What alternative higher resolution hydrologic models are available to drive the ecological models? What improvements can be made to existing hydrologic models or what new models need to be developed to improve predictive measures of salinity? How can existing model output be converted into other formats to allow data to be analyzed using different platforms and exported for use in GIS?	Modeling of vegetative production and changes in vegetative communities: • tree islands • mangrove vegetation • sawgrass prairie • vegetative communities important for endangered species, such as muhly grass • invasive or exotic species that are recognized to be in competition with the communities listed above **Landscape-scale land use compatibility assessment tools** Everglades Landscape Model (ELM) development Regional Simulation Model (RSM) ecological module development Development and validation of spatially explicit habitat suitability index models: • threatened and endangered species • indicator species sensitive to hydrologic change • certain established or potential exotic species Development and validation of stage-structured demographic models: • threatened and endangered species • indicator species sensitive to hydrologic change • freshwater fish functional group • estuarine fish functional group Development and validation of individual-based demographic models: • threatened and endangered species • key prey species (white-tailed deer) • certain wading bird species Development and validation of higher resolution ecological models Incorporation of models into the monitoring and adaptive assessment program Models that describe and link water management and hydrodynamics with habitat impacts, particularly related to marine and estuarine environments (ie. Submerged aquatics).	
	Comprehensive Integrated Water Quality Feasibility Study		
		Research to link WQ characteristics, such as performance targets, to ecosystem structure and function Phosphorus-reduction technologies Research to identify relevant links between water quality and ecosystem structure and function Research to identify degraded ecosystems and quantify the types and sources of pollution Better understanding of the water quality impact of ASR activities on the natural system	

SUMMARY OF HIGH PRIORITY LANDSCAPE-LEVEL SCIENCE NEEDS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Studies to Support Fish and Wildlife Friendly Siting and Operation of Reservoirs, STAs, and ASR Structures		
	What construction and operational considerations can minimize adverse effects of water projects on fish and wildlife values?	GIS habitat mapping to guide site selection for large reservoirs and STAs Studies of the effects of intake pumps and control structures Analyses of reservoirs and STAs as habitats for invasive exotic aquatic species	
	Risks to Fish and Wildlife from Soil-Borne Contaminants		
	How can we improve upon standard environmental assessment protocols to better characterize background contaminant levels on large parcels of land?	Site contamination assessments	
	What trust resources are at greatest risk from exposure to soil and sediment contaminants, and what is the risk of bioaccumulative contaminants?	Risk assessments • Risks associated with bioaccumulation • Risks associated with multiple contaminants	
	What is the relative risk of exposure to multiple contaminants compared to the risk of exposure to an individual contaminant?	Sediment quality assessment guidelines for mercury and selenium Research into the potential effects of copper on periphyton	
	How will rehydration affect risk from methyl mercury exposure or bioaccumulation?	Monitoring of actual uptake of contaminants into the food chain Research to determine direct and indirect (food web) effects of mosquito control chemicals on federally listed species	
	Landscape-Scale Monitoring and Assessment		
Assess the responses of ecological communities and species as a basis for adaptive management (continuation of DOI responsibilities outlined above)	What monitoring and assessment programs need to be put in place to provide information for interim goals and target assessments and CERP Updates?	Interim goals and targets development and assessment Additional tool development and research for Interim Goal predictions and desired restoration conditions	
	Which portions of the MAP should DOI fund to best support restoration of DOI resources (e.g. DOI lands and threatened and endangered species) and to ensure a sound science base for adaptive management?	Peer review and assessment methodology, analysis and data management	
	How can DOI ensure that the monitoring and research components proposed in the MAP contribute to recovery goals for the species and ecosystems of South Florida?	MAP implementation	
	How can data management systems allow for management decision-making and improved accessibility to; synthesis of information; synthesis of monitoring and assessment; and restoration evaluation data and analysis information.	Development of decision support tools to allow for better access to and analysis of monitoring data and evaluation assessment reports Development and implementation of long term storage of data, metadata, and analysis information	
	How will coastal communities be affected by the simultaneous effects of increased freshwater flows and sea-level rise?	Enhance hydrologic and meteorological monitoring networks **Develop accessible and shared databases.** Research to assess the current and historic interrelationships between sea level to support the development and validation of process-based models. Long-term monitoring of coastal community resources to detect early ecological responses to changes in sea-level.	

Landscape–Scale Modeling

Background

An overview of the landscape-scale models and how they are being used to direct individual projects is provided in the introduction to this chapter (see page 17).

What is Needed

Higher resolution hydrologic models. The ability to predict how fish and wildlife will respond to a given restoration project strongly relies on the ability to accurately simulate fine-scale hydrologic changes across the landscape. The development of higher resolution hydrologic models or enhancements of existing models, particularly to include flow projections, is needed to improve the reliability and usability of model output.

The effort to measure the topography in the southern Everglades provides data that has increased the accuracy of existing models and will be used to develop new higher resolution models. Further topographic data collection in the areas of Biscayne Bay, Big Cypress National Preserve, and the Arthur R. Marshall Loxahatchee National Wildlife Refuge is of particular interest to DOI.

Efforts to collect "real-time" field data are required to enhance model capabilities, reliability, and accuracy. The upgrade of existing and addition of new hydrologic monitoring stations at presently unmonitored locations will increase available flow, stage, salinity, and water quality data, including data on contaminants. Research to support the models should also focus on the collection of data that will facilitate the simulation of processes such as evapotranspiration, biochemical cycling in the soil and water column, and nutrient transport.

The development of higher resolution models will not supplant the ability to also consider the ecosystem in its broadest terms. Instead, a multi-scale capability will be retained.

Landscape-scale land use compatibility assessment tools. Land use and preservation/restoration decisions have significant, but highly uncertain impacts on water quality and quantity, flow patterns, and ecosystem health in the Greater Everglades Ecosystem. However, these environmental and ecological factors have economic values that are currently being ignored (or only partially considered) in these decisions.

Regional scale efforts are needed to assess the societal impacts of land management decisions that are based on natural science data and model outputs, to develop ecological - economic indicators that measure the impact of restoration efforts on natural and built environments, to estimate the economic values that result from projects that are designed to preserve critical ecological resources, and to assess land allocations and their economic values that includes the consideration of uncertainty.

A groundwater model is needed that addresses historical, current and projected groundwater flows between Everglades and Biscayne and Florida Bays A much better understanding is needed of the hydrogeologic framework affecting groundwater flows between Everglades and Biscayne National Parks

Model and monitoring of the surficial aquifer. Quantitative assessment and monitoring of seepage into the surficial aquifer (such as a 3-dimensional water tracing study) and surficial geology is needed. Model and monitoring of the wet and dry season hydrologic gradients in the surficial aquifer over time is also needed.

Modeling of vegetative production and changes in vegetative communities. Habitat succession models are required for regional assessments of how the landscape might change in response to implementation

of the CERP. Models of vegetative succession simulate how plant communities change in response to hydrology, nutrients, and other factors such as fire. The transport of nutrients and organic matter in water and the interactions of plants with water levels, soils, nutrients, and lower trophic level micro fauna all affect how vegetation changes over time. Computer models of habitat succession can simulate detailed changes in vegetation over various temporal and spatial scales, but are most accurate when applied to only well known community types. Look-up tables and diagrams of habitat continuums, though not dynamic, can provide reliable predictions of succession changes in vegetation when computer models are not available or not verified.

The following vegetative types are particularly important to model:

- tree islands (responses to water flow and depths)
- mangrove vegetation (responses of community to nutrients, water flow, and salinity)
- sawgrass prairie (responses to water depths and phosphorus)
- vegetative communities important for endangered species, such as muhly grass (breeding habitat of Cape Sable sparrow)
- invasive or exotic species that are recognized to be in competition with the communities listed above

Develop tools to describe the hydrology in the predrainage ecosystem. Develop tools to describe the hydrology in the predrainage ecosystem. Additional tools need to be developed to describe the predrainage ecosystem so that improved hydrologic targets for restoration can be established. The Natural System Model has been used to date, but its predictions have not been consistent with other research and empirical data in some parts of the ecosystem. Additional tools could provide improvements to understanding the predrainage ecosystem.

Models that describe and link water supply and hydrodynamics with habitat impacts. In particular, modeling of marine and estuarine production and changes in marine Communities are needed. There are no habitat succession models for assessing the effects on marine and estuarine communities of changes in water management and distribution resulting from the CERP and related water management programs. Such modeling is equally important in marine and estuarine ecosystems. Community structures and interactions are essentially unknown. Many of the CERP projects under development or construction will have a dramatic affect on marine and estuarine habitats, especially those along the mainland and embayment shorelines, which serve as important nursery areas for many species of fish and invertebrates targeted by recreational and commercial fisheries. Models that describe and link water management and hydrodynamics with habitat impacts (e.g., related to changes in the type or presence of submerged aquatic vegetation), community structure, and species interactions need to be developed to enable prediction of ecological consequences of various water management scenarios. Refinement of habitat assessment and restoration evaluation methodology are needed, including review of the potential for inclusion of statistical analysis and spatial quantification of ecological performance measures

Everglades Landscape Model (ELM) development. The ELM is intended to simulate how hydrology, soil water nutrient contents, periphyton biomass, vegetation biomass, and community type respond to changes in water quantity and quality. New data from the southern Everglades area, primarily from DOI lands, needs to be incorporated into the model to improve its accuracy in predicting landscape responses to different water management scenarios.

Regional Simulation Model (RSM) ecological module development. Currently the RSM does not include an ecological module. However, such a module is needed to link the simulation of ecologically significant processes to emerging hydrologic models. This will provide a method for comprehensive ecological evaluations of project alternatives. A vegetation succession module and a landscape utilization

module are needed to provide a more complete regional understanding of how vegetation, fish, and wildlife will likely respond to restoration efforts.

Spatially explicit habitat suitability index models. HSI models assess the suitability of particular areas throughout the south Florida landscape (or subregion of the landscape) and coastal estuaries for particular species, ecologically similar functional groups of species, or entire communities of plants, terrestrials animals, fish, and aquatic macro and micro invertebrates. These models synthesize information about environmental conditions, including vegetative composition and water levels, within a given geographic area and how those conditions change over the course of a year or period of years. The models use information about the preference, avoidance, or other responses of particular species or functional groups to particular vegetation types and patterns of water depth during the year. The resolution of the existing models is considered to limit the accuracy of the models; hence, enhancement of the models using finer scale topography and the collection of additional field data are necessary.

Species and functional groups for which habitat suitability models are likely applicable include the following:

- Cape Sable seaside sparrow
- long-legged and short-legged wading bird groups
- white-tailed deer
- American alligator
- American crocodile
- Everglades and slough crayfish
- apple snail
- Florida panther
- Everglade snail kite
- Snapper spp. (e.g., gray snapper)
- Spotted sea trout
- Red drum
- Macro and micro crustaceans
- Sponges
- Plankton

The hydrologic and ecological conditions that promote the spread of exotic species and the adaptation of freshwater organism to marine conditions should also be modeled to examine how CERP projects may influence their habitat. These models will provide valuable information for risk assessments of whether the design and management of restorations projects would affect the habitat suitability of invasive exotics.

Spatially explicit demographic models. Various approaches to demographic modeling are appropriate for different purposes. *Stage-structured models* describe population dynamics as composed of a number of life stages, each stage having different size, physiology, and environmental requirements. Sufficient data exist to develop stage-structured models of the following south Florida species:

- American alligator
- freshwater fish functional group
- estuarine fish functional group
- crayfish species
- apple snails
- Snapper spp
- Spotted sea trout
- Red drum
- Blue Crab
- Stone crab

Individual-based models describe populations by simulating each individual in the population as it goes through its life cycle. Detailed descriptions of reproduction, in particular, may be included. These models allow inclusion of a great deal of specific detail about the responses of individuals to environmental conditions. Sufficient data exist for development of individual-based models of the following species:

Cape Sable seaside sparrows

snail kites

white-tailed deer

Florida panthers

certain wading bird species

Higher resolution ecological models. In general, the ecological models have a higher resolution than the hydrologic models, but when these models are coupled, the detail of the final output is limited to the resolution of the hydrologic model. Hence, as the resolution of hydrologic models improves, both the programming and the interpretation of output from the ecological models need to be periodically refined.

Sensitivity and uncertainty analyses. Additional interagency effort is needed to quantify the uncertainty and sensitivity in the regional models used in the CERP, especially the hydrologic models, since outputs from these models are used as inputs into the various ecological and water quality models. Understanding the types of sensitivities that a model might have to various input data and how those sensitivities might differ at different locations across the modeled landscape are important to proper interpretation of the model results. Likewise, understanding how input data, computer program algorithms, formulas, and associated tools affect model predictions is key to characterizing the certainty of the results of computer simulations. Understanding and estimating model uncertainty will help refine monitoring programs and identify priority needs for more accurate data or additional information, or at least allow decision makers to consider the potential implications of a certain degree of scientific uncertainty.

Continuous calibration, testing, and peer review. Protocols for quality assurance and quality control, including model calibration and verification of existing and updated model codes and applications, are needed to maximize model accuracy. External peer reviews of model codes and applications will help ensure the models' proper uses in the analysis of proposed alternatives. Code and application level peer reviews are needed for all of the key regional hydrologic, water quality, and ecological models used in the CERP, including the MIKE series of models, the SFWMM (2x2 Model), the NSM, the ATLSS models, and the RSM and its utilities.

Improved accessibility of modeling data. Development of user interfaces that are capable of integrating numeric model output into different output graphics will allow decision makers to analyze results from multiple models simultaneously, expedite assessments of project-related ecological benefits, and improve the uniformity in how anticipated project benefits are assessed, quantified, and documented. Development of a tool that grants staff direct access to model input, output, and model code will provide each agency with the data necessary to run the models and view the output graphics for unique cases where further analyses of model outputs are required.

Incorporation of models into the monitoring and adaptive assessment program. Landscape level ecological models should play a role in post-implementation assessment and adaptive management. The available tools currently used to evaluate the performance of various restoration projects may not accurately predict the real responses in the upcoming years, for a variety of reasons. Field data collected

from monitoring efforts will be used to test model predictions and support decisions that improve the potential for successful restoration following the application of adaptive management.

Interagency Modeling Center. The Interagency Modeling Center (IMC) was created to satisfy the modeling needs of the CERP. However, the IMC is currently staffed to a level that supports only the application of regional hydrologic models. In addition to making the IMC a truly interagency effort, funding of additional DOI positions and appropriate computer hardware within the IMC will provide a means for the integration of hydrologic, water quality, and ecological models; quantification of model accuracy (e.g., sensitivity and uncertainty analyses); development of data interpolation tools; and the application of integrated hydrologic, ecological, and water quality models.

Comprehensive Integrated Water Quality Feasibility Study

Background

The needed science components for the Comprehensive Integrated Water Quality Feasibility Study (CIWQFS) will focus on identifying degraded water bodies, identifying and quantifying types and sources of waterborne pollution, establishing load reduction targets for pollutants, and conducting an inventory and evaluation of the suite of structural and nonstructural technologies that have the potential to improve water quality. DOI has a strong interest in assisting the multiagency CIWQFS Project Delivery Team in identifying the linkages between water quality targets and ecosystem restoration.

What Is Needed

Phosphorus-reduction technologies. The highest priority science needed at this time is to continue research to develop environmentally benign technologies to reduce STA phosphorus discharges down to 10 ppb. These types of technologies, such as existing STA optimization and wetlands dominated by periphyton or submerged aquatic vegetation, are likely to have lower operation and maintenance costs and fewer adverse environmental impacts than chemical treatment technologies. STAs augmented with these technologies may be used across the Everglades, including the urban basins on the eastern Everglades and the C-111 basin, as the Everglades Construction Project and the CERP are implemented. Seven years of research have improved these technologies greatly and have led to improvements in existing STAs, but the STAs have not yet achieved discharges consistently at or below 10 ppb.

Numerous CERP projects are planned to introduce water to areas of the Everglades that have been too dry for decades but consequently not subjected to nutrient enrichment. Examples include the northern portion of the Arthur R. Marshall Loxahatchee National Wildlife Refuge, the western portion of WCA-2A, and the northeastern portion of WCA-3A. Because it takes many decades for Everglades wetlands to recover from water and sediment nutrient enrichment, it is crucial that best management practices and water treatment technologies be in place to guarantee that this rehydration is accomplished with clean water. In addition, research is needed in the southern Everglades (e.g., C-111 basin) to determine the ecosystem-scale effects of adding very low levels of phosphorus. A key analytical tool for this is the Dynamic Model for Stormwater Treatment Areas (DMSTA) and refinement of this tool is needed.

Even as water quality restoration projects are implemented and water column and sediment phosphorus concentrations decrease, it is not known how Everglades plants and animals will respond. It may be necessary to actively manage some areas. For example, monocultures of cattail may not disappear immediately in response to improved water quality. Research is needed to determine what other management activities, such as fire, herbicide, or manual removal, may be needed to accelerate recovery of impacted areas.

Research to identify relevant links between water quality and ecosystem structure and function. Additional study is needed to better understand what water quality will sustain desirable ecosystem

characteristics and functions in the Everglades. A better understanding of contaminant linkages from terrestrial and freshwater systems to estuarine and marine systems (Florida Bay, Biscayne Bay, mangroves, southwest Everglades estuaries, and the Ten Thousand Islands area) is required to avoid unintentional water quality impacts that could result from implementation of Everglades restoration activities.

