South Florida
Ecosystem Restoration Task Force

Plan for Coordinating Science




2006

The South Florida Ecosystem Restoration Task Force approved this document on XX, x, 2006.

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Executive Summary

Background of the Plan:

The attempt to restore the South Florida Ecosystem involves a large and complex combination of initiatives intended to return the degraded ecosystem to a more natural and sustainable condition. The historic ecosystem is an 18,000 square-mile region of subtropical uplands, wetlands, and coastal waters; it extends from the Kissimmee Chain of Lakes south of Orlando through the Florida Bay and the reefs southwest of the Florida Keys and the Dry Tortugas. This large interwoven complex of restoration programs and projects requires a long-term process that involves the resolution of innumerable scientific, engineering, management, and policy issues. Continual improvements are needed in plans and designs that incorporate new information and lessons learned as restoration progresses.

Restoration involves the cooperation and coordination of multiple federal, state, and tribal organizations to address these issues and make the decisions necessary to achieve successful restoration. The U.S. Congress established the South Florida Ecosystem Restoration Task Force (Task Force). One of their duties is to coordinate policies and programs and exchange information among the member organizations responsible for the restoration, preservation, and protection of the South Florida Ecosystem. While the Task Force has no independent restoration or budgeting authority of its own, it was established to enhance coordination among the member organizations involved with the restoration. As part of their coordination role, the Task Force has developed this plan to help coordinate programmatic and strategic level science among the member organizations. Over the past decade, the member organizations have invested millions of dollars on restoration-related scientific activities, which have significantly advanced the understanding of the South Florida Ecosystem. The Plan describes the process and results of these efforts to identify what scientific understanding is the most critical to supporting restoration success and what tasks and actions the members of the Task Force can take to enhance the science and the coordination of science for the benefit of the restoration initiatives.

Fundamentals of the Plan:

Sound, relevant, and timely scientific information is critical to establishing restoration goals and making the decisions necessary to meet those goals. Restoration science, for the purposes of this Plan, includes research, modeling, and monitoring. Coordination by the Task Force is necessary to ensure that the most critical science needs across organizations, scientific disciplines, and ecological regions are addressed, and that quality science is produced and shared among the restoration partners. The Task Force established the Science Coordination Group (SCG) to help it develop this plan to improve science coordination across all restoration initiatives, to ensure that science is effectively communicated to managers and policy-makers, and to assist with the incorporation of sound science into decision making as effectively and efficiently as possible.

This Plan includes a description of the process and approach used to identify programmatic-level science needs and gaps to facilitate management decisions, operational tasks designed to fill the gaps, and strategic actions to coordinate efforts to fill these gaps and complete these tasks.

- Science Need: A science need is defined as an environmental or ecological process or phenomenon that must be well understood if ecosystem restoration decisions are to be scientifically based.
- Science Gap: A gap exists when there is not a good understanding of a process or phenomenon identified in the needs, or an effort is not in place to fulfill that science need in a timely manner.

Through the application of the needs and gaps identification process, the Plan lays out the needs and gaps the Task Force agrees are critical to an accurate scientific understanding of the ecosystem, and the actions the Task Force is applying to help ensure those science gaps are filled and the restoration of the South Florida ecosystem is successful. The Plan also includes a description of the Task Force's approaches to ensuring quality science and promoting more effective sharing of information among all organizations conducting science in support of restoration.

Development of the Plan: The SCG used an "expert-panel" approach to identify science needs and gaps. This approach relied on the current understanding of the cause-and-effect relationships in the ecosystem to identify research, modeling, and monitoring needs and gaps. The approach relied on the knowledge of many South Florida Ecosystem subject matter experts, including SCG members.

The universe of potential research, modeling, and monitoring needs was narrowed by using conceptual ecological models (CEMs) developed for sub-regions of the ecosystem to focus on understanding interactions that describe the system's structure and function (e.g., the relationship between upstream water management and salinity in Florida Bay). These relationships describe how the system operates and takes into account historical impacts. These CEMs are organized by regional modules with an additional CEM for the Total System. The SCG convened panels of subject matter experts to identify the relationships described in the CEMs that are the most critical to restoration success. These relationships were identified as the "science needs." The panels also identified prospective science needs from the evaluation of potential future impacts that were not as well described by the CEMs (e.g., invasive exotic species).

Subsequent work of the subject matter expert panels included evaluations of current science programs and documentation of how well the science needs were being addressed. Wherever a need was not being filled by an existing program, the SCG considered this a "science gap." The scientists involved in restoration then identified tasks designed to fill each gap. The SCG and Task Force developed programmatic/strategic level actions to assist in accomplishing these tasks, which are needed to fill the identified strategic science gaps. The needs, gaps, and associated tasks are presented in this report by regional module and for the Total System. Programmatic-level actions are structured to enhance science coordination system-wide. They also are intended to provide Task Force endorsement for filling the gaps through the implementation of the identified tasks. The Task Force does this in part through its support and encouragement of organizations to utilize the information in this plan when revising their science plans, developing their science budgets, and implementing their science programs.

Organization of the Plan: The current state of understanding varies by region within the South Florida Ecosystem. Therefore, the critical gaps can vary somewhat among the modules. However, some themes, such as knowledge of the fate and transport of nutrients and contaminants, or the management of invasive exotic species, are consistent among the regions. Based on the analysis conducted by the SCG panels, the following bullets, presented by module and for the Total System, outline the general themes of the identified gaps. The following general gap-themes were generated from the more specific gaps that are listed in the plan for each module, and in the tasks listed for each module.

- **Lake Okeechobee** – A major impact to this region is water management activities. The gaps primarily identified are associated with the impacts of water management activities on, among other things, the lake's vegetation and faunal communities, and nutrients. Additionally, greater basic bathymetric information is required to understand how lake stages affect different communities. These issues will be addressed through coordinated efforts using existing science plans and the Comprehensive Everglades Restoration Plan (CERP) Monitoring and Assessment Plan (MAP).

- **Northern Estuaries** – This region requires basic science, particularly monitoring and mapping of the estuary, development of predictive tools for submerged aquatic vegetation (SAV) and oysters, and an understanding of water quality impacts on the fish and oyster population. These gaps will be addressed through the MAP and an analysis of model needs.

- **Greater Everglades** – This region requires a more coordinated effort to assess a diverse set of science gaps. This could be accomplished through the development of an organization similar to the Florida Bay Program Management Committee (PMC). In addition to monitoring and mapping gaps, and a greater understanding of the impacts that restoration and water management have on soil and vegetation, this area requires an understanding of the best approaches for addressing fire impacts. These gaps will be addressed through the development and analysis of a Science Coordination Team for the Greater Everglades.

- **Southern Estuaries** – This region has the most well developed science coordination efforts of all the regions, with a more updated planning process for Florida Bay than Biscayne Bay. However, the majority of the gaps for this region have been identified in previously developed science plans. An issue here is whether funding is available to fill the gaps previously identified. The Restoration Coordination and Verification (RECOVER) Program will conduct an analysis of the MAP and science plans to determine whether any gaps cannot be filled with existing funding.

- **Total System** – Critical gaps for the Total System include defining restoration success and restoration goals, and addressing the major themes that cross regional boundaries, such as water quality and exotics. Additionally, it is important that existing and future system-wide and regional models are integrated (i.e., coupled) to support system-wide assessments and predictions.

The vast amounts of diverse data and information generated by research, modeling, and monitoring activities in South Florida must meet commonly accepted scientific standards to ensure that restoration decisions are based on sound science. Furthermore, to be relevant and effective, scientific information must be synthesized and communicated in a timely manner and in a useful format for managers and policy makers. The Task Force has also identified actions for promoting quality science and better coordination of scientific information among relevant organizations.

Use of the Plan: The Task Force views this plan as a reference document that should be used by all the Task Force organizations to better guide their own science planning and science-budget development. The Task Force and SCG clearly understood the limitations and even vagaries of funding during the development of this plan and view it not as a list of unfunded gaps and tasks, but more as a tool to guide organizations in prioritizing their own science activities that are related to South Florida Ecosystem Restoration. The Task Force organizations should use the plan to evaluate their own science programs, and where they are already filling an important science need they should continue to do so in order to prevent creating a new science gap. The organizations should also use the plan to evaluate their existing science programs and, where appropriate, revise those plans to better reflect the science priorities expressed here. By incorporating this plan into their planning activities, Task Force organizations may also be able to improve ongoing coordination among themselves and build new coordination opportunities to help address the gaps in this plan. Through evaluation and application of this plan, and through coordination in using it, organizations may well find that they individually and collectively can improve efficiency in science activities, funding, and budget planning. While completing all the gaps identified in this plan will require substantial funding, it was never anticipated that funding was necessarily available. However, with a more holistic view presented and documented in this plan, of the broad science initiative and strategies identified by the scientists involved with restoration, organizations will be in a better position to individually and collectively evaluate and review existing programs, reprioritize where appropriate, and seek funding.

This plan should become an integral element of all the organizations planning and budgeting activities related to south Florida Ecosystem restoration science.

1.0 Why We Need a Plan to Coordinate Science

South Florida Ecosystem restoration is comprised of a large and interwoven combination of initiatives intended to return the degraded ecosystem to a more natural and sustainable condition. These restoration efforts will take decades and require the resolution of complex environmental, engineering, management, policy, and technical issues by many federal, Native American, state, and local organizations. Managers in these organizations will have to make numerous project-specific and restoration-wide decisions as restoration proceeds. This will include evaluating options and predicting results; selecting, planning, and implementing options; comparing actual results to expectations; and continually improving the strategies, project designs, and operations to incorporate new information and lessons learned into future decisions. This process is referred to as "adaptive management." Quality scientific information that is coordinated among the involved organizations is essential to successful application of the adaptive management process.

> An **Ecosystem** is a discrete spatially identified unit that consists of interacting living and non-living parts.

Good management decisions require a sound scientific understanding of the ecosystem. It is vital that quality science be available in a timely fashion to support these decisions. This understanding is developed through sound and timely application of relevant scientific information that has been synthesized, distributed, and communicated to managers and policy makers. The adaptive management process ensures good management decisions by continually incorporating new scientific findings into restoration decisions. The successful application of adaptive management relies on frequent and integrated information from relevant scientific activities. Science coordination is essential to answering the most critical science questions with the most efficient use of resources and then making that information available to decision-makers in a concise, useful, and timely manner. Strategic level coordination of science as proposed in this plan includes identifying science needs and gaps, assuring that science gaps are filled, and resolving conflicts or competing priorities. Coordination supports efficient gathering of scientific information and reduces unnecessary or duplicative scientific efforts.

1.1 Why the South Florida Ecosystem Restoration Task Force is Developing this Plan

Task Force Goals:

Goal 1: Get The Water Right

Subgoal 1-A: Get the hydrology right

Subgoal 1-B: Get the water quality right

Goal 2: Restore, Preserve, and Protect Natural Habitats and Species

Subgoal 2-A: Restore, preserve, and protect natural habitats

Subgoal 2-B: Control invasive exotic plants

Goal 3: Foster Compatibility of the Built and Natural Systems

Subgoal 3-A: Use and manage land in a manner compatible with ecosystem restoration

Subgoal 3-B: Maintain or improve flood protection in a manner compatible with ecosystem restoration

Subgoal 3-C: Provide sufficient water resources for built and natural systems

Most Task Force member organizations have science programs that may operate both individually and collectively to provide technical information to support restoration decisions aligned with Task Force goals. In addition, partnerships, such as the Florida Bay and Adjacent Marine Systems (FBAMS) Science Program, have been established to coordinate scientific activities over a particular ecosystem region or restoration program. Over the past decade, these individual organizations and partnerships have invested millions of dollars on restoration-related scientific activities. This federal and state investment in science has improved our understanding of how restoration will occur and led to the development of some of the adaptive management tools needed for restoration. Notably, scientists have identified key factors responsible for ecosystem degradation such, as altered hydrology. Although much progress has been made, the scope of these individual agency or partnership programs does not include all South Florida Ecosystem restoration activities.

Science Coordination Goal:
Ensure sound, timely, and relevant scientific information is available to support decisions at all points in the restoration process through coordinating efforts, sharing information, and identifying and filling information gaps.

Coordination by the Task Force at the broadest level is important to help ensure that the most essential science needs and gaps are identified and communicated to the many organizations, and that projects address these science needs and gaps. The Task Force has developed this science plan to support its efforts to coordinate programmatic-level science for South Florida Ecosystem restoration. The plan includes a description of the formal approach developed to identify science needs and gaps, coordinate efforts to fill the gaps, and ensure quality science. It also includes the results of implementing the needs and gaps identification approach (discussed in Section 3).

Many federal and state agencies, Native American Tribes, and other state and local political representatives are involved in South Florida Ecosystem restoration. Each of these restoration partners has a unique mission and, therefore, a unique role in the restoration process. The Water Resources Development Act (WRDA) of 1996 created the South Florida Ecosystem Restoration Task Force (Task Force) to, among other duties, coordinate policies and programs, and exchange information among the members for the restoration, preservation, and protection of the South Florida Ecosystem. These duties include coordinating the science supporting restoration. The Task Force membership consists of senior representatives from each restoration partner to support the most efficient coordination. A primary focus of the Task Force is to coordinate the implementation activities of the individual members to support the overarching goals and subgoals of the Task Force.

The Task Force established a Florida-based Working Group to assist in carrying out its responsibilities. The Working Group established a Science Coordination Team (SCT) to help coordinate science activities. To ensure that science is incorporated into decision making as effectively and efficiently as possible, and to address GAO's and Congressional recommendations to improve science coordination, the Task Force created a Science Coordination Group (SCG) in December 2003 to replace the SCT. Members of the Task Force, SCG, and Working Group are identified in Appendices A – C.

The Florida Bay and Adjacent Marine Systems Science Program coordinates research in and around Florida Bay. It is led by the Program Management Committee, which is charged with providing policy makers reliable scientific information and science-based recommendations relating to areas within and adjacent to Florida Bay.

2.0 What This Plan Covers

2.1 How We Define the South Florida Ecosystem

WRDA 1996 defined the South Florida Ecosystem as "the area consisting of the lands and waters within the boundary of the South Florida Water Management District, including the Everglades, the Florida Keys, and the contiguous near-shore coastal waters of South Florida." This 18,000 square-mile region historically included subtropical uplands, wetlands, and coastal waters extending from the Kissimmee Chain of Lakes south of Orlando through Florida Bay and the reefs southwest of the Florida Keys. The area is shown in Figure 1.

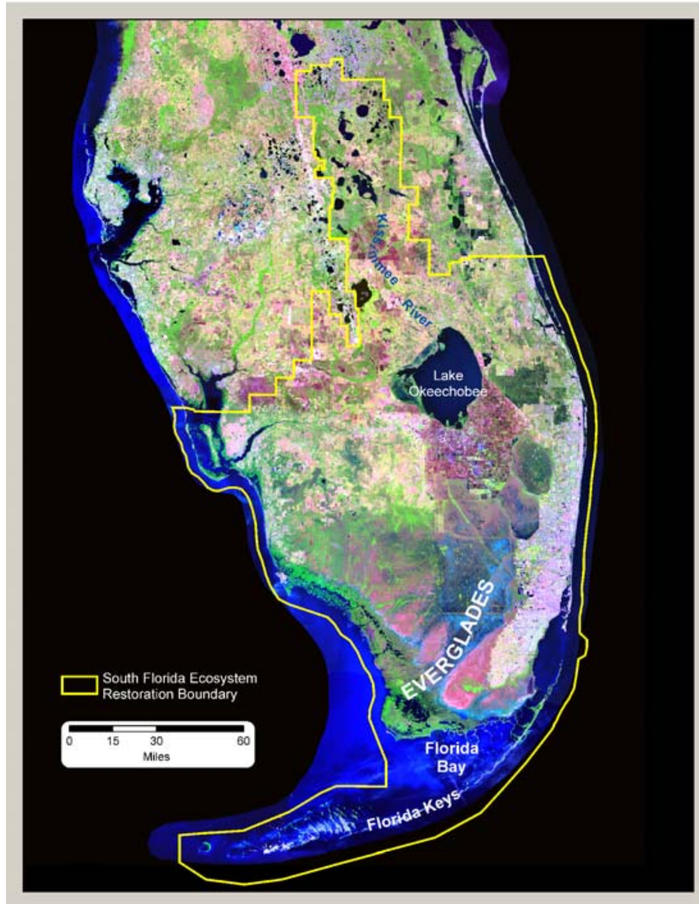

Figure 1. Areas within the yellow boundary line, including Florida Bay and Florida Keys, comprise the South Florida Ecosystem.

2.2 Restoration Activities Included in this Plan

South Florida Ecosystem restoration includes all restoration programs and projects within the geographic area described above. Many of the restoration projects are part of the CERP. CERP consists of more than 60 projects intended to restore, protect, and preserve the water resources of the South Florida Ecosystem through changes to the Central & Southern Florida (C&SF) Project. The C&SF Project includes approximately 1,000 miles of canals, 720 miles of levees, and several hundred water control structures designed primarily to provide water supply, flood protection, and water management to South Florida. The C&SF Project has adversely affected the south Florida Ecosystem by disrupting the natural flow of water across the landscape.

Other projects not included in CERP are also significant and equally crucial to South Florida Ecosystem restoration. These include, but are not limited to, the Modified Water Deliveries to Everglades National Park and C-111 Project, the Kissimmee River Restoration Project, the Multi-Species Recovery Plan, and the Special Report on the Role of Federal Agencies in Invasive Exotic Species Management with Regard to Everglades Restoration. The Task Force's role is to coordinate all South Florida Ecosystem restoration programs – both CERP and non-CERP.

The Modified Water Deliveries to Everglades National Park and C-111 Project will modify water flow to Everglades National Park to restore more natural hydrologic conditions to the Southern Everglades and Florida Bay.

The Kissimmee River Restoration Project is restoring over 40 square miles of river and associated wetlands by revitalizing headwaters of the upper river basin and reestablishing natural flooding patterns in the lower river basin to restore wetland conditions.

The Multi-Species Recovery Plan is designed to recover multiple species through the restoration of ecological communities over a large geographic area.

The Special Report on the Role of Federal Agencies in Invasive Exotic Species Management with Regard to Everglades Restoration will further clarify and identify the overall problem with invasive exotic species and the federal roles, and provide recommended actions and resources for federal agency activities with regard to managing invasive exotic species for Everglades Restoration.

2.3 The Kinds of Science Needed for Restoration

Scientific information is generated from a variety of activities. In addition to traditional scientific research, it also includes monitoring; detecting, assessing, predicting change or outcomes; and synthesizing scientific information to support management and policy decisions. Restoration science in the context of this plan includes three types of activities:

- **Research** – To generate new knowledge of and technologies required to better understand specific or collective functions of the ecosystem
- **Modeling** – To predict ecosystem response to changing conditions, including the ecological effects that projects or project options may have on the ecosystem (e.g., project alternative evaluations)
- **Monitoring** – To establish pre-restoration baseline conditions, and to assess and evaluate the performance of individual projects, the combined effect of multiple projects, and impacts of natural phenomena (e.g., droughts, tropical storms, freezes)

2.4 How Science is Coordinated Within and Among Participating Task Force Organizations

Ecosystem restoration science activities occur at multiple levels, as represented in Figure 2. The most fundamental level of coordination is the science managed by individual organizations. The next level of coordination is through a partnership of two or more organizations. This level may be focused on a restoration program, such as the RECOVER program that provides system-wide scientific support to CERP, or is focused on a specific geographic region (e.g., Florida Bay and adjacent marine sciences program). The third and broadest level of coordination is across an entire ecosystem, including all relevant geographical areas and restoration programs and projects. The Task Force operates at this highest strategic level by influencing the multiple South Florida Ecosystem partnerships and Task Force member organizations to coordinate their science efforts.

This Plan addresses coordination of all three types of science activities at the programmatic level. Coordination includes processes for identifying needs and gaps, taking coordination actions to complete the task designed to fill gaps, and ensuring the quality of the information. The overall approach for Task Force scientific coordination starts with the SCG using their expertise, and that of subject matter experts, to review what information is necessary to support making sound restoration decisions, and compare that to what is currently being done at the individual and multiple organizational levels. Where the SCG process identifies gaps, they make recommendations to the Task Force on how to restore the gaps. Because the Task Force has no authority as a body to take direct action to fill the gaps, it relies on the members to work collaboratively to address the gaps. The Task Force will coordinate with its members to address these gaps. At the request of the Task Force, the SCG developed a process for identifying the most essential restoration science needs and for conducting a gap analysis to determine those areas requiring more coordination at the Task Force level. Figure 2 shows how this process fits into the overall Task Force science coordination process. Descriptions of the methodology and results, as well as the coordination actions that are being applied by the Task Force to fill these gaps, are provided in Section 3.

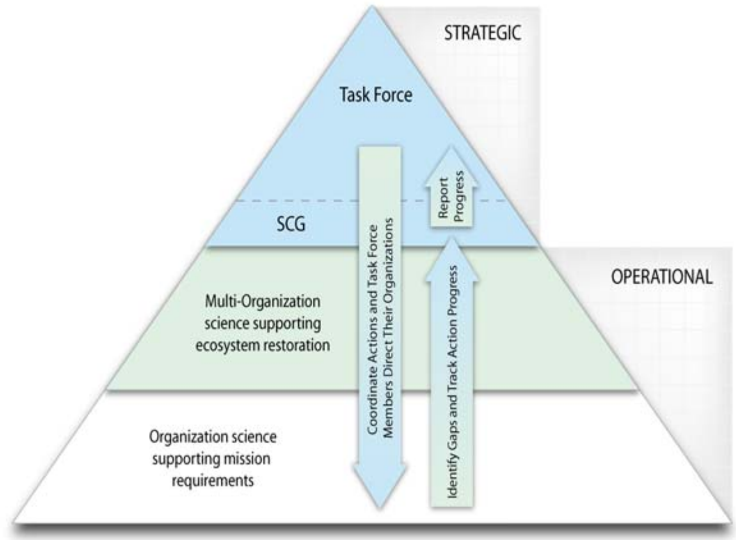

***Figure 2.** Science activities that support restoration can range from multiple science initiatives at the researcher level to high-level programmatic coordination that occurs at the Task Force level.*

3.0 How We Identified Strategic-Level Restoration Science

> A **Critical Science Need** is a scientific process or phenomenon that must be rigorously understood if ecosystem restoration decisions and actions are to be scientifically based. Failure to adequately elucidate these scientific understandings could jeopardize restoration success.

Science coordination at the Task Force strategic level is a complex process because of the number and diversity of restoration partners participating in the effort to collect and analyze scientific information to make decisions. Conducting a comprehensive analysis of the breadth of all science projects each restoration partner is involved in was considered too time and resource intensive for the purposes of this plan, and fell outside the congressional mandates of the Task Force.

For the Task Force to appropriately and efficiently address science coordination, the SCG used a "risk-based" approach to identify science needs. Through a series of "expert panel" workshops, SCG members facilitated panel discussions to identify the most critical scientific needs, and determine where needs were not being met (i.e., identify gaps). The SCG then worked with the expert-panel scientists to identify appropriate tasks to address the science gaps. Afterwards, the SCG and the Task Force developed programmatic level actions to assist in filling the gaps. The SCG also evaluated alternatives to assist the Task Force and member organizations in reinforcing the need for use (and where appropriate the development) of quality assurance procedures and protocols, and opportunities for sharing science information.

- **Identifying Needs** – Distinguishing the scientific knowledge or issues critical to restoration success
- **Identifying Gaps** – Evaluating ongoing science efforts to determine if there are gaps in research, modeling, or monitoring, for each identified critical restoration science need
- **Identifying Tasks** – Describing specific science (i.e., research, monitoring, and modeling) activities to be implemented that can effectively fill the gaps
- **Identifying Actions** – Encouraging coordination through individual agency science planning and budgeting, using the information in this plan when organizations revise or modify existing science plans or develop new ones, improving the compatibility among programs, resolving conflicting viewpoints, determining resource priorities for science gaps-planning-budgeting, identifying resource shortfalls, facilitating integration and synthesis, and providing science information to restoration managers in a timely and useful form
- **Ensuring Quality Restoration Science** – Making sure that restoration science is sound, relates to restoration goals, and is shared among stakeholders

3.1 How We Identified Science Needs

The SCG convened panels of subject matter experts (including SCG members) to identify critical research, modeling, and monitoring needs. Using the CEM, the panels evaluated the hypotheses developed by RECOVER (2006) that describe how the South Florida Ecosystem has been altered. These hypotheses were based on the current understanding of cause-and-effect relationships in the ecosystem (e.g., how water management practices can affect wading bird populations). It is important to understand that the hypotheses reflect the processes that resulted in the present system condition (i.e., retrospective). The panel also identified needs based on their understanding of what aspects of the ecosystem were not captured in the CEMs but have been determined to be likely future effects on the ecosystem as restoration is implemented, (i.e., prospective), for example, the impacts of invasive exotic species.

A series of CEMs were developed by RECOVER to help scientists reach consensus of how the Everglades' ecosystem worked (i.e., cause-and-effect, and structure and function relationships) (Ogden et al. 2005a; RECOVER 2006). There are CEMs that cover individual sub-regions (called modules), within the South Florida Ecosystem, and a CEM for the Total System (Ogden et al. 2005b). The South Florida CEMs illustrate the links among environmental stressors (including anthropogenic sources) and ecological responses to explain how and why natural systems in South Florida behave as they do, and how they have changed. CEMs are planning tools to help guide and focus scientific activities in support of South Florida Ecosystem restoration and to help develop hypothesis for scientific inquiry (Ogden et al. 2005a).

South Florida Conceptual Models

1. Total System
2. Big Cypress Regional Ecosystem
3. Biscayne Bay
4. Caloosahatchee Estuary
5. Everglades Mangrove Estuaries
6. Everglades Ridge and Slough
7. Florida Bay
8. Lake Okeechobee
9. Lake Worth Lagoon
10. Loxahatchee Watershed
11. Southern Marl Prairies
12. St. Lucie Estuary and Indian River Lagoon

All South Florida Ecosystem CEMs consist of a graphic representation and narrative that describe the dynamics of the region (see *Wetlands*, Vol. 25, No. 4. 2005 special issue on conceptual ecological models for Everglades restoration).

The model components include:

- **Drivers** – The major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces (e.g., hurricanes) or manmade (e.g., regional land use programs)
- **Stressors** – The physical, chemical, or biological changes that occur within natural systems that are brought about by the drivers, causing significant changes in the biological components, patterns, and relationships in natural systems
- **Ecological effects** – The biological responses caused by the stressors
- **Attributes** – Subset of the biological components of a natural system that are representative of the overall ecological condition of a system that can be used to represent the known or hypothesized ecological effects of the stressors (e.g., wading bird population in a particular area) and the elements of the system that have important human value (e.g., endangered species). Attributes are also known as endpoints.

