3.1 GREATER EVERGLADES WETLANDS MODULE

3.1.1 Introduction

The remaining portion of the Greater Everglades Wetlands includes a mosaic of inter-connected freshwater wetlands and estuaries (Figure 3-1). A ridge and slough system of patterned, freshwater peatlands extends throughout the Water Conservation Areas (WCAs) into Shark River Slough in Everglades National Park. The ridge and slough wetlands drain into tidal rivers that flow through mangrove estuaries into the Gulf of Mexico. Higher elevation wetlands that are characterized by marl substrates and exposed limestone bedrock flank either side of Shark River Slough. The marl prairies and rocky glades to the east of Shark River Slough include the drainage basin for Taylor Slough, which flows through an estuary of dwarf mangrove forests into northeast Florida Bay. The Everglades marshes merge with the forested wetlands of Big Cypress National Preserve to the west of WCA 3 and Everglades National Park. Also included in the Greater Everglades Wetlands are the Lake Okeechobee littoral zone and the hydric pinelands and seasonal wetlands of the J.W. Corbett/Pal Mar Wildlife Management Area.

The Greater Everglades Wetlands Module combines four conceptual ecological models: 1) Everglades Ridge and Slough, 2) Everglades Southern Marl Prairies including the Taylor Slough basin, 3) Everglades Mangrove Estuaries including the mangrove estuaries of Florida Bay and the Gulf of Mexico westward to Lostman's River, and 4) Big Cypress Basin eastern portions that will be influenced by the Comprehensive Everglades Restoration Plan (CERP). These are presented in detail in Appendix A. Simplified conceptual ecological models (Figures 3-2, 3-3, 3-4, and 3-5) were derived from the above models to focus specifically on CERP restoration expectations. These four regions share interrelated hydrologic patterns and ecological restoration goals in CERP, and they are combined and integrated at the regional scale in the Monitoring and Assessment Plan (MAP).

The simplified conceptual ecological models reveal that most of the restoration expectations for the ecological attributes of the greater Everglades pertain to 1) the recovery of wetland landscape patterns shown as attributes encircled by dashed lines in Figures 3-2 through 3-5 and 2) the renewal of functional trophic relationships in wetland food webs shown as attributes encircled by solid lines in Figures 3-2 through 3-5. Arrows represent linkages within the conceptual ecological model. Additional species-specific expectations are for the American alligator, the American crocodile, and the Cape Sable seaside sparrow. Restoration expectations for the stressors to the Greater Everglades Wetlands pertain to hydrologic patterns, coastal gradients, and water quality.

A number of CERP projects are expected to influence the stressors and attributes described in the simplified conceptual ecological model. Some of these effects will be direct, others indirect. A summary of the projects expected to affect the Greater Everglades Wetlands is provided in Appendix B.