Research to identify degraded ecosystems and quantify the types and sources of pollution. There is a need to fully understand the sources, cycling, and fate of critical chemical constituents. Although considerable effort has been put toward understanding sources, effects, and methods for controlling phosphorous, similar analyses are needed for other contaminants.

Water quality performance targets. Research is needed to link WQ characteristics, such as performance targets, to ecosystem structure and function. Additional research is needed to identify targets, which are indicative of restoration success, for estuarine system. Monitoring of ecology linked to water quality targets are needed to identify areas in need of adaptive management.

Better understanding of the water quality impact of ASR activities on the natural system. ASR is a critical water storage component of the CERP and is essential for restoring more natural hydrology to natural systems. However, the water quality impacts of the ASR technology are not completely understood. Critical issues that have not been addressed relate to the potential contamination of water while it is stored in a deep aquifer.

Studies to Support Fish and Wildlife Friendly Siting and Operation of Reservoirs, STAs, and ASR Structures

Background

The CERP projects call for approximately 158,000 acres of aboveground reservoirs and 33,000 acres of STAs, totaling 191,000 acres (300 square miles, or a little less than half the size of Lake Okeechobee). This total does not include the acreage of reservoirs and STAs in non-CERP projects, such as the 40,000 acres in the Everglades Construction Project. The CERP also calls for about 330 ASR wells, which often include surface storage reservoirs to provide additional water storage capability.

DOI managers need information to adequately address the potential for adverse effects on fish and wildlife associated with these engineered water bodies, in addition to their anticipated benefits. The potentials for adverse effects include a loss of upland and natural wetland habitats, the potential for introduction of invasive exotics, the potential for introduction of soil-borne contaminants (addressed separately, below), and the physical risks to fish and wildlife associated with large numbers of pumps and other structures.

What Is Needed

GIS habitat mapping to guide site selection for large reservoirs and STAs. Further refinement and expansion of the GIS-based habitat mapping tool developed for the Lake Okeechobee Watershed Project (see page 27) will allow its use for other CERP projects.

Studies of the effects of intake pumps and control structures. Studies are needed to identify better designs for intake pumps and control structures that will minimize impingement (trapping organisms against intake screens) and entrainment (passage of organisms through a pump) of aquatic organisms at intake sites.

Analyses of reservoirs and STAs as habitats for invasive exotic aquatic species. Research is needed to support engineering designs for reservoirs and STAs that avoid or mitigate the effects of aquatic invasive exotic species on wetlands, while allowing these structures to function as needed for ecosystem restoration.

Risks to Fish and Wildlife from Soil-Borne Contaminants

Background

As the CERP is implemented, thousands of acres of federal and state lands will be converted to water storage facilities, including STAs, ASR detention reservoirs, ASR wells, and aboveground and in-ground storage reservoirs. Many of these facilities will cover large expanses, sometimes thousands of acres, establishing local and regional aquatic ecosystems and providing foraging habitat for waterfowl and other aquatic wildlife. Ultimately, water from these facilities will be diverted downstream to hydrate natural system wetlands and preserve coastal estuaries. The CIWQFS addresses the need to establish water quality targets for the facilities themselves and for the downstream areas receiving these waters (principally targets for nutrients and bacteria, which are regulated by the state); however, that study does not address in detail the potential for contaminants that might, as indirect effects of the water storage and rehydration projects, affect fish and wildlife.

Threats Associated with Rehydration of Agricultural Lands

Much of the land to be acquired is currently managed for row crops, citrus, fruit orchard, sugarcane, or improved pasture. Conversion from farmland to wetlands will result in the release of residual pesticides, fertilizers, animal waste byproduct, and metals and metalloids into surface waters. Historical farm management practices, especially those associated with row crop farming, sometimes involved the application of organochlorine pesticides, many of which are no longer licensed for use in the United States, for insect control. Frequent applications of DDT, chlordane, and toxaphene were common in agricultural areas of South Florida over several decades, leaving significant residual concentrations of these toxic substances and their degradation byproducts in the topsoil.

Since detection of elevated levels of mercury in freshwater fish in 1989, it has become increasingly apparent that South Florida also has an extensive mercury contamination problem. Many agricultural lands also have some degree of contamination from metals and metalloids (e.g., copper, arsenic, and selenium). Water retention over contaminated soils presents a potential to release these contaminants into affected ecosystems through a combination of chemical desorption into the water and uptake through aquatic organisms into the food chain. At this time, it is not well known how water quality and nutrient cycles in STAs and reservoirs built on former agricultural lands will be affected by these residual soil-bound contaminants.

In South Florida, desorption from sediment to water and transport via food chain dynamics is probably the most important exposure pathway to consider regarding the design and operations of STAs and storage reservoirs. Fortunately, the fate and transport of most known organic and inorganic pollutants are well documented, including information about their mobility through air, water, soil, and sediment, and exposure pathways. Information regarding the many natural processes that transform and degrade soil- and waterborne contaminants (important in determining the bioavailability of contaminants such as mercury, selenium, organochlorine pesticides, copper, and lead) is also well documented.

Threats Associated with Aquifer Storage and in In-Ground Reservoirs

DOI is also concerned about the quality of water that will be discharged from the in-ground reservoirs and aquifer storage wells. The depth of the in-ground reservoirs and their method of construction ensure connection with deep groundwater strata, similar to the aquifer storage wells. These strata typically contain high concentrations of dissolved solids, whose potential effects on the ecosystem are unknown.

It is believed that geochemical reactions between stored water and the minerals associated with the aquifer host rock may produce increased concentrations of some metals and trace elements. Other changes to the physical and chemical properties of the water, such as temperature or dissolved oxygen, also represent areas of concern, as they may affect the structure or composition of aquatic communities.

What Is Needed

Site contamination assessments. Accurate site-contamination assessments are critical to assess the risks from contaminants. The most accurate assessments utilize a high sample density (e.g., one sample every square meter); however, budgetary constraints hinder site-contamination assessments for large agricultural tracts by limiting the number of samples that can be analyzed. A compromise must be reached in which reasonable certainty in assessment conclusions are attained given the funding available to perform such an assessment. Currently, sample density is one discreet sample per 10 to 20 acres for small tracts (< 500 acres), and one composite sample per 50 acres for large tracts (> 500 acres). This results in the sample number being sufficient to provide adequately narrow uncertainty bounds around the site average contaminant level for small tracts; however, high uncertainty levels remain for large tracts since only a portion of the tract is sampled.

Risk assessments. Risk management decisions are often based on what ecological component is at risk from a particular action, reflecting that certain components have greater management value than others. Determining the most at risk component will best be addressed by improving knowledge of *contaminant partitioning* among ecosystem components. Once contaminant partitioning is characterized, it will be possible to answer questions about which managed resources are at greatest risk, given potential contaminant exposures.

Accurate characterization of potential exposure scenarios for managed resources will help managers understand the risk from exposure to contaminants. Managers need to understand both bioaccumulative risks and risks associated with exposure to multiple contaminants.

Risks associated with bioaccumulation*:* Some currently banned pesticides and other contaminants that have been found on South Florida agricultural lands are known to accumulate in wildlife to concentrations that greatly exceed soil/sediment/water concentrations, resulting in greater risk to wildlife than indicated by contaminant concentrations. The degree to which contaminant accumulation occurs depends on the organism trophic level, soil/sediment parameters, and contaminant properties. Food chain models provide information about bioaccumulation of contaminants. They predict how sediment organisms are exposed to contaminants and, if not harmed by them, pass them up the food chain, leading to successively higher concentrations of contaminants in higher trophic level organisms.

The Florida Sediment Quality Assessment Guidelines (SQAGs) are used to screen potentially toxic contaminants and assess sediment quality in Florida inland waters based on the probability of effects on aquatic invertebrates. Current SQAGs reflect only direct toxicity to sediment dwelling organisms and no SQAG's exist for marine and estuarine sediment. Even when bioaccumulative contaminant concentrations in soil/sediment/water are well below SQAG values, indicating low risk to sediment dwelling organisms, significant bioaccumulation risk to higher trophic level organisms may still exist. Information gleaned from food chain models needs to be considered along with laboratory and biological data to assess the risks to fish and wildlife from exposure to particular contaminants.

The current food chain models used to predict contaminant accumulation for site assessments are not necessarily appropriate for all potential exposure scenarios. Additional research will provide the information necessary to calibrate existing models and to develop new ones where needed to ensure that the design of STA wetlands adequately protects the water quality in adjacent Everglades wetlands.

In addition to improving food chain models, a decision process needs to be developed that will determine if the risk of bioaccumulation needs to be assessed.

Risks associated with multiple contaminants*:* Fish and wildlife in South Florida are likely exposed to more than one contaminant at a time. The synergistic effects of multiple contaminants on an individual organism are unknown, and this has potentially significant ecological implications. Current regulatory processes and risk assessments usually address risk from individual contaminant exposure. Risk assessments will benefit greatly from toxicity tests designed to determine combined toxicity for contaminants commonly encountered on agricultural lands to be restored. This information will help managers assess the risks to wildlife simultaneously exposed to multiple contaminants.

Sediment quality assessment guidelines for mercury and selenium. Adequate SQAGs for mercury and selenium have not been developed for South Florida. Both mercury and selenium vary in their respective toxicity to fish and wildlife depending upon methylation and other organic transformations that occur in soil and sediment. Although considerable research has been performed on mercury methylation, the level of information necessary to establish meaningful screening values has not been reached. No SQAG criteria exist for selenium, which bioaccumulates and biomagnifies in the food chain and has the potential to adversely affect a large number of fish and wildlife in low concentrations in water, soil, or sediment.

Predicting bioavailability of mercury (methylation) following inundation of dry land based on soil and water chemistry. At the April 2003 Greater Everglades Ecosystem Restoration Conference, concerns were raised that sulfate introduction into recently flooded lands and the repeated wetting/drying cycle of those lands will promote methyl mercury production. More research will inform management of the risk that flooding mercury-contaminated lands will present to natural resources

Methylmercury concentrations and effects on a representative carnivorous wetland bird. The dynamics of mercury within the Everglades could change significantly as water quality and the location and timing of water flows are altered in the restoration process. Research is needed to assess the risk of mercury contamination for the federally endangered wood stork, other federally listed species, and three state listed species. Data on mercury effect thresholds are limited, making it difficult to assess current or future risks to wading birds. This research will determine mercury effect levels in wading birds so that risks to these species can be assessed with a higher level of certainty

Research into the potential effects of copper on periphyton. Many of the proposed STAs will be constructed over existing citrus groves that have been repeatedly treated with copper compounds used to minimize fungal infestations on the trees. Although copper is not known to bioaccumulate a great deal in the food chain, it is harmful to algae such as periphyton. Periphyton is an important Everglades ecosystem component associated with nutrient assimilation and marl production. Diminished periphyton production over an extended period of time could adversely affect Everglades habitats receiving STA effluents. Research is needed on potential effects of copper contaminated water from STAs on the Everglades ecosystem. Generally, copper binds well with soil particulates and appears to be found in the greatest concentrations within the top 6 to 8 inches of the soil. Copper desorption from soil and sediment into the water column is subject to several local water quality and sediment quality variables. Studies will determine the water quality and sediment quality parameters that influence copper desorption, and quantify the effects of copper on Everglades periphyton communities.

Monitoring of actual uptake of contaminants into the food chain. To determine whether residual soil-bound contaminants are being released into the Greater Everglades via STAs, on-site studies at newly constructed and operating STAs will be necessary. The primary focus of these studies will be to determine the rapidity of contaminant (organochlorines, mercury, selenium, copper, lead, etc.) uptake into the food chain by measuring each of these contaminants in the tissues of invertebrates, fish, and bird

eggs. Field collections will be spaced within given time intervals to provide a bioaccumulation/temporal relationship. A secondary focus of these studies will be to measure contaminant degradation and assimilation into the environment, resulting in half-life data based on local conditions. The resulting data will then be used to better estimate the risk to fish and wildlife from exposure to these contaminants and to develop best management practices and/or interim management plans.

Research to determine direct and indirect (food web) effects of mosquito control chemicals on federally listed species. Concerns over mosquito born diseases such as West Nile Virus are increasing and will result in increased pressure to allow application of chemical control agents on DOI managed lands. The short and long-terms effects of modern mosquito control pesticides on trust resources are not well understood. Some agents, while harmless to vertebrate species from direct contact, may nevertheless impact these species through reducing the prey items upon which they depend. Others are directly toxic to wildlife and have recently been implicated in shorebird deaths in South Florida.

Landscape-Scale Monitoring and Assessment

Effective adaptive management—and ecosystem restoration—will require both increasing the existing knowledge through monitoring and assessment and ensuring that knowledge is available to decision makers. The CERP MAP provides an integrated mechanism to monitor system response, change designs, and improve the chances of success of the CERP.

What Is Needed

Interim goals and targets. The CERP Programmatic Regulations require the CERP partners to agree to a process by which the success of the plan may be evaluated. *Interim goals* are descriptions of the desired purposes of restoration activities. The goals have been written to define a means to track restoration performance, report on restoration progress, and periodically evaluate the accuracy of predictions of system responses to the effects of the plan. *Interim targets* provide quantitative indicators of restoration performance and success. Indicators for interim targets include hydrologic, water quality, and biological parameters or "end-points" that describe what is believed to reflect the characteristics of a restored system. Interim goals and interim targets apply to the landscape scale of the Greater Everglades.

In order to track interim goals and targets, projects focused on research, monitoring, and scientific analyses are necessary. As one of the CERP partners, DOI has an interest in participating in the support for activities related to evaluating the success of restoration.

Additional tool development and research for Interim Goal predictions and desired restoration conditions. Additional research is necessary to provide improved quantitative performance predictions for the CERP. RECOVER's list of recommended indicators for the Interim Goals reflects the best available science, but many indicators need additional work to develop or refine their quantitative predictions. The results of this research will be provided to the RECOVER group as it refines its recommendations for CERP Interim Goals. Additionally, research is also needed to assist RECOVER in better defining the desired level of performance for these indicators to achieve restoration conditions. These desired performance levels will be key as restoration partners seek to improve the restoration plan.

Research to assess the current and historic interrelationships between increased freshwater flows and sea-level rise. Additional research on the interrelationships between sea-level, salinity, overland freshwater flows, tidal regimes, water budgets, and climate on coastal communities is necessary. This information will support the development and validation of process-based models of hydrologic fluxes, hydrogeologic framework, soil dynamics, productivity, and spatial variability in the mangrove and olgohaline zones of EVER.

Long-term monitoring of coastal community resources to detect early ecological responses to changes in sea-level.

MAP implementation. In order to help ensure successful implementation of the MAP it is important for DOI to determine which aspects of the monitoring components and research topics complement and supplement monitoring efforts within other DOI initiatives and to fund those as appropriate. Logical projects for DOI to support are elements of the MAP directly linked to agency missions, including

the effects of sea level rise on coastal wetlands and tidal creek dynamics and estuarine productivity within these habitats

the role of aquatic refugia habitats for aquatic fauna

the sublethal effects of contaminants on wading birds

West Indian manatee abundance and distribution relative to changes in freshwater flows and seagrass distribution as a result of implementation of the CERP

the role of submarine groundwater discharges to Biscayne Bay

trophic interactions of higher vertebrates (wading birds, waterfowl, Everglade snail kite) in the Lake Okeechobee food webs and the relationship of the lake's resource base to aquatic habitat structure

Enhance hydrologic and meteorological monitoring networks. The establishment of new weather and monitoring stations on DOI lands in the South Florida landscape will increase the understanding of the system and the ability to predict restoration and recovery outcomes from CERP projects.

Develop accessible and shared databases. The organization and sharing of data within and among agencies is critical to developing and implementing the science needed for restoration. Managers and scientists working on CERP or other restoration and resource management projects require access to the meteorological, hydrologic, water quality and ecological information that results from research and monitoring programs. The goal of data management programs is to capture, organize, catalog (=create metadata) and make available quality natural resource data, and to facilitate the transformation of data for complex analysis, synthesis and modeling. Databases need to be managed, designed, implemented and available to users to ensure that the scientifically sound information obtained through research is available for management decision-making, research, education, and promoting public understanding of South Florida's natural resources.

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4. Habitat and Species Recovery Projects

Introduction

Caribbean, temperate, and endemic influences converge in South Florida, resulting in a great diversity of communities, species, and genetic variations. This ecosystem supports the only subtropical ecological communities in the continental United States. About 60% of the native plant species south of Lake Okeechobee originated in the tropics.

The historic ecosystem was a rich mosaic of wetland, upland, and nearshore communities linked into a vast integrated system. Although this system has been significantly altered over time, remnants of the distinct ecological communities survive. Some of the communities that have been reduced and altered the most are now home to large numbers of threatened and endangered species.

Sixty-eight listed species are under the protection and management authority of the FWS, and several additional species are under the protection and management authority of the National Oceanic and Atmospheric Administration Fisheries. Many additional species are listed by the State of Florida (Fish and Wildlife Conservation Commission, Department of Agriculture and Consumer Services, Natural Areas Inventory, and Committee on Rare and Endangered Plants and Animals) as rare, of special concern, threatened, or endangered. All these species are considered to warrant high conservation priorities.

Threatened and endangered species within the Greater Everglades can be classified into two broad groups. The first group is composed of *wetland-dependent* species, for which restoration of natural hydropatterns and the quality of the water within the system may be the best option for achieving recovery. The second group includes *terrestrial* species, which may or may not directly benefit from restoration of pre-drainage hydrologic conditions.