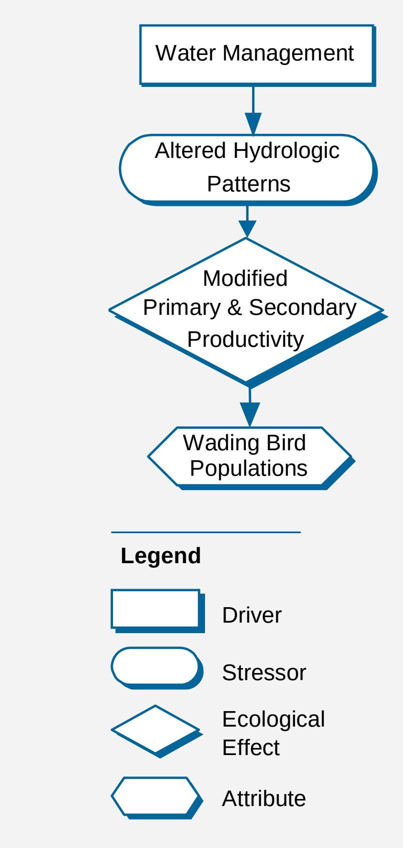

Figure 3. Example of a Path within the Total System Conceptual Ecological Model

Brief descriptions and diagrams of the twelve South Florida Ecosystem CEMs are provided in Appendix E. (See the *2004 CERP MAP* and the December 2005 special issue of the journal *Wetlands* 4:25 for detailed descriptions of the CEMs.)

RECOVER has grouped CEMs into regional modules defined to reflect the geographical and ecological similarities within ecological regions, and to address restoration goals that are common within a region (RECOVER 2006) (Figure 4). Because the CEMs encompass ecological regions, and modules are for assessments within module boundaries, the boundary areas defined by the regional modules and the CEMs are not identical. For example, the Big Cypress CEM includes a large region not encompassed by the Greater Everglades regional module; however, these differences do not affect the identification and analysis of the needs, gaps, and tasks for each region.

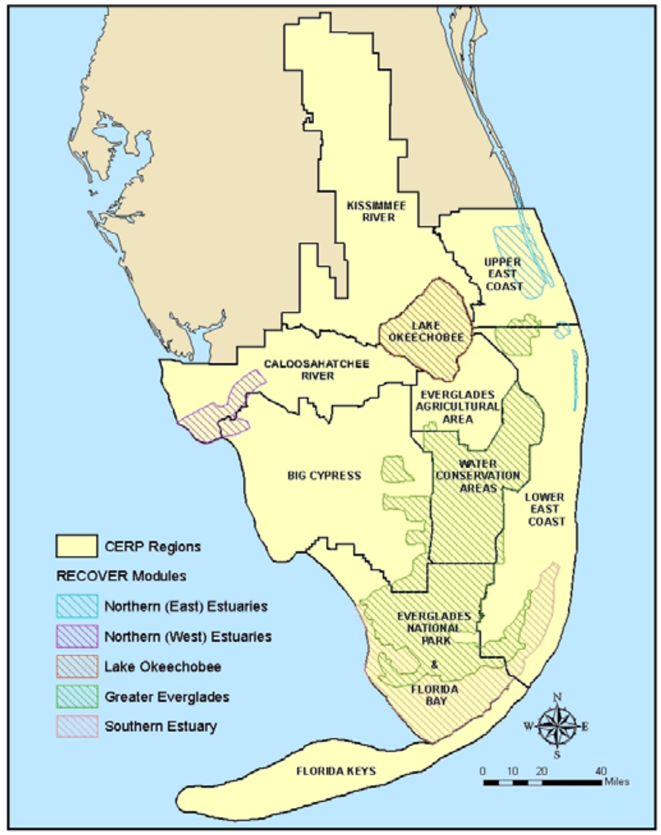

Figure 4. CERP Recover Modules

REGIONAL MODULE	CONCEPTUAL ECOLOGICAL MODELS
Lake Okeechobee	• Lake Okeechobee
Northern Estuaries	• Caloosahatchee Estuary • Lake Worth Lagoon • St. Lucie Estuary & Indian River Lagoon • Loxahatchee Watershed
Greater Everglades Wetlands	• Everglades Ridge and Slough • Southern Marl Prairies • Big Cypress Regional Ecosystem • Everglades Mangrove Estuaries
Southern Estuaries	• Biscayne Bay • Florida Bay

The Total System CEM — which is not represented by a RECOVER regional module — addresses the broadest relationships across the South Florida Ecosystem. The analysis of this CEM allowed the SCG to focus on and evaluate more system-wide and collective science needs and gaps for the ecosystem.

3.2 How We Identified Science Gaps

A central component of restoration science coordination is the evaluation of whether ongoing science efforts are addressing the science needs in scope and timeliness to support ecosystem-wide restoration goals. A gap is identified when information or mechanism, or the resources to obtain information (e.g., a model or monitoring program, funding), is insufficient, incomplete, or not timely to address an identified need (e.g., no transparent, multi-agency process or system currently exists to allow the efficient and effective exchange of data and other science information among scientists).

Needs and gaps were evaluated simultaneously in the expert-panel workshops. To identify gaps in the needs the SCG looked at existing science programs and initiatives, and compared those with each science need. If an existing program or project was meeting an identified need, there was no gap. The following criteria were used to help objectively determine whether a need had a gap.

- Alignment of science activity goals and objectives to need
- Adequacy of technical depth to address need
- Adequacy of spatial or temporal cover and resolution to address need
- Procedures followed to ensure the soundness of the science activity
- Process used to share the results with restoration managers
- Effort to synthesize data necessary to address a need
- Alignment with performance measures or other measures of restoration success
- Required coordination processes for multi-agency efforts
- Alignment of science information generation to restoration management timeline

3.3 How We Developed Actions to Address the Gaps and the Tasks

The Task Force develops and recommends actions through coordination and with support of its member organizations. Because the Task Force is a coordinating body, not an implementing one, actions are being developed using a list of science related tasks to ensure that Task Force actions have both credibility and traction with scientists, managers, and policy makers. The task list was developed by scientists and other experts involved in South Florida restoration. Tasks are derived directly from the gaps identified for each module. All tasks were scoped to the agency or individual project level and not intended for execution or oversight by the Task Force. All actions are being designed to support science coordination at the strategic and organizational level, yet be sensible enough to actually help accomplish the items in the task list that scientists say they need.

Coordination Action Options

- Clarifying roles and responsibilities
- Aligning or realigning programs to milestones
- Convening panels or work groups to evaluate options for addressing technical issues and propose solutions to the Task Force
- Developing or modifying partnerships
- Improving communication mechanisms
- Sponsoring science conferences and workshops to facilitate information sharing and clarify technical issues

The three areas of science that are identified in this report are monitoring, research, and modeling. All three of these areas have varying efforts of organization and coordination within their disciplines. For example, RECOVER has taken a strong lead on organizing, integrating, assessing, and coordinating monitoring for the restoration effort. It is reasonable for any Task Force actions related to monitoring to take this into account and assume that monitoring tasks would be vetted and incorporated into the RECOVER venue, or identified by RECOVER as important but outside their domain, in which case an alternative for accomplishing that task would be evaluated.

On the other hand, research and modeling do not have such system-wide organizing bodies to support and coordinate the overall research or modeling efforts that are ongoing in the restoration program.

3.4 The Needs and Gaps Identified for the Regional Modules and the Total System

The following sections describe the regional modules and Total System characteristics, and identify the needs and gaps for each module. Each section first focuses on the critical ecological relationships (links between drivers and outcomes) established in the CEMs that are the basis for the needs. Subsequent discussions describe the ongoing activities, how they relate to the needs and the gaps for each module, and identify critical tasks for filling the gaps. Lastly, the programmatic actions that the Task Force could take to assist in filling the gaps are identified.

Unless otherwise stated, all technical and background information for each module is drawn from the recently published CEMs (see: Wetlands, Vol. 25, No. 4. 2005 special issue on conceptual ecological models for Everglades restoration and the *2006 Assessment Strategy for the Monitoring and Assessment Plan* (RECOVER 2006)).

3.4.1 Lake Okeechobee Regional Module Needs, Gaps, and Tasks

Lake Okeechobee is a large (about 1,800 km^2) and shallow (average depth of less than 3 m) freshwater lake located in the north central region of the South Florida Ecosystem, south of the Kissimmee Chain of Lakes region and the Kissimmee River. The Lake Okeechobee Regional Module (RECOVER 2006) CEM is included in MAP II and has been revised and updated to better represent the lake ecosystem (Havens and Gawlik 2005).

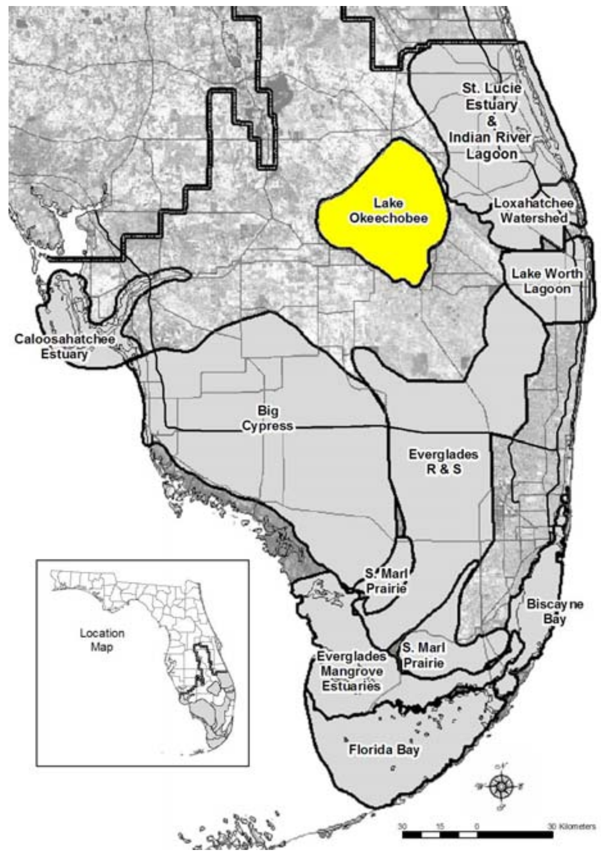

Figure 5. Lake Okeechobee CEM Region

Historically, Lake Okeechobee would seasonally overflow its banks producing a slow southward moving sheet water-flow. The annual cycle of sheet water-flow from the lake shaped the hydrological and ecological character for the rest of the South Florida Ecosystem region. Manmade structures (e.g., dikes and canals) built to control flooding and management practices (to regulate the lake water stages and deliver water to agricultural lands and urban areas) disrupted the natural southern hydrological flow. The disruption of the natural hydrology affected both the lake and downstream areas' physiography and supported habitats.

Critical to restoration of the lake's ecology, particularly the littoral zone, is an understanding of how historical and current anthropogenic activities (e.g., invasive exotics, nutrient inputs) and natural disturbances (e.g., storms) affect the nutrient and sediment dynamics (e.g., inputs, biogeochemical cycling, and exports), as well as the structure and function of ecological communities in Lake Okeechobee.

The primary ecological stressors identified for Lake Okeechobee from the hypotheses described in the Lake Okeechobee Regional Module (RECOVER 2006) are: (1) unnatural variations in water levels caused by the operation of canals and other man made structures, (2) anthropogenic inputs of nutrients from agricultural and other land uses, and (3) invasion by exotic species.

Water Levels

The water levels of the lake are affected by natural variations in rainfall, evapotranspiration, and the operation of C&SF Project (i.e., water management). Major water inflows to Lake Okeechobee are from the Kissimmee River on the north, while major outflows are through the Caloosahatchee River on the west, St Lucie Canal on the east, and various canals on the south and south east side of the lake. In general, the conveyance capacity of lake inflows far exceeds the capacity of available outflow conveyance. This frequently results either in rapid and environmentally damaging major increases in lake level, or massive releases to surrounding water bodies. For example, increases in lake levels threaten the integrity of the Herbert Hoover Dike, resulting in large and environmentally damaging releases to the eastern and western estuaries to reduce lake levels. Water levels of Lake Okeechobee are also radically affected by the dike around the lake. The dike modified the lake's boundaries and bathymetry, reducing the size of the pelagic and littoral zone, and decreasing its depth. Because of these effects on current lake conditions, changes in water levels of less than 1.5 meters above or below the lake's idealized stage envelope can result in lake stages (i.e., surface elevation) that can either excessively flood or completely dry the littoral zone.

Nutrients

During the past decades, the lake has received large quantities of nutrients (i.e., phosphorous, and to a lesser extent nitrogen) from agricultural and urban activities from both the north (due to runoff) and from the south (due to backpumping) on the lake watershed. High nutrient loadings have resulted in accumulations in the lake sediments and episodic high concentrations of nutrients in the water column, which have fostered eutrophic conditions (e.g., algal and noxious cyanobacteria blooms, increased accumulation of soft organic mud, and reduced water transparency). Eutrophic conditions resulting primarily from canalization of tributaries and agricultural runoff, and more recently from urban runoff, have reduced the lake's water quality and negatively impacted critical communities. Storm events frequently re-suspend bottom sediments and associated accumulated nutrients, exacerbating the nutrient concentrations in the lake water column.

Excess nutrients are also hypothesized to cause other effects, such as reducing the lake's biodiversity, and negatively impacting the productivity of higher trophic levels, including important commercial and recreational fisheries. For example, phytoplankton blooms frequently reduce water transparency and negatively affected emergent and submerged aquatic plants that provide essential habitat for many species of wading birds and native fish.

The current nutrient conditions in Lake Okeechobee reflect decades-long activities that resulted in high accumulation of nutrients in the lake benthos, and the ecological disruption of a large freshwater mesotrophic body of water central to the South Florida hydrological system. Current phosphorous loading exceeds 500 metric tons per year, close to three times the Total Maximum Daily Load (TMDL) mandated by the state of Florida. The total phosphorous concentration of the lake water (greater than 110 ppb) is more than twice the values measured 30 years ago, while the top 10 centimeters of the lake bottom sediments contain more than 30,000 metric tons of phosphorous. Understanding the nutrient dynamics of Lake Okeechobee is critical for the restoration of the South Florida Ecosystem because the water that flows from the lake is a major factor influencing the rest of the South Florida Ecosystem.

Benthos refers to the region of substrates at the bottom of a body of water.

Invasive Exotic Species

Many exotic species, both plants and animals, are documented as naturalized in Lake Okeechobee. The lake's littoral zone is the area most severely impacted by invasive species, particularly plants. At least 15 invading plant species have been recorded. The two dominant plant invasive species are *Melaleuca quinquenervia* (Cav.) Blake and *Panicum repens* L. (torpedo grass). These two species, originally introduced for dike stabilization (*M. quinquenervia*) and cattle grazing (*P. repens*), spread throughout the littoral zone, displacing native plants and reducing the quality of the lake's habitats. Herbicides are being used with good success to control the spread of *Melaleuca* and with some success to control the spread of torpedo grass.

However, torpedo grass still covers over 10,000 acres of the lake's littoral zone. Water management drawdowns appear to be causing an increase in the cover of this species, and it is not included in the exotic plant indicator monitoring program. In addition, the continued use of herbicides may be affecting non-target species in ways that are not being monitored. Other exotic plant species (especially West Indian Marsh Grass, *Hymenachne amplexicaulis*) are invading, and control efforts for these are not well known and are not effective. Several exotic animal species, such as fish (e.g., tilapia, *Tilapia aurea;* sailfin catfish, *Pterygoplichthys* spp.), mollusks (Asian clam, *Corbicula fluminea*), channeled apple snail (*Pomacea canaliculata*), and microinvertebrates (*Daphnia lumholtzi),* occur in Lake Okeechobee. Scientists are concerned that *Daphnia lumholtzi* may have negative effects on North American ecosystems. The large spines make it difficult for young fish (larval and juvenile stages) to consume this exotic. Native *Daphnia* have fewer, smaller spines and, therefore, are more readily consumed by fish. The protection from predation afforded by its spines may allow *Daphnia lumholtzi* to replace native *Daphnia* species. If this replacement occurs, the amount of food available to larval and juvenile fishes may be significantly reduced. This could result in reduced survivorship of young sport and food fishes in lakes, rivers, and fish hatcheries where *Daphnia lumholtzi* becomes abundant. However, the potential threats to the lake's ecosystem from most of these animal invaders have not been well studied and are essentially unknown.

■ **Lake Okeechobee Needs.** The review by the SCG of the major hypotheses in the Lake Okeechobee Regional Module resulted in the identification of the three science needs listed below. These needs focus on the link between water levels and the ecological dynamics of the lakes, the factors controlling the lake's nutrients, and the role of the exotic species in the lake.

LAKE OKEECHOBEE NEEDS

- ✓ To understand how water management activities, including extreme highs and lows, timing, inundation and recession rates, duration, and frequency of lake stages affects Lake Okeechobee ecosystem structure, and function.
- ✓ To understand how historical and current anthropogenic activities (e.g. invasive exotics, nutrient inputs) and natural disturbances (e.g., storms) affect the nutrient and sediment dynamics (e.g., inputs, biogeochemical cycling, and exports) and the structure and function of ecological communities in Lake Okeechobee.
- ✓ To understand and predict how restoration activities affect the dynamics of exotic plants and animals in Lake Okeechobee, including their impact on the structure, function, and health of the lake ecosystem (e.g., displacement of native organisms, reduction of dissolved oxygen, reservoirs, or vectors for disease).

> **Mesotrophic Lake Systems** have evolved to function with relatively low nutrient inputs and concentrations of nutrients. Such systems are susceptible to anthropogenic eutrophication.

Understanding of how water management activities and lake stages are linked to the ecological aspects of the lake is needed to answer many critical science restoration questions. These questions include, but are not limited to, the determination of the current and potential spatial extent of SAV, elucidation of the factors controlling phytoplankton growth, evaluation of quality and abundance of fish foraging and spawning habitat, determination of the distribution and ecological success of shoreline and interior marsh vegetation, and prediction of the spread of invasive species (e.g., *Melaleuca*). The ecology of the areas downstream from Lake Okeechobee is heavily influenced by the lake's water management activities. Large volumes of freshwater discharges from Lake Okeechobee can reduce the salinity, increase the turbidity of nearby estuaries (see Northern Estuaries module for further details), damage feeding and nesting habitats for wading birds, and carry excessive nutrient loads to otherwise oligotrophic wetlands and coastal ecosystems of the South Florida Ecosystem.

Approximately 80 non-native plant species and over 100 non-native animal species have been documented in Lake Okeechobee. The vast majority of exotic control efforts on the lake have been focused on exotic plants including: *Melaleuca*, torpedo grass, alligator weed, and water hyacinth. Cattail, though not strictly an exotic is also the subject of routine control efforts because of its rapid spread and displacement of communities of more desirable emergent species. Nearly all the *Melaleuca* on the lake have been eliminated and the current practice is to do maintenance control of seedlings only. Annually, 4000 or more acres of torpedograss have been treated during the last several years. Estimates are that at its peak in 2002, more than 25,000 acres were invaded by this plant. Current estimates suggest that there are still approximately 10,000 acres of torpedograss within the lake. Water hyacinth, and occasionally water lettuce, treatments have been relatively effective and appear to be at maintenance control levels, and treatments are now typically in response to obstructions to navigation. Over the past several years, 1000-2000 acres of cattail have been treated annually [in separate programs by the South Florida Water Management District (SFWMD) and the Florida Fish and Wildlife Commission Conservation (FFWCC)] to encourage the restoration of more desirable native vegetation.

■ **Lake Okeechobee Gaps.** During the last ten years, scientists working in Lake Okeechobee have made significant advances in understanding the lake ecosystem structure and function, and its response to anthropogenic and natural disturbances. Some of this progress is the result of efforts to develop and implement the 1997 Surface Water Improvement and Management (SWIM) plan for the lake (SFWMD 1997), and the Lake Okeechobee Protection Plan (SFWMD et al. 2004). Examples of current efforts for Lake Okeechobee include Lake Okeechobee Algal Bloom Monitoring Program and the Water Quality Monitoring Program, both by the SFWMD.

The review of the identified needs and the ongoing science programs resulted in the identification of the five gaps listed below.

LAKE OKEECHOBEE GAPS

✓ There is insufficient information regarding how restoration and water management activities particularly those related to extreme lake stages, (high/low, duration, frequency and timing) affect the lake's communities, including submerged and emergent aquatic vegetation and associated fauna.

✓ The resolution and detail of the bathymetric information available for Lake Okeechobee and its littoral zone are insufficient to assess the impacts of lake management and storms.

✓ There is insufficient information to evaluate the effects that lake management activities and storms will have on:

- Re-suspension and movement of nutrients.
- Nitrogen dynamics under current conditions, and when phosphorous levels reach restoration goals.

LAKE OKEECHOBEE GAPS
• Changes on the species composition of the submerged and emergent marsh community.
✓ There is insufficient information to understand the linkage between the primary producers and the structure of the upper level trophic constituents, and the effects of water management on that linkage.
✓ There is insufficient information to understand if exotic species management activities are affecting non-target elements of the lake's ecosystem flora and fauna.

Two gaps address the lack of clear understanding of how lake stages affect the critical plants and animal communities of the lake. Particularly important is developing an accurate representation of the lake's bathymetry and littoral zone to support understanding of how the lake stages and storms affect the deep and shallow water habitats.

Another gap focuses on the monitoring and evaluation of nutrients and associated sediments not currently addressed by the ongoing water quality programs. A significant aspect of this gap is the lack of understanding of how nitrogen dynamics will be affected when the phosphorus levels reach desired targets. It is unknown whether nitrogen could emerge as a new nutrient problem, destabilizing the lake ecosystem once phosphorous levels are controlled.

Another gap addresses the lack of understanding of the relationship among the lake's primary producers (e.g., littoral vegetation, SAV, phytoplankton) and upper trophic levels like fish, alligators, and raptors, and how these relationships can be affected by restoration activities. For example, littoral plants provide important habitat for wading birds, migratory species, and fish.

The last gap addresses the need for a greater understanding of how to improve the control of invasive species. Significant progress has been achieved in the control of various exotic plants using herbicides, but these controls may be also impacting native vegetation. A Lake Okeechobee exotic species plan (SFWMD et al. 2003) was developed that identifies the main species of concern and recommends actions for control. The plan needs to be further refined to address selective control of exotics while evaluating the effects on non-target species.

■ **Lake Okeechobee Tasks.** The analysis of the identified five gaps for the Lake Okeechobee Regional Module resulted in the four Tasks listed below. The tasks identified for Lake Okeechobee require the review of the existing plans (i.e., LOPP and SWIM), and the updates of the plans when the gap identified is not addressed in the plans.

LAKE OKEECHOBEE TASKS
✓ Review existing science plans for Lake Okeechobee (e.g., LOPP, SWIM) to verify that identified lake stage gaps are addressed by the plans. If they are not addressed, develop a science plan to address lake-stage research gaps in Lake Okeechobee.
✓ Review existing Lake Okeechobee science plans (e.g., LOPP, SWIM) and determine if nutrient research gaps are addressed by the plans. If they are not addressed, develop a science plan to address nutrient research gaps in Lake Okeechobee.
✓ Review, modify, and update the CERP MAP to ensure that funding and projects exist to map sediments every decade and after every major storm.
✓ Review existing science plans for Lake Okeechobee (e.g., LOPP, SWIM) to verify that identified exotic and nuisance species gaps are addressed by the plans. If they are not addressed, develop a science plan to address exotic and nuisance species research gaps in Lake Okeechobee.

3.4.2 Northern Estuaries Regional Module Needs, Gaps, and Tasks

The Northern Estuaries regional module includes the areas represented by the CEMs for the Caloosahatchee Estuary (Barnes 2005), St. Lucie Estuary and Indian River Lagoon (Sime 2005), Loxahatchee Watershed (Vanarman et al. 2005) and Lake Worth Lagoon (Crigger et al. 2005). These estuaries provide important habitat for commercial and recreational fisheries, and are currently being impacted by unnatural freshwater inflows, habitat loss, and poor water quality. Regulated freshwater releases from Lake Okeechobee result in abnormal and extreme salinity fluctuations in the St. Lucie Estuary and Indian River Lagoon, Loxahatchee Watershed, Lake Worth Lagoon and Caloosahatchee Estuary.

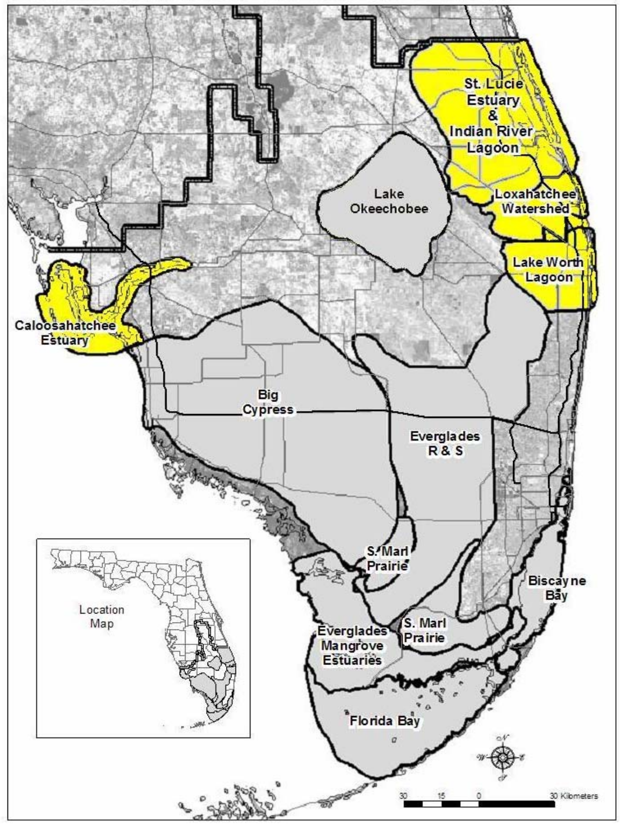

Figure 6. Northern Estuaries CEM Region

The Caloosahatchee Estuary on Florida's west coast connects with Lake Okeechobee through the Caloosahatchee River. This estuary and river system has been reconfigured and stabilized by navigation, irrigation, and drainage canals, and associated lock and dam structures to control river flow and water stages. Estuarine habitats have been correspondingly affected by changes in hydrology, nutrients, and salinity.

The St. Lucie Estuary is a large brackish body of water adjacent to the south end of the Indian River Lagoon. The St. Lucie Estuary connects to Lake Okeechobee through the St. Lucie Canal. The Indian River Lagoon is a coastal lagoon with high species diversity. The lagoon also receives freshwater discharges from various creeks and canals. Drainage canals built to support urban and agricultural growth have increased the watershed of this estuarine system. St. Lucie Estuary and Indian River Lagoon have been subjected to extreme changes in timing and volume of freshwater discharges, and reduction in water quality resulting from water management practices and land use development.

Loxahatchee Watershed, south of the St. Lucie Inlet, was a large system of inland wetlands that slowly drained through the Loxahatchee Estuary and Indian River Lagoon. The system has been modified by dredging of the river and estuary, urban development, and now it mostly drains through the Jupiter Inlet. The present hydrology enables saltwater intrusion that has negatively affected the freshwater wetland vegetation community.