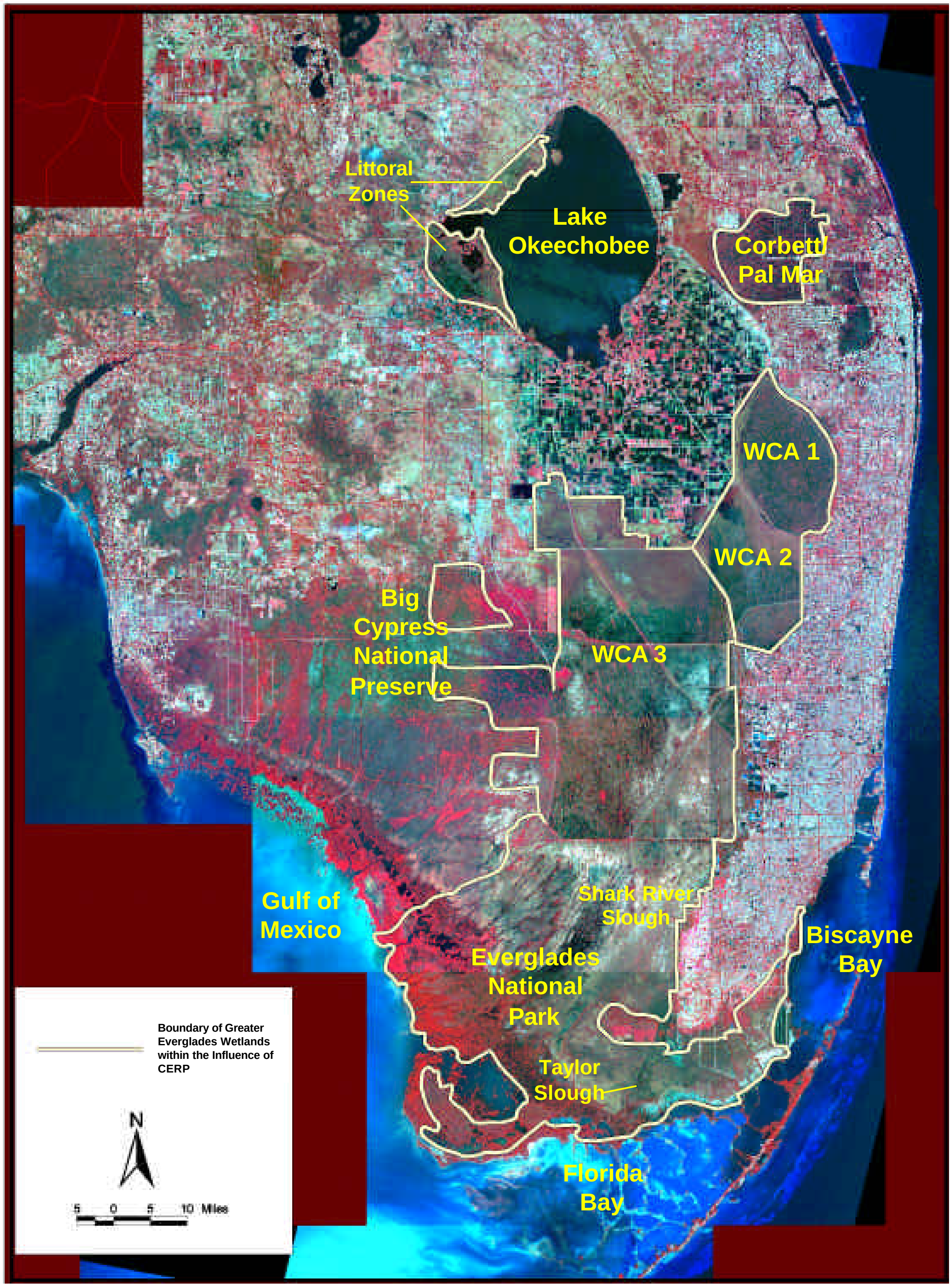

Figure 3-1: Boundary of Greater Everglades Wetlands within the Influence of CERP

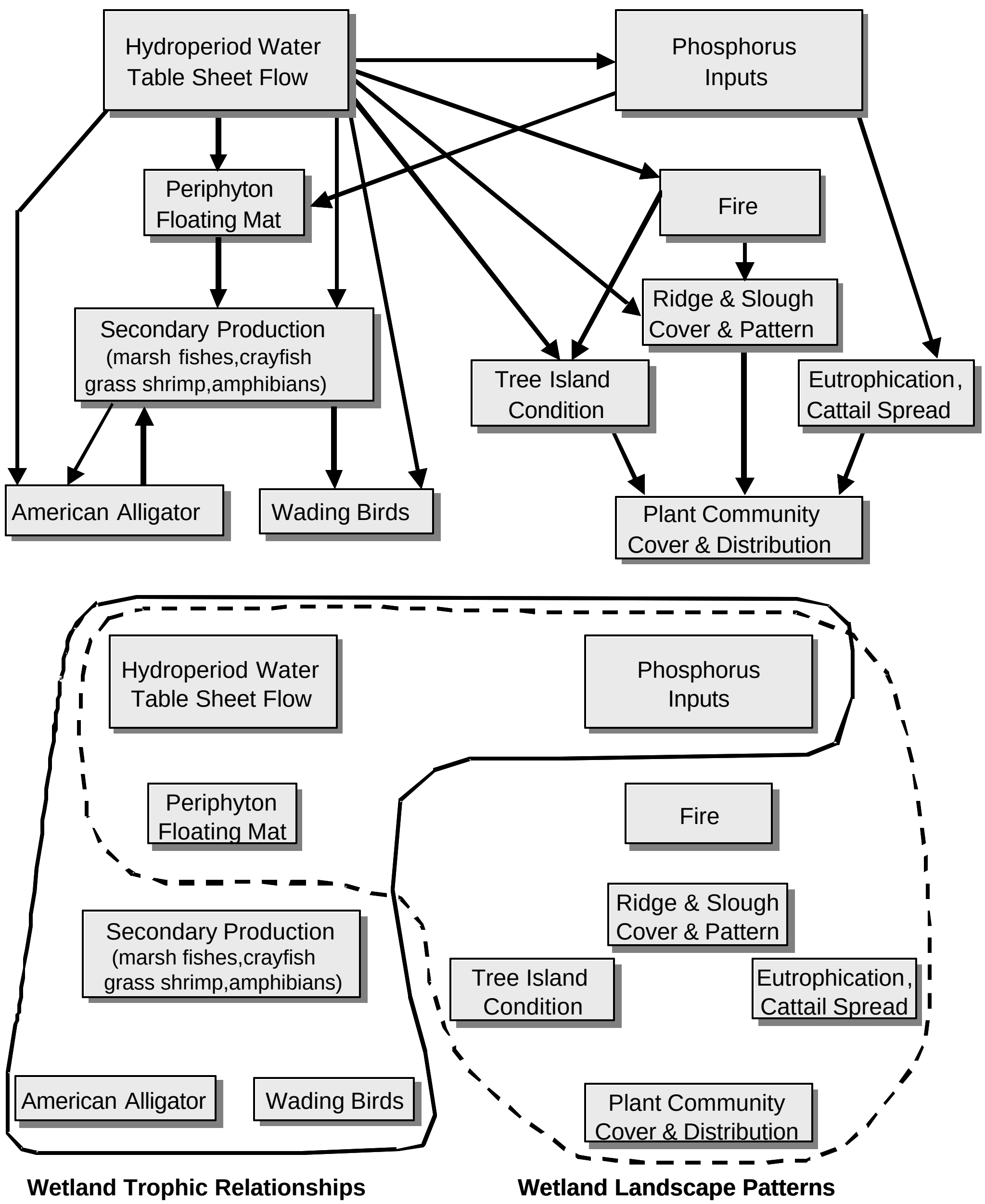

Figure 3-2: Simplified Conceptual Ecological Model to Reflect Expected CERP Influences in Everglades Ridge and Slough