Overview of Activities and Authorities

DOI has three broad responsibilities for threatened and endangered species and other species of concern under the Endangered Species Act, Migratory Bird Treaty Act, Fish and Wildlife Conservation Act, and Fish and Wildlife Coordination Act:

> Restore the ecological communities of South Florida in ways that will optimize benefits to the greatest number of imperiled species.
>
> Assess the responses of ecological communities and species as a basis for adaptive management.
>
> Meet the recovery needs of particular species on federal, and where possible on nonfederal, lands and waters.

The Endangered Species Act establishes policies and procedures for identifying, listing, and protecting species threatened or endangered with extinction and for the conservation of ecosystems upon which these species depend. The act requires the development and implementation of recovery plans for the conservation and survival of threatened and endangered species. Such plans include management actions necessary to achieve the goal of recovery and survival, as well as objective, measurable criteria that determine when a species is recovered. The FWS establishes recovery plans for all threatened and endangered species (for South Florida it has established a multi-species recovery plan) and it coordinates with other federal, tribal, state, and local agencies and private citizens to implement these plans where suitable habitat for species recovery currently exists or might be restored. In addition, section 7(a) (1) of

the act directs federal agencies to utilize their authorities to carry out conservation programs for listed species. Section 7(a) (2) of the act prohibits any federal agency from conducting an activity that would jeopardize the continued existence of threatened or endangered species or adversely modify designated critical habitat. Under Section 7, the federal agencies consult with the FWS on the effects of their proposed actions on threatened and endangered species and designated critical habitat.

The Migratory Bird Treaty Act of 1918, as amended, provides protection for a wide variety of migratory bird species. This act protects species from pursuit, killing, trade or possession of bird parts, and from destruction of nests or eggs. The FWS is the lead agency for ensuring compliance with this act. Executive Order 13186 identifies the responsibilities of all federal agencies to promote conservation of migratory birds, in cooperation with the FWS.

The Fish and Wildlife Coordination Act of 1934, as amended, provides the basic authority for the FWS's involvement in evaluating impacts to fish and wildlife from proposed water resource development projects. It requires that fish and wildlife resources receive equal consideration to other project features. It also requires that federal agencies that construct, license, or permit water resource development projects must first consult with the FWS (and the National Marine to be given to FWS recommendations. Oceanic and Atmospheric Administration Fisheries in some instances) and with the state fish and wildlife agency regarding the impacts on fish and wildlife resources, and take measures to mitigate these impacts. Full consideration is

The Fish and Wildlife Conservation Act of 1980 includes provisions for the FWS to aid states in the protection of nongame species, including birds.

The *South Florida Multi-Species Recovery Plan* (MSRP) completed in 1999 recognizes that the Greater Everglades must be restored and managed as a whole, not species by species. This recovery plan is specifically designed to recover the 42 federally listed species under FWS authority that occur only in South Florida and also represents contributions to existing recovery plans for those 26 federally listed species that occur in South Florida but also occur elsewhere and have current, approved recovery plans. The MSRP broadens the scope of recovery planning and implementation to the landscape level, where the fundamental question to be answered is, *What are the highest priority management actions needed to achieve multi-species recovery?*

This approach is precedent setting for the FWS, and is wholly consistent with the magnitude and complexity of the ecosystem restoration initiative for South Florida. The successful recovery of the Greater Everglades will depend upon the success of perpetuating the mosaic of ecological communities unique to the region, and on protecting a large number of highly vulnerable species—many of which are currently dependent upon extensively altered sites for their remaining habitat—while restoring a more natural ecological pattern to the landscape.

The Multi-Species/Ecosystem Recovery Implementation Team (MERIT), appointed by the FWS to oversee implementation of the MSRP, has drafted an implementation schedule to prioritize the restoration and recovery tasks identified in the MSRP. The purpose of the implementation schedule is to prioritize tasks, estimate their costs, and provide suggestions as to which entities may best be able to carry out the tasks. The implementation schedule for the MSRP will focus on combining tasks that apply to multiple species. The draft implementation schedule has undergone a public review and comment period and is being finalized by the FWS.
The tasks included in the MSRP implementation schedule address (1) direct management of DOI conservation lands, (2) coordination with other federal, tribal, state, and local agencies to facilitate their roles in species recovery, and (3) incentives for private landowners and other partners to participate in recovery activities.

Overview of Science Support for DOI Managers

By focusing on the restoration of ecological communities, as well as individual species, the FWS and its partners hope to achieve the greatest benefit for the ecosystem as a whole. This approach requires achieving conditions within the region's ecological communities that support all of the species (aquatic and terrestrial) that inhabit them. This approach also requires an understanding and appreciation of how management to enhance or restore one community and its associated species may affect other communities within the ecosystem.

Habitat management focused on multi-species recovery requires three kinds of scientific information for CERP ecosystem restoration efforts:

> **Comprehensive models of habitats for all federally protected species.** Managing habitats and species at a landscape scale will require comprehensive models of the spatial distributions of all the species listed in the MSRP. To create these models, existing GIS data (from the Florida Fish and Wildlife Conservation Commission, the USGS Gap Projects, the Florida Natural Areas Inventory's public lands coverage, and the SFWMD land cover maps) will be collected and integrated to show the current spatial distributions of all federally protected species and to assess the availability of potential habitats under current and alternative management scenarios. This kind of modeling will allow managers to identify and assess potential conflicts among species that might result from restoration activities.
>
> **Risk assessments and threat analyses for listed species.** Risk assessments and threat analyses for listed species will be integrated into the habitat models. These assessments and analyses will allow managers to assess the feasibility of recovery for individual species and to prioritize habitat requirements based in part of the best habitats for the most vulnerable species.
>
> **Identification of unprotected habitats.** This work will involve the use of the habitat-prioritization information to identify areas essential to recovery and to target them for conservation and private land partnerships.

The projects highlighted in this science plan are among the highest priorities for implementation of the MSRP because they address the most urgent needs for species recovery.

The review of scientific knowledge and remaining needs for information for each project will provide the basis for prioritizing the activities needed to implement the multi-species approach to threatened and endangered species recovery in South Florida.

Projects to Recover Vegetative Communities and Multiple Animal Species

SUMMARY OF DOI SCIENCE NEEDS RELATED TO RECOVERY OF VEGETATIVE COMMUNITIES AND MULTIPLE ANIMAL SPECIES

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Avian Species Recovery		
Restore the ecological communities of South Florida in ways that will optimize benefits to the greatest number of imperiled species (Stewardship responsibility for all federal lands; possible partnership opportunities on nonfederal lands)	What specific habitats require restoration or management for the suite of federally protected avian species in South Florida? How do we optimize the benefits of restoration for protected avian species in South Florida while minimizing tradeoffs caused by conflicting habitat needs?	Development of key habitat-management information for avian species Research and possible model development or refinement to support decision making where restoration activities pose the potential for multi-species tradeoffs affecting • wading birds • wood stork • roseate spoonbill • snail kite • white ibis • Cape Sable seaside sparrow • red-cockaded woodpecker • Florida grasshopper sparrow • Audubon's crested caracara Landscape-scale ecological modeling Determination of connectivity and importance of South Florida populations for widely distributed species Development of species-specific information needed for recovery planning: • Cape Sable seaside sparrow • Everglade snail kite Identifying critical limiting factors and optimal conditions for avian species Studies of migratory birds in South Florida	Avian Species Component of MSRP Implementation Schedule Species Recovery Plans for which the FWS Vero field office has the agency lead are rolled into the MSRP Implementation Schedule Draft: April 12 2004 Final: 2005
	Recovery of Scrub Community:		
	Is sufficient habitat protected to support recovery of scrub and high pineland plants? How should scrub habitat be managed, including use of prescribed fire and mechanical methods, for continued protection of scrub and high pineland plants?	Updated surveys, inventories, and monitoring data Population viability analyses Assessment of the adequacy of the conservation land network Population augmentation Research of long-term vegetation changes following fire and mechanical treatments Information about the effects on scrub habitat of land management and other practices	
	Recovery of Scrub-Dependent Animals		
	Is sufficient habitat protected to support recovery of the Florida scrub-jay, sand skink, bluetail mole skink, and Highlands tiger beetle?	Habitat and population viability analyses of Florida scrub jay, sand skink, and bluetail mole skink Updated information about the Highlands tiger beetle	Species Recovery Plans for which the FWS Vero field office has the agency lead are rolled into the MSRP Implementation Schedule Draft: April 12, 2004 Final: 2005

SUMMARY OF DOI SCIENCE NEEDS RELATED TO RECOVERY OF VEGETATIVE COMMUNITIES AND MULTIPLE ANIMAL SPECIES

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	How should scrub habitat be managed, including use of prescribed fire and mechanical methods, for continued protection of scrub-dependent animals?	Effects of human activities on sand and bluetail mole skink Information about the effects of land management and other practices	
	Recovery of Pine Rockland Community: Miami-Dade County		
	Is the existing pine rockland habitat sufficient for recovery of its listed species? How should remaining pine rockland be managed to encourage recovery of its listed plant species?	Population viability analyses Natural forest community mapping and mapping of individual species Analysis of mechanical treatment to recover habitat Research to support species propagation and reintroduction	Species Recovery Plans for which the FWS Vero field office has the agency lead are rolled into the MSRP Implementation Schedule Draft: April 12, 2004 Final:2005
	Recovery of Florida Keys Species		
	Is sufficient habitat protected to support recovery of threatened and endangered Keys species? How should habitat be managed, including use of prescribed fire and control of anthropogenic factors, for continued protection of Keys species? Are habitat restoration and species augmentation efforts appropriate and/or sufficient for recovery of Keys species?	Determine how secondary effects of development are affecting threatened and endangered species of the Keys Analysis of life history requirements Research the preferred method of habitat manipulation to improve the survival of the Key Largo woodrat in north Key Largo. Determine how to maintain and prevent degradation of crocodile nesting habitat and improve nesting success of the American crocodile on North Key Largo Research to determine individual species' responses to fire Analysis of minimum habitat requirements for species introduction	Species Recovery Plans for which the FWS Vero field office has the agency lead are rolled into the MSRP Implementation Schedule Draft: April 12, 2004 Final:2005
Assess the responses of ecological communities and species as a basis for adaptive management	Avian Species Component of MSRP Implementation		
	What are the effects of management activities and resulting ecological changes on key indicator species? What are the changes in the biological status of listed avian species?	Monitoring plan for the avian species component of the MSRP Use detailed field assessments to validate and calibrate models	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed
	Recovery of Scrub Community:		
	What are the long-term effects of fire on plant species in scrub communities?	Monitoring of long-term vegetation changes following fire	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed
	Recovery of Scrub-Dependent Animals		
			Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed
	Recovery of Pine Rockland Community: Miami-Dade County		

SUMMARY OF DOI SCIENCE NEEDS RELATED TO RECOVERY OF VEGETATIVE COMMUNITIES AND MULTIPLE ANIMAL SPECIES

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	What are the effects of rehydration projects on listed plant species in pine rocklands in Miami-Dade County?	Monitoring of the ecological response to hydration	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed
	How do resource management activities affect populations of invertebrates and reptiles (e.g. butterflies)?	• Surveys to determine the status and distribution of imperiled invertebrates • Effects of prescribed fire on imperiled pineland species, including planning for fire frequency and size and distribution of burn blocks • Effects of Park Maintenance and Exotic Plant Control activities On invertebrates and reptiles	
	Recovery of Florida Keys Species		
	Has there been a change in the biological status of any Keys species, particularly the Key deer or American crocodile?	Monitoring and biological status assessments	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed

Avian Species Recovery

Project Purpose and Major DOI Interest

The Greater Everglades support habitats for 13 federally listed threatened or endangered bird species that spend all or part of the year in Florida. It is also home for many migratory bird species, which are protected under the Migratory Bird Treaty Act, and most of the 48 species that have been identified by the FWS as birds of conservation concern in peninsular Florida. Early implementation of strategies to conserve these species may prevent the need to list additional avian species as endangered or threatened.

Protected species have differing habitat requirements. In several of South Florida's ecological communities, conditions that are optimal for one species are detrimental to others. Consequently, the restoration of native habitats may displace or otherwise adversely affect protected species that have adapted to a disturbed condition and currently use a site. Similarly, management actions designed to benefit a particular species or community may adversely affect species or communities in another part of the system. For example, management options for restoring more natural hydrologic patterns within Everglades National Park may benefit some protected species within the park and adversely affect others that reside in habitats upstream from the park.

The purpose of avian multi-species conservation is to optimize the benefits of restoration for protected avian species in South Florida while minimizing tradeoffs caused by conflicting habitat needs. This requires a multi-species approach to management and a thorough understanding of how management will affect a wide variety of species.

What Is Known

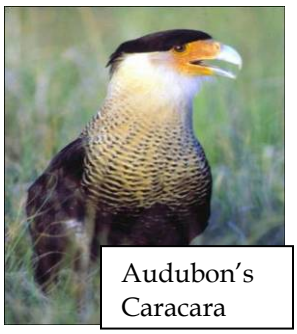
Generally, substantial information exists about the habitat requirements for most federally listed avian species in South Florida, including areas used for loafing, roosting, and migration, as well as critical resources such as feeding sites, nesting areas, and protective cover. In addition, ecological models are

available for several South Florida species to evaluate habitat suitability and species responses to habitat change. Resource managers are broadly aware of appropriate species-specific management actions, and of the geographic areas that require management attention.

Still more information is needed to refine habitat models and to define in detail the requirements of several species that will be affected by the CERP and other restoration projects. In particular, the ability to project the long-term population responses of species with differing degrees of habitat specificity, population elasticity, and freedom of movement needs to be improved to ensure that restoration is not accomplished at the expense of particular species or critical ecosystem components, when measures could be employed to avoid or minimize impacts.

Snail Kite

In an effort to increase available information and to focus research on crucial information gaps, DOI sponsored a two-part Avian Ecology Workshop in 2003. The workshop produced an expert scientific assessment of the current state of knowledge regarding habitat and conservation needs of four wetland-dependent bird species that characterize the Everglades system: Cape Sable seaside sparrow, wood stork, Everglade snail kite, and roseate spoonbill. Workshop participants evaluated potential tradeoffs among these species' populations resulting from hydrologic restoration of the Everglades and identified specific strategies needed to address the potential conflicts. The workshop reports helped refine the list of key science needs to support informed decision making for avian species recovery and Greater Everglades restoration.


Audubon's Caracara

Similar potential for tradeoffs exists in other areas of South Florida. The Florida grasshopper sparrow and Audubon's crested caracara both inhabit the highly modified dry prairie landscape that makes up much of central Florida's rangelands. These species rely on somewhat different habitat conditions, and restoration efforts that benefit one species are generally detrimental to the other. A third example of conflicting habitat needs involves the Florida scrub-jay and the red-cockaded woodpecker. Where they both occur, different management strategies could be applied to promote one or the other species or to maintain both at suboptimal conditions. In these tradeoff situations, additional, research will help optimize management and restoration actions to meet the conservation needs of all affected species.

In 2004 and 2005, the FWS was able to provided Reprogrammed funds to initiate over 20 new research projects involving these avian species issues that will directly address many of the high-priority research and information needs identified herein. Results from these projects are just beginning to become available. Once the primary information needs are addressed, another suite of needs will doubtless arise that will allow further improvement of management actions, and we are beginning to formulate the next generation of needs as the primary information gaps are filled.

What Is Needed

Development of key habitat-management information for avian species. Managers need additional information about the impacts of hydrology, fire, and other driving forces on habitat conditions and habitat maintenance in South Florida. Improved understanding of the relationship between hydrologic management and succession in wetland plant communities will help managers assess how changes in hydropattern may affect habitat suitability for the suite of avian species of concern in South Florida. This understanding is most important in developing effective habitat restoration strategies. A detailed understanding of the responses of vegetation to different fire treatments--in different seasons, of various

intensities, and under various hydrologic conditions--is also needed to allow resource managers to achieve desired habitat conditions. Understanding of the elasticity of avian populations and their response to habitat changes in conjunction with this information will improve the ability to accurately predict a species' response. (See also "Fire Management Projects," page 148.)

Research and possible model refinement to support decision making where restoration activities pose the potential for multi-species tradeoffs. Detailed studies of the habitat requirements of individual species in potential conflict will improve understanding of the key factors to be considered in management decisions, thereby reducing the potential for adverse effects on the species. In addition to the four focal species discussed previously, the Avian Ecology Workshop panelists identified a need to evaluate other species that may be more sensitive to wetland restoration. Evaluating these other species will both aid in avoiding potential detrimental impacts and provide additional information about responses to restoration actions that can be used to fine-tune projects within an adaptive management framework.

For Everglades wetland birds, priority studies include the following:

Develop sensitive, responsive methods of monitoring wading bird reproduction in the Everglades and the water conservation areas, to assess the effects of water management and other restoration activities.

Continue the study of wood stork dispersal, survival, and movements to support modeling of potential impacts on the wood stork population resulting from restoration and other projects in South Florida.

Continue and broaden research to determine roseate spoonbill survival, movements, and demography in Florida. Evaluate the degree of connectivity among primary breeding areas in Florida to determine how water management and other restoration activities affect the spoonbill population.

Develop ecological models for predicting the effects of hydrologic change on roseate spoonbills.

Further develop and validate snail kite population models to explicitly address local habitat conditions and to identify appropriate management regimes within all kite habitats, and continue long-term monitoring of snail kite nesting and population status.

Monitor white ibis as a sensitive indicator of wetland conditions.