Lake Worth Lagoon is an estuarine system south of the Loxahatchee Watershed. Originally a freshwater coastal lagoon, the system changed to a more estuarine system as result of multiple modifications during the last 100 years, including the opening and stabilization of inlets and completion of the Atlantic Intracoastal Waterway. In addition, the lagoon is surrounded by highly developed urban areas, which increased anthropogenic influences such as urban runoff and associated contaminants (e.g., metals, EPOCs). Major freshwater discharges from multiple canals that drain into the lagoon affect the lagoon ecosystem as well as the adjacent communities of the continental reef system via the lagoon inlet.

It is hypothesized that hydrological alterations and existing water management practices have severely impacted the northern estuaries' dominant communities (i.e., oysters, fish, SAV, and benthic infauna). These impacts can be direct (e.g., salinity changes, flooding, droughts) or indirect (e.g., modifying sediment composition and deposition rates, influencing transport and biogeochemical cycling of contaminants). Another aspect of changes of freshwater flows is the response that manatees may have to changes on the outflow sources of freshwater. Manatees are frequently observed in or near freshwater sources, and changes in the timing, volume, and spatial distribution of freshwater discharge could affect the distribution of manatees by promoting their distribution away from the canals (where they face increased risks of boat collisions and entrapment in water control structures) to coastal creeks.

Sea-level rise and possible concurrent changes in the intensity, frequency, timing, and distribution of tropical storms may have considerable impacts on coastal wetlands. Persistence of these wetlands relies on the interactions of climate and anthropogenic effects, particularly how people respond to sea-level rise and its possible effects on CERP restoration activities. Long-term changes in sea level and storms will likely affect biotic functions, such as biodiversity, as well as underlying ecological processes such as nutrient cycling and productivity. Dependable predictions of climate change on Everglade's coastal wetlands requires a better understanding of the linkages among the ecological, climatological, and human constituents and how they interact (Michener et al. 1997).

Oysters

Oysters are benthic filter feeders that, in large number, can improve water quality, and develop large reefs that provide habitat for many organisms. The oysters of the Northern Estuaries are susceptible to adverse effects from major freshwater flows that drastically reduce the estuaries' salinity and increase the amount of suspended sediments. Not currently as much of a problem in the Northern Estuaries, but worth noting, is that excessively high salinities can provide conditions conducive to increased levels of disease and predation of oysters. These stressors affect the oyster population by reducing reproductive success and overall health, increasing death due to predation and sudden mortality caused by extreme and long-term low salinity events. Furthermore, sediment accumulation also reduces the habitat suitable for the settlement of oyster larvae.

Fish

Reduction in water quality caused by freshwater discharges from water management activities affects the fish from the Northern Estuaries. This reduction in water quality includes decreases in dissolved oxygen and increases in nutrients and suspended sediments. Excess nutrients have been associated with the incidence of harmful algal blooms (HAB), which are known to cause fish mortality. Drastic changes in salinity and deposition of anoxic muck-type sediments can also negatively affect the fish populations of the Northern Estuaries. Anoxic sediments do not support healthy communities of invertebrates that are important prey of many species of estuarine fishes.

SAV

The SAV of the Northern Estuaries provide important habitat for fish and other estuarine fauna. A decrease in the spatial extent and functionality of SAV from the Northern Estuaries has been attributed to degradation on water quality (e.g., decreased water transparency), displacement of natural sand dominated substrate by fine silt and clay sediments, and overgrowth by epiphytes. SAV loss has the concomitant effect of decreasing the suitable habitat available for the successful recruitment of larval and adult fish, and other SAV associated fauna.

Benthic Infaunal Communities

Benthic infaunal communities are a very important, and sometimes overlooked, component of the Northern Estuaries. They are food sources for many fish and bird species, and through the process of bioturbation, mix sediments, which improve the quality of benthic habitats and the biogeochemical cycling of nutrients across the boundary between the bottom sediments and overlaying waters. Like other communities in the Northern Estuaries, benthic communities can be displaced by drastic reduction in salinity caused by the freshwater released from water management practices. Excessive organic content associated with sediments that may be entrained with the freshwater can cause anoxic conditions that stress the benthic infaunal community, lower production, and impact other communities (e.g., fish and wading birds).

■ **Northern Estuaries Needs.** The review of the major hypotheses for the Northern Estuaries resulted in the identification of the four science needs listed below. These needs focus on elucidating the spatial and temporal distribution of major components of the Northern Estuaries; effects from water quality, salinity, and contaminants on the Northern Estuarine major communities; and effects from stressors such as how excess nutrients affect the environmental health events of the system.

NORTHERN ESTUARIES NEEDS

✓ To understand and characterize the current and historical spatial distribution, conditions, and ecological relationships within and among Northern Estuaries':

- Submerged substrates.
- SAV.
- Associated benthos.
- Oysters.
- Fish.

✓ To understand how changes in water quality and salinity associated with restoration activities and natural events (e.g., storms) affect the Northern Estuaries':

- SAV and associated epibionts.
- Associated benthos.
- Oysters.
- Fish.
- Coral reefs.
- Nursery function.

NORTHERN ESTUARIES NEEDS
✓ To understand how restoration activities that influence the transport, biogeochemical cycling and ultimate fate of contaminants, such as pesticides, heavy metals, and EPOCs, affect the Northern Estuaries': • SAV. • Associated benthos. • Oysters. • Fish. • Coral reefs. • Nursery function.
✓ To understand how changes in hydropatterns and associated stressors (e.g., excess nutrients, EPOCs) relate to detrimental environmental health events in the Northern Estuaries, such as harmful algal blooms and fish abnormalities (e.g., lesions).

To properly manage and restore the Northern Estuaries requires a sound understanding of the existing and historical spatial distribution of the dominant ecological communities and associated benthic habitats, the ecological relationships among the communities, and the natural and anthropogenic conditions that foster or jeopardize their ecological success. It is important to note that the word "historical" in the Northern Estuaries does not mean that setting targets based on a period prior to any anthropogenic effects. Large scale changes, such as opening and stabilizing connections to the ocean, permanently changed the nature of these water bodies, several of which used to be freshwater dominated systems with little to no real estuarine zones. The targets for the Northern Estuaries are based on restoring and maintaining a healthy, functioning estuarine ecosystem.

The first need addresses the requirement to understand and characterize current and historical spatial distribution of the dominant communities (e.g., SAV, oysters, fish), associated benthos, and submerged substrates. This understanding will provide objective information on the stage of degradation of the ecosystem. With a clear understanding of the ecological relationships among the communities within the Northern Estuaries, resource managers (with Task Force support and coordination) will be able to support the establishment of realistic and achievable restorations goals for the region, and to assess the progress of the restoration activities.

The second need focuses on the understanding required to evaluate the impact on water quality and salinity of the Northern Estuarine and continental shelf community, resulting from water management and natural events. Acquiring this understanding will allow scientist to differentiate and assess natural and anthropogenic influences, and provide information to evaluate the effectiveness of the restorations activities.

Another need identified for the Northern Estuaries module is to understand how water management activities, including restoration activities, associated with new water storage facilities, will affect contaminant impacts in the Northern Estuaries communities. The impact of a contaminant depends on its transport, fate, and toxicity to a particular organism, which is usually correlated to the mode and length of exposure. Restoration activities will change the distribution, timing, and volumes, and therefore it is expected will cause variations in the exposure to potential contaminants.

The last need identified for the Northern Estuaries focuses on understanding relationships and linkages of environmental stressors to environmental health events. This need is different from the previous need addressing contaminants because the effects are not related to the toxicity of a contaminant or agent, but how a stressor, which could be a biological or chemical agent, may compromise the health of the ecosystem (e.g., a nutrient or chemical that may promote the development of infectious virus or bacteria).

■ **Northern Estuaries Gaps.** Over the last five years, significant efforts have been made to improve the level of scientific understanding of the major ecological processes of the Northern Estuaries and the impact water management and restoration activities may have on the system. Examples of these efforts include the *Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan* (SJRWMD and SFWMD 2002), the *Indian River Lagoon South Feasibility Study* (USACE and SFWMD 2003), Northern Estuary Module of the CERP MAP (RECOVER 2004), and the 2006 RECOVER System Status Report (August 2006 draft). However, compared with other regions of the South Florida Ecosystem, the Northern Estuaries coordinated science programs are less mature and cohesive.

SCG members and scientists with direct working experience with the ongoing research, monitoring, and modeling programs for the Southern Estuaries identified the following 11 gaps.

NORTHERN ESTUARIES GAPS

✓ Current monitoring programs are insufficient with respect to appropriate metrics, scale of the present metrics, and effectively assessing the species-specific spatial extent and geo-referenced locations of SAV in the Northern Estuaries, and the temporal and spatial changes in SAV that occur in relation to:

- Photosynthetically active radiation (PAR) and light fractionation.
- Water quality.
- Salinity.
- Suitable substrate.
- Sediment dynamics.

✓ The functionality and dependencies of estuarine faunal associations with SAV communities are not well characterized, including how their relationships with SAV species are affected by the Northern Estuaries water quality and salinity.

✓ Additional species-specific SAV models are needed for predicting and assessing the effects of water management and restoration activities in all Northern Estuaries.

✓ The existing oyster model does not cover the east coast estuaries. Oyster models are needed for predicting and assessing the effects of water management and restoration activities in all Northern Estuaries.

✓ The current interim goal for oysters in the Northern Estuaries addresses only magnitude of spatial dimension (i.e., acres of oysters) and does not include other relevant ecosystem information that is currently being collected in the Northern Estuaries-wide monitoring program such as:

- Reproductive success.
- Abundance and population size classes.
- Health.
- Predation.
- Population growth/decline rates.

NORTHERN ESTUARIES GAPS
✓ There is insufficient understanding and prognosis of how estuarine communities, including oyster communities, respond and are affected by the fate, transport, and bioaccumulation of contaminants (e.g., pesticides, metals, and EPOCs), and sediments.
✓ Mapping and fish monitoring programs that relate fish and other aquatic fauna habitats to high-resolution bathymetry and bottom classification of the Northern Estuaries are not available.
✓ A comprehensive benthic monitoring program for the Northern Estuaries that includes sampling in seagrass beds, such as the one for St. Lucie, is not available.
✓ The contaminants (e.g., pesticides, metals, and EPOCs) of the Northern Estuaries are not well characterized, and their role and effects, particularly as they relate to restoration activities, are not fully understood.
✓ The effects that multiple chronic stressors have on fish are not understood in the Northern Estuaries; specifically, there is a lack of information on how these stressors relate to abnormalities (e.g., diseases, tumors, lesions, etc.) and to the freshwater discharges.
✓ The relationship between red tides, harmful algal blooms, and changes in hydropatterns and nutrient dynamics because of restoration activities is not well understood.

Five of the 11 gaps identified enhancements, expansion, or creation of monitoring and mapping programs for SAV, oysters, fish, and benthic communities. This points to an area within the ongoing science efforts that needs to be addressed in a coordinated way to avoid duplicity of efforts and to maximize use of available human capacity and limited funding resources. For example, monitoring for water quality, salinity, and other physical parameters needs to be modified to be able to correlate water management activities with current and future changes in the spatial extent and conditions of SAV, oysters, fish, and benthos. The ongoing efforts and information currently available are not sufficient for the assessment of changes in these communities that may result from restorations activities.

Another gap identifies the requirement for a functional assessment of SAV including the characterization of epifauna, epiflora, and benthic communities coexisting with SAV; and the linkage between species diversity, density, and composition; and SAV-dependent fisheries. This gap is related to the previously mentioned monitoring and mapping gaps, because it will first require, an understanding of the spatial extent and conditions of the SAV to ensure that the sampling design for the characterization of the epifauna, epiflora, and benthic community is representative. Linkages between fisheries and the sessile-habitat indictor species (e.g., SAV and oyster) and benthic monitoring needs increased understanding.

A species-specific SAV modeling gap was identified for the evaluation of restoration activities. This gap also relates to the monitoring and mapping gaps previously identified. Models will allow the evaluation of restoration impacts to SAV under different scenarios; however, development and validation of models requires robust information on the condition of the SAV and the factors that affect them.

Four other gaps identified for the Northern Estuaries address the lack of understanding that contaminants and environmental stressors may have on the health of the ecosystem.

Contaminants, such as mercury and pesticides, are known to occur in the waters of the Northern Estuaries. Occurrence of some of these contaminants is associated with urban and agricultural practices occurring on the system's watershed. However, the presence, magnitude, and effect of these contaminants have not been well characterized, which compromises the prognosis of the effects contaminants may have on the ecosystem as result of restoration. In addition, other stressors, such as nutrients or biological agents (e.g., viruses), may cause degradation of ecosystem health by promoting undesirable conditions. For example, excess nutrients have been identified as a potential factor promoting the occurrence of harmful algal blooms (Carpenter et al. 1998). Multiple stressors may occur in the system with unknown synergistic effects. These stressors need to be characterized, and the relationship with changes in hydropatterns has to be established to evaluate how they may be affected by restoration. Since the lesion outbreak in the St. Lucie Estuary in 1998, research conducted by the Florida Fish and Wildlife Conservation Commission (FWC) has implicated the water mold *Aphanomyces invadans* as a significant cause of lesions in Florida estuarine and freshwater fish. *Aphanomyces invadans* has been found to be the causative agent of lesion on estuarine fish along the eastern seaboard of the United States and in Southeast Asia, Japan, and Australia. Infections by this organism in other geographic areas have been termed "ulcerative mycosis," "epizootic ulcerative syndrome," "mycotic granulomatosis," and "red spot disease." Ulcerated estuarine fish have been collected in coastal areas throughout Florida. Scientists at FWC's Fish and Wildlife Research Institute (FWRI) were able to successfully identify *Aphanomyces invadans* from lesions on fish from the St. Lucie estuary, the Caloosahatchee River, Lake Teneroc (Hydrilla Lake), the Orange River, the Tomoka River, Tampa Bay, Cedar Key, and the Choctawhatchee River (see: http://research.myfwc.com/features/view_article.asp?id=25293).

■ **Northern Estuaries Tasks.** The SCG and scientists with experience with the Northern Estuaries recommended the 20 tasks listed below to address the previously identified gaps. The large number of tasks identified for this module reflects the relatively less mature science programs for the Northern Estuaries, when compared with the longer established science programs in other regions of the South Florida Ecosystem. Some of the actions have similar goals and requirements for various components of the ecosystem (e.g., modeling, monitoring, mapping), and when possible, those tasks should be addressed together to promote their coordination.

NORTHERN ESTUARIES TASKS
✓ Develop a multi-scalar sampling approach to SAV mapping in the Northern Estuaries that defines the appropriate scales of resolution necessary to support the assessment hypotheses.
✓ Develop a continuous monitoring program for water quality (WQ), salinity and physical parameters (e.g., sediments, PAR, light attenuation) at the appropriate spatial and temporal scale to support species-specific spatial extent of SAV in the Northern Estuaries as part of the RECOVER MAP.
✓ Develop species-specific SAV maps and identify the relationships between SAV species and infaunal communities to WQ and salinity.
✓ Map and characterize the extent of suitable SAV substrate in the Northern Estuaries, including defining how the suitability of any area may change over time.
✓ Develop remote sensing spectral signatures for seagrasses.

NORTHERN ESTUARIES TASKS
✓ Identify what species of epiflora and epifauna (trophic links) inhabit different types of SAV beds/communities.
✓ Develop species-specific SAV models that can be applied to selected water bodies in the Northern Estuaries.
✓ Develop WQ models that include a sediment transport component that is complete, calibrated, and useful for making predictions in the Northern Estuaries.
✓ Develop an oyster mapping program that incorporates clarified oyster goals into the oyster monitoring efforts to include distribution, abundance and other components, in addition to the spatial magnitude (i.e., acres), and revise the RECOVER MAP to include oyster mapping.
✓ Develop a continuous WQ and contaminant monitoring program, in coordination with NOAA Coastal Ocean Observing System (COOS) program, to provide the data for assessing oyster hypotheses.
✓ Develop critical salinity targets for the various life stages of the oyster (e.g., impacts of low salinities during spawning, spat formation, or larval stages) in relation to restoration.
✓ Develop a monitoring program for the communities associated with the oyster reefs in order to understand the ecological relationships among oysters, benthos, and finfish.
✓ Develop bathymetric maps that support investigation of bottom type and fish/fauna population dynamics.
✓ Adapt existing fish monitoring techniques to develop a long-term continuous fish monitoring program (i.e., sonar for fish identification, etc.).
✓ Implement benthic monitoring in the seagrass beds, in addition to the sampling that is already occurring in the soft sediment environments.
✓ Implement benthic sampling across the Northern Estuaries beyond the current sampling being done in St. Lucie Estuary and Loxahatchee.
✓ Develop a program to understand the role of multiple stressors on fish over time in the Northern Estuaries; specifically, how these stressors relate to abnormalities (e.g., disease, lesions, etc.) and the relationship of these abnormalities to the freshwater discharges.
✓ Evaluate contaminant research, monitoring, and modeling efforts to identify and describe the relevant contaminants of the Northern Estuaries and their relation with restoration activities.
✓ Research/determine effects of nutrient loading and other external drivers that control the occurrence of red tides and other harmful algal blooms.
✓ Develop a research program that adequately includes components to allow comparison between current and historical assessments of the Northern Estuaries.

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3.4.3 Greater Everglades Regional Module Needs, Gaps, and Tasks

The Greater Everglades regional module includes the areas represented by the CEMs for the Everglades Ridge and Slough (Ogden 2005), Southern Marl Prairies (Davis et al. 2005a), Big Cypress Regional Ecosystem (Duever 2005), and Everglades Mangrove Estuaries (Davis et al. 2005b). This module, located centrally within the South Florida Ecosystem, links the Northern Estuaries and Lake Okeechobee regions with the Southern Estuaries Region.

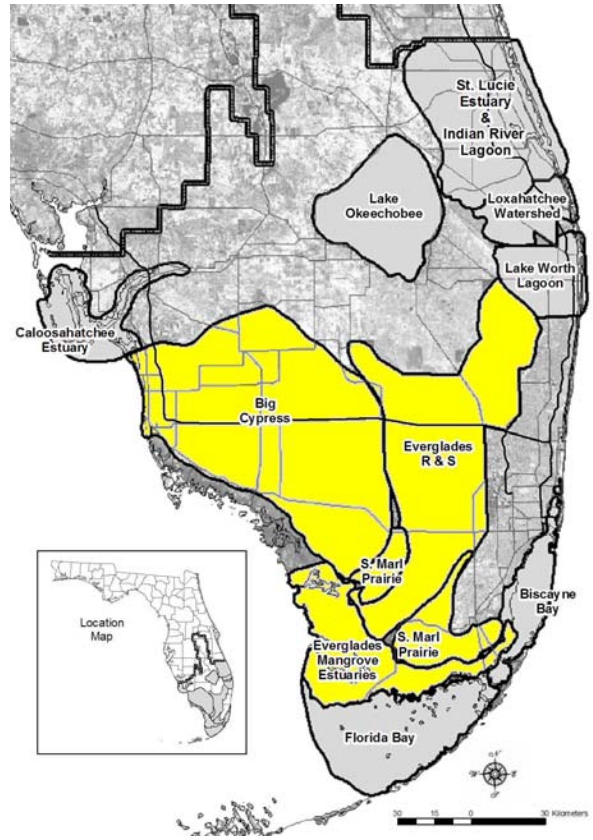

Figure 7. Greater Everglades CEM Region

Before the implementation of the C&SF Project, the Everglades Ridge and Slough region consisted of a freshwater marsh of alternating sawgrass ridges and sloughs, and discreet tree islands. The region was characterized by long hydroperiods, low velocity sheet flow, low nutrient waters, and moderate to deep organic soils. This was the dominant landscape pattern in the Greater Everglades and supported a large number of wading birds and alligators. The current system is one that has experienced reduction in spatial extent, increased nutrient loading that degrades water quality, reduction in natural water storage capacity, compartmentalization into hydrologically independent sub-regions, and invasion by exotics species (Ogden 2005).

The Southern Marl Prairies consist of a mosaic of wet prairies, sawgrass, tree islands, and tropical hammock communities with a high diversity of plant species. This region is located on both sides of the southern portion of the Everglades Ridge and Slough. It has predominantly higher elevations than the Everglades Ridge and Slough, and its substrate consists of marl or exposed limestone bedrock. Because of the higher elevation, water level frequently drops to below ground levels in the Southern Marl Prairies. During dry seasons, the Southern Marl Prairies fauna find refuge in alligator holes, solution holes, and adjacent sloughs (Davis et al. 2005a).

The Big Cypress region, located on the west side of the Greater Everglades, is composed of a mix of forested wetlands, marshes, wet prairies, and upland pinewoods and hammocks. The region ranges from fairly undisturbed areas of the Big Cypress National Preserve to more developed areas of the coastal ridge from Fort Myers to Naples. Forest comprises the dominant communities of the Big Cypress. Area hydrology and fire regime are major factors regulating the natural system. Excess nutrients, invasive species, and land fragmentation are some of the major factors affecting the Big Cypress region (Duever 2005).

The Everglades Mangrove Estuaries region is an ecological transition zone that separates the Southern Biscayne Bay, Florida Bay, and the Gulf of Mexico from the freshwater Everglades (Davis et al. 2005b). The region is characterized by annual fluctuations in salinity gradient that may play an important role in the biochemical transformation of constituents as they flow from the Greater Everglades to the estuarine regions.

The dominant hypotheses for this region address: (1) integrated hydrology and water quality; (2) coastal transgression, including tidal channel characteristics, salinity gradients, and mangrove forest productivity; (3) wetland landscape and plant community dynamics; (4) wading bird predator/prey interactions; and (5) Everglades' crocodilian populations.

Integrated Hydrology and Water Quality

Before the C&SF project, the hydrology and water quality of the Greater Everglades region was characterized by slow sheet flow of low nutrient water from the Lake Okeechobee region and local rainfall that moved across the Everglades Ridge and Slough, and Marl Prairie, eventually discharging across the coastal mangroves of the Southern Estuaries (Davis and Ogden 1994). Today, man-made structures such as canals from Lake Okeechobee, roads, and levees transverse the region and fragment the landscape and the extent, volume and timing of the sheet flow. These obstructions to flow also result in artificial ponding of deep water and overdrainage across large areas. The Greater Everglades region now frequently experiences unnatural episodes of flooding and droughts, which impaired the functionality, and productivity of the ecosystem. In addition, excess nutrients, particularly phosphorous from agricultural runoff, are present in the water that flows through the Greater Everglades. The high nutrient waters have degraded the water quality, affecting the plant and animal communities inhabiting the area. Contaminants, such as mercury (NAS 2005) and sulfates/sulfides, are also found in the Greater Everglades waters exacerbating the regions water quality impacts.

Coastal Transgression, Tidal Channel Characteristics, Salinity Gradients, and Mangrove Forest Productivity

As freshwater from the Greater Everglades region transverses the coastal mangrove regions, it mixes with the more saline coastal water resulting in a salinity gradient vital for the many estuarine species. This ecotone is the site for many biogeochemical transformations (e.g., changes in nutrients) that are important for the communities of the mangrove system and adjacent estuarine and coastal waters. The volume and quality of the freshwater currently flowing across the mangroves and the aerial extent of this ecotone are greatly influenced by the water management practices that occur upstream, and are the result of the balance between the freshwater sheet-flow and sea-level of the coastal zone. The aerial extent and salinity regime of this ecotone are also likely to be affected by sea-level rise (Michener et al. 1997). During the past century, the sea level has risen at a rate of 3.0 mm per year. Recent climatic research has suggested this will increase to about 10.0 mm per year in the next decade or so (Overpeck et al. 2006). With such dramatic increases expected, it is likely that seawater may transgress the shoreline and intrude across the mangrove region and into the freshwater wetlands of the Greater Everglades. Long-term changes in sea level and storms will likely affect biotic functions such as biodiversity, as well as underlying ecological processes such as nutrient cycling and productivity. Dependable predictions of climate change on Everglades' coastal wetlands require a better understanding of the linkages and interactions among the ecological, climatological, and human constituents (Michener et al. 1997).

Wetland Landscape and Plant Community Dynamics

The hydrology, ecological connectivity, fire regimes, and nutrient cycles of the Greater Everglades affect plant community dynamics and regulate organic soil accretion rates. Increases or decreases in the rate of organic soil accretion are a function of the organic matter produced by plants and periphyton, oxidation, and combustion processes, and the distribution of sediments as influenced by water flow. Soil accretion alters the micro-topography of the region, introducing spatial heterogeneity, which in turn promotes the formation of the ridge and slough systems and tree islands. Overland flow also affects soil accretion rates through sediment transport. The heterogeneity in localized, microtopographic gradients as modified by the processes described above, increases the diversity of available habitat, and promotes the region's high species richness. Changes in plant communities can also have severe impacts on the landscape. For example, alterations in plant community composition can result in an increase in abundance of high-intensity burning plants, which can increase the intensity and frequency of fires. High intensity fires can scorch organic soils affecting the landscape patterning and the communities these soils can support.

Wading Bird Predator Prey Interactions

Large nesting colonies of wading birds were a dominant biological feature of the Greater Everglades region. Their presence is hypothesized to be related to the availability of aquatic prey. The density, distribution, and relative abundance of prey have been affected by the altered hydrology, which in turn, has caused significant reduction of the wading bird nesting colonies. The altered hydrology also affects the formation of floating periphyton mats, which provides food and habitat for the invertebrates that support the wading birds' food web.

Everglades Crocodilian Populations

The distribution, population, and reproduction of the population of American alligator, a top predator of the greater Everglades ecosystem, are related to the hydrology and salinity of the system. The modified hydrology of the system has affected the density of the population in some areas of the system, and has resulted in movement of alligators to less optimal areas like canals. However, protective measures implemented during the past four decades have resulted in an increase and improvement in the alligator populations.

■ **Greater Everglades Needs.** The review of the major hypotheses for the Greater Everglades Regional Module resulted in the identification of the four science needs listed below. These needs focus on the links among water management, restoration activities, and natural events (e.g., hydrology of the system, nutrients, plant dynamics, fire, and wading bird interaction).

GREATER EVERGLADES NEEDS

- ✓ To understand and predict the interactive effects that water management, restoration activities, and natural events (e.g., variability in rainfall and temperature, hurricanes, and sea-level rise) have on the hydrologic cycles and water quality of the Greater Everglades.
- ✓ To understand and determine how the biota, soil, and peat dynamics of the Greater Everglades are affected by and interact with biogeochemical cycles, including the transport and ultimate fate of sediments, contaminants, and nutrients.
- ✓ To understand and determine how hydrology, fire events, and substrates in the Greater Everglades interact with vegetation and soil dynamics to create and maintain the ridge and slough, short-hydroperiod wetlands, mangrove communities, and tree island systems.

GREATER EVERGLADES NEEDS

✓ To understand and determine how the hydrology and primary production in the Greater Everglades ecosystem affect the predator-prey interactions of wading birds and aquatic fauna forage base, including:

- Formation of super colonies.
- High density prey patches.
- Crayfish dynamics.
- Periphyton production.

The first need focuses on an understanding of the hydrology of the current system as it relates to water management, restoration, and natural events. Hydrology is the dominant factor controlling the ecology and determining the basic character of the Greater Everglades. The ability to predict the effects of water management, restoration, and natural events on the system requires a thorough understanding of the factors controlling water depths, hydroperiods, and surface and groundwater flow patterns observed in the current system.