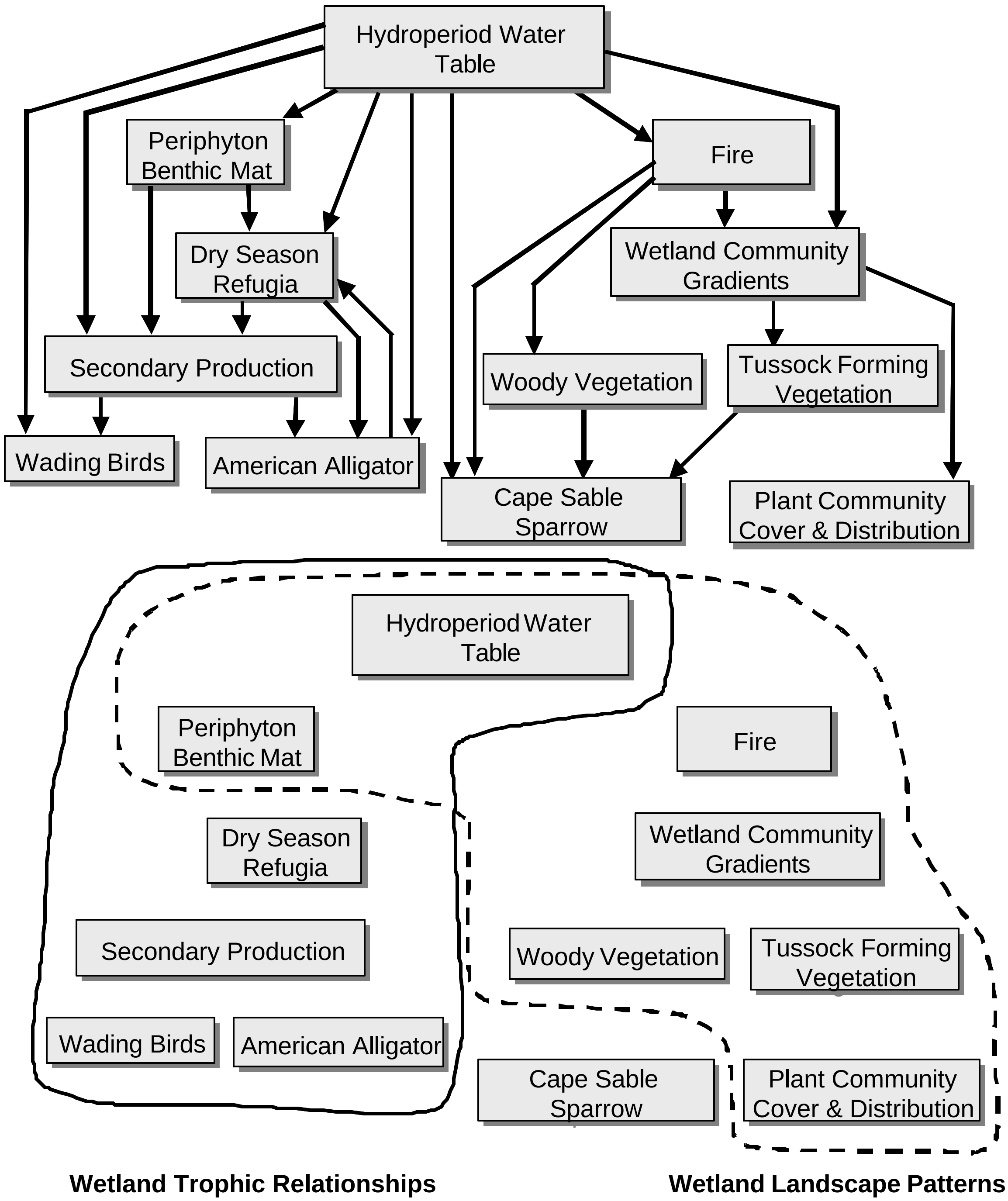

Figure 3-3: Simplified Conceptual Ecological Model to Reflect Expected CERP Influences in Everglades Southern Marl Prairies