Assess the effects of hydrologic influences on wood storks, using satellite telemetry analysis to determine foraging and nesting productivity and success.

Implement a program to improve the understanding of threats, responses, and habitat conditions of the Cape Sable seaside sparrow, and develop tools to facilitate and improve detailed consideration of the sparrow during South Florida restoration efforts.

Initiate a comprehensive field investigation of demography, movements, and habitat use in all Cape Sable seaside sparrow populations and across a range of environmental conditions, to refine population models and to identify sensitive characteristics.

Outside, as well as within, the Everglades, priority studies include the following:

Identify the critical habitat needs for South Florida red-cockaded woodpeckers.

Improve the understanding of the habitat requirements and use of nonnative pastures by Florida grasshopper sparrows.

Assess Florida grasshopper sparrow response to habitat restoration.

Assess the cause of the decline of Florida grasshopper sparrow populations.

Assess the response of Audubon's crested caracara to restoration of dry prairies

Landscape-scale ecological modeling. Improved species-habitat information and demographic data will support development of improved ecological models. Such models will allow investigation of how hydrologic change, habitat change, and population characteristics interact to affect the survival and persistence of a suite of avian species in South Florida. Such models will improve managers' abilities to predict species' responses and optimize restoration projects.

Identification of optimality and critical limiting factors. The ability of models to accurately represent and predict species responses to conditions requires a detailed understanding of the critical limiting factors and accurate representation of optimal conditions. Closely-related avian species may be limited by different resources, or during different times within the life cycle.

For example, the hydrologic conditions that allow Everglade snail kite nesting and foraging are well-known. However, the additional complexity of the their dependence on apple snails, and the necessity of also incorporating the hydrologic conditions that maintain healthy populations of apple snail make identifying optimal hydrologic conditions for snail kite nesting and foraging difficult. Similarly, identifying the hydrologic conditions that critically limit the snail kite population are also difficult. For many of the avian species, the current resolution of information may only allow resource managers to determine whether resource and environmental needs are generally consistent among a suite of species, but information is lacking to truly optimize the relationships. Integrating information across disciplines and across research projects currently appears to offer the greatest potential to improve our understanding of critical limiting factors and optimal relationships with respect to many species.

Evaluating diverse threats Scientists working to develop population models to predict the responses of avian species to restoration and other habitat modifications usually look to empirical measurements of species populations to calibrate and validate models. This approach assumes that the primary factors affecting the focal taxon's population is habitat conditions or quality. Identifying and understanding other possible mechanisms that affect a taxon's population, such as disease, accidental mortality, catastrophic events, and competition with other species may help clarify modeling results. In addition, understanding the role of these possible factors, as well as potential interactions among several mechanisms, is essential to achieving effective management.

Determination of connectivity and importance of South Florida populations for widely distributed species. Additional information is needed on the interactions of South Florida populations and other populations of some species that are relatively widely distributed and mobile. The Avian Ecology Workshop panel recognized the need to evaluate how effects in a portion of a species' range will affect the population as a whole. The wood stork, roseate spoonbill, and Everglade snail kite all have distributions that extend beyond the Everglades and South Florida, and they are all mobile to varying degrees. Confidently predicting the responses of such species requires a solid understanding of what portions, if any, of the species' distribution is critical to the well-being of the population. On a smaller scale, similar information is needed to predict the responses of different subpopulations of the locally distributed Cape Sable seaside sparrow as habitat conditions change in response to restoration activities within portions of their current range.

Development of species-specific information needed for recovery planning. Some species will require focused biological investigations to support conservation planning. The Avian Ecology Workshop panel identified species-specific needs, particularly for the Cape Sable seaside sparrow. These measures include

evaluation of translocation as a management tool, improved knowledge of nest success and productivity in relation to habitat conditions, and more detailed understanding of demographic parameters and the variability in these parameters among subpopulations and under different conditions. Additional actions are discussed under "Recovery of Cape Sable Seaside Sparrow," page 131. As mentioned above, the Everglade snail kite is another species that warrants collection of detailed information and may require focused management actions. Recent trends in data suggest that the current level of information may not be sufficient to ensure protection for kites.

Studies of migratory birds in South Florida. Significant information gaps exist for unlisted bird species that are protected under the Migratory Bird Treaty Act. Surveys and studies conducted to understand the importance of South Florida habitat to these species, their sensitivity and resilience to manageable human impacts, and the potential impacts and benefits of hydrological restoration projects, especially the CERP, will help ensure that these migratory species are not inadvertently adversely affected by projects intended to benefit other protected avian species.

Monitoring plan for the avian species component of the MSRP

Recovery of Scrub Community:

Project Purpose and Major DOI Interest

Of the 68 federally listed threatened or endangered species under FWS jurisdiction in South Florida, 32 (almost half) utilize scrub habitat. The term "scrub" in Florida refers to sand ridges and dunes that are well drained and support scrubby evergreen oaks and other distinctive, specialized plants and animals, including numerous species that occur nowhere else. Scrub was historically concentrated along the coasts, especially the Atlantic coast from Cape Canaveral south to Fort Lauderdale, and inland along the Lake Wales Ridge, which forms the elevated "backbone" of peninsular Florida between Lake Okeechobee and Orlando. The Lake Wales Ridge alone is home to 24 federally listed species; an additional species is a candidate for federal listing. All of the listed Lake Wales Ridge plants depend on the persistence of the scrub ecosystem. Atlantic coastal scrub has only three federally listed plant species, all extremely limited in distribution.

As a result of conversion to citrus farms and other forms of development, scrub communities have disappeared in disproportionate amounts compared to many other types of habitat, such as pine flatwoods, and they are becoming an increasingly rare habitat type in Florida. By the early 1980s an estimated 66% of scrub habitat had been lost within the Lake Wales Ridge, and by some estimates, that number has increased to 90% lost, primarily to citrus groves. Fire suppression combined with fragmentation has disrupted historic fire regimes, which means that prescribed fires must be applied to

maintain scrub vegetation to prevent it from becoming overgrown and useless for many of its specialized plants and animals.

The purpose of habitat restoration is to meet the recovery criteria for the scrub community established in the MSRP. The recovery tasks include protection of scrub habitat, management including appropriate use of prescribed fire, demographic studies to affirm the likelihood of species persistence over time, and monitoring to insure stable and sustainable populations. Management plans for scrub need to be refined to address the recovery criteria for listed plants.

The State of Florida has acquired approximately 60,000 acres on the Lake Wales Ridge for conservation and protection of the scrub ecosystem. Small, but very significant, tracts of scrub are protected on the Atlantic Coastal Ridge.

A 1999 report by the Florida Natural Areas Inventory found that several listed plants may be more widespread and abundant on conservation lands than previously thought. This and other research indicate that it is time for the FWS to assess whether threats to listed Lake Wales Ridge plants have diminished enough to warrant reclassification or delisting. The Endangered Species Act of 1973, as amended, provides that decisions to delist or to reclassify listed species be based on sufficient scientific information to assess each species relative to established recovery criteria.

What Is Known

Surveys of Lake Wales Ridge scrub during the 1980s identified 193 tracts of scrub representing the best habitats for listed plants. These surveys also documented the rapid disappearance of the scrub ecosystem, and led to the conclusion that conservation of scrub species would require expansion of existing conservation lands to create a network of protected and managed scrub habitat. Much progress toward this goal has occurred, primarily owing to the State of Florida's land acquisition programs, with additional help from private land purchases and the creation of the FWS's Lake Wales Ridge National Wildlife Refuge. The State of Florida continues to purchase land and an up-to-date inventory of these conservation lands is maintained by the Florida Natural Areas Inventory.

Fire is a dominant factor in the scrub ecosystem and a crucial management tool on conservation lands. Many plants of the Lake Wales Ridge occupy sunny gaps in the vegetation that are opened and maintained by fire. During intervals between fires, shrubs encroach into these gaps. A study using experimental fire regimes has yielded useful information on how individual species and vegetation respond following fire. Research shows that fires on Lake Wales Ridge were more frequent historically than they are today; hence, there is a backlog of prescribed burning needed to restore vegetation. However, prescribed fire is not feasible on all conservation lands because of proximity to homes or other sensitive areas. Unpublished research suggests that mowing holds promise as a pretreatment to fire, but not as a substitute. Recovery from fire is a crucial aspect of the life history of every scrub plant. Ongoing plant monitoring and studies to interpret the monitoring data will help managers better understand the effects of fire on rare plants.

Other plant species, which are endemic to coastal scrub habitat, are experiencing low population numbers and continued threats. For example, the Lakela's mint is known to exist as a single population that occurs only at six isolated sites in an area one-half mile wide by three miles long in southern Indian River and northern St. Lucie Counties. The mint was listed as endangered in 1985 because of its small range and the rate at which its habitat was being destroyed. Only two of the six sites within the historic range are protected. All others are in private ownership. One of the protected sites was recently discovered, is currently suffering from habitat degradation, and contains as few as forty individuals. The other protected site received 794 plants as part of an introduction in 2002. However, the population was severely reduced to 71 individuals following Hurricanes Frances and Jeanne in September 2004. The

FWS recently changed the scope of work for an existing grant to begin re-assessing and augmenting populations.

The four-petal pawpaw is an aromatic shrub found in sand pine scrub habitat. This plant was listed as endangered in 1986 because most of its habitat was being lost to urban development, which continues to be a threat to its existence. This species is also threatened by encroachment of non-native species. In a survey conducted in 2003, 1,277 plants were located in 19 sites in Martin and Palm Beach Counties. In 2005, the FWS will be funding a study to assess the impacts of Hurricanes Frances and Jeanne that made landfall in September 2004 near these populations.

What Is Needed

Updated surveys, inventories, and monitoring data. To determine whether sufficient habitat for listed plants is protected, the presence and abundance of these species must be evaluated throughout the network of conservation lands. On most conservation lands, monitoring concentrates on the more critically endangered species, leaving plants that may be close to recovery with out-of-date information. Updating surveys, biological inventories, and monitoring data will allow an assessment of the status of species that may qualify for reclassification or delisting.

Population viability analyses. Population viability analyses will support reclassification decisions. These analyses, which are the preferred scientific approach to assessing a species' long-term prospects, evaluate a species' probable persistence using demographic data, information on population genetics, and a thorough evaluation of the species' life history traits, including the persistence of local populations and their sometimes fugitive local habitats. Population viability analyses contribute to the design of rare plant monitoring programs by guiding decisions on how best to distribute limited scientific resources for data collection.

A population viability analysis for wireweed was designed to help determine whether wireweed qualifies for reclassification to threatened status. Additional monitoring and synthesis of is making this analysis applicable to the species as a whole.

Population augmentation. To recover and maintain sufficient populations and genetic diversity of listed plants, these populations must be augmented and properly managed. Studies should be conducted to monitor these reintroductions and determine suitable protocols for future augmentations

Assessment of the adequacy of the conservation land network. The ambitious land acquisition projects have created a network of conservation lands for recovering the scrub ecosystem. This growing network of conservation lands needs to be comprehensively assessed to detect deficiencies that could be corrected through limited additional acquisitions and to set priorities for restoration and management. A vegetation history for Lake Wales Ridge is being developed for use in this assessment.

Research and monitoring of long-term vegetation changes following fire and/or mechanical treatments. Valuable research on the effects of fire on the life history and demography of endemic scrub plants provides guidance for additional needed research on plant demography and long-term vegetation changes following fire and mechanical treatments such as roller-chopping.
Monitoring programs that document changes in plant populations will provide a basis for assessing the effectiveness of burning regimes and the negative effects to rare plants from use of mechanized equipment in vegetation and fire management.

DOI managers also need information about patterns of dispersal and colonization of new habitat patches following fire. Papery whitlow-wort, sandlace, and several other listed plants have disappeared from large areas of scrub that became overgrown due to fire suppression and found refuge in artificially

created open areas. It is important to know whether these "refugee" populations are able to recolonize new scrub habitat as it becomes available following prescribed fires.

Information about the indirect effects on scrub habitat of land management and other practices. The Florida Fish and Wildlife Conservation Commission proposes to study the effects of mowing as an alternative to prescribed fire. Other land use practices that could affect the persistence of rare scrub plants, including off-road driving, dumping, and trespass, should be evaluated to support appropriate recommendations in management plans.

Recovery of Scrub-Dependent Animals

Project Purpose and Major DOI Interest

Three federally listed animal species and one candidate insect species are found in South Florida scrub: the Florida scrub-jay, sand skink, bluetail mole skink, and Highlands tiger beetle. The purpose of this project is to meet the recovery criteria for the three federally listed animals, established in the MSRP. More information is needed on the highlands tiger beetle to determine the urgency of the need to list and to determine actions that could be undertaken to avoid the need to list.

What Is Known

Florida Scrub Jay

Once thought to be a subspecies of scrub-jays commonly found in California, the Florida scrub-jay is now recognized as a separate species found primarily in the southern and central part of the state. Florida scrub-jays are dependent on scrub communities, where they form complex family groups and maintain permanent territories. Since this species' listing as a threatened species in 1987, the population of the Florida scrub-jay has declined by approximately 50% because of the destruction, fragmentation, and degradation of scrub communities throughout peninsular Florida. The distribution of Florida scrub-jays was surveyed statewide during the first half of the 1990s; however, there has been considerable loss of habitat since that time. While quite a bit is known about the habitat needs of scrub-jays, serious questions remain about maintaining viable (meta) populations throughout the species' range.

The modification and destruction of scrub communities in central Florida was a primary consideration in listing the sand skink and the bluetail mole skink as threatened in 1987. The sand skink is found primarily on the Lake Wales Ridge, and the bluetail mole skink is found only on that ridge. A total of 114 known sand skink sites were reported in 1997, and 34 bluetail mole skink sites were located. In a current study funded by the FWS, sand skink densities appear to be lower than those sampled previously. This may be due to differences in fire management; the fire-return interval on those sites where densities were higher may have been much longer than that in the current study and these sites may have had fewer predators and competitors.

It was once thought that the Highlands tiger beetle only occurred in two scrubs on the southern Lake Wales Ridge, both of which were destroyed by development. Surveys since 1992 have found new occurrences of the Highlands tiger beetle, but fewer than 1,000 individuals. Due to a lack of recent information on the species' status, the FWS funded a rangewide status survey for the tiger beetle in 2004.

Specific objectives of the survey included: determining the current distribution and abundance of the tiger beetle, including adult population sizes, potential habitat, and utilized habitat at each site; estimating larval abundance and recruitment at all sites with medium to large populations; determining the threats and limiting factors to the habitat and the beetle population at each site and re-examining relevant biological characteristics of the species; and providing site-specific management recommendations for protection and recovery of the species. According to preliminary results, sites occupied by the tiger beetle during the 1996 survey are still occupied, and additional sites were found. A final report is not yet available.

What Is Needed

Habitat and population viability analyses for the Florida scrub jay, sand skink, and bluetail mole skink. To determine whether sufficient habitat for scrub-dependent animals is protected, the presence and abundance of these species must be evaluated throughout the network of conservation lands and habitat must be assessed.

Habitat viability and population viability analyses will determine the appropriate reserve design for maintaining a stable population of Florida scrub-jays. This design should consider the extent to which maintaining five genetically distinct subpopulations is necessary to achieve this goal. The population viability analysis will project the likelihood of the species' persistence using demographic and other data from detailed, multi-year studies. Because of continued loss of scrub habitat since the early 1990s, the survey for occupied habitat in South Florida needs to be updated. The FWS received funding following the 2004 hurricane season to assess impacts of the storms on Florida scrub-jays. Results from this assessment could be used in the development of population viability analyses.

Except for a few locations where intensive research has been conducted, there is little definitive information about the presence, abundance, or trends of the sand skink and the bluetail mole skink. The species' diminutive sizes and secretive habits make them difficult to study. More recent studies have provided new information about their distributions, but little information is currently available to assess the species' status or trends. A risk assessment and population viability analyses will identify the number of protected sites needed to ensure a 95% probability of persistence of these two skink species over the next one hundred years. Monitoring to determine if these skink populations are stable or increasing will require development and implementation of specialized methods. . As suitable habitat becomes more fragmented from development pressure, it will be necessary to explore alternatives to fire management to maintain scrub habitat and determine effects on skinks from human activities, such as pesticide use. Management prescriptions for scrub should be studied to determine the relationship between time-since-fire and the needs of skinks versus scrub-jays.

Updated information about the Highlands tiger beetle. Current data on the Highlands tiger beetle point to a stabilized, yet extremely imperiled, population. Information regarding the magnitude of threats, the population status, the percentage of tiger beetle habitat in public trust, the potential for further land acquisition, and the quality of remaining habitat needs to be updated, especially in the wake of land acquisitions that may have benefited the species. The study

Highlands Tiger Beetle

funded in 2004, is expected to provide important information to help assess the threats to the species.

Information about the effects of land management and other practices. DOI managers need Information about how to minimize negative effects from mechanized equipment used in fire management and alternatives to fire management in small fragmented parcels where burning is not feasible.. The Florida Fish and Wildlife Conservation Commission proposed to study the effects of mowing as an alternative to prescribed fire. Where monitoring data are available on lands that have been managed using prescribed fire, changes in the size and location of animal populations will be documented to assess how burning regimes may have affected these species.

Recovery of Pine Rockland Community: Miami-Dade County

Project Purpose and Major DOI Interest

The pine rocklands are home to five federally listed plant species, plus five that are candidates for listing. Nine of the species are herbs and one is native crabgrass.