The second need focuses on the oligotrophic nature of the system and how changes in biogeochemical cycling of nutrients and contaminants (e.g., mercury) in the soil and water column may affect the Everglades biota. For example, the Greater Everglades ecosystem has evolved in and adapted to low nutrient conditions. Increasing nutrients such as phosphorus and nitrogen in the system leads to changes in vegetation composition and dynamics, trophic interactions, and changes in organic soil physio-chemical properties and accretion rates. Because of the current high nutrient levels observed in parts of the system, it is imperative that the transport and fate of nutrients and contaminants within and across the systems are understood. Hydrologic connectivity between the freshwater marshes and the coastal zones indicates that any changes in nutrients or contaminant status in the inland areas may also affect downstream estuarine and marine communities.

The third need focuses on understanding the dynamic equilibrium that exists between vegetation, hydrology, fire, and soils, which results in the formation and maintenance of ridge and slough, short-hydroperiod wetlands, and tree islands. For example, plant communities in the Greater Everglades are controlled largely by ecosystem drivers such as hydrology and fire. However, plant communities can themselves modify the landscape by influencing surface-water flow rates and evapotranspiration, modifying intensity and frequency of fire events, and changing the geomorphology of the system by controlling the accretion rate of organic soils. The balance among formation and accretion, erosion, oxidation and combustion of organic soils is crucial in determining the micro-topography and habitat value of the ridge and slough, and the tree island mosaic. Plants also provide food and habitat to higher trophic levels. Without an understanding of the dynamic interactions between plant communities and ecosystem drivers across the landscape, there is a risk that restoration efforts will not have a holistic approach, instead be piecemeal, and management will be reactive. Therefore, understanding the dynamics of plants in the Greater Everglades is required for the successful evaluation of restoration.

The last need addresses the understanding of the wading bird-prey dynamics. These dynamics include factors that control the density, availability, and quality of the prey, and how these factors are affected by water management and restoration activities. A healthy population of wading birds is a desired attribute of the Greater Everglades. Restoration actions must take into consideration how they affect the prey base, because this is thought to be a major factor regulating the population success of wading birds.

■ **Greater Everglades Gaps.** Several academic institutions (e.g., Florida Atlantic University, Florida International University and University of Florida) and government agencies (ENP, SFWMD, and USGS) have ongoing research, monitoring, and modeling efforts in the Greater Everglades region, including the Critical Ecosystem Studies Initiative of the ENP. During the last 10 years, these efforts have substantially augmented the understanding of the ecological factors operating in the Greater Everglades region.

The review of the identified needs and the ongoing science programs resulted in the identification of the twelve gaps listed below.

GREATER EVERGLADES GAPS
✓ The current monitoring and research programs are insufficient to characterize and understand the hydrological and water quality relationships throughout the Greater Everglades at a spatial and temporal scale that is relevant to both restoration assessments and biological investigations.
✓ There is a lack of understanding of the role of extreme events and sea-level rise, and how they will interact with freshwater flows and water management to control the structure and function of coastal ecosystems.
✓ There is a lack of understanding of soil dynamics (e.g., accretion, decomposition, sediment transport) in relation to hydrology and water management, vegetation, and fire in the Greater Everglades.
✓ There is a lack of understanding of the physiological requirements and hydrologic tolerances (e.g., resilience to changes in hydroperiod and depth) of the dominant herbaceous and woody species in the Everglades communities.
✓ There is a lack of understanding of the hydrologic connectivity and nutrient exchanges across tree islands and the surrounding marshes as influenced by tree island geomorphology, soil types, marsh characteristics, and vegetation.
✓ There is a lack an understanding of the role of fire in creating and maintaining landscape patterns and plant communities.
✓ There is a lack of understanding of the pre-drainage landscape processes and characteristics (e.g., soils, vegetation, and hydrology), and trophic interactions.
✓ There is a lack of understanding of the factors controlling the current distribution of native plant and animal species, particularly on tree islands, in short hydroperiod marshes, and in the sloughs.
✓ There is a lack of understanding of the distribution and impacts of exotic and invasive species.
✓ The sources, dynamics, and effects of sulfates and sulfides on the biota of the Greater Everglades that are independent of the interactions with mercury are not well understood.

GREATER EVERGLADES GAPS

- ✓ There is a lack of understanding of the dynamics of nitrogen cycling in the Greater Everglades and the impacts it may have on Florida Bay through freshwater transport.
- ✓ There is a lack of understanding of the aquatic fauna forage base in relation to the formation of super colonies of wading birds, particularly how they use crayfish as prey, and the relative role of periphyton and hydrology as limiting factors for the development of prey base.

The first gap recognizes that even though several research, modeling, and monitoring programs are ongoing, the resolution of the hydrologic and water quality data (e.g., number and frequency of samples, spatial and temporal scales) is not sufficient for robust assessments of restoration actions or biological investigations. This gap refers to the need to quantify, for example, the water budgets of the primary basins in the C&SF domain, overland flow patterns, and trends in water quality (e.g., nutrient status) with respect to water management strategies, landscape features such as roads, and climate. Field assessments of biological processes and trophic interactions frequently require time-series of water depths at spatial scales on the order of 10 m or less. Topographic data at these scales are needed to derive the relevant hydrologic parameters (e.g., hydroperiods) for localized biological investigations using the regional water level recorders. The Everglades Depth Estimation Network, operated by USGS, is beginning to address some of these issues, but the effort must be coordinated and supported over the long term.

In addition, cohesive and comprehensive programs to understand and monitor the effects of extreme events, sea-level rise, and freshwater flows on coastal ecosystems, ridge and slough, short hydroperiod marshes and tree islands have not been developed. Because of the low vertical topographic relief of the Greater Everglades landscape, changes in sea level could have impacts across large portions of the ecosystem. The extent and severity of these impacts are likely to be dependent upon the timing, amount, and distribution of freshwater flows reaching the coast from interior marshes or through managed structures. The mechanisms by which these ecosystem drivers will interact and affect the sediment dynamics, vegetative communities and trophic interactions in the coastal regions is not well understood. In addition, the ridge and slough, short hydroperiod marshes, and tree islands are prominent features of the Greater Everglades landscape but the dynamic equilibrium that exists among these vegetation communities, soil accretion rates, flow patterns, fire, and nutrient cycles is not well understood. Information regarding the physiological requirements, hydrologic tolerances, productivity rates, life history strategies, and seed dispersal mechanisms of the dominant species in these communities is necessary to increase the ability to model succession and to predict how the landscape will change in response to inter-annual variability in climate, hydrology, fire, and restoration. An effort to address this gap includes the Across Trophic Level System Simulation (ATLSS) Program models developed for vegetation succession and fire that incorporate the effects of hydrology (USGS 2004). However, current models do not effectively evaluate changes in plant communities with restoration.

Fire is a major determinant in community structure. A consensus has been reached among resource managers about the dominant role of fire in species succession and plant community structure. As such, fire management is an important component of the ENP resource management activities. However, with the exception of the pineland communities, assessments of areas where natural fires regimes have been suppressed or eliminated have not been conducted. A better understanding of the effects of fire, and the characteristics (i.e., frequency and intensity) of a natural and managed fire regime, is needed so that fire management plans can be developed for the areas where they do not currently exist.

The next gap focuses on the lack of understanding of the ecosystem drivers and stressors in the pre-drainage system that led to community-level characteristics (e.g., species diversity and distribution, productivity, and succession) on tree islands, in short hydroperiod marshes, and in the sloughs. This information is necessary to develop restoration targets for these systems. Comparable datasets from the current managed system are also necessary so that trajectories of change can be predicted under different restoration scenarios. The next gap identifies the lack of understanding in the current distribution and impacts of exotic and invasive species in response to ecosystem drivers and stressors, particularly the stressors derived from human impacts and those that may be affected by restoration.

The next two gaps identify the lack of understanding of the sulfur cycle and nitrogen dynamics in the Greater Everglades marshes and in the downstream estuaries. Sulfur dynamics have been examined previously with respect to mercury cycles and methylation, but the independent effects of sulfides and sulfates on the biota are not well understood. Similarly, while phosphorous cycles have been the subject of investigation over the last several years, little attention has been paid to nitrogen cycles in the Greater Everglades. New information is emerging that indicates the export and form of nitrogen from the inland marshes has implications for the downstream estuarine biogeochemistry.

The last gap identified addresses the current lack of understanding between wading birds population success and prey base, and how the abundance, quality, and availability of prey relate to hydrology and periphyton. Research on components of this science problem is ongoing. However, this understanding has not yet been developed sufficiently to evaluate restoration.

■ **Greater Everglades Tasks.** The analysis of the identified eight gaps for the Greater Everglades Regional Module resulted in the ten tasks listed below.

GREATER EVERGLADES TASKS
✓ Develop an organization similar to the Florida Bay PMC to help coordinate research efforts for the Greater Everglades region.
✓ Coordinate existing ridge and slough, and tree island research addressing interaction of flow patterns, fire, and nutrients.
✓ Implement research that evaluates which parts of the Ridge and Slough and tree island microtopographic system are sustainable, given the current hydroperiod, fire regime, and nutrient conditions in the Greater Everglades.
✓ Support the implementation of monitoring and research (through implementation of the RECOVER MAP) necessary to demonstrate the relationship between and among hydrologic parameters.
✓ Continue to support the Greater Everglades nutrient monitoring and research activities in the RECOVER MAP (e.g., conduct experimental studies in Florida Bay to determine if increased nitrogen is affecting algal blooms).
✓ Expand the research and monitor of sulfates/sulfides and their interactions within the Greater Everglades ecosystem to determine and evaluate their impact (i.e., phytotoxicity) to the ecosystem.

	GREATER EVERGLADES TASKS
✓	Develop a cohesive and comprehensive program that evaluates the effects of relative changes of sea level and freshwater flow on restoration success, including through the use of hydrological models.
✓	Conduct vegetation studies and develop models to evaluate how vegetation community patterns change with hydrologic patterns.
✓	Develop a comprehensive system-wide fire management program for the Everglades to advance the understanding of the role of fire in maintaining landscape patters and plant communities.
✓	Develop a coordinated, comprehensive system-wide program to study the relationships between crayfish population dynamics and wading birds.
✓	Expand existing research to determine the relative role of periphyton and hydrology as limiting factor for the development of the wading birds prey base.

3.4.4 Southern Estuaries Regional Module Needs, Gaps, and Tasks

The RECOVER Southern Estuaries Module includes the regions represented by the Florida Bay (Rudnick et al. 2005) and Biscayne Bay (Browder et al. 2005) CEMs, and the areas of Whitewater Bay and the rivers connecting the Shark River Slough to the Southwest Florida Shelf, which do not have CEMs developed. Upstream water management has lowered groundwater levels (and groundwater input) as well as altered overland flows throughout the Southern Estuaries. Some areas have experienced substantial saltwater intrusion into the shallow aquifer due to the reduction in upstream pressure heads. The distribution and abundance of species like Florida Manatees or oysters, whose distribution is closely coupled to the timing and distribution of freshwater inputs into the estuaries, has noticeably changed even within "natural" or protected areas of the Southern Estuaries.

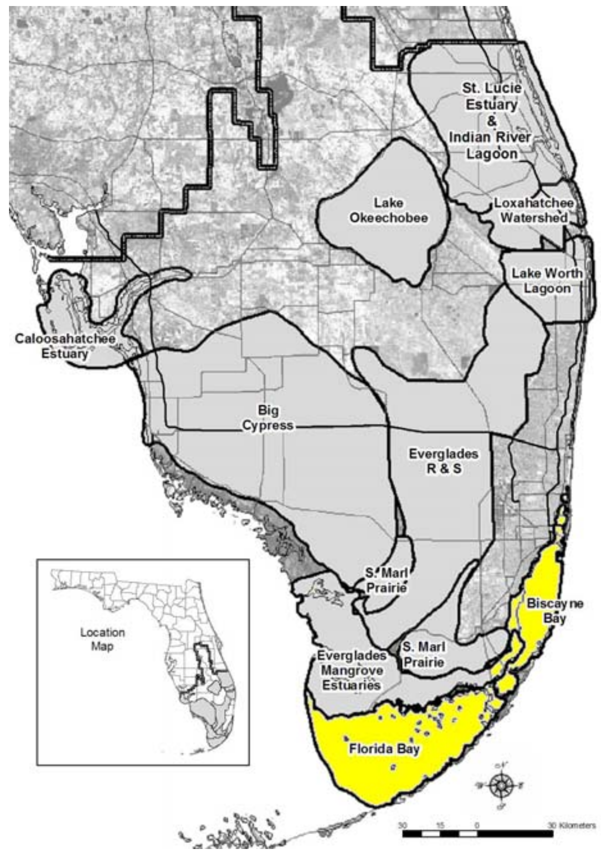

Figure 8. Southern Estuaries CEM Region

Florida Bay is a shallow, triangular bay with an average depth of three feet and an area of 850 square miles. The bay is bordered on the north by the Everglades, on the east by the Florida Keys, and on the west by the Gulf of Mexico. A spatially complex system, the bay is characterized by a diverse array of shallow basins, banks, and islands. Florida Bay provides habitat to many endangered and protected species and migratory birds, and supports important commercial and recreational fisheries resources. Sediments are predominately carbonate mud, which can efficiently sequester phosphorus from the water column influencing the nutrient dynamics of the bay. Numerous influences affect the salinity of the bay, including freshwater inflows from the Everglades, local rainfall and evaporation rates, and the circulation of water within the bay, as well as the exchange of water with the Gulf of Mexico and Atlantic Ocean. The bay can experience rapid and dramatic increases in salinity during periods of low precipitation. Hypersalinity is most frequent and intense in the north-central bay, which is somewhat isolated from both freshwater inflow and oceanic exchange; however, hypersaline conditions sometimes spread to cover most of upper bay (Lee et al. 2002).

During the last century, water management practices have decreased the volume and disrupted the timing and distribution of freshwater inflow into the bay. Structures built to support an overseas road and railroad through the Florida Keys reduced the circulation between Florida Bay and the Atlantic Ocean. Understanding the effects of upstream water management projects and the Florida Keys structures on the temporal and spatial scales of salinity distributions within the Florida Bay are essential in making sound decisions on both upstream projects and activities in the Florida Keys. Moreover, with its bank and basin bathymetry and very low elevations (and slope) of the upstream watershed, Florida Bay will, over the next century, be markedly altered in its geomorphology and possibly hydrodynamic connectivity, due to the rise in sea level.

Biscayne Bay is a shallow, naturally clear-water bay, rich in tropical flora and fauna with a surface area of about 220 square miles. Bordered on the east by barrier islands, Biscayne Bay is bordered on the west by largely developed uplands of Miami-Dade County. Prior to development, mangrove and herbaceous wetlands provided a natural border for most of the bay; groundwater flow, sloughs, tributaries, and coastal embayments allowed for hydrological connectivity to the Greater Everglades and Florida Bay system. Shallow depths and clear-water favor a largely benthic-based productivity with extensive seagrass and hardbottom communities, which in turn provide habitat for diverse fisheries resources and wildlife, including protected and endangered species. Activities such as dredge and fill, sewage pollution, causeway construction, and shoreline modifications have altered circulation and nutrient cycles. The greatest impact has been observed near Miami (see Smantz and Forrester 1996, LaPointe et al. 1990, Roessler and Beardsley 1974).

Historically, freshwater reached Biscayne Bay through tributaries, wetland tidal creeks, and groundwater flows distributed gradually over a large geographic area. Estuarine characteristics prevailed in nearshore areas. However, flood control and water management practices over the last century altered the delivery and timing of freshwater discharges and intercepted flows and stormwater runoff through a network of canals, with releases regulated by coastal water control structures.

Dredge and fill activities for navigation and urban development directly impacted benthic communities, coastal wetlands, and circulation patterns, particularly in north Biscayne Bay. The results of these human impacts include loss of consistently estuarine habitats, extreme fluctuations in nearshore salinity, and conveyance of urban and agricultural contaminants (Valiela and Cole 2002) to waters and sediments. Regional restoration plans are expected to redirect existing freshwater flows and supplement freshwater requirements of the nearshore and coastal wetlands through use of highly treated wastewater. These plans offer an opportunity for enhancement or re-establishment of natural estuarine values, yet present uncertainties related to nutrients and other contaminants that may be present in urban runoff and reclaimed wastewater (Browder et al. 2005).

Major hypotheses identified for this module focus on how the implementation of the restoration activities will affect the system’s water quality, benthic habitat and SAV nearshore nursery function, nearshore community structure, and toxins and contaminants.

Another aspect of changes of freshwater flows is the response that manatees may have to changes from the outflow sources of freshwater. Manatees are frequently observed in or near freshwater sources. Changes in the timing, volume, and spatial distribution of freshwater discharge could affect the distribution of manatees by promoting their distribution away from the canals (where they are susceptible to a higher risk of boat collisions and entrapment in water control structures) to coastal creeks.

Water Quality

The waters of the Southern Estuaries are highly oligotrophic and sensitive to changes in water quality (e.g., water clarity and nutrient availability). Increases in nutrient loadings from agricultural and urban areas can have deleterious ecological effects (e.g., promoting the development of phytoplankton blooms that can reduce water transparency and diminish the Photosynthetically Active Radiation (PAR) required by seagrass and coral reef communities).

Florida Bay (and very recently Biscayne Bay) has experienced severe persistent algal blooms. Of particular relevance to Florida Bay and Whitewater Bay is the uncertainty associated with the bioavailability of organic nutrients such as dissolved organic nitrogen (DON). With respect to Biscayne Bay, the most significant issue may be the degree to which upstream restoration or the acquisition of alternative sources of water, especially reclaimed wastewater, will affect the input of readily available inorganic nutrients like soluble reactive phosphate. Understanding the impacts of upstream restoration projects on water transparency and nutrients is critical to protecting seagrass habitats and coral reefs. Where it is still well developed (e.g., Whitewater Bay and rivers connecting the Shark River Slough to the Southwest Florida Shelf, the north side of Florida Bay, and the west side of South Biscayne Bay), the mangrove transition zone plays a critical role in influencing the nutrient loads and chemical species resulting from restoration activities (Valiela and Cole 2002).

Toxicants and Contaminants

While there is no clear indication that ecosystem function or structure in Florida Bay or Whitewater Bay have been affected by the introduction of regulated toxicants or contaminants, a relatively high incidence of morphological abnormalities has already been reported in fish in some locations of Biscayne Bay (Browder et al. 1993, Gassman et al. 1994). In addition, there is concern about bottlenose dolphin toxicant body burden (Browder et al. 2005). Limited data for selected locations in Biscayne Bay indicate a correlation between fish abnormalities and sediment contaminants (Gassman et al. 1994). There is little question that the quality of the water introduced into the Southern Estuaries resulting from the implementation of CERP could change. The source waters may be influenced by agricultural practices (e.g., use of pesticides) from adjacent farmlands, urban runoff, water reuse practices, and biogeochemical transformation of these chemical compounds that occurs prior to their discharge into the estuaries. Some contaminants, such as mercury, are already prevalent in the Everglades (NAS 2005) and measurable in Florida Bay fishes at levels representing a human health concern. Toxins and contaminants, including pesticides, metals, and emerging pollutants of concern (EPOCS), stress and affect the health of fish and wildlife. EPOCs, such as unregulated pharmaceutical residues, personal care products, or fire retardants, are typically present in wastewater. As analytical methodologies improve, EPOCs are detected in receiving water bodies. In fish, reports note relatively high incidences of morphological abnormalities (Browder et al. 1993, Gassman et al. 1994) from some estuaries in southern Florida; however, little is known about the extent of their occurrence and ecological effects in sensitive natural systems (Barnes et al. 2002). An understanding of how changes in the distribution and sources of freshwater inputs will affect the distribution, fate, transport, or ecological effect of toxicants and contaminants of the Southern Estuaries will help to ensure protection of the ecosystem.

There is a growing realization of the influence of groundwater seepage on nutrient inputs to Florida coastal waters (e.g., Hu et al. 2006). Meeder et al. (1997) found high nutrient concentrations in groundwater inputs to South Biscayne Bay and a relationship to the distribution of benthic plant communities. Groundwater inputs, as well as surface water inputs of nutrients to the bay, may be influenced by planned changes in routing of water to Biscayne Bay

Benthic Habitat and SAV

Seagrasses (i.e., *Thalassia testudinum*, *Halodule wrightii*, *Syringodium filiforme*, and *Halophila decipiens*) are the dominant SAV and the principal benthic habitat type of the Southern Estuaries. The seagrasses' high primary production is a critical factor sustaining the Southern Estuaries food web and the productivity of higher trophic levels. Seagrass beds also provide important habitat for commercial and recreational fishery species and their prey, and endangered species such as manatees and sea turtles. The seagrasses' extensive rhizomes and blade system act as physical sediment traps collecting and consolidating suspended sediments (Fonseca and Fisher 1986). Elevated nutrient concentrations generally favor epiphytes, benthic algae, and macroalgae (Ferdie and Fourqurean 2004). The central role of seagrasses in the Southern Estuaries ecosystem health was demonstrated following the massive seagrass mortality that occurred in Florida Bay during the late 1980s (Robblee et al. 1991, Fourqurean and Robblee 1999, Zieman et al. 1999). Documentation of dramatic ecological effects included increases in suspended sediments, reduction in water transparency, and modification of the food web structure (Fourqurean and Robblee 1999, Thayer et al. 1999). Because of the potential impacts that changes in salinity and nutrients can have on these estuaries, it is important to understand the potential consequences water management and restoration activities may have upon benthic habitats, in particular seagrass beds.

Nearshore Nursery Function

The nursery role of estuaries has been well-established (Beck et al. 2003). In South Florida's Southern Estuaries, submerged mangrove prop root and seagrass beds provide habitats for many life stages of multiple species such as oysters, pink shrimp, spotted seatrout, red drum, and snappers. For example, commercial fisheries operating on the Florida Shelf between the Marquesas and the Dry Tortugas capture pink shrimp that spend their juvenile stage in Florida Bay (Costello et al. 1966). The catch rate of pink shrimp in the commercial bait fishery in Biscayne Bay is related to density estimates in throw-traps three months previously (Johnson et al. 2006). Several fish species that use the Southern Estuaries as nursery grounds are the basis of recreational and commercial fisheries. The value of the estuaries as nursery grounds suggests a relationship with observed salinity patterns (Serafy et al. 1997, Browder et al. 2002) and water quality. Optimal salinity values vary among species and life-cycle stages within a species. The implementation of CERP will result in modifications in the volume, timing, and distribution of the freshwater deliveries to the Southern Estuaries, which will likely impact salinity. A sound understanding of the nearshore nursery function in relation to salinity patterns and sea-level rise—and its possible effects on CERP—is required to ensure that upstream restoration activities do not disrupt natural patterns and relationships.

Long-term changes in sea level and storms will likely affect biotic functions such as biodiversity, as well as underlying ecological processes such as nutrient cycling and productivity. Dependable predictions of climate change on Everglades' coastal wetlands will require a better understanding of the linkages among the ecological, climatological, and human constituents, and a sound understanding of the nearshore nursery function to ensure that upstream water management and restoration activities affect estuarine nursery function naturally (Michener et al. 1997).

Nearshore Community Structure

Current and past water management practices have degraded many of the nearshore habitats of the Southern Estuaries, resulting in inadequate conditions for the freshwater, brackish, and marine flora and fauna communities that would otherwise inhabit the region. Examples of some of the major factors degrading the Southern Estuaries habitats are lack of a persistent positive salinity gradient across Florida and Biscayne Bays, episodes of hypersalinity, high sediment loads, and a complete loss of oyster beds. Redistribution of some of existing freshwater flows from canals to new and restored coastal marshes and creeks, combined with changes in the volume and timing of discharges, are expected to reestablish a positive salinity gradient across the estuaries and reduce the input of sediments. This change, if successful, should have a positive impact on the diversity, abundance, and distribution of the nearshore community of the Southern Estuaries. However, the success of restoration requires consideration of expected future environmental conditions that will result from climate change and climate variability.

■ **Southern Estuaries Needs.** A review of the major hypotheses for the Southern Estuaries module resulted in the identification of eight science needs. These needs focus on the linkages among water management practices and restoration activities and salinity, critical habitats, and key species; role of contaminants; distribution of oysters; development of baseline biological information along the Southwest coast and Whitewater Bay; and effects climate change and variability has on estuarine ecosystems.

SOUTHERN ESTUARIES NEEDS
✓ To understand and predict the effect of restoration and water management upon coastal salinity and nutrient gradients and distributions, as well as upon nutrient loading into the Southern Estuaries.
✓ To understand and predict the effect of restoration water deliveries on seagrass community distributions and patterns of *Halodule wrightii*, *Thalassia testudinum*, *Syringodium filiforme*, and *Halophila decipiens*.
✓ To understand and predict the relationship between salinity and the distribution and productivity of pink shrimp and key fishes, including forage species.
✓ To understand the functional relationships between freshwater inputs and manatee abundance and distribution.
✓ To develop baseline biological information (i.e., fish, benthic, oyster communities, etc.) along the Southwest Florida coast and inside Whitewater Bay.
✓ To understand the historical distribution of oyster beds.
✓ To understand and predict the effect of restoration activities (including changes in sources or distribution of freshwater) on the occurrence, fate, transport, and effect of contaminants (e.g., pesticides, metals, and EPOCs) upon the Southern Estuaries ecosystem.
✓ To understand and predict the implications of climate change (e.g., sea-level rise, ocean acidification, global warming) and climate variability (e.g., tropical storm incidence and intensity) upon estuarine ecosystems, estuarine geomorphology, and restoration project effectiveness.

The first need addresses the requirement to understand the influence of salinity and nutrient dynamics of the Southern Estuaries from restoration and water management activities. This understanding requires hydrodynamic models capable of predicting the input of freshwater into the estuaries, and the circulation, mixing, and dilution within the receiving waters. In addition, the hydrodynamic models must have a water quality component or be coupled to separate water quality models capable of depicting the constituent concentrations entrained with the freshwater inputs, and how these constituents are transported and distributed across the estuaries. Without this predictive capability, assessments of restoration activities are in jeopardy.

The next five needs, addressing the nursery function of the Southern Estuaries, closely link to the first need. These needs include understanding and predicting the effect of restoration water deliveries on seagrasses, the relationship between pink shrimp and other key species and salinity, and the relationship of manatee populations and freshwater discharges. Two needs address improved understanding of the nursery function in the Southern Estuaries. Addressing baseline information along the Southwest Florida coast and inside Whitewater Bay, and historical distribution of oysters will provide information currently not available to evaluate the effectiveness of the restoration activities.

The next identified need focuses on the role of contaminants on the Southern Estuaries ecosystem. Closely related to the first need, this need requires hydrodynamic and water quality models to help predict the distribution and occurrence of contaminants in order to evaluate potential exposure within the ecosystem. This need also identifies the required characterization of the effects the contaminants will have within the Southern Estuaries ecosystem.