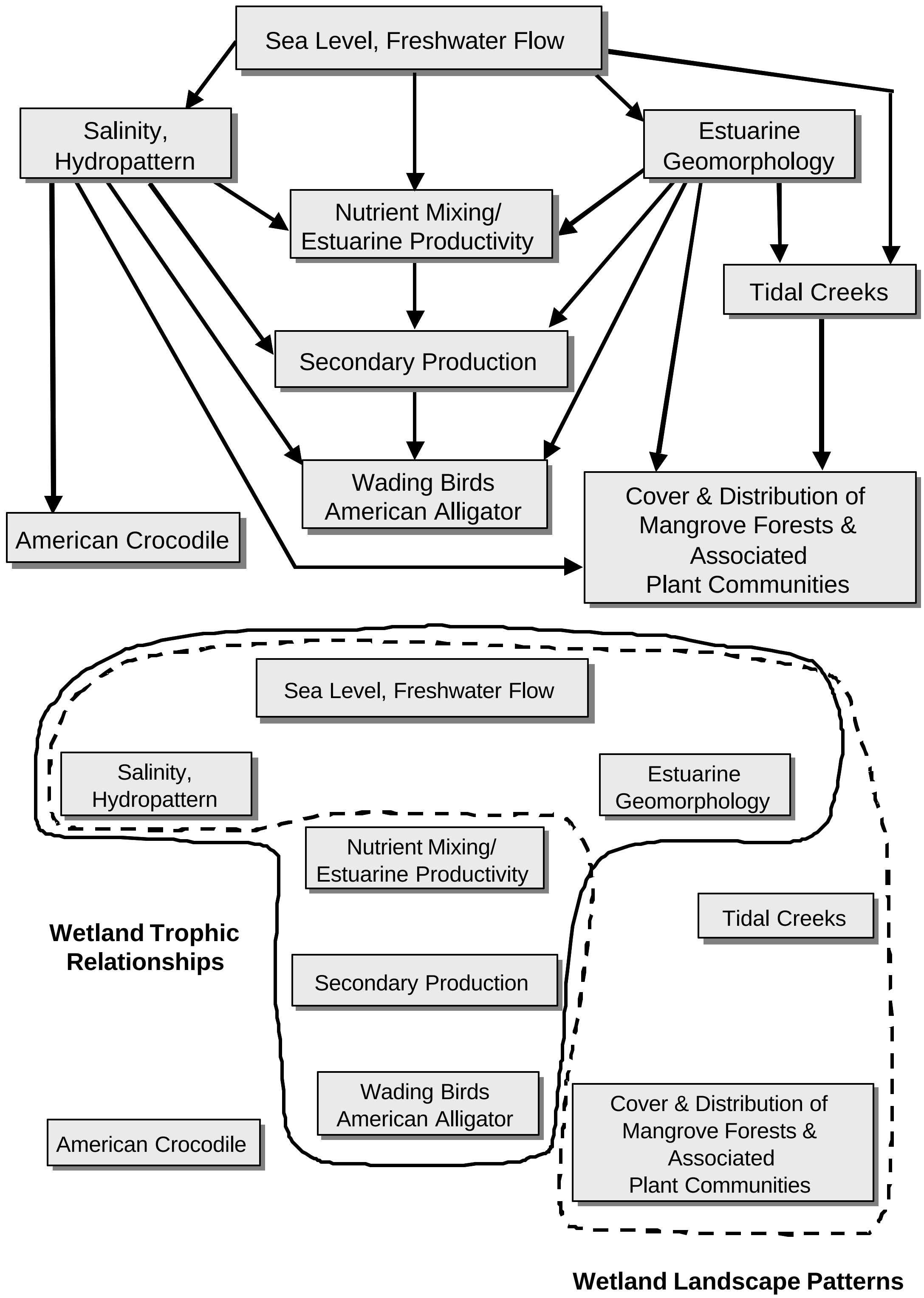

Figure 3-4: Simplified Conceptual Ecological Model to Reflect Expected CERP Influences in Everglades Mangrove Estuaries