Miami-Dade County's pine rocklands were largely destroyed by the time the conservation value of their tropical flora was realized. Limestone bedrock at the surface of the ground, and an understory of tropical shrubs and herbs beneath the slash pines that visually dominate this community, distinguish pine rocklands from the sandy pinelands that covered much of the rest of Florida. Historically, the pine rocklands occupied the highest ground in the Miami area, constituting upland "islands" in a predominantly wetland landscape. Much of present-day Miami and its southern suburbs were built on pine rocklands, as were most of the county's valuable farmlands. The farmlands have been "rockplowed" to produce finer-textured material that serves as soil. The largest surviving tract of pine rockland in Miami-Dade County is the 19,000-acre Long Pine Key, an island of higher ground within Everglades National Park. However, most of the listed plant species are found outside of the park, typically in small isolated tracts. Of the original 161,660 acres of pine rocklands outside of Everglades National Park, only about 1.5% remain, according to a new mapping project conducted by FWS and several of its partners.

The purpose of habitat restoration is to meet the recovery criteria for pine rockland plants, established in the MSRP. Recovery tasks include protection of pineland habitat, management including appropriate use of prescribed fire, demographic studies to affirm the likelihood of species persistence over time, and monitoring to ensure stable and sustainable populations and appropriate land management. The recovery of pine rockland plants is constrained by the limited area of habitat remaining for all but the threatened Garber's spurge. Limited but important opportunities exist to restore badly degraded pinelands or to recreate pinelands where they have been destroyed.

The surviving pine rockland habitat is adversely affected by invasive exotics and suppression of fire. Miami-Dade County has developed effective methods to kill exotic pest plants and to minimize reinfestations. Many pineland sites, including some that are relatively large, have achieved maintenance status. A program by The Nature Conservancy to persuade landscapers, nursery operators, and homeowners not to landscape with invasive plants may further decrease the threat to pinelands and native tropical hardwood forests caused by exotic plant species. . A Private Stewardship Grant to the nonprofit Institute for Regional Conservation will prepare 14 privately-owned sites for prescribed fire, and train their owners in landscape maintenance to preserve and protect pine rockland habitat containing listed and imperiled species.

The C&SF Project resulted in the lowering of groundwater levels in some of the areas where native pine rocklands still persist. Several CERP projects offer limited opportunities to partially restore historic water tables to pine rocklands that were dried out by the extensive drainage system in southeastern Miami-Dade County (e.g., the Cutler Slough drainage area). However, implementation of CERP seepage management projects also has the potential to further lower the water table in some areas through seepage management projects.

What Is Known

Publicly owned pine rocklands are reasonably well inventoried, and Miami-Dade County has purchased and is restoring pine rockland remnants. Monitoring studies over the past 15 years have provided basic information to assess population stability. The responses of listed plants to fire and exotics removal have been observed, often in the context of habitat restoration in the wake of Hurricane Andrew. A digital mapping project, conducted by the FWS and its partners, whose first phase was completed in early 2005 provides the most accurate assessment yet of the extent and condition of pine rocklands.

What Is Needed

Monitoring. Continued long-term monitoring of plant populations is essential, in large part to ensure that they are not lost through poor management or neglect.

Population viability analyses. Any reclassification decisions will require population viability analyses or studies that can detect serious threats to viability. Population viability analyses are inherently labor intensive and require several years; therefore, such assessments should be conducted only when there is reason to believe that the life histories of the plants and the availability of appropriate study sites make the assessments feasible.

Natural forest community mapping. Miami-Dade County found that accurate natural forest community maps, which show both vegetation and the locations of important plant populations, are essential for management of county lands, for outreach assistance to private landowners, and for support for the county's regulations that promote the preservation of natural forest communities. The county completed an intensive 18-month mapping and inventory project, with the FWS providing GIS support. This project has provided the first truly accurate maps and will soon be expanded with mapping of important plant populations. The mapping will greatly assist the County's tax incentive program for owners of natural forest communities.

Recovery of imperiled pineland invertebrate and reptiles. South Florida has a suite of rare butterflies and tree snails, which may have been adversely affected by habitat loss, pesticide spraying, and illegal collecting. DOI lands may provide protected areas for managing rare pineland invertebrates and reptiles. Resource management activities (including hydrological alterations, prescribed fires, spraying of pesticides and herbicides, and mowing and trimming) can adversely affect these species, so requirements

of these species need to be considered in restoration and management plans. Collecting information about the status and ecology of these rare animals on DOI lands will assist land managers in conducting their activities to ensure that these species are protected and conserved.

Analysis of mechanical treatment to recover habitat. Mechanical treatments, amounting to heavy-duty mowing in lieu of prescribed fire, appear to be useful when removing exotic pest plants, reducing overgrown native woody plants, or maintaining sites where prescribed fires are not feasible. Due to the proximity of development and other land uses to these habitats, the use of fire is sometimes problematic, making mowing an important alternative. Experimental treatments with assessments of results will guide future uses of this approach.

Research to support species propagation and reintroduction. Insufficient data exist to support the successful collection of native pine rockland seeds or whole plants, other than slash pine, and the successful propagation of these species. Experimental pine rockland restoration projects will guide the development of the necessary horticultural methods and infrastructure. Species-specific reintroduction methods for the endangered Carter's flax , the spurges, and several candidate species will help ensure the success of restoration efforts. In both cases, once the plants are introduced, the sites will be monitored for several years to assess the success of the introductions. Crenulate leadplant also needs introductions, but managers are already experienced with this species.

Monitoring the ecological response to rehydration. Where rehydration occurs, monitoring will assess whether the slash pines and herbaceous understory plants are benefiting as anticipated. Long-term monitoring of pine rockland plan species, especially in protected areas, is needed to provide the baseline data for comparison of changes in communities due to rehydration from CERP or to other factors stemming from human development.

Recovery of Florida Keys Species

Project Purpose and Major DOI Interest

The Florida Keys, a 130-mile arc of islands extending from Soldier Key to Key West, are home to twenty federally listed species and six candidate species. Seven of the listed species and three of the candidate species are endemic to the Keys and occur nowhere else. The seven listed endemic species are Key Largo woodrat, Key Largo cotton mouse, Schaus swallowtail butterfly, Stock Island tree snail, Lower Keys marsh rabbit, rice rat, and Key deer.

The purpose of this project is to meet the recovery criteria for the Florida Keys species, established in the MSRP. Although the listed species rely on different habitats for their continuing survival, the recovery tasks for all the species include protecting and managing habitat, restoring potential habitat, increasing population sizes and ranges, controlling anthropogenic factors, and monitoring to ensure stable and sustainable populations.

Biscayne National Park, Crocodile Lake National Wildlife Refuge, National Key Deer Refuge, Great White Heron National Wildlife Refuge, Key West National Wildlife Refuge, and the Florida Keys Wildlife and Environmental Area, along with several state parks, support much of the remaining habitat for the endemic species. Native habitats in the Upper Keys consist of hardwood hammock, freshwater wetlands, and mangrove wetlands. Native habitats in the Lower Keys consist of hardwood hammock, pine rockland, mangrove wetlands, freshwater wetlands, and salt marsh.

The MSRP recommends augmenting wild populations of several Keys species by reintroducing animals to unoccupied suitable habitat. The plan also addresses captive breeding.

Habitat protection, restoration, and/or population augmentation may allow some species to recover to the point where reclassification or delisting will be possible.

Management plans for the conservation areas will address habitat fragmentation and degradation associated with saltwater intrusion, exotic vegetation and animals, fire suppression, and other impacts associated with human manipulation of the environment. These plans will also address the effects of human encroachment adjacent to conservation lands. For example, reluctance to reintroduce the role of fire into ecosystems bordering on developed areas may be depriving some species of a critical element of their habitat that is dependent on this disturbance event.

What Is Known

Listed species are monitored on most conservation lands throughout the Keys.

The Key Largo woodrat is an endemic species with the only known population occurring in the hammocks of north Key Largo. Based on trapping from March-September 2002, the Key Largo woodrat population was estimated at 106 individuals (with a range of 30-182 individuals) and at risk of extinction. Trapping conducted during 2003-2004 continued to indicate a declining population. Assumed threats for the Key Largo woodrat include secondary impacts as a result of development such as free-ranging cats, raccoons, black rats, and fire ants. The effects of these threats on the woodrat population are difficult to evaluate because few data are available on the abundance and distribution of these species. The magnitude of threat from each of these species on the woodrat is difficult or impossible to determine without further study.

No recent population surveys have been conducted for the Key Largo cotton mouse. Although cotton mice are captured on a regular basis during Key Largo woodrat trapping, accurate population density estimates cannot be made from the collected information. Threats to the cotton mouse are assumed to be similar to those listed for the Key Largo woodrat and efforts to minimize these threats are believed to be beneficial to both species.

Annual monitoring of the American crocodile in Florida indicate that criteria for reclassification from endangered to threatened have been achieved. In March 2005, the FWS proposed to reclassify the Florida distinct population segment of the American crocodile from endangered to threatened. The number of crocodiles known to nest in south Florida has more than doubled since 1975. Most nesting sites in north Key Largo are the result of dredge and fill activities which require annual maintenance to prevent their degradation. Of the currently known nesting location nests on Crocodile Lake National Wildlife Refuge are most likely to fail as the result of desiccation.

Preferred habitat of the Schaus swallowtail butterfly includes hardwood hammocks in the Upper Keys, which suffered a direct hit from hurricane Andrew in 1992. The FWS sponsored a captive breeding program that helped Schaus populations recover and expand through the mid-1990s, although more recent surveys show declining numbers. Habitat loss, pesticide use, and over collecting are the primary causes for this species' decline. Hammock fragments are increasingly rare in the Upper Keys as a result of development activities, making preservation of the remaining large contiguous forest fragments essential.

The Stock Island tree snail is virtually absent from its historic range on Stock Island and Key West. The primary threats to the conservation of the snail include loss of habitat from development, application of pesticides, fragmentation of habitat, and predation by black rats and exotic fire ants. Populations of the snails were established at six locations outside of its historical range; however, surveys indicate continued threats and declines at most of those locations.

Habitat destruction has limited the Lower Keys marsh rabbit to small populations on a few keys. Population estimates range between 100 and 300 rabbits. The majority of the remaining habitats are

isolated from each other by urban areas, and population interchange seems unlikely. A population viability analysis conducted for the rabbit predicted that this species may become extinct in 20 to 30 years. The rabbit is threatened by habitat alteration, contaminants, road mortality, poaching, domestic animal predation, , exotic fire ants, and exotic vegetation. Woody encroachment by native trees, as well as exotic species, is occurring within many existing habitat patches

The rice rat occurs in freshwater and tidal wetlands on several islands in the Lower Keys. This species requires large, intact marsh systems. A large amount of occupied rice rat habitat is protected through public acquisition and management, but significant areas remain in private ownership. The conservation of the rice rat may be adversely affected by construction activities for residential and commercial development, mangrove trimming, and impacts to natural hydrologic cycles due to fill roads, borrow pits, and mosquito ditches.

The Key deer's population is increasing due to prohibitions on hunting, habitat management, and habitat protection. There is, however, a contraction in the range of Key deer, which may be at or near ecological carrying capacity. In May 2003 the FWS initiated a plan to augment deer on sparsely populated keys by moving selected deer from their more densely populated core areas. Current threats include habitat loss and degradation from development, fencing, fire suppression, invasive exotic plants, lack of freshwater, density-dependent disease, and road mortality.

The Key tree-cactus occurs on several Keys ranging from Upper Matecumbe to Big Pine. The Big Pine Key population, occurring within the National Key Deer Refuge, is much larger than the others. The species inhabits low elevation hardwood hammock and may be particularly susceptible to sea-level rise and salt-water intrusion. During 2004, a decline phenomenon was detected. By spring 2005, a massive die-off had occurred throughout the range, including Big Pine Key. Potential causes include exotic pathogens, high salinity levels, and competition with hardwoods following maturation of hammock stands. The complex suite of stressors has likely brought about the decline.

What Is Needed

Determine how the secondary effects of development are affecting the threatened and endangered species of the Keys. Further research is needed to determine the degree to which secondary effects of development are impacting listed species. Assessing the status of and impact on listed species by free-ranging cats, raccoons, blacks rats, fire ants, and potentially other non-native or other over-abundant species is needed. Although land in north Key Largo was set aside for the various threatened and endangered species this only addresses one of the threats (i.e. habitat loss) that contributes to the decline of many of these listed species. Because the refuge and state botanic sites are surrounded by large developments (and contain private inholdings), active management is required to maintain these areas as suitable habitat. A long-term plan for address secondary effects from development needs to be developed and implemented.

Analysis of life history requirements. The fact that many species continue to decline despite protection indicates the need to assess the genetic consequences of small population size and how human activities adjacent to conservation lands might be adversely affecting population sizes. Determinations of whether sufficient habitat for listed species has been protected, and whether the current protective management strategies are adequate, will require knowledge of the life history requirements and the status of each species, both on and off conservation lands.

Many Keys species depend on hardwood hammocks for their survival. Management of the remaining hammocks has largely focused on maintaining mature hammock vegetation and the removal of exotic

vegetation. An adaptive management approach needs to be taken to determine how habitat manipulation within some of these areas may benefit the threatened and endangered species occupying these areas. **Determine the preferred method of habitat manipulation to improve the survival of the Key Largo woodrat in north Key Largo.** The once typical stick nests of the Key Largo woodrat have all but disappeared in north Key Largo. Many of the stick nests are now located in rock piles resulting from dredging or proposed developments or in debris piles that were illegally dumped on abandoned roads. Whether we can mimic the rock piles and/or debris piles and whether they will be utilized by the woodrat needs to be determined.

Research to determine individual species' responses to fire. Studies of species' responses to fire are needed not only in the pine rockland community but throughout the entire upland and transitional area landscape of the Keys. The role of fire in maintaining habitats of the Key deer and Lower Keys marsh rabbit needs to be investigated. Further analysis of this kind will help identify where natural disturbance regimes should be restored, and where other measures for maintaining communities, such as hardwood hammock communities in the vicinity of pine rocklands, should be investigated to protect species that are not fire tolerant.

Analysis of minimum habitat requirements for species introduction. Before reintroducing animals to unoccupied habitat, it is important to define and understand their minimum habitat requirements, patterns of dispersal, and whether enough suitable habitat exists to support a population.

Population augmentation will be monitored to determine the long-term viability of translocated populations and to ensure that restored habitat remains suitable and that translocated animals remain within the expanded range.

Monitoring and biological status assessments. Ongoing monitoring of habitats,populations , and population correlates throughout each species' historic range, and comparison of findings with the recovery criteria listed in the MSRP, will guide determinations of changes in species' status and when recovery goals are achieved.

Species Recovery Projects

SUMMARY OF DOI SCIENCE NEEDS RELATED TO SPECIES RECOVERY PROJECTS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Conservation Strategy for the Florida Panther in South Florida		
	How do panthers use various habitat types and land uses throughout their ranges?	Tracking data and analysis	FWS is updating the Florida panther recovery plan. FWS Vero field office has the lead.
	What areas serve as important habitat linkages?	Evaluation of potential habitat	
	How can we cultivate public acceptance of Florida panther population expansion or reintroduction	Public attitude surveys and strategies development	Schedule Draft:: 2005 Final: 2006

SUMMARY OF DOI SCIENCE NEEDS RELATED TO SPECIES RECOVERY PROJECTS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Meet the recovery needs of particular species on federal, and where possible on nonfederal, lands and waters	How should the conservation needs of panthers be coordinated with private development and public works projects? How will panther habitat be affected by implementation of the various aspects of the CERP and what will this ultimately mean to panther population viability and distribution over the long term?	Information needed to mitigate the adverse effects of development Research to detect responses to habitat changes	
	Recovery of Cape Sable Seaside Sparrow		
	What actions will restore potential habitat for the Cape Sable seaside sparrow and create opportunities for recolonization?	Study and long-term monitoring of habitat response to hydrologic change and fire Study of Cape Sable seaside sparrow responses to changing habitat conditions	Species Recovery Plans for which the FWS Vero field office has the agency lead are rolled into the MSRP Implementation Schedule Draft: 2004 Final: 2005
	How does subpopulation structure affect the long-term viability of this species?	Detailed study of small populations Assessment of the importance of genetic exchange among subpopulations	
	West Indian Manatee: Accessibility to and Mortality and Entrapment Risk in the Central and Southern Florida Canal Systems and Structures		
	Where do West Indian manatees enter the C&SF Project canal system? Where do West Indian manatees go once they enter the C&SF Project canal system? What areas in the system pose entrapment risks to West Indian manatees?	Database of accessible areas, travel routes, and entrapment risks	CERP Manatee Conservation Plan being Developed – Anticipated Draft FY 2004
	What management changes are needed to protect manatees?	Tools for managers	
Assess the responses of species as a basis for adaptive management	Conservation Strategy for the Florida Panther in South Florida		
	What are the effects of management activities and resulting ecological changes on the Florida panther?	Monitoring to detect responses to habitat changes	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed
	Recovery of Cape Sable Seaside Sparrow		
	What are the effects of management activities and resulting ecological changes on the Cape Sable seaside sparrow?	Monitoring of Cape Sable seaside sparrow responses to changing habitat conditions	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed
	West Indian Manatee: Accessibility to and Mortality and Entrapment Risk in the Central and Southern Florida Canal Systems and Structures		
	What are the effects of management activities and resulting ecological changes on the West Indian manatee?	Monitoring and analysis of West Indian manatee response to habitat changes	Post-implementation monitoring and assessment ESA calls for updated recovery plans every 5 years, as needed

Conservation Strategy for the Florida Panther in South Florida

Project Purpose and Major DOI Interest

The Florida panther once ranged from eastern Texas and the lower Mississippi River Valley eastward through the Southeastern Coastal Plain. This wide-ranging predator now survives only in South Florida. The current population of approximately 85 panthers occupies an estimated 2 to 3 million acres, or 5% of its historic range. Established threats include geographic isolation, habitat loss and fragmentation, small population size, and road mortality. Trends in human population and development in South Florida indicate that loss of panthers and degradation of panther habitat will continue. South Florida does not contain enough space or habitat to recover the panther, but conservation of its one remaining population is crucial to panther survival and rangewide recovery.