The last need addresses the requirement for incorporating climate change and variability into restoration planning. Because estuaries are the transition zone between freshwater flowing from terrestrial systems and the marine environment, they are especially susceptible to climatic stressors (e.g., storms and droughts). Regional climate variability and global climate change patterns affects the magnitude and frequency of climate stressors. There is scientific consensus that the Earth is undergoing a process of climate change, which may be affecting natural oscillations in climate variability. A review of scientific evidence indicates that in the last decades of the 20th century, the Northern Hemisphere was warmer than during any comparable period of the preceding millennium (NAS 2006). Planned restoration activities must take into consideration the expected future climate affecting the ecosystem, otherwise they risk becoming ineffective.

- **Southern Estuaries Gaps.** Of all the regions of the South Florida Ecosystem, the one with the most advanced and coordinated science program is the Southern Estuaries, particularly the Florida Bay region. The three major ongoing science efforts addressing Florida Bay critical science needs are the Florida Bay and Adjacent Marine Systems (FBAMS) Science Program, the Florida Bay Florida Keys Feasibility Study (FB/FKFS), and the Southern Estuary Module of the CERP MAP (RECOVER 2004, 2006).

For the last decade, the FBAMS Science Program, under the guidance of the Florida Bay PMC has been leading and coordinating the research, modeling, and monitoring efforts for Florida Bay. In 1994, the Florida Bay PMC developed the first interagency science plan for the bay. Revised in 1997 into a Strategic Science Plan, the plan was updated recently into the *2004 Strategic Science Plan for Florida Bay*. The 2004 plan focuses on five science areas linked to ongoing or planned modeling efforts: physical processes, water quality, benthic habitats, higher trophic levels, and mangrove-estuarine transition processes. In addition, because of the underlying sensitivity to hydrodynamic models of shallow systems to local bathymetry, research is being conducted on the dynamics of Florida Bay's mudbank stability or change, including the response to sea-level rise.

Development of coupled hydrodynamic and hydrological models for Florida Bay is progressing. An instrumental factor in this progress has been the science coordination efforts of the Florida Bay PMC and the FB/FKFS.

The FB/FKFS, a joint effort led by the U.S. Army Corps of Engineers (USACE) and the SFWMD, is determining modifications required to successfully restore the water quality and ecological conditions of the bay, while maintaining or improving conditions in the Florida Keys. The FB/FKFS relies on the development of hydrodynamic, water quality, and ecological models that integrate existing data. The water quality modeling in Florida Bay is not advancing as rapidly as the hydrodynamic and hydrological modeling.

The intention of the CERP MAP is to regularly assess the performance of CERP by providing the sustained physical, hydrological, and biological observations required to calibrate and validate models, conduct adequate ecological assessments, and support adaptive management. The implementation of the MAP will generate scientific and technical information to evaluate CERP performance and system responses, and to produce assessment reports describing and interpreting the responses. MAP describes monitoring aspects and supporting research, and the assessment process.

Biscayne Bay, like Florida Bay, has a strategic science plan. However, the Biscayne Bay plan is somewhat outdated. The areas of Whitewater Bay and the rivers connecting the Shark River Slough to the Southwest Florida Shelf do not have a science plan; basic biological information for the area is lacking.

SCG members with direct working experience with the myriad of ongoing research, monitoring, and modeling programs for the Southern Estuaries identified the following 15 specific gaps in the present effort.

SOUTHERN ESTUARIES GAPS

- ✓ Biscayne Bay lacks coupled hydrodynamic and water quality models, linked with regional hydrological models that can be used to evaluate effects of restoration on the introduction and distribution of nutrients or contaminants, (these have been initiated within the Biscayne Bay Feasibility Study).
- ✓ There is insufficient baseline information about groundwater quality in the Biscayne Bay watershed, despite recommendations in the Biscayne Bay Strategic Science Plan.
- ✓ There is insufficient information on the rates of atmospheric nutrient loading into the Southern Estuaries, despite recommendations in the Florida Bay Strategic Science Plan.
- ✓ There is insufficient information on the flux of nutrients from sediments in the water column in Biscayne and Florida Bays, despite recommendations in both Strategic Science Plans and in the FB/FKFS plans.
- ✓ There is insufficient information on benthic algal mats in terms of functional importance and as an indicator of eutrophication, despite recommendations in both Strategic Science Plans.
- ✓ There is insufficient information on the ecological risk of contaminant (e.g., pesticides and trace metals) exposures that may result from restoration changes in the sources, distribution, and flows of freshwater introduced into the Southern Estuaries, despite recommendations in the Biscayne Bay Strategic Science Plan.
- ✓ There is insufficient information on concentration and distribution of EPOCs in the Southern Estuaries and their watersheds and in alternative sources of water, such as reclaimed wastewater, that may be needed to meet natural system and other water supply needs in Biscayne Bay.

SOUTHERN ESTUARIES GAPS
✓ There is a lack of information about mercury speciation and methylation within estuarine systems, despite recommendations in the Florida Bay Strategic Science Plan.
✓ There is a lack of fish tissue contaminants information for nearshore environments in the Southern Estuaries (with the exception of mercury in Florida Bay), despite recommendations in the Florida Bay Strategic Science Plan.
✓ Salinity tolerances and optima for key Biscayne Bay fish and invertebrates have not been determined, despite recommendations in the Biscayne Bay Strategic Science Plan and a priority assignment within MAP.
✓ There is insufficient information about the functional relationships between freshwater inputs and manatee abundance and distribution, despite priority assignment within MAP.
✓ Little is known about the historical distribution of oyster reefs in Biscayne Bay, despite recommendations in the Biscayne Bay Strategic Science Plan and priority assignment within MAP.
✓ Little is known about the specific habitats in Shark River Slough, Whitewater Bay, and adjacent rivers (Robert's to Lostman's) and the nursery functions they serve with respect to red drum, snook, tarpon, and other estuarine-dependent fish species, despite priority assignment in MAP.
✓ Little is known about the degree to which climate change (e.g., sea-level rise, global warming, and ocean acidification) will affect the Southern Estuaries system and its geomorphology between now and 2050, despite inclusion in the Florida Bay Strategic Science Plan and increasing recognition of the issue during the MAP assessment process.

The first gap addresses the requirements for completion of models that couple the hydrology and water quality, including groundwater, from the Greater Everglades with hydrodynamic and water quality models of Biscayne Bay. Efforts to achieve this for Biscayne Bay have languished due to lack of funding and modeling staff at key organizations. The second identified gap is closely related to the first gap, because the development of water quality models requires the establishment of baseline information about groundwater quality in the Biscayne Bay watershed.

The next two gaps reflect the lack of an accurate quantification of nutrient loads to the system. This information is required for the development of nutrient mass balance models and budgets, the evaluation of nutrient changes, and assessment of impacts that may occur as result of restoration activities. The next gap addresses the lack of understanding of benthic algal mat dynamics. Changes in benthic algal mat cover have been associated with changes in seagrass cover and nutrient dynamics. The functional role of these mats is unknown, the repercussion and impact they may have on the system is not well understood, and their potential utility as indicator of eutrophication has not been established.

The next four gaps reflect the current incomplete understanding of the impacts contaminants may have on the system. Preliminary information, such as the observed correlation between fish abnormalities and sediments contaminants, ubiquitous presence of mercury in the Greater

Everglades region, use of pesticides in agricultural and urban lands, and occurrence of EPOCs in wastewater, suggests that contaminants may have a major role in the health of the Southern Estuaries. However, how the role of contaminants may change with modification of freshwater flows and sources is unknown.

The next two gaps relate salinity changes and the ecological responses. One of the major factors affecting the salinity of the Southern Estuaries is the freshwater inflows from the Greater Everglades region. However, bioassays describing the salinity tolerance and optimal level have not been completed for all key species from Biscayne Bay. Therefore, the success and distribution of key species may be affected by changes in salinity in ways that are currently unknown. Another aspect of changes of freshwater flows is the response that manatees may have to changes on the outflow sources of freshwater. Manatees are frequently observed in or near freshwater sources, and changes in the timing, volume, and spatial distribution of freshwater discharge could affect the distribution of manatees by promoting their distribution away from the canals (where they are susceptible to a higher risk for boat collisions and entrapment in water control structures) to coastal creeks.

The next gap addresses the lack of habitat information available from Shark River Slough, Whitewater Bay, and adjacent rivers (Robert's to Lostman's), and the role these habitats play for many important fish species. These areas are expected to experience hydrological changes resulting from restoration activities with unknown consequences to habitat modifications and ecological impacts. Without adequate baseline information, the impact of restoration on these habitats cannot be adequately assessed.

The last gap addresses the current unknowns about the impacts of climate change and variability on the system. The gap recognizes the lack of understanding of the expected consequences, including modifications of system geomorphology that climate change (e.g., sea-level rise) and fluctuations in climate variability will have on the Southern Estuaries system. The gap focuses on recent scientific projections that suggest a systemically higher level of precipitation and an increase in tropical storm incidence and intensity for the South Florida Region, in comparison to the storm activity of the last three decades (Wang et al. 2005). The South Florida planning and modeling efforts have primarily used the last 30 years as the baseline to define climatic driving forces (e.g., precipitation). However, scientific information indicates that this period was low in storm activity and intensity; the system is changing to a more active one (Goldenberg et al. 2001, Landsea et al. 1998). Therefore, planning and modeling efforts may have inadequately captured the significance of an increase in strong episodic events (e.g., major hurricanes) or long-term climatic changes (e.g., increase in sea-level rise) and their affect on restoration.

- **Southern Estuaries Tasks.** The SCG members reviewed the identified gaps and provided recommendations. Some address ongoing efforts that are experiencing uncertain completion, while other tasks identify new efforts that need to be implemented. All require the collaboration and cooperation of multiple task force organizations. Furthermore, the SCG members identified the need to ensure the sustainability of ongoing research and monitoring efforts as a critical overarching task that must be pursued. The biggest threat to the success of the CERP MAP is significant reductions in the funds available to complete research and continue monitoring already underway.

SOUTHERN ESTUARIES TASKS

✓ Fund the development of a coupled water circulation and water quality model for Biscayne Bay, comparable to those for Florida Bay, as described in the Southern Estuaries MAP, Florida Bay Feasibility, and Florida Bay Plans.

✓ Fund the ongoing salinity, water quality, ecological, and circulation monitoring being conducted within the Southern Estuaries as part of MAP.

✓ Enhance biogeochemical monitoring in the Southern Estuaries as part of a comprehensive integrated water quality study of the entire watershed, to include the following subtasks:

- Establish monitoring of groundwater and atmospheric nutrient flux into the Southern Estuaries
- Develop baseline information on the distribution of toxics and contaminants within the Southern Estuaries and in the adjacent coastal watersheds, emphasizing flow pathways and sources contemplated by CERP, and conduct a comprehensive risk assessment for potential ecological hazards
- Determine occurrence of EPOCs in alternative sources of freshwater and evaluate effectiveness of treatment technologies in removing or reducing EPOC concentration
- Conduct research into the biogeochemical processes for methylation of mercury (and consequent bioavailability) across a range of salinity regimes from brackish to hypersaline
- Conduct research on the importance of algal mats with regards to nutrient flux and primary production in Biscayne Bay and Florida Bay, including the degree to which increased mats may be indicative of progressive system eutrophication

✓ Evaluate, initiate, and/or improve research and monitoring, targeting environmental requirements of key indicator species and undersampled habitats, to include the following subtasks:

- Evaluate manatee monitoring and research programs to determine if the information being collected is sufficient to establish a functional relationship between freshwater discharges into the Southern Estuaries and the abundance and distribution of manatees
- Undertake additional laboratory experiments relating salinity tolerances upon Biscayne Bay fish species
- Expand the faunal monitoring domain to match the SAV domain within the Southern Estuaries, including Whitewater Bay
- Expand efforts to assess the historical distribution of oyster beds in Biscayne Bay

✓ Assure the compatibility of restoration plans and expectations with global and regional climate change, to include the following subtasks:

- Link regional physical models to global climate change models
- Run project evaluation models under different climate scenarios
- Conduct research into the geomorphological implications of continuing current climate change trends over the current decades

3.4.5 Total System Science Needs, Gaps, and Tasks

The Total System addresses the entire watershed, including near-shore estuaries and coral reefs, and land and waters extending from the Kissimmee Chain of Lakes through Florida Bay and the reefs southwest of the Florida Keys, as outlined in the Scope of this Plan. The SCG used the external drivers and stressors defined by the Total System CEM (Ogden et al. 2005b) and a prospective review of other factors (e.g., invasive exotic species) that may influence ecosystem restoration to identify the critical science needs from a whole system perspective as opposed to the assessment module perspective. Unless otherwise specified, all technical and background information for the Total System is based on Ogden et al. (2005b) and references therein. The three main drivers of the Total System are: (1) water management, (2) land use management and development, and (3) climate change and sea-level rise. These drivers operate on the system stressors, which in turn modify the defining characteristics of the entire ecosystem.

Water Management

Water management operations and the current structural system of levees, canals, and roads have substantially altered hydro-patterns in the South Florida Ecosystem. Alterations include changes in the total flow and volume of water available; changes in the natural temporal and spatial patterns of water depth, distribution, and timing of flows; and a shift from slow-moving sheet flows to point source releases. For example, alterations have resulted in unnaturally abrupt changes in salinity levels in all estuaries and adjacent wetlands. The overall effect of water management activities has modified stressors, such as natural fire patterns and nutrient cycling. These water management modifications have caused significant changes in the physical and biological characteristics of many Everglades' habitats. Understanding the relationship of water management activities to salinity regimes, nutrient and sediment dynamics, detritus, and ecological attributes of wetland systems provides the essential foundation for restoration decisions about the design and operation of restoration projects.

> **Detritus** consists of fragments and particles of decomposing organic matter, which can be very important for the support of aquatic food webs and in the formation of sediments. Plants are a major source of detritus in wetland ecosystems.

Land Use Management and Development

Land use management/development has altered landscape patterns and processes. Changes in land use and new land development can alter hydrologic and fire patterns. Runoff from development or from agricultural lands can cause increased inputs of nutrients, pesticides, and other contaminants to the system. Installation of agricultural and urban Best Management Practices (BMPs) can reduce inputs from of nutrients, pesticides, and other contaminants to the system. Understanding of the effectiveness of individual BMPs and effects of land use conversion from agriculture to urban/residential uses is needed. The combined effects of water management practices and further development in South Florida will continue to create challenges to restoration success. Understanding and predicting the effects of land use management and development on landscape and hydrological patterns and processes is critical to making local decisions on land use and restoration projects.

Global Climate Change and Sea-Level Rise

Sea-level rise and possible concurrent changes in the intensity, frequency, timing, and distribution of tropical storms may have considerable impacts on coastal wetlands. Persistence of these wetlands relies on the interactions of climate and anthropogenic effects, particularly how people respond to sea-level rise and its possible effects on CERP restoration activities. During the past century, sea level has risen at a rate of 3.0 mm per year (Overpeck et al. 2006). Recent climatic research suggests an increase of about 10.0 mm per year within the next decade or so (Overpeck et al. 2006). With such dramatic increases expected, it is likely that seawater may transgress the shoreline and intrude across the mangrove region and into the freshwater wetlands of the Greater Everglades. Long-term changes in sea level and storms will likely affect biotic functions such as biodiversity, as well as underlying ecological processes such as nutrient cycling and productivity. Dependable predictions of climate change effects on Everglades' coastal wetlands requires a better understanding of the linkages and interactions among the ecological, climatological, and human constituents (Michener et al. 1997). An understanding of the limitations of restoration activities in the face of global climate change to ensure their effectiveness is needed.

Toxicants and Contaminants

Subject matter experts recognize contaminants and toxicants, even though not identified as main drivers or stressors within the Total System CEM, as important factors for consideration during the restoration of the South Florida Ecosystem. Land use practices and atmospheric inputs introduce contaminants into the South Florida Ecosystem. Contaminants include, but are not limited to, pesticides, herbicides, and heavy metals (e.g., mercury). Sources of mercury include atmospheric deposition from industrial and waste incinerators, while runoff from agricultural and urban activities can carry pesticides offsite. Mercury contamination and bioaccumulation (e.g., from methyl mercury) are pervasive in sediments and aquatic food chains throughout most of the South Florida Ecosystem (NAS 2005), posing a risk of chronic toxicity to humans and top predators that consume fish. These contaminants have been shown to impact the health of animals and plants throughout South Florida.

The implementation of CERP will result in the modification of the timing, volume, and distribution pattern of freshwater flow into the Southern Estuaries. The constituents in the water will be influenced by agricultural practices (e.g., use of pesticides) from adjacent farmlands, urban runoff, water reuse practices, and biogeochemical transformation of these chemical compounds that occurs prior to their discharge. Some contaminants, such as mercury, are prevalent in the waters across the Everglades (NAS 2005). Toxins and contaminants, including pesticides, metals, and EPOCs are known to stress and affect the health of fish and wildlife. As analytical methodologies improve, EPOCs, such as unregulated pharmaceutical residues, personal care products, or fire retardants, are typically present in wastewater and detected in receiving water bodies. However, the extent of their occurrence and ecological effects in sensitive natural systems is unknown (Barnes et al. 2002).

■ **Total System Needs.** Based on the review of the Total System CEM and a prospective review of other factors that may influence ecosystem restoration, SCG members identified the following system-wide needs:

TOTAL SYSTEM NEEDS

✓ To understand and predict the effects of water management and restoration activities on ecological attributes, biogeochemical dynamics, and hydrological flows of wetland systems, including:

- Salinity regimes.
- Nutrients.
- Metals.
- Pesticides.
- EPOCs.

TOTAL SYSTEM NEEDS
• Sediments. • Detritus. • Habitat diversity. • SAV. • Wading birds.
✓ Long-term comprehensive monitoring is needed to provide ecological and physical data to assess status and trends and support adaptive management and adaptive assessment.
✓ To understand and predict the effects that modifications in land use management and development, as a result of population growth and changes in agricultural practices, have on landscape patterns (e.g., wetlands spatial distribution) and processes (e.g., biogeochemical dynamics, surface and groundwater hydrology, fire), and ecosystem restoration and sustainability.
✓ To understand how habitat fragmentation and loss of spatial extent affect ecological structure and function, including the impacts of large-scale natural disturbance and the impact to successful restoration and ecosystem sustainability (e.g., sustainability of higher trophic-level species, biodiversity, water storage capacity).
✓ To understand and predict the dynamics of invasive species in the South Florida Ecosystem, including the factors that foster their establishment and proliferation, and their impact on restoration through research to understand their effects on ecosystem structure and function.
✓ A scientifically based characterization (description/definition) of what successful ecological restoration should look like
✓ Restoration goals at the Total System scale to support the prioritization of restoration activities
✓ CEMs for all other areas of the sub-regions of the South Florida Ecosystem

The first need addresses the overarching role that water management practices have on the chemical, biological, and physical characteristics of the system. For example, fluctuations in salinity regimes are very important in defining the health of South Florida estuarine waters. Current water management practices occasionally result in freshwater inputs to estuaries that significantly reduce the salinity of the system. Extreme fluctuations in the range of salinity values, spatial extent of estuarine waters, or timing of natural salinity cycles can have detrimental effects on estuarine habitats (see Northern and Southern Estuaries Module sections), as well as communities (e.g., seagrass beds) and key species (e.g., spotted sea trout and pink shrimp) they support. Most often, wide and rapid fluctuations in salinity are brought about by huge water management "flood" releases from Lake Okeechobee or the central Everglades that, in addition to drastically and rapidly altering salinity, also bring large volumes of sediment and nutrient and chemical pollutants entrained within the sediment and water. Recently such events have caused toxic algal blooms (cyanotoxins) not only within the Lake, but also in estuaries where water releases bring both nutrients and cyanotoxins. Cyanotoxins are known to cause ecological and biological harm (Mankiewicz et al. 2003, Zimba et al. 2001, Rohrlack et al. 2001).

Understanding the linkage between the biogeochemical dynamics of the system and restoration activities (the second identified need) is critical for the reestablishment of the system defining attributes. These biogeochemical dynamic needs address both the nutrients and contaminants of the systems.

Elevated levels of phosphorus and nitrogen introduced by anthropogenic activities have substantially altered community structure and composition, and natural system patterns of productivity in freshwater wetlands and estuaries in some areas of the South Florida ecosystem. Adverse responses include changes in species dominance from sawgrass to cattails, shifts in species composition in periphyton mats from green algae/diatom communities to calcitic blue-green algae communities, and an increased frequency of extensive algal blooms in Lake Okeechobee and in estuaries (Newman et al. 1996, Twilly et al. 1985). These changes have resulted in structural degradation of wading bird foraging habitat, changes in rates of biological processes, altered food webs, and reductions in secondary productivity. Understanding the system-wide transport, transformation, and effect of nutrients is critical to adequately addressing anthropogenic inputs and their impacts, and differentiating between anthropogenic and natural effects. The Comprehensive Integrated Water Quality Feasibility Study (CIWQFS) has not been completed (for both contaminants and nutrients) in the South Florida Ecosystem. The CIWQFS, co-sponsored by the USACE and Florida Department of Environmental Protection (DEP), is the result of a recommendation of the Central and Southern Florida Project Comprehensive Review Study (Restudy). The Restudy recognized the need for a comprehensive water quality plan that would integrate CERP projects and other federal, state, and local government programs.

> **Anthropogenic eutrophication** is over stimulation of primary production caused by excess nutrients introduced to a water body by human activity. The excess nutrients may cause undesirable shifts in the composition of the plant community, or promote hyperproduction of plants, which accelerates organic decomposition thereby reducing dissolved oxygen concentration in the water body. Both decrease the quality of aquatic habitats.

The third and fourth needs focus on the required understanding of how the spatial extent and landscape patterns of the South Florida ecosystem are affected by anthropogenic (e.g., human population growth) and natural disturbances (e.g., invasive exotic species, fires, storms). Two of the defining attributes of the South Florida Ecosystem are complex landscape mosaics and interactions and the capability to support animals with large spatial requirements (Ogden et al. 2005a). The large spatial extent of South Florida natural areas was essential for supporting genetically and ecologically viable populations of species with narrow habitat requirements (e.g., Cape Sable seaside sparrow) or large feeding ranges (e.g., Florida Panther). Extensive space, in combination with regional differences in topography and physical geography patterns, created a mosaic of habitat options that supported the levels of primary and secondary productivity necessary to sustain highly mobile animals during variations in seasonal, annual, and multi-year rainfall, and surface water conditions. Reduction in spatial extent of natural wetlands and system fragmentation (i.e., creation of unnatural boundaries such as the eastern protective levee) drastically reduced the system-wide capacity for water storage; altered natural patterns of flow direction and volume; and impacted water supply, flooding, and drainage options. These alterations in hydropatterns resulted in shortened hydroperiods and over-drained wetlands, particularly in higher elevation marl and cypress prairies. These alterations also reduced total system levels of primary and secondary aquatic production, habitat options for animals with large foraging ranges,

> **Primary productivity** is the rate at which organic material is produced by plants and algae through photosynthesis.
> **Secondary productivity** is the rate at which organic material is produced by animals from ingested food.

> **Carrying capacity** is the maximum number of individuals of a determined species a given environment can sustain without detrimental effects.

regional carrying capacity for animals with specialized or limited habitats, system-wide biodiversity, habitat diversity, and connectivity at regional levels. Understanding the impacts of changes in spatial extent and fragmentation to primary and secondary productivity, population dynamics, and biodiversity is essential to making restoration decisions that protect upper trophic species.

The fifth need focuses on how non-native invasive species can severely affect the health and sustainability of the South Florida Ecosystem. Approximately 33 percent of all plant species in Florida are non-native; approximately 26 percent of all mammals, birds, reptiles, amphibians, and fish in South Florida are not native to the region. Florida and its ecosystems support one of the largest populations of non-indigenous species in the world (Wunderlin 2003, Corn et al. 1999).

Within the Central and Southern Florida Restudy Area, six species of invasive exotic plants replaced approximately 1.9 million acres of habitat (Doren and Ferriter 2001). One species alone, Old World climbing fern (*Lygodium microphyllum*), is spreading exponentially over the last two years. Its current range covers more than 125,000 acres across seven South Florida counties in Everglades' habitat. Model predictions for this species estimate more than 5 million acres covered by 2014.

Understanding the interactions between invasive species, the ecosystems and habitats they invade, and ecosystem properties that affect the ability of the invasive species to establish and spread is critical for: (1) predicting which species may become invasive, (2) developing effective restoration activities that will help control existing exotic and invasive species, and (3) preventing new introductions.

The next two needs address the required understanding of what is the desired outcome of the restoration efforts. The development of a working definition of restoration success and of attainable restoration goals is required for the effective prioritization of tasks and the evaluation of restoration efforts.

The last need addresses the requirement to ensure that all components of the South Florida Ecosystem are represented by CEMs. These models prove to be useful tools for the evaluation of the ecosystem based on the drivers and stressors that affect the system.

■ **Total System Gaps.** A review of the above critical science needs and ongoing science efforts resulted in identifying 10 Total System science gaps.

TOTAL SYSTEM GAPS
✓ There is no planned effort to evaluate and update the current characterization or definition of restoration success, or to define restoration goals at the Total System scale to support the prioritization of restoration activities.
✓ Only four modules have had CEMs (and their sub-models) developed; all other eco-regions of the South Florida Ecosystem need CEMs.
✓ The Comprehensive Integrated Water Quality Feasibility Study has not been completed (for both contaminants and nutrients) in the South Florida Ecosystem.
✓ The current scope and schedule for the RECOVER MAP, including the monitoring not funded by CERP but by the other Task Force member organizations, is not assured.

TOTAL SYSTEM GAPS
✓ Multiple models developed for particular regions of the South Florida Ecosystem are not coupled across the regions.
✓ The Natural System Model (NSM) does not simulate predrainage hydrology; some NSM predictions are considered unrealistic based on other scientific expectations and evidence. The NSM does not adequately address the transition from wetlands to coastal areas, and requires better elevation data to create a more accurate representation of the natural system baseline.
✓ The Natural System Regional Simulation Model is several years from development and use.
✓ The species-specific ecology, biology, reproduction, and biological impacts of exotic species invading the South Florida Ecosystem are not well understood, preventing effective management and control.
✓ There is a lack of biological risk assessment tools, including unified system-wide monitoring, biological control programs, and indicators, to predict species invasiveness and evaluate and prioritize management actions to support a comprehensive and unified management approach for invasive species.
✓ Restoration planning and modeling do not account for anticipated changes in sea-level rise, rainfall, and tropical storm frequency and intensity for the coming decades.

The first gap identified by SCG members addresses the lack of clear updated characterizations or definitions of restoration success, which is required for establishing effective and attainable restoration goals and prioritizing restoration activities. This gap closely relates to the second gap identified, the need to develop CEMs for the remaining bioregions of the South Florida Ecosystem. In order to identify and define restoration and prioritize and evaluate restoration activities, CEMs are needed to help scientists understand the ecological drivers, processes, and attributes for these areas.

The third gap identifies the need for completion and development of the CIWQFS for South Florida. This study recognizes the need for a comprehensive water quality plan integrating CERP projects and other federal, State, and local government programs. The CIWQFS will evaluate all ongoing plans, programs, and projects throughout the South Florida Ecosystem that address water quality, including permitting programs and State, regional, and local planning efforts. Completion of the CIWQFS will be critical for ensuring a coordinated approach to addressing water quality in CERP.

RECOVER developed the MAP to provide the data required to regularly assess the performance of CERP. The MAP describes monitoring requirements, and includes implementation of the MAP to generate scientific and technical information in evaluating CERP performance and system responses and produce assessment reports. Already designed, the MAP is being implemented with the assumption that existing monitoring will continue from existing funding sources, and collaborating organizations will contribute funding and/or will participate in implementation of the MAP. A gap was identified because the scope and schedule of the MAP is not assured by all participating organizations

Of the several tools developed to describe the current understanding of pre-C&SF hydrology, the most significant is the NSM. Created from the hydrologic South Florida Water Management Model (SFWMM) and developed by the SFWMD, the NSM predicts hydrologic changes in the Everglades based on operational and structural changes in the C&SF Project (see: https://my.sfwmd.gov/portal/page?_pageid=1314,2555871,1314_2554443&_dad=portal&_schema=PORTAL). The NSM does not attempt to simulate the pre-drained hydrology. Modifications to the original SFWMM created the NSM based on the best available information reflecting conditions in South Florida prior to the implementation of the C&SF Project. The NSM estimates the pre-drainage hydrologic responses of the Everglades. The NSM is a valuable tool in designing features to achieve restoration. Its use allows for relative comparisons between the responses of the natural, pre-drained system to that of the managed system.

However, like all models, there are uncertainties in the NSM that derive primarily from two sources. The first uncertainty is inherent in the SFWMD model, of which the NSM was derived from. The second uncertainty arises in how the original system operated hydrologically, underlying the assumptions in the NSM. For part of its domain, improved topography is incorporated into the NSM. It is not yet clear whether this is sufficient to overcome some of the uncertainty. In addition, scientists consider the NSM predictions for water depths and volumes to incorrectly model what occurred historically. Moreover, concern remains that the NSM does not yet adequately address the hydrologic transition from wetlands to coastal areas, a critical requirement to accurately predict the inflow of freshwater to Florida Bay.

The last two gaps identify the importance of ensuring that models developed for particular regions of the South Florida Ecosystem are, to the degree possible, improved, coupled, and compatible to ensure a holistic evaluation of the system. This is especially true for the development and use of the SFWMD Regional Simulation Model (in progress) and indicates the importance of planned development of a Natural System Regional Simulation Model (see: https://my.sfwmd.gov/portal/page?_pageid=1314,2555966,1314_2554338&_dad=portal&_schema=PORTAL&navpage=rsm)

There are multiple efforts in place for invasive species evaluation and control. However, these efforts are mostly region specific; a comprehensive south Florida-wide management program does not exist. This is critical because restoration activities, such as removal of existing structures that have compartmentalized the ecosystem, may have the unwanted effect of removing barriers that could foster the spread of exotic invasive species (NAS 2005). There is also a lack of biological risk assessment tools to help predict species invasiveness, and evaluate and prioritize management actions to support a comprehensive approach for managing invasive species.

Exotic species become invasive when introduced and established to a new ecosystem. The reasons some species become invasive and others do not is not well understood. There are several theories to explain the possible biological and ecological underpinnings of invasion. The species-specific ecology, biology, reproduction, and biological impacts of exotic species invading the South Florida Ecosystem are not well understood, preventing effective management and control. Invasive species can displace native species often by competing with them for space, light, and nutrients. In severe invasions, invasive species may eliminate local populations of native species, and in some cases, have caused species extinctions. Invasive species often alter the structure and function of the ecosystems they invade. These effects can change the physiographic character of the ecosystem by affecting parameters such as soil composition and chemistry, sedimentation and erosion rates, fire regimes, water quality, and hydrology.

■ **Total System Tasks.** Based on a review of the Total System gaps and a prospective review of other factors that may influence ecosystem restoration, the SCG members identified the following system-wide tasks.

TOTAL SYSTEM TASKS

- ✓ Develop restoration goals at the Total System scale using multiple lines of empirical data.
- ✓ Develop a forum/venue to refine the term "success" in terms of future uncertainties.
- ✓ Validate CERP hypothesis 3.3.2.2 "The restoration of hydrology toward NSM conditions within the Northern Estuaries will result in a reduction in nutrient concentrations and loads from inflow structures at levels that provide water quality conditions that reduce the frequency and intensity of algal blooms and epiphytic plant growth and improve water clarity sufficient to promote establishment of oysters, seagrasses, and other SAV in the estuaries. Additionally, restoration of volume, timing, and spatial distribution of freshwater flows will provide for conditions."
- ✓ Develop CEMs for areas that require them (e.g., Florida Keys) to support South Florida Ecosystem restoration.
- ✓ Incorporate monitoring and assessment elements of the South West Florida Feasibility Study into the CERP MAP.
- ✓ Assess the occurrence of natural fires, and develop and implement a plan to reestablish a natural fire regime supporting restoration of the South Florida Ecosystem.
- ✓ Develop a comprehensive multi agency Master Plan to support invasive exotics species management efforts (both plants and animals) that includes comprehensive monitoring and research sections, biological control programs, development of a risk assessment tool(s), indicators, performance measures, and CEMs to support the development of hypotheses, and evaluation and prioritization of research and management actions.
- ✓ Review the current status of the CIWQFS and implementation of the CERP MAP, including funding status of individual elements of the plan.
- ✓ Ensure that models are coupled across regions.
- ✓ Work with implementing organizations to address necessary improvements in the NSM.

3.5 The Actions Identified to Address the Gaps

The Task Force identified the following three strategic and programmatic level actions to address the tasks identified by the subject matter experts, including SCG members.

TASK FORCE ACTIONS
✓ Each Task Force member will distribute the PCS within their organization to communicate to managers and scientists the critical science needs and gaps for South Florida Ecosystem Restoration to achieve the following goals. • Reinforce the priority that the Task Force places on filling these gaps. • Encourage managers and scientists to utilize the critical science needs, gaps, and tasks in the PCS to: ➢ Set science priorities. ➢ Develop and revise science plans. ➢ Establish science coordination or research oversight committees. ➢ Coordinate and support science meetings or conferences, particularly focusing on filling gaps and sharing information. ➢ Set funding priorities to address gaps. ➢ Review current science program activities and research projects taking PCS needs, gaps, and tasks into consideration. ➢ Vet monitoring projects and proposals through the RECOVER MAP planning process for strategic integration and coordination. ➢ Use the PCS Information Sharing concepts and recommendations and inter-agency agreements to allow access to science information and data bases for the joint USACE/SFWMD Task Force science information internet cataloging system (EdCat).
✓ A Task Force organization already conducting critical science that addresses identified needs will continue those science activities to prevent creating a new gap; and where this is not possible, the Task Force organization will consult with and inform the Task Force to prevent creating a new science gap.
✓ Task Force organizations will utilize Task Force meetings, or relevant conferences or workshops, to update the Task Force on efforts to fill gaps, ensuring that progress can be monitored by the Task Force and new or modified coordination actions taken as appropriate.

3.6 Why it's Important to Ensure Quality Science

The quality of restoration decisions is directly dependent on the quality of the supporting scientific information. While uncertainty is accepted as a basic component of science and environmental decision-making at all levels, uncertainty can be reduced significantly when the science supporting restoration decisions is sound, current, and shared by all partner organizations in a timely manner.

Task Force member organizations have programs addressing the quality of data from the point of initial gathering or research to synthesis for decision-making. Member organizations generally use standard quality assurance/quality control procedures for collecting and analyzing samples, maintaining laboratories, and managing data. Organizations generally also use traditional peer reviews to assure the quality of research proposals and publications. Peer reviews are an independent evaluation of scientific work by other qualified scientists to assess the validity of the scientific activity (e.g., research project).

Science activities that support South Florida restoration generate vast amounts of diverse data and information. Coordination of this information at the Task Force level depends on organizations using standard quality assurance/quality control procedures. There are no generally established standards for independent scientific reviews, and synthesizing and communicating information among organizations. A protocol must be established to track progress in addressing science gaps.

3.6.1 How the Task Force Member Organizations Ensure their Science is Sound

The appropriateness of restoration decisions is directly dependent on the quality of the supporting scientific information. Furthermore, effective coordination and sharing of scientific information among Task Force member organizations is dependent on the use of well-documented and scientifically accepted methods to generate, analyze, and report data. The SCG has confirmed that all Task Force member organizations have established policies and protocols for handling scientific information that they use internally and share externally.

Sound science requires that data, facts, or conclusions to support decision are the results of studies that have:

- Readily testable hypotheses
- Systematic and well-documented experimental, monitoring, or analytical methods
- Appropriate data analysis tools (e.g., models)
- Results that support the conclusions
- Results that can be used to evaluate the hypotheses

To ensure that sound science continues to be the basis of Task Force coordination and decision-making, the Task Force recognized the need for a statement of agreement to which member organizations would abide to regarding the application of quality science policies and protocols. The Task Force unanimously approved the following statement of agreement.

> *Scientific data collection and analyses shall be conducted according to current industry and academic standards, under transparent and reproducible procedures that support restoration projects, decision-making, and information sharing among Task Force member organizations.*

3.6.2 How the Task Force Ensures Sound Science Products

The Task Force also recognized the need to establish quality assurance/quality control procedures for scientific research and reports developed by and for the Task Force. The Task Force and SCG reached consensus to continue the use of independent science reviews (ISR) as the principal means to assure quality of Task Force documents that support restoration decision-making.

The SCG has assembled ISR panels to review the Phase I Plan for Coordinating Science in 2005 and the Draft System-wide Indicators for Restoration in 2006. Similarly, the Task Force convened topic specific workshops, such as the avian ecology workshops held in 2003. The Task Force will continue to exercise its ability to conduct ISRs and convene other groups of experts through the SCG to promote quality science and ensure that high-quality information in restoration decision-making.

3.6.3 Sound Science and Uncertainty in Everglades' Restoration

Scientists and policymakers do not always deal effectively with the enormous uncertainty inherent in environmental issues, nor do they tend to deal with uncertainty in the same ways. First, uncertainty should be accepted as a basic component of science and environmental decision-making at all levels, and communicated by scientists and policy-makers. Second, it is important to differentiate between risk, which is an event with a known probability, and true uncertainty, which is an event with an unknown probability.

One of the goals of science is to reduce uncertainty to acceptable levels that allow sound conclusions and defensible decisions when not all aspects of an issue are known and a decision is based on the best available information. Uncertainty in Everglades' restoration science and environmental management may be considered essentially a continuum ranging from zero for some aspects of restoration science to intermediate levels for areas where statistical uncertainty and known probabilities (risk) exist to high levels for information with true uncertainty or indeterminacy. Risk assessment is the central guiding principle at the U.S. Environmental Protection Agency (EPA) and other environmental management agencies, but true uncertainty is not adequately incorporated into environmental protection strategies (Costanza and Cornwell 1992).

The approach used in this plan to identify needs and gaps relied on the knowledge accumulated from decades of research, modeling, and monitoring that served as the basis of the CEMs, and from input by subject matter experts, including SCG members. The SCG convened an independent scientific review panel, which found the overall approach to be sound. However, the SCG recognizes that this approach, like all scientific endeavors, is not perfect and retains some level of uncertainty. The process of adaptive management and assessment recognizes that uncertainties exist. As new evidence is accumulated and our understanding advances through scientific investigations, corrective actions may be taken to refocus restoration efforts.

The SCG process to develop and identify needs and gaps helped identify two key areas of uncertainty for restoration, one of which is inherent in the approach used to develop this Plan. The two areas are: (1) uncertainties associated with the relative importance of hypotheses in the CEMs, and (2) uncertainties associated with the use of new technologies (e.g., aquifer storage and recovery (ASR) wells, Lake Belt storage, reuse of reclaimed water) in the restoration process.

The identification of science needs and gaps is based on the evaluation of the dominant CEM hypotheses describing how the critical ecological processes for each regional module have been affected by major driving forces, such as water management practices, hurricanes, and fires.

Research, modeling, and monitoring efforts have vastly improved the understanding of the South Florida Ecosystem; however, this understanding is still imperfect because potentially, not all processes may have been fully described and documented. In addition, a quantitative evaluation or sensitivity analysis of the relative importance of each of the hypotheses has not been performed that allows for the ranking of hypotheses. The possibility exists that not all relevant processes and hypotheses are identified. These unknowns affect the selection of the parameters applied to evaluate restoration. Scientific uncertainties also reflect upon the number of indicators that may be needed to adequately assess restoration. As we are better able to understand the ecosystem, we will be better able to optimize the number of indicators and more rigorously assess their ability to evaluate restoration individually and collectively. The pattern of identifying large numbers of indicators (often several hundred) over several years of scientific observation and research, and narrowing the selected indicators to an important few has been proven valid for other large-scale and complex restoration projects (e.g., Chesapeake Bay).

CERP incorporates the implementation of a suite of technologies to help improve the storage capacity and the spatial, temporal, and volumetric distribution of water throughout the ecosystem. These new technologies (e.g., ASR wells, Lake Belt storage, reuse of reclaimed water) are being pilot tested to reduce uncertainties related to these technologies as much as possible before full scale implementation (NAS 2005); however, additional uncertainty exists about the adequacy of extrapolating results from pilot projects to full scale operational projects. The effectiveness of these new technologies is anticipated, and in some cases required, in order for restoration to be successful; however, it is by no means proven. For example, it is unknown if constituents in the re-used water for which no water quality criteria or regulations currently exist (e.g., EPOCs) may have detrimental ecological effects. Further scientific evaluations of these new technologies may be required to reduce associated uncertainties that ultimately may impact restoration success.

3.7 How We Share Science Information for South Florida Restoration

Timely and efficient data sharing enables decision-makers to consider the newest and best understanding of the environment when evaluating restoration progress and adjusting next steps. Sharing relevant information also minimizes the potential for unnecessary or duplicative scientific efforts among the organizations involved in ecosystem research, modeling, and monitoring.

There are two general categories of South Florida science information:

- Electronic and hardcopy source data, and meta-data previously distributed for use, and
- Raw and preliminary data in analysis or in press.

The first category of information is stored in multiple file formats and in many locations across several organizations and departments. Typically, the owners and custodians of the data are institutions with a wide range of missions, locations, and internal information sharing policies. The second category of information is almost exclusively controlled by principal investigators (PIs) conducting research projects and organizations collecting monitoring data for a specific purpose (e.g., water management, animal censuses).

The Task Force is supporting two initiatives to improve and enhance South Florida science information sharing.

3.7.1 Information Sharing Initiative 1 — Electronic Information Catalog

To increase the accessibility of distributed (and incompletely distributed) science information, the SFWMD and USACE Information and Data Management staff (based in Jacksonville, FL) are developing an electronic data cataloging system (using software called EDCat) that will function similar to how Google™ searches the internet. This tool will enable users to search, locate, and link to science information related to South Florida restoration work.

It is important to understand that this EDCat-based tool will not establish a new or separate database, nor will it store data belonging to organizations or upload information to organizations' databases. All original (source) information and data remain in the host databases, maintained and controlled by the organizations responsible for those databases. In a manner that is transparent to the user and interoperable through a web interface (i.e., the internet), the information catalog will collect, organize, and report summary information and attributes of information that are maintained on agency databases. All information searched and reported by the information catalog will be done through permission and support of the individual organizations, under agreements to provide access to agency information systems and databases.

From keyword and data-attribute queries, the information catalog will provide a list of indexed information and links to the information sources. The catalog will *not* copy, retrieve, or send data files and documents to users, nor will it store or upload data to the queried databases. Such file-level management services (i.e., Documentum, Data Access Storage and Retrieval (DASR)) are provided by CERP Zone and other databases maintained by organizations that support restoration research or projects.

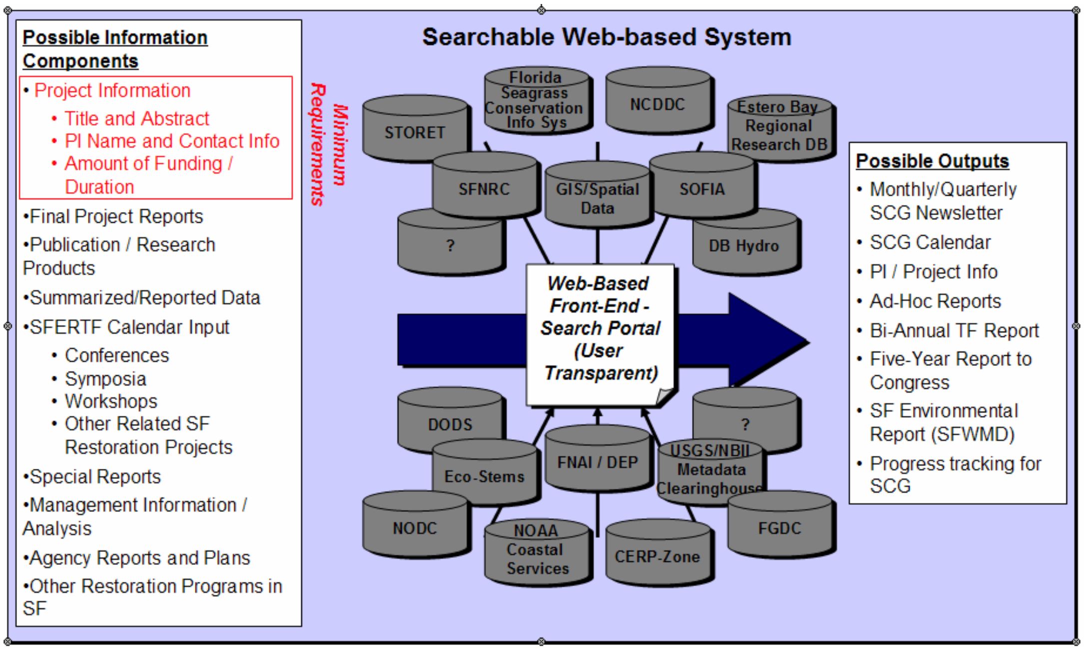

Figure 9. Conceptual diagram of proposed searchable web-based information sharing system

Initially, the information catalog will be a tool for identifying the availability of CERP information. Depending on the tool's utility, applications, and development funding, an expansion into a gateway to data housed by other organizations could occur, as these stakeholders join the system.

Examples of information sharing using the information catalog include the following:

- Scientific research project information
- Conference, symposium, and workshop information

- Agency-initiated information collection efforts
- Agency-initiated data and information sharing IT projects
- Observational data (e.g., tide tables, rainfall, etc.)
- Scientific project reports
- South Florida Ecosystem restoration current events and calendar information
- Modeling code, research results, and PI metadata
- Scientific research and publication abstracts

At the completion of Phase I (currently in production as a prototype), the tool will enable users to search for information and data by keywords or data-attribute queries. Outputs will include an indexed information display and data path links directing users to the source files by query. For example, if data is available related to research a scientist might be planning, the information catalog will direct the user to the person or place where these data may be obtained.

Phase 2 development of the catalog (anticipated by the first quarter of 2007) will include query enhancements for combined keyword and data-attribute queries, and map-view searches (i.e., obtaining science information based on outlining regions of a map of the Everglades). Output enhancements will include website URLs. Phase 3 (anticipated in the second quarter of 2007) will add additional searchable databases (from trusted ecosystem restoration stakeholders and partners), data mining tools for external sites, and expanded stakeholder and partner access. Phase 4 (anticipated in the forth quarter of 2007) will provide public web access.

Successful development and application of the information catalog is dependent on continued support from the Task Force, including the following information sharing actions:

- Assist in developing agreements with South Florida organizations to share restoration related information
- Foster collaborative development of information sharing concepts and protocols
- Communicate and advertise the development and existence of the catalog among Task Force organizations
- Encourage organizations to avoid duplicate information sharing development efforts
- Help identify and secure funding to ensure complete and timely development of the information catalog

3.7.2 Information Sharing Initiative 2 — Science Conferences and Workshops

To expedite the sharing of raw and preliminary data that are in the analysis phase, recently published, or not yet published and distributed to stakeholders, the Task Force is also supporting periodic South Florida science conferences and workshops. These events will serve as venues for sharing ecosystem restoration and management-related research, monitoring, and modeling information, and encouraging science communication, integration, and coordination among PIs and resource managers.

Science information needs and their progress provide the justification for a major conference on a 12-18 month recurring interval. Smaller, more focused topical workshops could occur on shorter intervals, or in response to unexpected events (such as major storms or construction of a restoration project).

To reduce the burden or staff commitment among any one agency, the Task Force is proposing that a small group of agency science managers share the responsibility of organizing conferences and workshops by subject matter or theme. This group should rely on contractors experienced in meeting planning and management to perform the majority of the administrative functions. To assure maximum benefit for adaptive management and related decisions, the conferences and workshops will include oral presentations and posters on priority science issues aligned with science plan needs, gaps, and actions.

Expected information-sharing benefits of Task Force-led conferences and workshops include the following.

- **Advances in scientific understanding of ecosystem function and response.** The conferences and workshops should provide forums for learning and teaching, discussing or evaluating new ideas or methods, receiving feedback from peers, establishing collaborative associations, and answering priority science questions.

- **Communication, collaboration, and synthesis within and across disciplines.** Conferences and workshops focused on South Florida restoration themes should provide opportunities for interdisciplinary review and discussion of recent data, analysis, and application of findings from each science branch to assessment of restoration and related adaptive management decisions.

- **Early access and sharing of results for scientists and managers.** Regularly occurring conferences and workshops should encourage early sharing and discussion of provisional data, preliminary study results of studies, beta versions of models and analytical methods, and awareness of data repositories.

- **"Adaptive assessment" of science approaches.** The preview of results and interpretations in collaborative conference or workshop settings is a principal way that the science community practices adaptive assessment within the conduct of science. The insight and feedback gained in face-to-face meetings should lead to adjustments in approach, methods, or application of results that improves the quality of underway science projects.

- **Building consensus and defining the mainstream.** The conference and workshop setting should be an objective venue for airing diverging hypotheses or interpretations (as opposed to the media or legal challenge). The exchange of ideas and ensuing healthy discussion helps build consensus and define the mainstream point of view, while at the same time providing context for assessing opposing theories held by individual scientists.

3.8 How We Will Ensure that We are Coordinating Science to Focus on the Most Critical Gaps and Will Keep Our Science Current

The Task Force requires a tracking and updating procedure that includes an assessment of the success and relevance of its own coordination efforts. Elements of this effort include a periodic evaluation of the processes used to identify needs, gaps, and actions; tracking of the progress made towards addressing the actions that fill the gaps identified; and the periodic update of the overall Plan for Coordinating Science.

3.8.1 How We Track Our Progress in Completing Actions and Tasks to Fill Science Gaps

A critical component of the Task Force coordination effort is to track the progress made in addressing actions by the many organizations conducting science in support of South Florida

Ecosystem restoration. To ensure restoration success, actions that fill the gaps must be addressed in a timely manner. This requires tracking actions from the point of identification to resolution. In addition, lessons learned and methods used in addressing actions must be available to decision-makers to facilitate resolution of future issues. The Task Force directed the SCG to track progress in addressing gaps and to report this progress to the Task Force.

To meet its Task Force charge to evaluate the progress on actions, the SCG established a process for tracking progress on a continuing basis for each gap and action in the Plan. The tracking process uses an Excel®-based status documentation tool to communicate progress achieved in addressing the identified gaps and actions. As part of its periodic meetings, the SCG will review action status with the appropriate action leads, and identify reasons for delays, if necessary. As actions are completed, the SCG may recommend supplemental or follow-on actions to the Task Force, as appropriate.

To ensure that the Task Force is abreast of issues affecting science coordination, the SCG will brief the Task Force quarterly on the status and progress made for completing actions. The SCG briefing to the Task Force will consist of a concise summary of the status and progress of programmatic science activities and the outcomes of completed activities. An annual briefing will include the expected progress on addressing actions in the upcoming annual review period. On a biennial basis, the SCG will conduct an analysis of needs and gaps similar in scope to the analysis described in this Plan. This analysis will be documented in an update of the Plan. Future tracking sections of this Plan will include a detailed assessment of the progress achieved and challenges encountered in addressing each previously identified gap. Because each gap will have its own unique technical and programmatic challenges, the assessment will be gap specific. At a minimum, each gap assessment will include the following:

- Schedule for fulfilling the gaps, with corresponding ownership assignments for individual actions
- Relationship of the gap schedule to support associated management decision(s)
- Opportunities that expedited or challenges that slowed the progress in addressing the gap
- All interim and final measures taken to address the gap
- Lessons learned applicable to better track and expedite addressing other gaps

3.8.2 How We Ensure that We are Continually Focusing on Filling the Most Critical Science Gaps

The restoration of the South Florida Ecosystem will require sustained efforts spanning multiple decades. Therefore, for the science activities that support restoration to be effective, they require periodic realignment with the priorities that emerge as the ecosystem is restored. The Task Force, in coordination with the SCG, will ensure updates of the Plan on a biennial basis. The biennial review will consider at least the following:

- A review of the needs and gaps previously identified by the Task Force to determine what gaps have been filled
- A review of the activities of the Task Force and each individual organization to determine whether each is meeting the goals and responsibilities outlined in the Plan

- A review of the impact of the coordination plan to assess whether Task Force actions are implemented appropriately and in a timely manner, and whether the actions taken are in agreement with the stated goals of the Task Force and Plan
- A review of the needs and gaps identification process to determine if changes are necessary to make the process more effective and efficient
- An identification of new science needs that have emerged as a result of the restoration process
- An identification and evaluation of new gaps and the actions required to address them
- A review of quality science protocols, information sharing, and tracking procedures to determine whether changes are necessary and to describe the lessons learned in applying these processes

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Glossary

Adaptive management — A process that includes making decisions, evaluating the results, comparing the results to predetermined performance measures, and modifying future decisions to incorporate lessons learned.

Anthropogenic eutrophication — Over stimulation of primary production caused by excess nutrients introduced to a water body by human activity. The excess nutrients may cause undesirable shifts in the composition of the plant community, or promote hyper production of plants, which accelerates organic decomposition thereby reducing dissolved oxygen concentration in the water body. Both decrease the quality of aquatic habitats.

Attributes — Subset of the biological components of a natural system that are representative of the overall ecological condition of a system that can be used to represent the known or hypothesized ecological effects of the stressors (e.g., fish population in a particular area) and the elements of the system that have important human value (e.g., endangered species). Attributes are also known as endpoints.

Bioaccumulation — The process by which chemicals are taken up by a plant or animal, either directly from exposure to a contaminated medium (soil, sediment, water) or by eating food containing the chemical, and stored in the tissues at concentrations well above those prevailing in the environment.

Biodiversity — All aspects of biological diversity, including species richness, ecosystem complexity, and genetic variation.

Biogeochemical cycling — Relating to the path by which elements cycle between the non-living environment and living organisms.

Bioavailability — Describes the accessibility of a substance to be absorbed or metabolized by living organisms.

Carrying capacity — Maximum number of individuals of a determined species a given environment can sustain without detrimental effects

Conceptual Ecological Models (CEMs) — Models that reflect the current scientific understanding of external drivers and anthropogenic stressors upon natural systems. CEMs illustrate the links among societal actions, environmental stressors, and ecological responses and provide the basis for selecting and testing the set of relationships that best explain why the natural systems have been altered.