The purpose of this project is to help ensure survival and achieve a component of the recovery objective of the Florida panther, as described in the MSRP. According to the MSRP, the range-wide recovery objective for the panther is to achieve three viable, self-sustaining populations within the species' historic range. More specific recovery objectives for the panther are being developed as part of the third revision of the *Florida Panther Recovery Plan.*

In February 2000 the FWS appointed a Florida Panther Subteam of the Multi-species/ Ecosystem Recovery Implementation Team to develop a landscape conservation strategy for the Florida panther in South Florida using an open and collaborative venue. The primary goal of the Panther Subteam was to identify a strategically located set of lands containing sufficient area and appropriate land cover types to ensure the long-term survival of the panther. The Panther Subteam focused its efforts on the area south of the Caloosahatchee River, where the only reproducing Florida panther population currently exists. The Panther Subteam's *Landscape Conservation Strategy for the Florida Panther in South Florida* was submitted to the FWS in December 2002. The FWS plans to publish a notice of availability in the *Federal Register* to obtain comments on this document from the broad scientific community and general public, to ensure the highest level of quality possible. Comments from the scientific community and general public may result in changes to the landscape strategy.

In addition to identifying lands essential for the continued conservation of panthers in South Florida, the strategy also identifies a landscape linkage to provide for population expansion north of the Caloosahatchee River to aid in the recovery of the species. Augmentation of the existing population south of the Caloosahatchee River may be possible by providing the opportunity for panthers to expand their occupied breeding range into suitable areas north of the river in south-central Florida. Several young radio-collared male panthers have crossed the Caloosahatchee River and moved across central peninsular Florida as far north as the Disney Wilderness Preserve, southwest of Orlando. However, no females have been documented north of the Caloosahatchee River since the 1970s.

Panther conservation planning in the 1990s focused on protecting large blocks of forested habitat. Scientists and managers now recognize that panther conservation must consider the full range of land use and land covers, and the linkages among them, within the landscape used by panthers. Preventing and minimizing land use intensification within the landscape used by panthers is important and will require the development of active conservation partnerships with private landowners and a variety of public

land managers. Panther conservation planning needs to be integrated with planning for private development and public works projects, including transportation projects funded by the Federal Highway Administration. Smart planning and coordination are essential to maintaining the large spatial extent, landscape configuration, and mosaic of land use / land cover types critical to panther survival in South Florida.

What is Known

Tracking of panthers since the 1980s has contributed much of what is known today about South Florida panthers. Initially, panthers were tracked and radio-collared on accessible federal or other public lands containing large, relatively undisturbed tracts that provide cover, prey, and overlapping home ranges. Most location data were collected during daytime hours when panthers were likely to be at rest in cooler forested habitats. Habitat use by panthers during nighttime hours is not as well documented but is important to understanding the full range of life history and habitat requirements. Furthermore, privately owned ranchlands and other agricultural lands represent a significant portion of panther landscape use, although they provide less-ideal habitat than do extensive, protected public lands.

Of the 77 radio-collared panther mortalities that occurred from 1981 through June 2003, 42% were due to intraspecific aggression (males killing other panthers), 23% to unknown causes, 21% to vehicles, 6% to other causes, 5% to infection, and 3% to disease.

What Is Needed

Tracking data and analysis. Although much is known about the panther population in South Florida, important gaps exist. These gaps include information about 24-hour-a-day panther movements and habitat use, subadult dispersal, less intrusive monitoring methods, the consequences of ongoing genetic restoration efforts, and future methods to ensure the genetic health of the population.

The relative values of agricultural and range lands (and other nonforested components of the landscape) as panther habitat are not well understood. Because conversions among various agricultural land uses in South Florida are certain to occur, the relative value of different forms of agriculture in providing prey and cover, and the effects of land conversion on habitat configuration, need further investigation. Reanalysis of existing data on panther movements and habitat use will help guide panther conservation efforts within and outside South Florida and determine if and how landscape planning and conservation efforts may need to be adjusted. Use of Global Position System (GPS) technology to track collared panthers 24 hours a day will provide a better picture of how panthers move across landscapes at all times and life-history stages. Furthermore, tracking of panthers that use private lands will document how panthers respond to continuing changes in the South Florida landscape.

Landscape use data are especially needed for breeding female panthers and dispersing subadults. Female panther kittens do not disperse as far from their natal areas as do males. Radio-telemetry data will help determine the habitat requirements needed for young females to disperse and for adult females to successfully rear kittens. Research on techniques to reestablish native plant communities preferred by panthers and their prey is also needed. Conservation planning should continue to include the identification of additional lands that are high priorities for panther conservation and seek their protection through all appropriate means.

GPS tracking of the subadult males dispersing north of the Caloosahatchee River will help identify habitat linkages that will be needed if female panthers are to disperse or can be translocated north of the river to expand the panther's breeding range.

Evaluation of potential habitat. An evaluation of the quantity and quality of panther habitat north of the Caloosahatchee River will determine its ability to support a new breeding segment of the existing

population. Relationships with and support from landowners in these areas will be an essential precursor to conducting any translocation project. Working with landowners to make the landscape more compatible for the panther is important for survival and recovery of the species.

Public Acceptance of Panther Reintroduction. Although public attitudes have improved since the early days of panther persecution, approximately a third of the public still considers panthers to be a nuisance to livestock and to be equally dangerous to man. However, both a statewide survey in Florida (Duda and Young 1995) and a survey in the counties around the north Florida study area for a Florida panther reintroduction feasibility study (Cramer 1995) found that support for panther preservation and reintroduction increased with increasing level of education and income and decreased with increasing age. Likewise, the amount of concern with regard to human safety, safety of pets and livestock, landowner rights, and effects on deer populations decreased with increasing level of education and income and increased with increasing age. Also, those residents living closest to the reintroduction site were more likely to oppose reintroduction efforts. A strong negative attitude developed among those residing near the established mountain lion population during the reintroduction feasibility study. These attitudes coalesced into organized and vocal opposition.

Whether it be panther population expansion north of the Caloosahatchee River or reintroduction into other areas of suitable habitat within the historic range, people who live around the reintroduction site must be supportive of the idea of panther reintroduction. Public attitudes will probably be the major factor affecting success of re-establishment efforts, and these attitudes need to be examined prior to any trial releases. Surveys need to be conducted in the vicinity of potential panther expansion or reintroduction sites to determine public attitudes toward re-establishing panthers and strategies developed to work on cultivating public acceptance of the program.

Information needed to mitigate the adverse effects of development. Panther conservation planning needs to be integrated and coordinated with planning for development and public works projects being carried out by the numerous governmental jurisdictions in South Florida. These coordinated efforts should specifically focus on infrastructure needed to support additional development including transportation projects funded by the Federal Highway Administration and the Florida Department of Transportation. Research on ways to reduce road-related panther mortality is needed. Information on panther movements should be analyzed in relation to transportation and land development plans to identify areas of likely conflict and develop preventive measures.

Research and monitoring to detect responses to habitat changes. Research and monitoring will assess how panther behavior and movement are affected by implementation of the conservation strategy and other ecosystem restoration projects, particularly those included in the CERP.

Information needed to analyze the potential effects of CERP projects on panthers includes (1) understanding of water depth effects on panther and panther prey species activity; (2) determination of water depths that exclude panthers or panther prey from areas; (3) monitoring of changes in panther movements across Shark River Slough associated with rising water levels; (4) monitoring of panther responses to ecological community changes; and (5) monitoring possible effects of changing mercury levels and other contaminants following hydrologic restoration.

Information needed to assess the success of the panther conservation strategy will include panther responses to landscape improvements, analyses of how development affects panther behavior, and monitoring on private and public lands. Monitoring to assess the response of panthers to the conservation strategy and other ecosystem restoration efforts should be conducted annually to ensure appropriate and timely actions by the agencies entrusted to conserve the panther and their partners, who will play a critical role in preserving the habitat critical to panther survival.

Recovery of Cape Sable Seaside Sparrow

Project Purpose and Major DOI Interest

Historic populations of the Cape Sable seaside sparrow have been severely impacted by losses of habitat associated primarily with water management and habitat conversion to other land uses.

The purpose of this project is to meet the recovery criteria for the Cape Sable seaside sparrow, established in the MSRP. The recovery tasks include protection of existing habitat, restoration of habitat west of Shark River Slough and in Taylor Slough; elimination of loss of functional habitat; prevention of invasion of woody and exotic plant species by implementing appropriate use of prescribed fire and other vegetation management techniques; continuation and expansion of population surveys; and continuation of research on the ecology of the Cape Sable seaside sparrow outside of the breeding season.

Understanding how management may affect a wide variety of species dependent on a mosaic of ecological communities found only in the Everglades will be critical to the recovery of the Cape Sable seaside sparrow and help ensure that actions to recover this species do not jeopardize the recovery of other ecological communities or species.

During the Modified Water Deliveries Project, a jeopardy biological opinion was issued because of impacts from increased hydroperiods on nesting by a subpopulation of the Cape Sable seaside sparrow that has been identified as extremely important for recovery. Resolution of this impact required holding water upstream of sparrow habitat under certain hydrologic conditions, with possible effects on upstream nesting and foraging habitat of the Everglade snail kite.

What Is Known

Historically Cape Sable, in what became Everglades National Park, was the only known breeding range for the Cape Sable seaside sparrow. The freshwater vegetative communities occupied by the sparrows as late as the 1930s have since shifted to mangroves, bare mud flats, and salt-tolerant plants, with the result that Cape Sable seaside sparrows no longer use this area. Hurricanes in 1935 and 1960, sea level rise, and reduced freshwater flows due to upstream water management are all likely factors contributing to the vegetation shift on Cape Sable.

The Cape Sable seaside sparrow is nonmigratory. Breeding males demonstrate high site-fidelity, and many will defend the same territory for two to three years. During the nonbreeding season, the sparrows appear to congregate and fly short distances within their range. Cape Sable seaside sparrows have never been observed outside of nesting habitat areas during the wet season. The results of a radio-telemetry study conducted during the 1997-98 wet season indicated that the Cape Sable seaside sparrows were generally sedentary or moved short distances (less than about ½ mile), although they sometimes moved longer distances (about 3 to 4 miles) within marl prairie habitat areas.

The Cape Sable seaside sparrows have very specific habitat preferences. The current nesting habitat of Cape Sable seaside sparrows appears to be short-hydroperiod, mixed marl prairie communities that often include muhly grass and other moderately dense, clumped grasses, with open spaces at the base permitting ground movements. Sparrows tend to avoid tall, dense, sawgrass-dominated communities, coastal spike-rush marshes, extensive cattail monocultures, long-hydroperiod wetlands with tall, dense vegetative cover, and sites supporting woody vegetation. Cape Sable seaside sparrows also avoid sites

with permanent water cover. Cape Sable seaside sparrows currently occur only within the six remaining patches of habitat within Everglades National Park and adjacent public lands.

The features that make short-hydroperiod, mixed marl prairie communities suitable for the Cape Sable seaside sparrow are sustained by a combination of annual hydropatterns and episodic fires. To achieve restoration of these communities, the current altered hydropattern needs to be replaced with more natural patterns of attenuated sheet flow. Episodic fire events will prevent hardwood species from invading the wet prairies and also prevent the accumulation of dead plant material, both of which decrease the suitability of these habitats for Cape Sable seaside sparrows. Fire management and control of exotic woody vegetation, such as Brazilian pepper and melaleuca, will be essential to restoration and maintenance of Cape Sable seaside sparrow habitats.

Emerging information. During the past few years, the population of the CSSS west of Shark River Slough has continued to decline, despite efforts to provide hydrologic conditions that would allow for population maintenance or growth. More intensive surveys of the population have indicated that the number of sparrows in that area may be as low as 10 individuals, and evidence of breeding is lacking. During 2004, scientists documented two movements of sparrows among widely separated populations that had previously been assumed to be isolated, suggesting that while limited, the sparrow's dispersal capability may be greater than previously thought.

Reprogrammed funds allocated in 2004 for sparrow research are addressing most of the primary information needs. Efforts to increase survey effort within small sparrow populations have suggested that these populations may be even smaller than previously thought, and the dynamics of these populations may differ from those within the larger populations.

What Is Needed

Study and long-term monitoring of habitat response to hydrologic change and fire. The effective management of Cape Sable seaside sparrows will require a thorough understanding of the appropriate hydrologic regimes and fire management necessary to support the short-hydroperiod marl prairie communities upon which they depend. Long-term experimental studies of the response of marl prairie communities to flooding and fire events will generate data to support adaptive management of the restoration projects.

A long-term monitoring program will track vegetation response to changes in hydrologic and fire regimes. Periodic review of water management effects on habitat utilized by the Cape Sable seaside sparrow will support recommendations about adaptive management to prevent degradation of existing habitat.

Study and monitoring of Cape Sable seaside sparrow responses to changing habitat conditions. Information about vegetation community response though time and the time required for the Cape Sable seaside sparrow to move from changing existing habitat to new suitable habitat will help ensure that this species is adequately protected during ecosystem restoration.

Detailed population assessment. In response to the new information suggesting that population dynamics in small sparrow populations differ from those in larger populations, additional focus on the small populations and the factors regulating these populations is needed. The sparrow has the theoretical potential to increase in population size rapidly under favorable conditions, but large increases

have not been documented in the small populations. Evaluation of our ability to accurately document population size in these areas and measure changes that would signal either increase or decline are needed to allow identification of the environmental and habitat characteristics that result in population changes.

Assessment of the importance of genetic exchange among subpopulations. An assessment of the evidence of genetic exchange between subpopulations of the Cape Sable seaside sparrow will further understanding of how subpopulation structure affects long-term viability of this species. Understanding the rate of movements among the populations also has critical implications for evaluating the likelihood of recolonization of habitat that may be restored.

West Indian Manatee: Accessibility to and Mortality and Entrapment Risk in the Central and Southern Florida Canal System and Structures

Project Purpose and Major DOI Interest

The purpose of this project is to protect West Indian manatees from the risk posed by the existing and proposed C&SF Project canals and water control structures and alteration of hydrologic flow patterns. At this time, an estimated 117 new structures are proposed for CERP implementation.

This effort is essential to the wellbeing of the species. Between 1974 and 2002, 140 federally listed West Indian manatees died in the C&SF Project canal system and associated structures. The two major areas of structure-related manatee mortality in the C&SF Project are the South Dade Conveyance System in Miami-Dade County (49% of the mortality) and Lake Okeechobee, including the St. Lucie Canal and the Caloosahatchee River (47 % of the mortality).

Although West Indian manatees are expected to benefit from long-term improvements in estuarine conditions and increased seagrass abundance and distribution associated with CERP projects, they could also be adversely affected by CERP projects through construction of new canals/levees and impoundments; changes in locations of water control structures; changes in the volumes and locations of freshwater inflows into estuaries; thermal effects; and water quality issues.

The FWS has identified 30 CERP project components in manatee-accessible waters:

Lake Okeechobee Watershed Project
Lake Okeechobee ASR Project and ASR Pilot
Indian River Lagoon South Project
Big Cypress L-28 Project
Decompartmentalization Project (Parts 1 and 2)
North Lake Belt Storage Project
ENP Seepage Management Project
C-111 Project
Florida Keys Tidal Restoration Project
Lake Belt In-Ground Reservoir Pilot Project
C-4 Eastern Structure Project
WCA-2B Flows to ENP Project
Henderson Creek/Belle Meade Project
North New River Project
Lake Istokpoga Project
C-43 Storage Reservoir Project
EAA Storage Reservoirs Project (Parts 1 and 2)
Flow to NW and Central WCA 3A Project
Broward County Secondary Canals Project
Central Lake Belt Storage Project
Biscayne Bay Coastal Wetlands Project
Picayune Strand Project
Caloosahatchee ASR Pilot Project
Broward County Water Preserve Areas Project
WCA-3A/3B Flows to Central Lake Belt Project
Water Preserve Areas Conveyance Project
Lakes Park Restoration Project

Without adequate mitigation, structural alterations to the C&SF Project canal system will result in situations in which manatees are reasonably certain to experience adverse effects.

The FWS is coordinating with the USACE and SFWMD to develop a CERP Manatee Conservation Plan. This effort is intended to provide guidance needed to minimize impacts on manatees related to the implementation of CERP projects. The plan will examine ways to block manatee access to high risk areas, identify various structure and culvert designs that avoid or minimize adverse effects on manatees, provide guidance to minimize adverse temperature effects on manatees, identify important manatee aggregation sites, which should be protected, and describe other aspects of manatee ecology for consideration during CERP planning and implementation. The plan will ensure that assessments of risks to manatees conducted for different CERP projects and CERP consultations by the FWS will be as consistent as possible.