Contaminant — Any physical, chemical, or biological substance that has a potential harmful effect on living organisms or the ecological value of air, water, or soil.

Critical science need A process or phenomenon that must be rigorously understood if ecosystem restoration decisions and actions are to be scientifically based. Failure to adequately elucidate these scientific understandings could jeopardize restoration success.

Detritus Fragments and particles of decomposing organic matter, which can be very important for the support of aquatic food webs and in the formation of sediments. Plants are a major source of detritus in wetland ecosystems.

Driver The major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces (e.g., sea-level rise) or anthropogenic (e.g., regional land use programs).

Ecological effects The biological responses caused by stressors.

Ecosystem A discrete spatially defined unit that consists of interacting living and non-living parts.

Emerging Pollutants of Concern (EPOCs) Unregulated or emerging chemical contaminants, including pharmaceuticals and personal-care products (e.g., hormones and antibiotics) and fuel and solvent additives, which may cause chronic biological or human health effects. EPOCs are associated with sewage and wastewater effluent, animal feedlots, and certain industrial processes. Advances in analytical techniques have detected the presence of these compounds in ground and surface water.

Fate and transport The movement, transformation, and resultant products of chemicals introduced into ecosystems.

Fragmentation The breaking up of large and continuous ecosystems, communities, and habitats into smaller discontinuous areas that are surrounded by altered or disturbed lands or aquatic features.

Gap identification Evaluating all ongoing science programs relative to previously identified critical science needs to determine if there are gaps in research, modeling, monitoring, or science applications.

Hydrology The study of the properties, distribution, movement and effects of water on the land surface and in soil, underlying substrate, and the atmosphere.

Hydro-pattern The depth, duration of flooding, and timing and distribution of freshwater.

Hydroperiod The amount of time that the ground or soil is saturated with water or flooded, as well as the spatial distribution of this water. Hydroperiod is often expressed as a number of days or a percentage of time flooded or saturated over an annual period.

Invasive species	Species not native to an area that establish self-sustaining, reproducing, and expanding populations. In natural areas, they are capable of altering ecosystem structure and function.
Modeling	Applying representations of the organization or operation of a system to evaluate the relative importance of different processes, assess scenarios from changes in organization or operation, and predict the effects caused by changes to inputs in the system.
Monitoring	The organized acquisition and analysis of field measurements and observations to elucidate temporal and spatial patterns.
Needs identification	Describing the critical scientific understanding required to ensure restoration success.
Oligotrophic ecosystem	A system that has evolved to function with low inputs and concentrations of nutrients. Such ecosystems are susceptible to anthropogenic eutrophication problems.
Peer review	Independent review of scientific work by other qualified scientists to evaluate the validity of methods employed, results obtained, the analysis performed, or the inference made based on those analyses.
Performance measure	The specific feature(s) of each attribute to be monitored to determine how well that attribute is responding to projects designed to correct the adverse effects of the stressors (i.e., to determine the success of the project).
Primary productivity	The rate at which organic material is produced by plants and algae through the process of photosynthesis.
Project	A sequence of tasks with a beginning and an end that uses time and resources to produce specific results. Each project has a specific, desired outcome, a deadline or target completion date, and a budget that limits the amount of resources that can be used to complete the project.
Quality science	Ensuring science is sound, relevant, and communicated in a form useful for decision making.
Research	A systematic study directed toward obtaining a fuller scientific knowledge or understanding of the subject studied.
Restoration	The recovery of a natural system's vitality and biological and hydrological integrity to the extent that the health and ecological functions are self-sustaining over time.

Science
The application of the scientific method to uncover information and knowledge regarding the function or operation of general laws or theories. In the context of this plan, science includes research, modeling, monitoring, and science application.

Secondary productivity
The rate at which organic material is produced by animals from ingested food.

Sound science
Studies that have readily testable hypotheses, systematic and well-documented experimental, monitoring, or analytical methods, appropriate data analysis tools (e.g., models), and yield results that support the conclusions and that can be used to evaluate the hypotheses.

South Florida Ecosystem
An area consisting of the lands and waters within the boundaries of the South Florida Water Management District, and the contiguous nearshore coastal waters of South Florida, including the Florida Keys National Marine Sanctuary.

Stressors
The physical or chemical changes that occur within natural systems that are brought about by the drivers, causing significant changes in the biological components, patterns, and relationships in natural systems.

Sustainability
The state of having met the needs of the present without endangering the ability of future generations to be able to meet their own needs.

Target
A measurable desired level of achievement during or following implementation of projects described in a strategy.

Upper trophic species
Fish, wildlife, and other animals that depend on plants or organisms at the base of the food web.

Wetlands
Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of plants or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction.

Acronyms

C&SF	Central and Southern Florida Project
CEM	Conceptual Ecological Model
CERP	Comprehensive Everglades Restoration Plan
CIWQFS	Comprehensive Integrated Water Quality Feasibility Study
CROGEE	National Research Council Committee on the Restoration of the Greater Everglades Ecosystem
DON	Dissolved Organic Nitrogen
EPA	U.S. Environmental Protection Agency
ENP	Everglades National Park
FBAMS	Florida Bay and Adjacent Marine Systems
FB/FKFS	Florida Bay and Florida Keys Feasibility Study
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FWC	Florida Fish and Wildlife Conservation Commission
FKNMS	Florida Keys National Marine Sanctuary
FKWQIP	Florida Keys Water Quality Improvements Program
FWS	U.S. Fish and Wildlife Service
MAP	Monitoring and Assessment Plan
NOAA	National Oceanic and Atmospheric Administration
QA	Quality Assurance
RECOVER	Restoration Coordination and Verification Team
SCG	Science Coordination Group
SCT	Science Coordination Team
SFWMD	South Florida Water Management District
Task Force	South Florida Ecosystem Restoration Task Force

USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WRDA	Water Resources Development Act

Appendix A – South Florida Ecosystem Restoration Task Force Members

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Appendix E – Conceptual Ecological Models of the South Florida Ecosystem

Total System

This model is designed to represent the ecological linkages among the working hypotheses and cause-and-effect relationships that explain the important consequence of system-wide stressors on the Greater Everglades ecosystem. The model integrates major, system-wide working hypotheses that are common to several or all of the regional conceptual models.

Big Cypress Regional Ecosystem

This model covers the Big Cypress region, which includes the freshwater portions of the area extending from the southern edge of the Caloosahatchee River watershed boundary and west of the Everglades. The water table throughout this region is defined as being at the top of the superficial aquifer, which would be above ground over much of the area during the wet season and below ground over most of these same areas during the dry season.

Biscayne Bay

Biscayne Bay is a naturally clear-water bay with tropically-enriched flora and fauna. Because of the Bay's shallow depths and clear waters, its productivity is largely benthic-based. The two principal drivers of this model are watershed development and water management.

Caloosahatchee Estuary

The Caloosahatchee Estuary is located on the lower west coast of Florida, extending 105 kilometers from Lake Okeechobee to San Carlos Bay. Major changes in the hydrology of the Caloosahatchee watershed are the result of significant modifications in land and canal development and watershed management policy.

Everglades Mangrove Estuaries

This model covers the 24-kilometer-wide brackish water ecotone of coastal bays and lakes, mangrove and buttonwood forests, salt marshes, tidal creeks, and upland hammocks. This region separates Florida Bay from the freshwater Everglades. Because of its location at the lower end of the Everglades drainage basin, the Everglades mangrove estuaries are potentially affected by upstream water management practices that alter the freshwater heads and flows that drive salinity gradients.

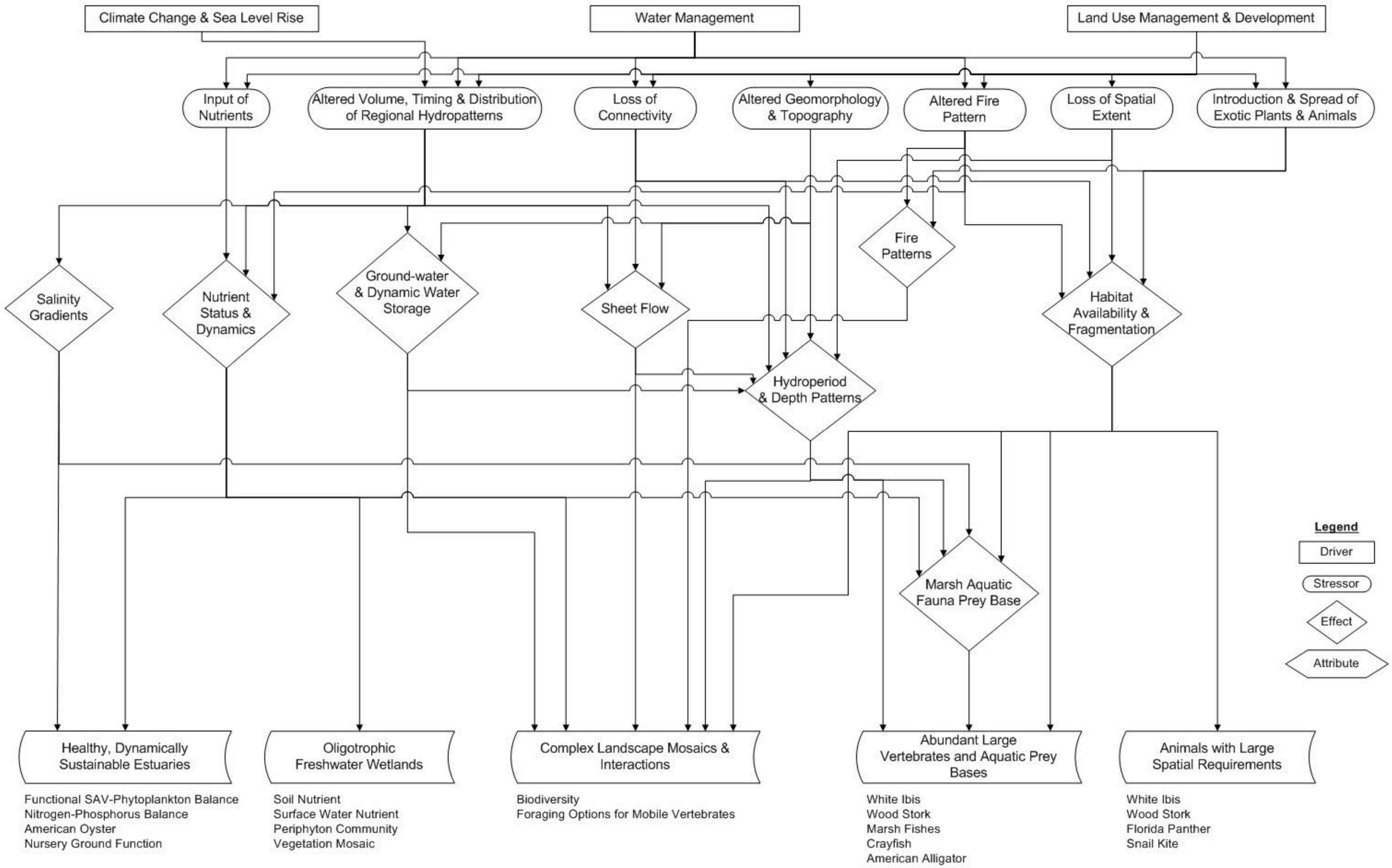
Everglades Ridge and Slough

This model covers the portion of the Everglades basin where there are Loxahatchee or Everglades Peat soils. The ridge and slough system makes up the deeper central portion of the total Everglades basin.

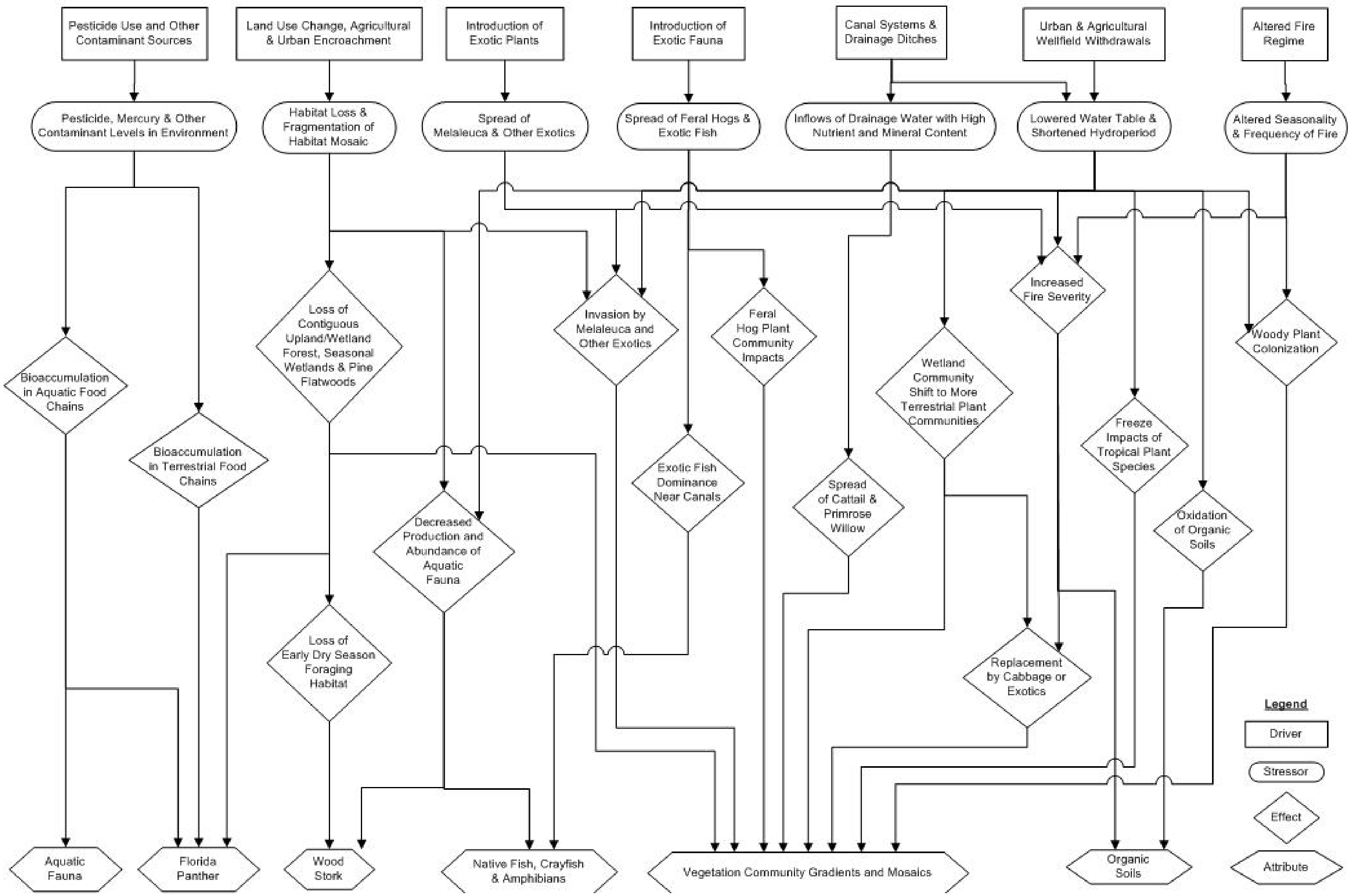
Florida Bay

Florida Bay is a triangularly shaped estuary, with an area of about 850 square miles, between the southern tip of Florida mainland and the Florida Keys. A defining feature of the bay is its shallow depth. Florida Bay is a complex array of basins, banks, and islands that differ across a set of regions.

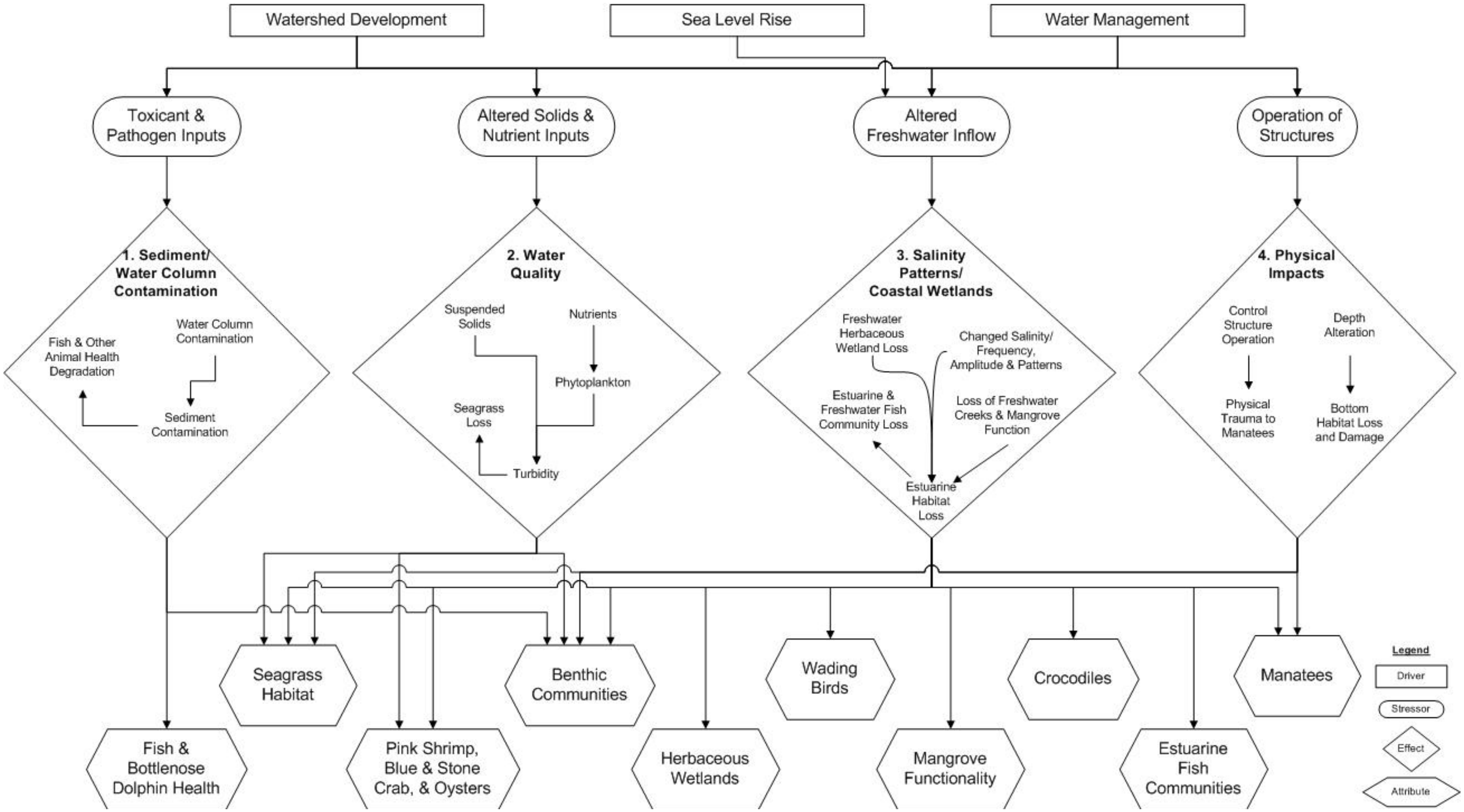
Appendix E: Total System Conceptual Ecological Model Diagram



Appendix E: Big Cypress Regional Ecosystem Conceptual Ecological Model Diagram



1 # Appendix E: Biscayne Bay Conceptual Ecological Model Diagram



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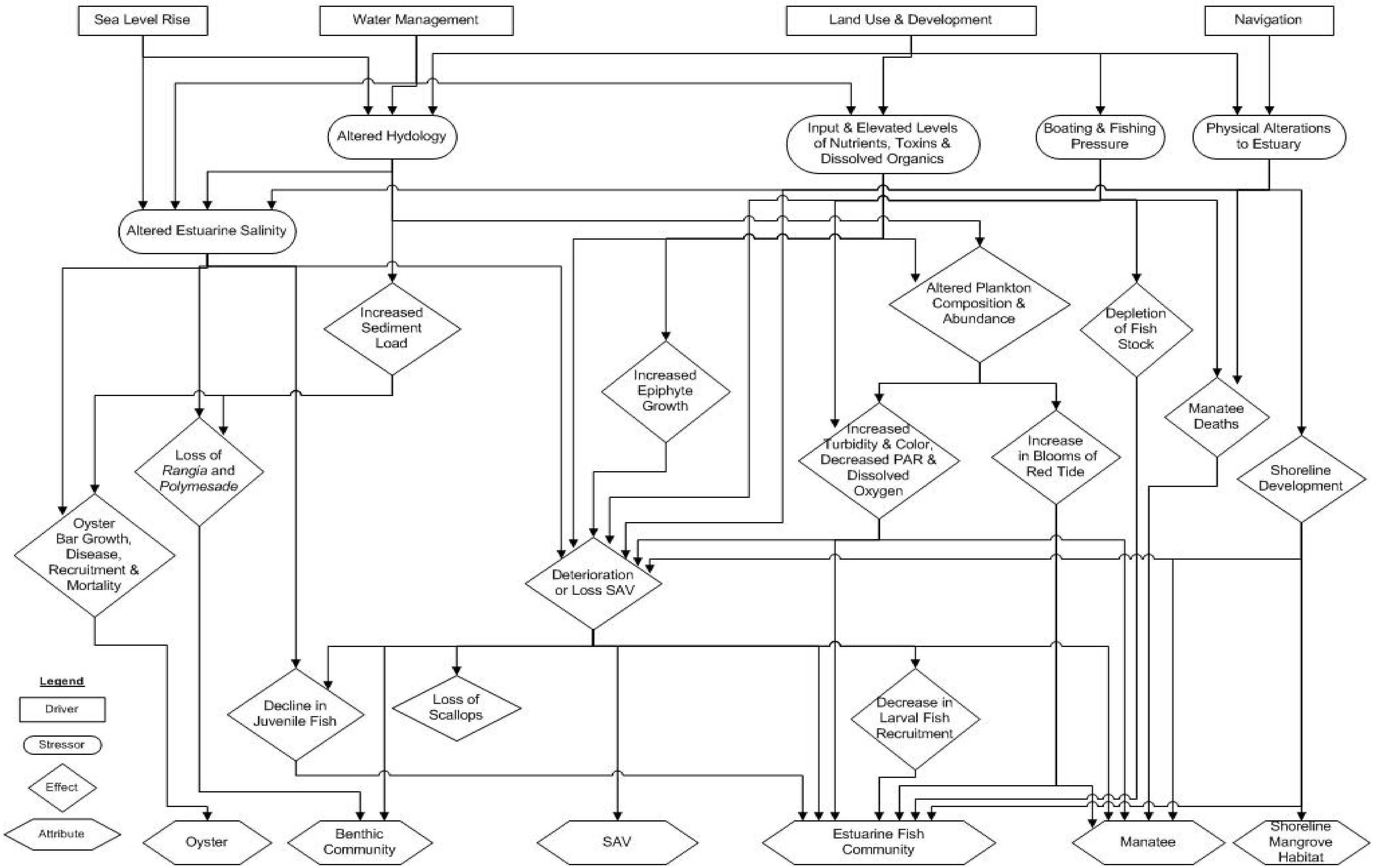
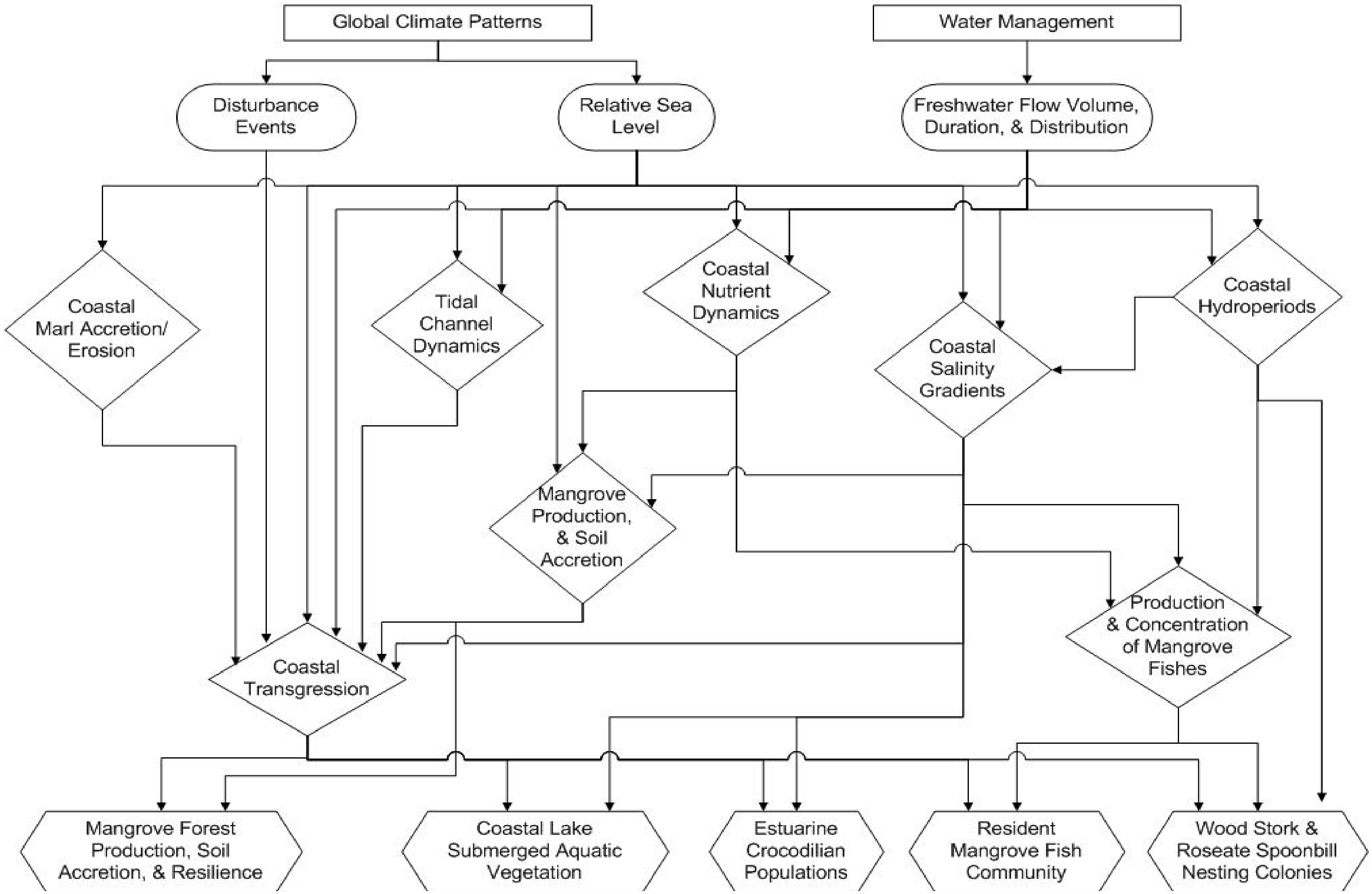
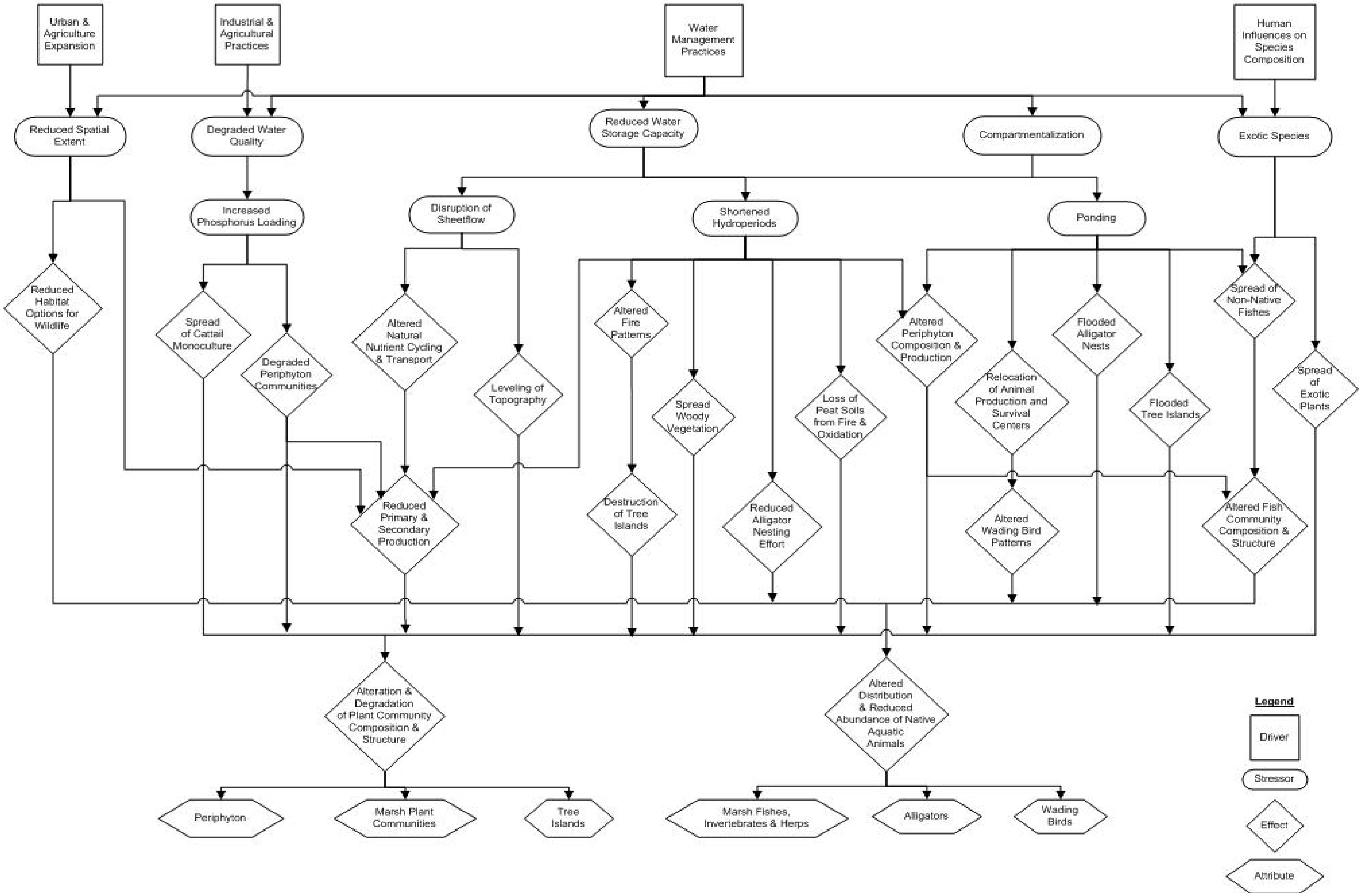
Appendix E: Caloosahatchee Estuary Conceptual Ecological Model Diagram



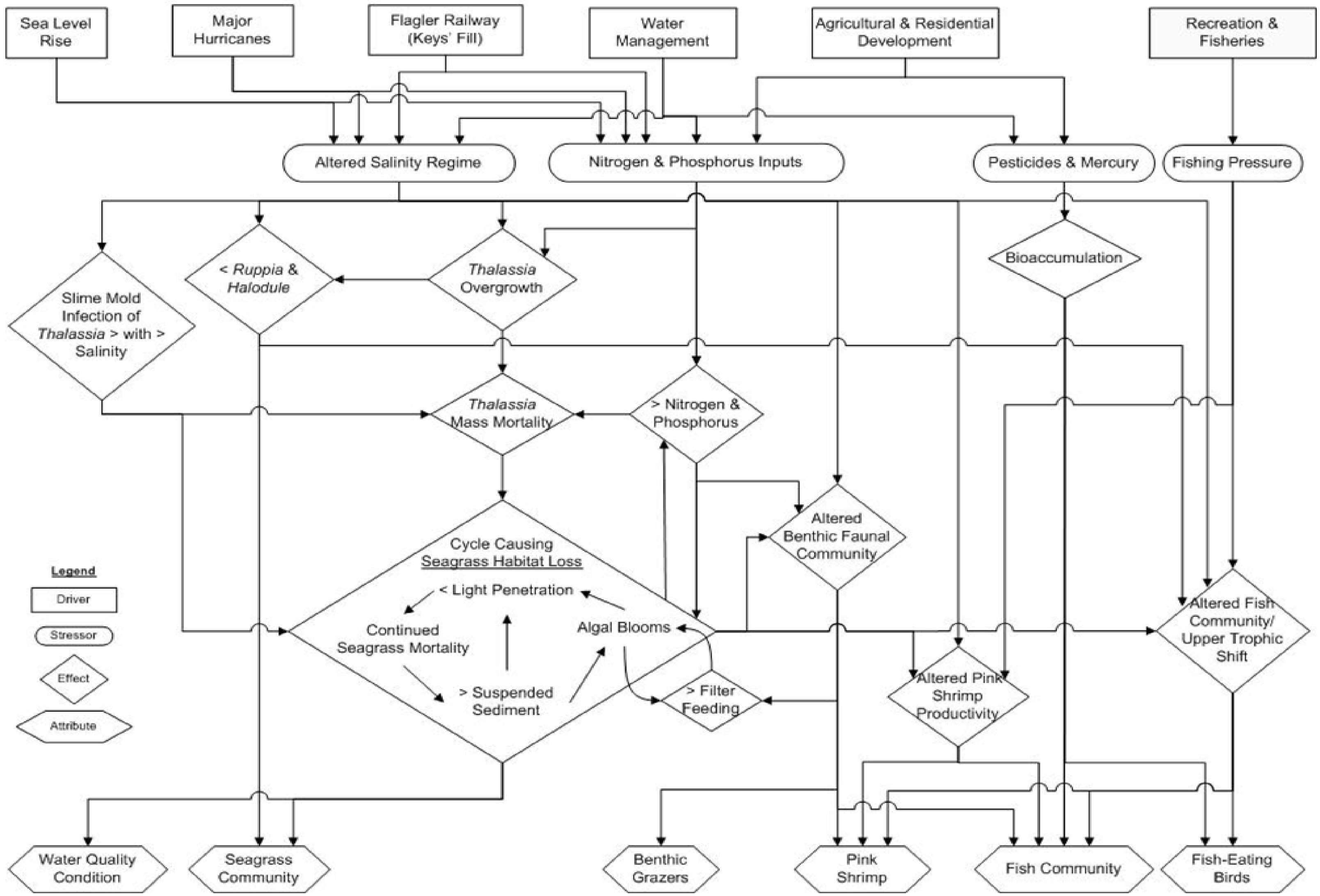
Appendix E: Everglades Mangrove Estuaries Conceptual Ecological Model Diagram



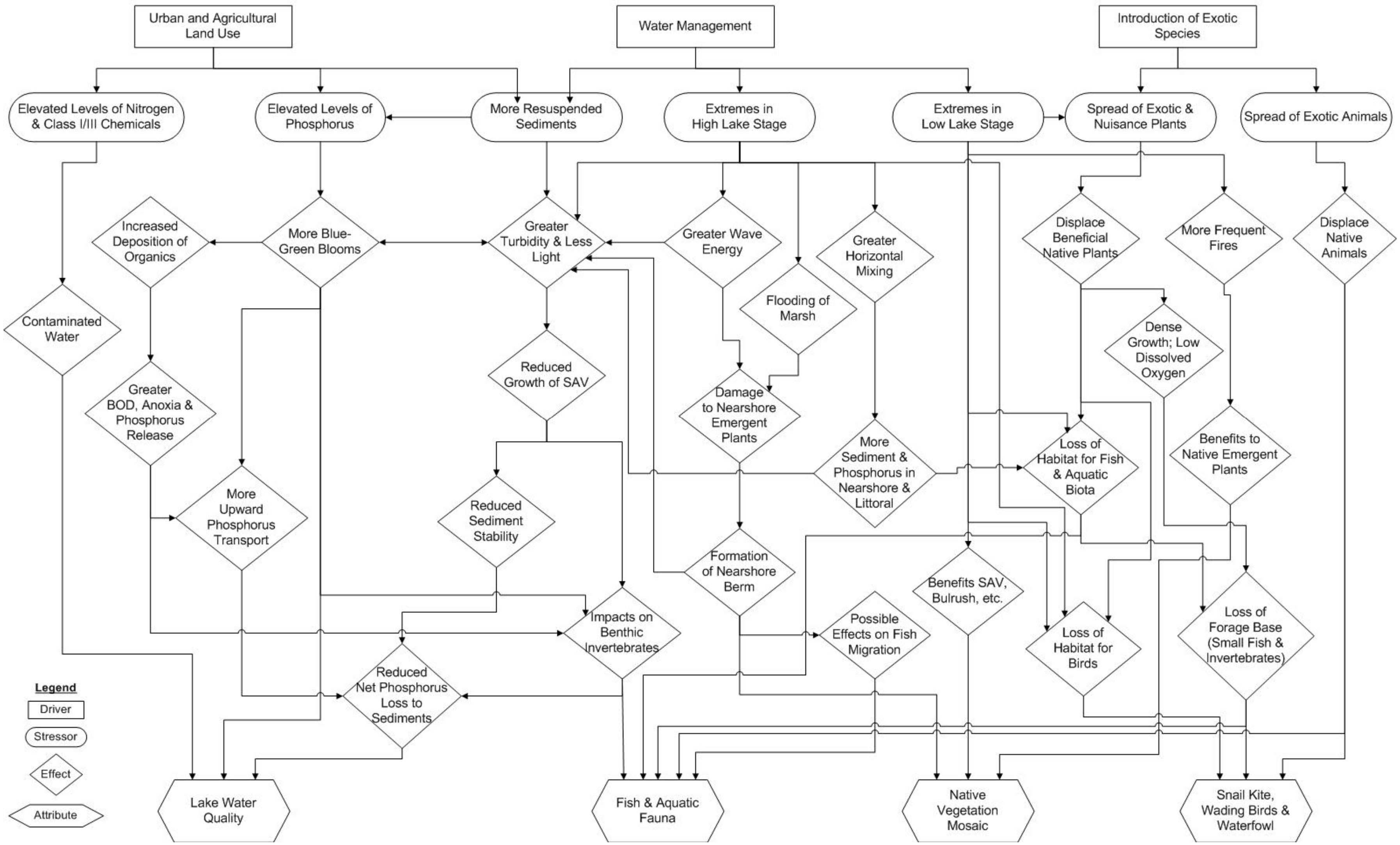
Appendix E: Everglades Ridge and Slough Conceptual Ecological Model Diagram



Appendix E: Florida Bay Conceptual Ecological Model Diagram



1 ## Appendix E: Lake Okeechobee Conceptual Ecological Model Diagram



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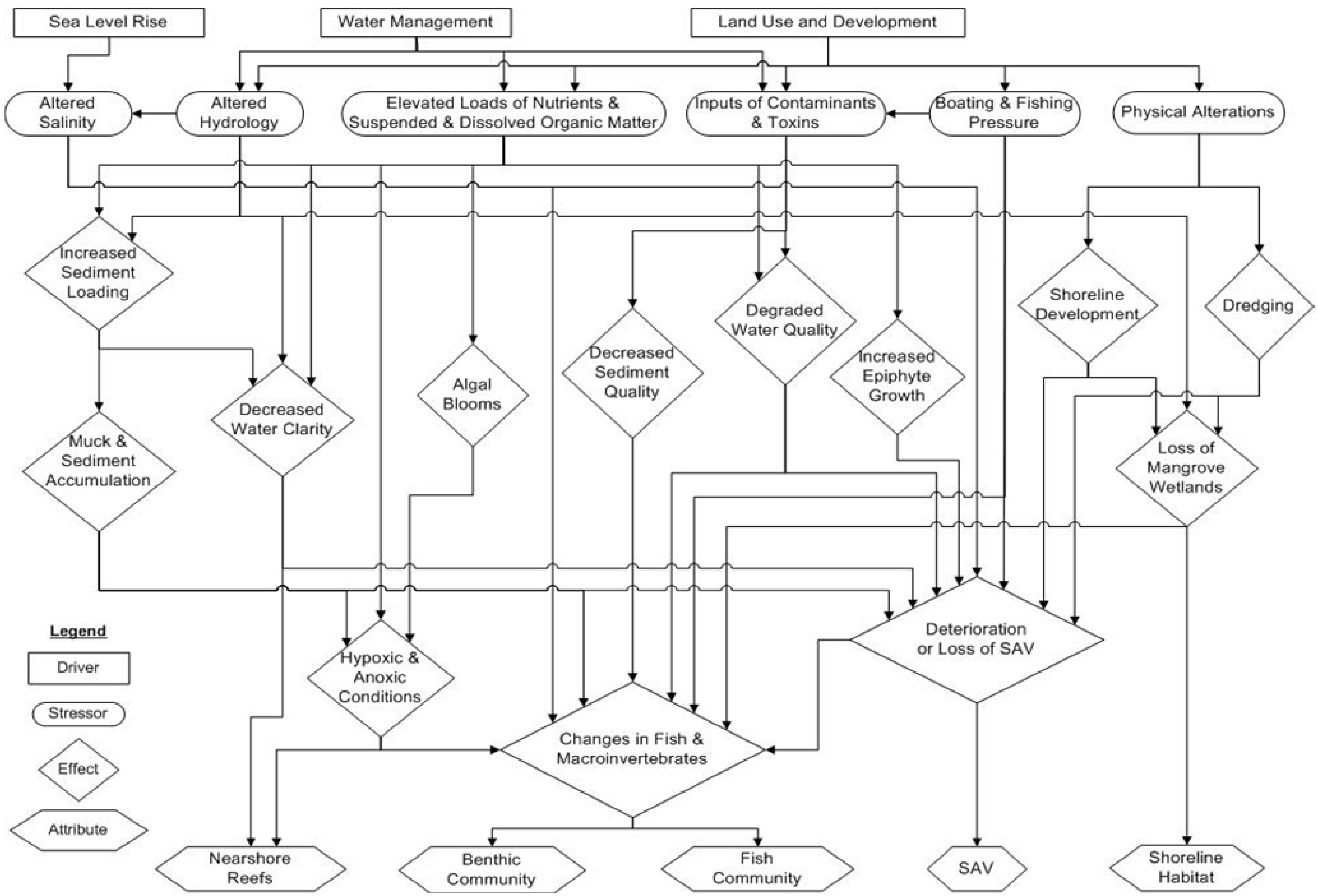
Appendix E: Lake Worth Lagoon Conceptual Ecological Model Diagram



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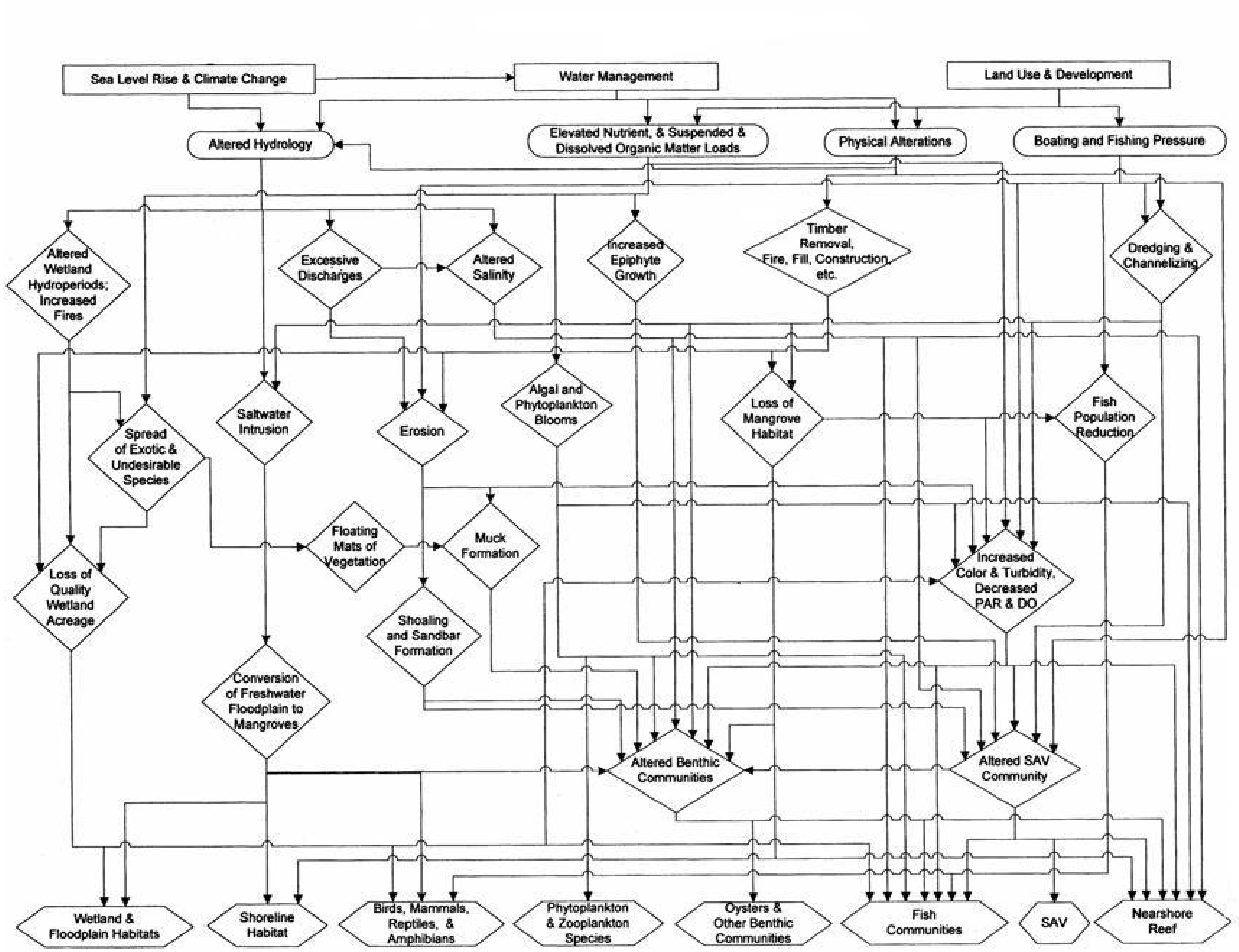
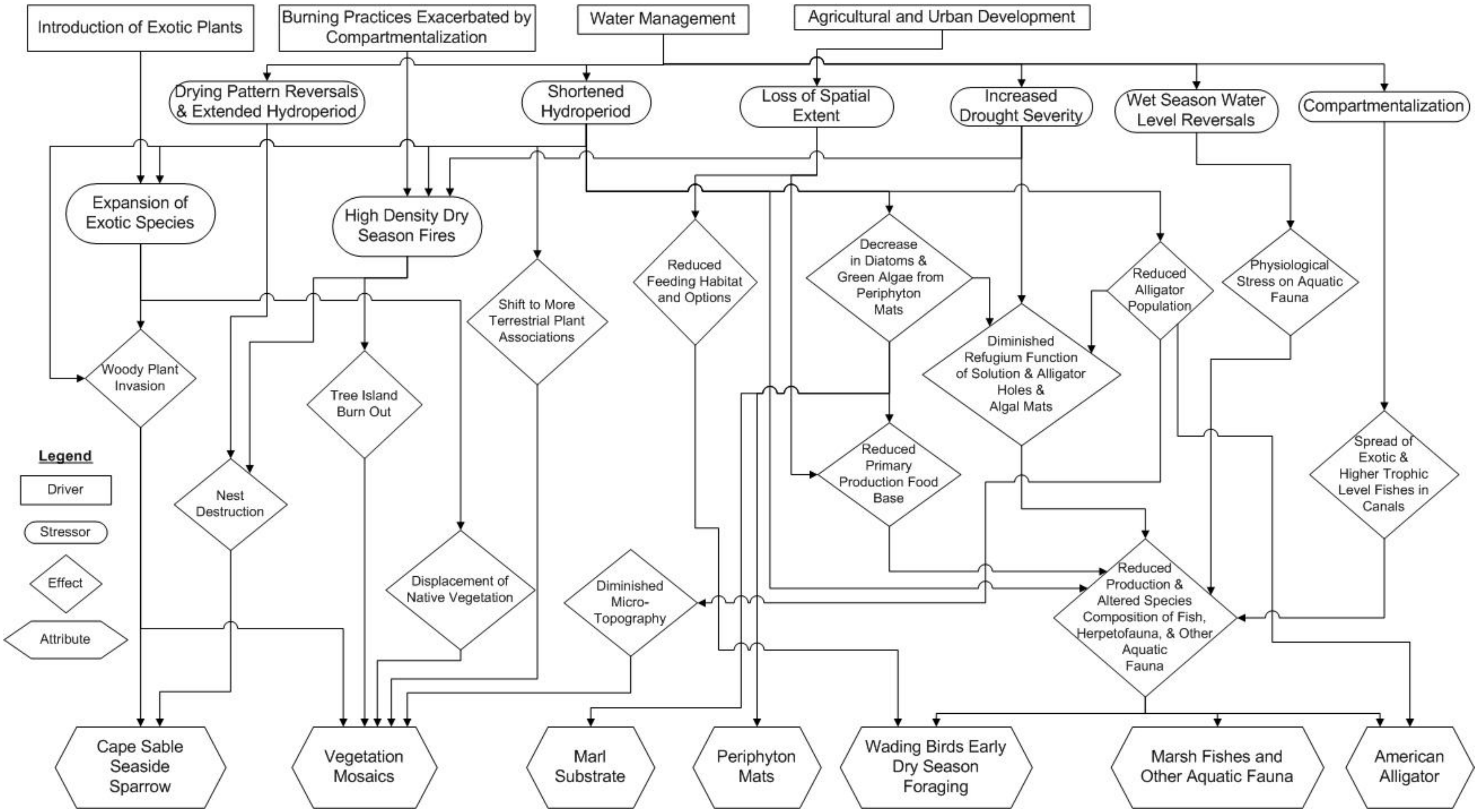
Appendix E: Loxahatchee Watershed Conceptual Ecological Model Diagram



1 ## Appendix E: Southern Marl Prairies Conceptual Ecological Model Diagram



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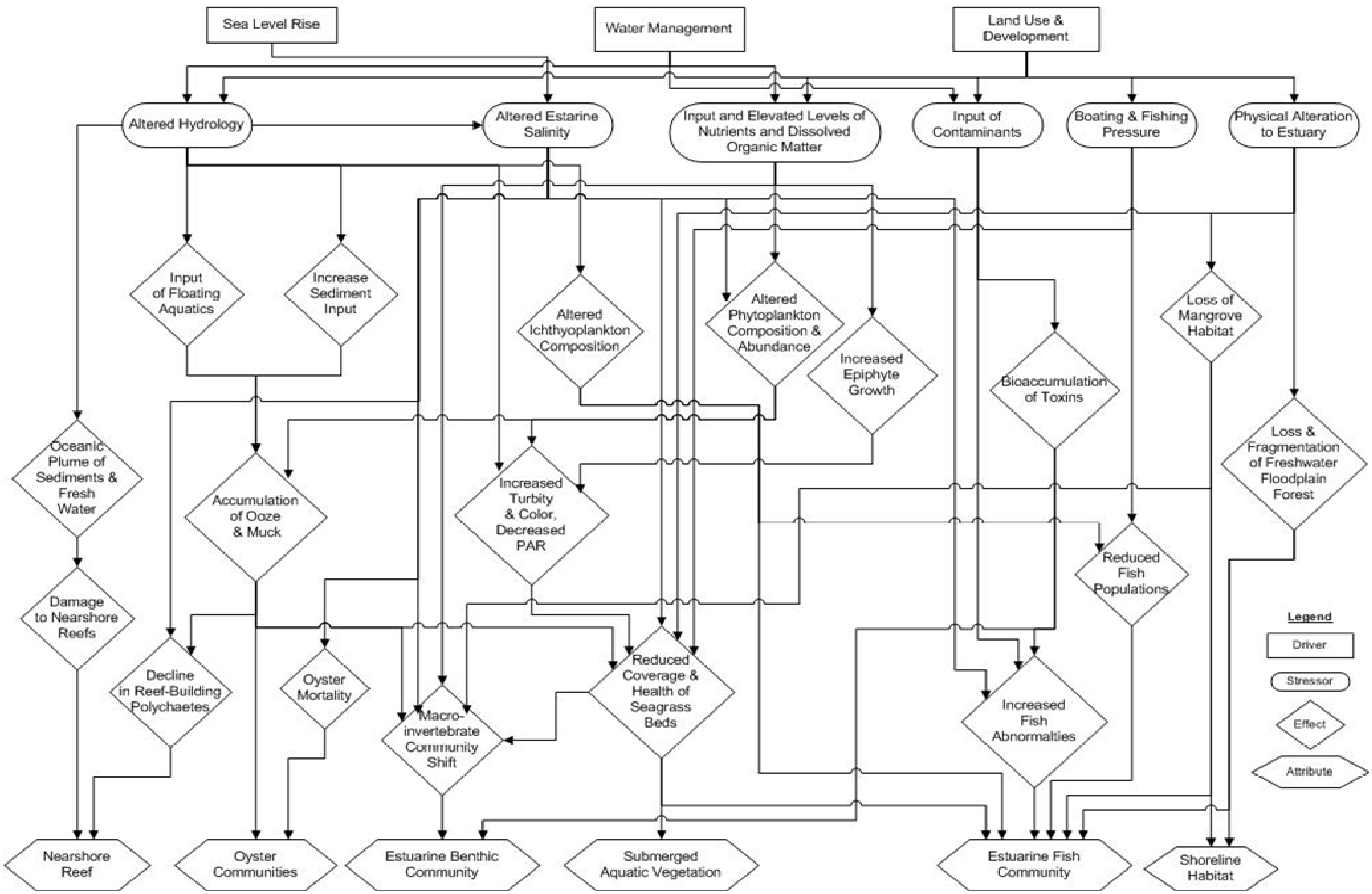
Appendix E: St Lucie Estuary and Indian River Lagoon Conceptual Ecological Model Diagram



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