What Is Known

Little is known about the number and distribution of West Indian manatees in the C&SF Project canal system, including Lake Okeechobee. During their movement, West Indian manatees encounter many types of flood control structures that can result in their death or injury. These structures include drop gates, screw gates, trash rakes, pump structures, hurricane gates, and culverts. Manatees become entrapped after swimming through open structures that then remain closed for long periods of time, resulting in starvation or cold stress. Entrapment in canal systems may cut off manatees from access to a more suitable habitat, limit access to essential foraging resources, isolate manatees from others, and expose manatees to higher concentrations of toxins. Manatees have also died in culverts because of their inability to turn around or lack of air space.

What Is Needed

Database of accessible areas, travel routes, and entrapment risks. Information is lacking on where West Indian manatees enter the C&SF Project canal system, their movements within the system, and what areas pose an entrapment risk to the species. Mortality and rescue data provide an outline of probable areas where manatees frequent; however, these data do not provide possible travel corridors or an evaluation of the relative safety of these areas.

The FWS is working with the USACE to fund the first year of a three-year West Indian Manatee Movement and Distribution Study to better understand manatee accessibility to the C&SF Project system and their movements within the system. The project will intensively investigate and inventory all existing structures and major canals in Southeast Florida to determine accessibility to manatees. Manatee distribution and movements through the system will be documented using satellite telemetry and aerial surveys. This information will be used to develop a database of accessible areas, travel routes, and entrapment risks related to all existing major structures and canal systems. By determining possible travel routes and risk, manatees can be excluded from areas where they might become entrapped.

Tools for managers. The accessibility and risk information, along with the satellite telemetry and aerial survey data, will be compiled into GIS coverages from which user-friendly maps will be produced to help managers and field personnel address areas of concern regarding West Indian manatee use in the C&SF Project canal system. This information will allow managers to make informed decisions to equip structures with appropriate manatee protection devices, to make areas determined to be an entrapment risk inaccessible to manatees, or to take other appropriate actions allowing projects to continue without manatee protection precautions.

Monitoring and analysis of West Indian manatee response to habitat changes. The database and GIS coverages of the West Indian manatee will also provide a baseline for comparing changes in manatee foraging behavior, distribution, movement, reproduction, and aggregation sites in response to habitat

changes associated with CERP implementation. This information will support recommendations for adaptive management to ensure that manatees are adequately protected during ecosystem restoration.

5. LAND AND RESOURCE MANAGEMENT PROJECTS

Overview of Management Activities and Authorities

As the steward responsible for the protection and management of more than 3.25 million acres in the Everglades ecosystem, DOI conducts two primary activities related to ecosystem restoration:

> **Effectively manage DOI lands and waters to restore, preserve, and protect natural habitats and species.** This requires physically protecting the land from development, restoring natural ecosystem characteristics and processes, and mitigating or avoiding impacts on resources caused by adjacent land uses, management actions, and visitor use.
>
> **Assess the responses of ecological communities and species as a basis for adaptive management**

In addition to the overarching issues related to the CERP, each management unit poses its own set of challenges. Included in these challenges are deciding how a particular habitat should be managed to meet unit-specific objectives, and how to evaluate and mitigate the impact of various activities on native plants, animals, and habitats. Many of these questions faced by individual managers are local in scope and are therefore not addressed in this science plan, which is focused on the questions that need to be addressed to support implementation of the highest priority restoration projects. Nonetheless, these unit-specific issues still need to be addressed and require science support.

Restoration of appropriate hydrology and water quality, as discussed in other sections, will be critical for long-term protection of DOI resources. The projects in this chapter address the additional need for appropriate, science-based management of exotic plant and animal species and the restoration and use of the natural processes, such as fire, that helped shape and maintain the natural system.

More than 1,200 introduced plant and fish species have become established in Florida and now comprise 31% of all the plant species documented in the state. Approximately 225 of these introduced species are successfully reproducing and invading natural areas. The introduction of invasive exotic plants is the second greatest threat to biodiversity, next to habitat destruction. More than $90 million per year is spent in Florida by local, state, and federal agencies to control invasive exotic plants.

National recognition and guidance for management of invasive exotics has only been forthcoming in the past decade. The Nonindigenous Aquatic Nuisance Prevention and Control Act (1990) was reauthorized in 1996 as the National Invasive Species Act.

In February of 1999, the National Invasive Species Council (NISC) was established by Executive Order 13112 to provide leadership and coordinate federal efforts to curb invasive species. NISC is an inter-departmental council that helps to coordinate and ensure complementary, cost-efficient and effective federal activities regarding invasive species. Council members include the Secretaries of the Interior, Agriculture, Commerce, State, Defense, Homeland Security, Treasury, Transportation, Health and Human Services, and Administrators for the Environmental Protection Agency, and the U..S. Agency for International Development. NISC works with the Invasive Species Advisory Committee (ISAC), which was established to advise the federal government on the invasive species issues and act as representatives of many interested parties and stakeholders. A key to achieving success with the issue of invasive species was the development of a National Invasive Species Management Plan, which provided a framework for stakeholders to solve issues with exotics strategically.

The Federal Interagency Committee on the Management of Noxious Exotic Weeds (FICMNEW) coordinates federal agency activities on exotic weeds and develops a national "early-warning system" for

invasive plants. The Federal Interagency Committee on Invasive Terrestrial Animals and Pathogens (ITAP) provides a forum for technical coordination and cooperation on problems associated with invasive plant and animal pathogens, insects, and other vertebrate and invertebrate animal pests in terrestrial ecosystems.

Control activities and planning are further advanced for exotic invasive plant management than for exotic invasive animal management. Scientists are generally able to provide quantitative predictions of invasiveness for individual plant species where sufficient studies are available. Predictions of invasiveness for groups of similar plants, plant communities, or regions are more qualitative and less reliable. A risk assessment system to evaluate existing and forthcoming species and a comprehensive invasive species information scheme are needed for Florida and the United States.

Fire management is another critical component of ecosystem restoration. Because fire was a natural process that helped shape the Everglades, hydrologic restoration without the incorporation of fire will not result in true restoration. Fire has the potential to both help and hurt efforts to control exotic species and recover threatened and endangered species.

Exotic Plant and Animal Control Projects

SUMMARY OF DOI SCIENCE NEEDS RELATED TO EXOTIC PLANT AND ANIMAL CONTROL PROJECTS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
Identify and effectively manage the invasive exotic plant species in the Greater Everglades that directly affect DOI lands and resources	**Implementing an Exotic Plant Management Strategy**		
	Which high priority species directly affect DOI lands and which high priority species may pose future threats to DOI lands?	DOI support of the interagency comprehensive invasive exotic plant management program for South Florida restoration	Special Reconnaissance report on the federal role and interest in invasive species management May 2004 PIR for biological control of melaleuca and other exotic species Jan 2005
	Which additional species, if different from those affecting DOI lands, pose the greatest threat to ecosystem restoration?	Risk assessment model to determine the potential threat posed by existing species and possible future invaders of DOI lands	
	What are the effective control and management methods for these species?	Research into the best control methods for species by life form	
	Invasive Exotic Plant Detection and Monitoring		
	Invasive Exotic Plant Management in the Arthur R. Marshall Loxahatchee National Wildlife Refuge		
	What are the measures for evaluating whether or not maintenance control of *Lygodium* has been achieved?	Measurable targets for maintenance control of *Lygodium*	Next scheduled performance review per the lease agreement between DOI and SFWMD 2007
	What management methods will prevent the spread and reduce the current distribution of *Lygodium*?	Research to identify effective control methods for *Lygodium*	
	Aquatic Exotic Animals		
	Does the C&SF Project influence the introduction of aquatic exotic animals into the Greater Everglades system?	Research to determine the role of canals as conduits for the introduction of exotic fish	Assessment of the problem and priority species for control October 2004 Strategic Plan for the management of invasive exotic animals January 2006
	How do exotic aquatic animals affect native species?	Research into the ecological impacts of invasive exotic species on native species, created habitats (filter marshes, reservoirs, etc.), and natural habitats	
		Research into life history and ecology on non-indigenous species	
		Research to better understand the extent and role of deep solution holes as refugia and impact on survivability of native species when exotic aquatic species present	
	What are the best methods for eradication and control of exotic aquatic animal populations?	Research to develop effective control methods to reduce or eradicate introduced exotic aquatic animals, particularly before populations and distributions have expanded	
		Studies to support water project designs that might have an affect on the introduction and/or persistence of aquatic exotic animals	
		Model characteristics of existing pests to develop screening for potential future pests and prevent introductions	

SUMMARY OF DOI SCIENCE NEEDS RELATED TO EXOTIC PLANT AND ANIMAL CONTROL PROJECTS

Major DOI Responsibilities and Interests	Major Unanswered Questions	Needed Science	Timeline
	Implementing an Exotic Plant Management Strategy		
Assess the responses of invasive exotic species as a basis for adaptive management	What is the magnitude of infestation by invasive exotic plant species in South Florida? What management programs are most successful?	Monitoring and assessment of the overall invasive exotic plant problem on DOI lands, sharing information with other agencies	Post-implementation monitoring and assessment
	Are invasive exotic removal projects improving the conditions for native species, and where removal is not occurring are native species in decline as a result of invasive exotics?	Monitoring and assessment to determine the responses of native species to management activities designed to control invasive exotics	
	Invasive Exotic Plant Detection and Monitoring		
	How are the populations of invasive exotic species changing through time and what are the factors involved in the spread of these species?	Prototype development of remote sensing field system	Report & Recommendations from Conference on Invasive Plants in Natural and Managed Systems: June 2004 Identify detection projects in CERP special reconnaissance report: May 2004 Identify detection project in CERP PIR for biological control program: January 2005
	Invasive Exotic Plant Management in the Arthur R. Marshall Loxahatchee National Wildlife Refuge		
			Post-implementation monitoring and assessment
	Aquatic Exotic Animals		
	What are the effects of restoration efforts on the introduction and persistence of aquatic exotic animals in the Greater Everglades system?	Development of non-indigenous species risk assessment Development of effective, early detection monitoring program for introduced aquatic animals Systemwide monitoring program to document the changes in invasive species resulting from project modifications, and modeling to assist in predicting possible future changes resulting from project management and operations	Post-implementation monitoring and assessment

Implementing an Exotic Plant Management Strategy

Project Purpose and Major DOI Interest

Invasive exotic species pose serious threats to the South Florida restoration efforts. They replace native plants and animals, including threatened and endangered species, alter ecosystem functions like soil formation, hydrology, and nutrient processes, and form monocultures of exotic plants where species-rich and diverse natural communities once flourished. Recognizing the seriousness of this threat, the Task Force and Working Group authorized the Noxious Exotic Weed Task Team (NEWTT) to address invasive exotics concurrently with other work being directed by the CERP and the MSRP. This team produced a report called *Weeds Won't Wait* that documents the problems caused by invasive exotic plants throughout Florida and the Everglades and outlines a comprehensive strategy for their management.

The purpose of this strategic implementation project is to identify and address the invasive exotic plant species in the Greater Everglades that directly affect USDI lands, and to articulate the associated activities that require USDI input and involvement, recognizing that effective control activities must be interagency in scope. The major approaches to managing invasive exotic species include (1) reducing the impact and distribution of existing exotics identified as most critical, (2) preventing new exotic weeds from being introduced and becoming established, (3) generating public awareness of the threats posed by invasive exotic plants, and (4) marshalling interagency resources to better integrate and coordinate common activities and resources related to the management of invasive exotic plants. Coordination with the national invasive species strategies and programs is also a component of invasive exotic plant management in the Greater Everglades.

Serious environmental threats to USDI lands have focused USDI scientists on developing a strategy for managing invasive exotic species holistically as well as managing the impacts of individual species at specific locations. Defining the USDI role in exotic plant management is important for USDI science program planning. However, it is crucial that USDI science be coordinated with other agency and interagency activities to manage and control invasive exotic plants.

Currently the USACE is preparing two reports. The first is a special reconnaissance-type report based on *Weeds Won't Wait* that will further describe the overall problem and make recommendations regarding the federal interest, potential federal sponsors, and integration of the invasive species control and management actions of all the federal Task Force agencies. The second report is a PIR for biological control of melaleuca and other exotic species. This PIR will guide the federal agencies and the CERP sponsor (SFWMD) regarding use of CERP funding for the biological control program at the new Davie quarantine facility.

What Is Known

Scientists have identified and prioritized 50 different species of invasive exotic plants that pose the greatest threat to South Florida ecosystem restoration. They are ranked into three categories: A (most pressing for management), B (critical but not as pressing as category A), and C (least pressing, but species that must be addressed and monitored because of their potential threat). An example of how species are ranked is provided by melaleuca: It is included in category C for South Florida because (1) a great deal is known of its biology and ecological effects, (2) a comprehensive and extremely effective management plan has been in operation for 15 years, and because of effective control and management, it is decreasing in extent and rate of invasion, but (3) because of its abilities to proliferate quickly, it remains a focus for management.

Scientists have developed management plans for six key invasive exotic species that are now in various stages of implementation. These species are melaleuca, Old World climbing fern, Brazilian pepper, water hyacinth, water lettuce, and hydrilla. These management plans outline numerous tasks and activities considered essential for managing invasive exotic plants, including strong coordination among all the affected agencies. NEWTT also identifies the numerous tasks and activities that are part of carrying out the four major approaches outlined previously, along with the individual agencies that are either taking a lead role or would consider taking a lead role should adequate resources become available.

What Is Needed

DOI support of the interagency comprehensive invasive exotic plant management program for Greater Everglades restoration. DOI science now needs to focus activities and attention on the problem of invasive exotics in a way that enhances control and management of these intrusive and damaging plants on DOI lands and also supports the broader interagency ecosystem approach. An implementation plan for the exotic plant management strategy is needed. The plan will help identify individual agency roles in

invasive exotic plant management for this ecosystem and help integrate and coordinate resources and actions.

Risk assessment model to determine the potential threat posed by existing species and possible future invaders of DOI lands

Research into the best control methods for species by life form. Research at the life form level will help determine if there are control methods that might be useful across life forms or if independent research into control methods by species is necessary.

Monitoring and assessment of the overall invasive exotic plant problem on DOI lands, sharing information with other agencies

Monitoring and assessment to determine the responses of native species to management activities designed to control invasive exotics

Invasive Exotic Plant Detection and Monitoring

Project Purpose and Major DOI Interest

The purpose of this project is to identify a set of detection and monitoring methods that can be used by the various agencies across Florida to develop a comprehensive understanding of the magnitude of infestations by invasive exotic plant species and the success (or failure) of existing management programs. Agencies currently use a variety of methods of varying quality and accuracy to locate, map, and monitor invasive exotic plants and to assess the success of control programs. The lack of uniformity and consistency among these methods has made it impossible to create a spatially precise, consistent geographical reference system that all agencies can use to locate invasive exotic plants and document the effects of management actions.

What Is Known

Multiple techniques for vegetation mapping and community or species classification are available.

Remote sensing using imaging systems (photographs, thematic imagers, etc.) is generally not applicable or practical in instances where both very detailed and high resolution results are required, or where extremely large areas are being covered. In the case of extremely large areas of coverage, modeling seems to be a practical alternative for locating the most probable locations of exotics both for control and budget planning.

Simple, low-tech and low-cost tools are essential to field managers who are on the ground trying to find and control invasive exotic species. Existing low-tech field remote sensing methods are practical, cost-effective, and achieve basic agency aims; however, the results of these methods are not sufficient to meet other critical information needs, such as consistency and repeatability of data collection, precision of species location data, retreatment information, ecological and landscape use relationships, and more rigorous aerial extent and invasion rate calculations. In particular, more precision is needed in spatial coordinates for species locations.

What Is Needed

Prototype development of remote sensing field system. With numerous technologies available for locating invasive exotic plants, a priority is to combine and use the existing technologies (including hardware and software) to create an affordable, field applicable (ground or aircraft), user friendly, data rigorous tool for accurately detecting and monitoring invasive exotic plants. A prototype will be developed by first evaluating all the field detection programs currently in use by Florida agencies. From

this evaluation a single system or small number of systems will be configured for use by both field managers, for whom the data collection system (especially of spatial data) will be transparent, and researchers, who may use the spatial data in their studies.

Invasive Exotic Plant Management on the Arthur R. Marshall Loxahatchee National Wildlife Refuge

Project Purpose and Major DOI Interest

The Arthur R. Marshall Loxahatchee National Wildlife Refuge *Comprehensive Conservation Plan* identifies invasive pest plant management as the highest priority and proposes that populations of several of the more aggressive exotic pest plants be reduced to *maintenance control* levels within the next 15 years (2015). In addition, reduction of exotics to maintenance control by 2017 is a performance measure agreed to by the SFWMD and the FWS in conjunction with the renewal of the refuge license agreement in 2002.

Two invasive exotics, melaleuca and Old World climbing fern (*Lygodium*), cover more than 90,000 acres (60%) of the refuge. *Lygodium* alone covers nearly 25,000 acres (15%) of the refuge. Research on the biology and control technologies for melaleuca has been underway for at least 10 years. Because *Lygodium* is a fairly recent invader, much less is known about its biology and methods of control.

Lygodium poses a threat to threatened and endangered species in the refuge, to native plant communities, and to the Greater Everglades. Long-term restoration and management of the refuge and the entire South Florida ecosystem will depend on success in achieving maintenance control levels of this and other exotic pest plants. NEWTT considers the short-term management control of *Lygodium* to be critical for South Florida restoration. The information needed to maximize control efforts must be developed within the next five years, before *Lygodium* affects significantly more acreage on the refuge, to avoid increasing the ultimate cost of control both on the refuge and throughout South Florida. Spread models for *Lygodium* show that within ten years it will be in every habitat in South Florida.

Managers will not be able to determine when they have reached maintenance control until they can express maintenance control in measurable terms. Florida legislation (§ 369.22 (1) (d)) defines maintenance control as "applying management techniques on a continuous basis to keep non-indigenous plant populations at the lowest feasible levels. Under maintenance control there is a reduction in: navigation restrictions, irrigation and flooding problems, sedimentation and lake aging, management costs, competition with native plants, loss of fish and wildlife habitat, and use of herbicides." This objective standard needs to be quantified in order to measure the success in meeting it.

What Is Known

The Florida Exotic Pest Plant Council Lygodium Task Force has prepared a *Lygodium Management Plan* for Florida that discusses the current, rather limited knowledge about the species and summarizes strategies and needs for future management. Efforts have been underway since 1993 to map the distribution of

Lygodium within South Florida via aerial surveys. Identification of dense concentrations and outlier populations is a first step in developing a treatment strategy.

Initial research on methods using fire and herbicides to control *Lygodium* is available, and the SFWMD has conducted aerial applications of herbicides in Dupuis Reserve and the refuge. The effectiveness of these treatments, and the nontarget effects, are being evaluated.

The SFWMD and the USDA Agricultural Research Service are conducting limited biological control research to develop possible biological control agents. Because of the nature and rate of spread of *Lygodium*, some experts think that biological control will be the only long-term effective management tool. However, this program is not adequately funded, and physical control agents are needed while the biological control agents are being developed, to prevent *Lygodium* from invading large areas of South Florida.

Little is known about the ecological requirements of *Lygodium* in Florida. *Lygodium* is documented to grow in both wetland and upland habitats and to reproduce throughout the year. Ongoing research on the reproductive ecology of *Lygodium* may discover possible weaknesses in its life cycle and help determine more effective control approaches.

Efforts are underway to integrate what is known about *Lygodium* at the refuge, the available control technologies, and costs into a decision tool that the refuge manager will use to evaluate alternative control strategies and optimize the use of existing resources for *Lygodium* management.

What Is Needed

Measurable targets for maintenance control of *Lygodium*. Quantitative definitions of "ecologically acceptable" will be required in order to establish measurable targets for maintenance control. Ecologically acceptable levels can be determined through field studies. Research shows, for example, that in tree islands with almost 100% cover of *Lygodium* there is a significant reduction in the abundance of native plant species. Determining what percent cover of *Lygodium* begins to alter the flora and fauna will help quantify management targets and prioritize control efforts.

Research to identify effective control methods for *Lygodium*. Developing effective *Lygodium* control methods and approaches will require continued partnerships among agencies and universities. Efforts to develop biological control methods need increased priority and funding. Additional study will identify the most cost-effective and ecologically beneficial chemical and physical control treatment for *Lygodium* in refuge habitats. Ongoing studies of the effectiveness of various control methods should continue while biological control programs are in the development phase. A better understanding of weaknesses in the life cycle of *Lygodium*, and factors that inhibit *Lygodium* growth, may enhance the ability to effectively control this species.

Aquatic Exotic Animals

Project Purpose and Major DOI Interest

Unintentional introductions of aquatic exotic animals have generally been harmful, in some cases catastrophic. Although control has been successful in some cases, such as in the early stages of colonization by nonnative fish species, complete eradication is often not economically feasible once the populations have become well established. Because eradication of established introduced species is often of limited success, the best strategy may be to avoid operations that are likely to facilitate the introduction of nonnative species from canals, borrow pits, and water detention ponds into natural areas of the Everglades.

The purpose of this project is to provide DOI managers working in partnership with the USACE and the SFWMD with the scientific information they need to ensure that the potential for introduction of aquatic exotic animals is adequately considered during planning for restoration projects and water management operations. For example, canals are documented to serve as corridors for the movement of nonnative animals, and as deepwater thermal and dry-season refuges for both native and introduced aquatic species. The extensive canal system is typically dominated by nonnative fishes in South Florida. Because the canals act as pathways for dispersal, their filling would slow the colonization of introduced aquatic organisms that occur east of the Everglades. Some canals will be filled under the CERP, but a new set will be excavated. Therefore, it is critical to understand the consequences of this artificial aquatic habitat with regard to introduced species.

Other structures also need to be evaluated. For example, pumps and other structures at points of inflow to natural areas in the Everglades are typically not designed to prevent the movement of aquatic animals through them, as they are at many water control structures throughout the United States.

Additionally, some of the water management actions being used to achieve hydrological restoration (such as overflow of water from canals) may pose an increased threat of introducing nonnative species to natural areas. Also, hydrological operations designed for other purposes, such as flood control or even protection of endangered species, have the potential to introduce nonnative species to natural areas if not properly planned. Water management actions and operations that limit direct connections of canal and marsh surface habitats will help prevent the dispersal of exotic animals.

What Is Known

South Florida supports greater numbers of exotic fishes than most other states, owing to the subtropical climate, and the vast network of inter-connecting canals. Most invasions of introduced fishes and gastropods occur in proximity to pump stations and canals, which allow for the persistence and dispersal of these species.

Canals and water detention areas along the northern and eastern boundaries of natural areas provide a source of exotics to Everglades marsh habitats. Although all the exotic fishes established in the area are tropically derived, and many are sensitive to cold temperatures, canal and borrow pond habitats provide a refuge from cold temperatures. Seven species of exotic fishes were reported as established in Everglades National Park in 2000. Since the summer of 2000 three new exotic species have been collected. Exotic fishes are now a large component of deep solution hole habitats in the Rocky Glades in the eastern marl prairies of Everglades National Park.

Publications and technical reports describing South Florida vertebrates, including the growing number of nonnative species, are available, particularly for Everglades National Park and Big Cypress National Preserve. A complete fish and amphibian inventory is underway in the Big Cypress National Preserve. Nonnative invertebrates are only partly inventoried in Everglades National Park because of sampling and identification difficulties and lack of funding, but data are available for some taxa.

What Is Needed

Research into the ecological impacts of invasive exotic species on native species, created habitats (filter marshes, reservoirs, etc.), and natural habitats. Research will support a better understanding of the magnitude of predation on native aquatic populations and the indirect effects on consumer groups, such as wading birds. Populations of native and introduced predatory fishes (e.g., the outstanding largemouth bass fishery in Everglades canals) may be sustained by energy subsidies from adjacent wetlands. A comparison of community patterns and seasonal dynamics in canals that cut through natural wetlands and canals that are isolated from wetlands will indicate the extent to which this occurs.

Research to develop effective control methods for exotic aquatic animals. Research and development of control methods will provide the tools managers need to reduce or eradicate introduced animals.

Studies to support water project designs. Analyses of canals as habitats and movement corridors for exotic fishes will support engineering designs for canals and pumps that avoid or mitigate the effects of aquatic invasive exotic species on wetlands, while allowing these structures to function as needed for ecosystem restoration. Wetlands adjacent to filled canals will be compared before and after filling, and those conditions will be compared to the conditions in wetlands adjacent to operating canals. Movement patterns by fishes will be studied using tagging and radio tracking.

Systemwide monitoring program to document the changes in invasive species resulting from project modifications, and modeling to assist in predicting possible future changes resulting from project management and operations. An effective early detection monitoring program for nonnative aquatic animals will allow for management action when it has the greatest chance of success, before populations and distributions have expanded. The monitoring program should track the dispersal of exotic fishes from canal and water detention ponds into Everglades marshes. In addition, Model characteristics of existing pests will be developed to screen for potential future pests and to prevent introductions.

Better monitoring for future detection. All non-indigenous fish species presently found in the Everglades have entered the ecosystem via canals. Further monitoring of canals (both in urban and more pristine areas) needs to be conducted to identify sources of future invasions, as early detection is key to control efforts.

Research into life history and ecology of non-indigenous species. A better understanding of the life history and ecology of non-indigenous aquatic species in both their native and introduced habitats is key to understanding their potential for expansion and the subsequent ecological impact in their new habitat. Comparisons of these factors with those of native fishes (novel functions vs. functional redundancy) will aid in determining the magnitude of impact they have on native organisms. Experiments assessing their direct impact on native species (i.e., predation, competition) are key– gut content analysis and studies utilizing stable isotopes for diet and trophic position will be particularly insightful. Furthermore, understanding the conditions that cause greatest stress to the non-indigenous species at various life stages will aid in the development of control methods.

Non-indigenous species risk assessment. Risk assessment methods (empirical comparisons of ecological, behavioral, physiological and life history traits) should be applied to increase our ability to screen and identify potentially harmful species prior to extensive invasions. Identification of which species may be more likely to spread and impact the system will allow for better prioritization of control efforts.

Better understanding of the role of canals. An understanding is needed of the role of canals as sources of colonists after the dry-season, and/or sinks for wetland production at the end of the wet-season. It is important to differentiate these scenarios for different fish species, as they may vary. It is also important to analyze canals as habitats and movement corridors for exotic fishes, and determine if they result in higher colonization rates by exotic animals into wetlands, and how far into wetlands native and non-native fishes move from these artificial habitats.

Better understanding of the extent and role of deep solution holes. In the Rocky Glades, deep solution holes (holes that retain water throughout the dry season) often primarily contain communities of non-indigenous fishes. Extensive surveys should be conducted to determine how many of these dry-season refuges exist and their potential role as sources of non-indigenous colonists as marshes re-flood. Research describing the physiological limitations of both native and non-native fishes will aid in

understanding each species' ability to survive the dry-season in these refuges and reemerge as potential marsh colonists in the wet season. Identification of primary dry-season refuges may allow for systematic removal to manage populations.

Fire Management Projects

SUMMARY OF DOI SCIENCE NEEDS RELATED TO FIRE MANAGEMENT PROJECTS

Major DOI Responsibilities and Interests	Major Unanswered Questions	**Needed Science**	**Timeline**
	DOI Lands Fire Management Plan		
Manage fire to support natural ecosystem recovery on DOI lands	What is the prehistoric and predrainage fire history of the Everglades?	Research to determine prehistoric and predrainage fire frequencies and occurrences	ENP , LNWR, FPNWR, Florida Keys NWR, J.N. Ding Darling Fire Management Plans Endangered Species Act, Section 7 Consultation: As needed Fish and Wildlife Coordination Act Report: As needed
	How will restoration of hydrology in the Everglades affect the fire ecology of various ecosystems and how will fire and its natural role in the Everglades affect the restoration program?	Research to understand the links between hydrology and fire ecology Predictive models simulating ecological changes due to hydrologic restoration activities	
	What is the relationship of fire to ecosystems now overrun with invasive exotics species, with special emphasis on fire and *Lygodium?*	Research on the tolerance of exotic species to fire and hydrologic change	
	How will fire affect water quality?	Monitoring and research to track and explain the relationships between fire and water quality.	
	How does fire affect the various threatened and endangered species, with special emphasis on all threatened and endangered plant species and the Cape Sable seaside sparrow?	Research to understand the link between the seasonal occurrence of fire and the life cycles of threatened and endangered species	
	DOI Lands Fire Management Plans		
Assess the responses of ecological communities and species as a basis for adaptive management	What are the long-term effects of fire in various vegetative ecosystems of Everglades National Park?	Identification and monitoring of indicator species	Post-implementation monitoring and assessment

DOI Lands Fire Management Plans

Project Purpose and Major DOI Interest

Fire Management Plan are a detailed program of action, which carries out established fire management policies and achieves fire goals and objectives in a safe and cost-effective manner. All DOI lands on which prescribed burning occurs must have an approved fire management plan. Everglades National Park was the first unit in the national park system to use fire to manage vegetation, and its fire management program remains a progressive institution, evolving with the body of knowledge about ecology and natural system management. In addition to ENP, LNWR, FPNWR, Florida Keys NWR, and J.N. Ding Darling NWR use fire for natural system management

Fire is and always has been an integral part of the development and maintenance of the Everglades. The pervasiveness of fire in the predrainage Everglades and its associated long-term ecological influence is evidenced by the common occurrence of charcoal fragments (fusinite) in soil core samples taken throughout South Florida. By the 1950s researchers were concluding that "the herbaceous everglades and the surrounding pinelands were born in fires" and that "enlightened administrative procedures will require a background of full information on all aspects of fire effects in the area." By the late 1960s and early 1970s ENP management was moving away from the "fire control plan" approach toward a more

adaptive "fire management plan." In 1989 the recommendations of an Interagency Fire Management Team were adopted as NPS policy. Today, based upon historic and current research, it is clear that fire is an important natural ecological process and necessary in the preservation and conservation of ecosystems within Everglades National Park and on other DOI managed lands.

What Is Known

Fire has been one of the most influential and important ecological disturbances in the development and maintenance of ecosystems in South Florida. Fire was, and continues to be, important to the development and survival of many vegetative communities in the Everglades. Historically, fire preserved the dominance of sedges and grasses in short- and long-hydroperiod prairies by removing less fire-resistant species that might otherwise tend to gradually encroach upon them. Fire helped to clear areas of surface fuels, thus decreasing the potential for more severe, catastrophic fires. Fire aided in reducing live hardwood species in areas where softwoods, like South Florida slash pine, were dominant. Above all else, fire maintained the mosaic of species compositions and individual densities throughout the Everglades region.

Fire histories in ENP between 1948 and the 1950s are known to have inaccuracies; all fires ignited during this time period were typically recorded as "incendiary" or "human started" because local attitudes were that lightning did not ignite fires. Inadequate detection techniques from 1940-60 resulted in underestimation of lightning fire frequencies. Other than statistical work conducted with fire records and an analysis of various documented sources from 1910 forward, no comprehensive long-term fire history studies have occurred.

Perhaps the strongest biological evidence for relatively frequent fire occurrence prior to European arrival relates to the habitat requirements of some of the native plants. Documentation of the ecology and occurrence of more than 15 species of native herb species in the ENP pinelands in various long-term studies has shown that favorable conditions for these species rapidly decline as the fire-free interval (period of time when no fires occur) increases. Within a few decades of fire exclusion, pinelands turn into closed hardwood hammocks, which contain none or very few of the endemic herbs. More than 70% of the approximately one hundred herbaceous and low-shrub species native to southeast Florida occur in communities maintained by periodic fire.

The role of fire in the control of exotic plant species is generally understood for some species, including melaleuca and Brazilian pepper, but is not as clear for others, including *Lygodium*. Melaleuca is highly fire adapted. Melaleuca has a thick fire insulating bark and a high volatile oil content in its leaves, leading to high intensity fires. In areas where melaleuca is mixed with fire adapted native species, these high fire intensities typically result in the mortality of the native species. Melaleuca has serotinous capsules that are stimulated by fire to open and release seeds. Following a fire an average tree can release upwards of 10 million seeds on competition-free, nutrient-rich seed beds. This results in monotypic even-age stands of melaleuca that are commonly seen in natural areas of South Florida. Thus, fire should be excluded from areas containing mature melaleuca. Prescribed fire can be utilized post treatment to control seedlings. Melaleuca seedlings less than one meter in height are usually killed by fire, but this requires specific time of the burns and this procedure is not commonly used on NPS lands.

Fire can be a useful tool for controlling Brazilian pepper seedlings and saplings, but it provides very poor control of mature trees and no control in monotypic stands. In ENP, pine rockland areas are maintained largely free of Brazilian pepper through a five-year fire rotation; however, fire is not an effective control for mature trees.

Fire has been shown to reduce biomass accumulation and reduce herbicide needed to control *Lygodium,* although fire alone is not an effective control. *Lygodium* is fire tolerant and can cause natural/prescribed

fires to spread into tree canopies of pine and cypress communities and kill canopy and subcanopy trees. *Lygodium* can also lead to the increased incident of spot fires. It is currently understood that cypress strands, hammocks, etc., should not be burned if *Lygodium* is present because trees may be injured or killed by burning *Lygodium*. The role of fire in *Lygodium* reproduction is not fully understood.

Though it is known that fire is a natural process and can help to improve habitat conditions care must be taken when using fire to ensure that it is not contributing to the water quality issues. Fire is known to alter soil nutrient concentrations with varying effects. Generally, the extent of the effects is related to the type of soils, vegetation present, and the type of fire. Surface fires in areas where soil moisture is relatively high and where only a portion of the above ground biomass is consumed may have little impact on soil nutrient status. More severe ground fires (peat fires) may result in the combustion of soil organic matter and a change in soil nutrient status making nutrients such as phosphorus more available to wetland vegetation. The exact relationships between fire, soil phosphorus, and water column total phosphorus are unknown.

What Is Needed

Research to determine prehistoric and predrainage fire frequencies and occurrences. An accurate fire history record for Everglades National Park and other DOI managed areas will require soil sample analysis as well as review of the records of historical human influences on fire. The historic documentation describes the occurrence of fire in an ecosystem that was increasingly altered by hydrologic changes. Little information exists about the natural fire ecology associated with predrainage hydrologic conditions.

Research to understand the links between hydrology and fire ecology. Additional paleoecological research is needed to evaluate the interrelationships between hydrologic and ecological processes and disturbance regimes, such as fire, in the predrainage Everglades.

Predictive models simulating ecological changes due to hydrologic restoration activities

Research on the tolerance of exotic species to fire and hydrologic change

Research to understand the link between the seasonal occurrence of fire and the life cycles of threatened and endangered species

Identification and monitoring of indicator species

Monitoring and research to understand the links between fire and water quality