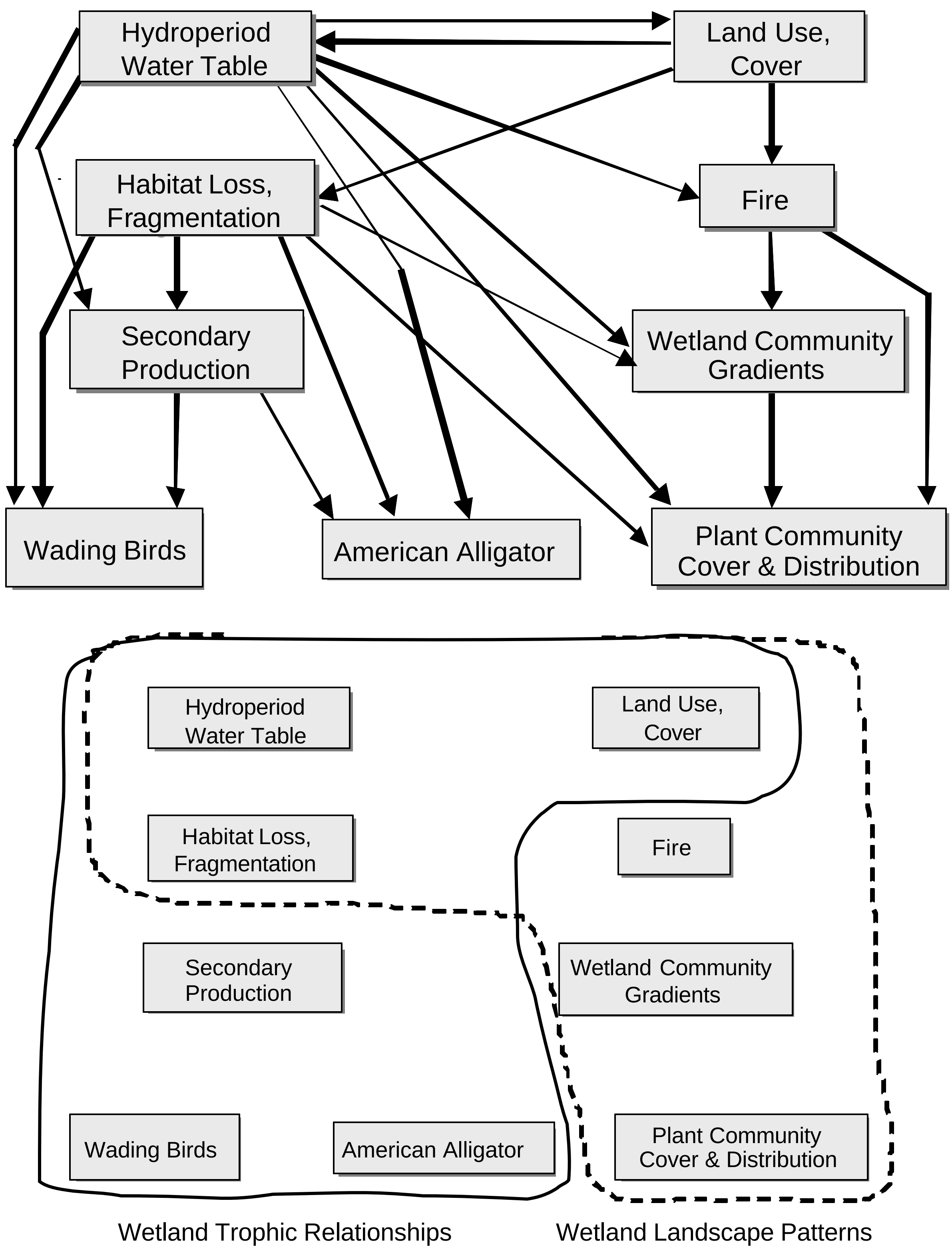

Figure 3-5: Simplified Conceptual Ecological Model to Reflect Expected CERP Influences in Big Cypress Basin

3.1.2 Ecological Premises and CERP Hypotheses as the Basis for Monitoring Components and Supporting Research

Four ecological premises form the basis for most of the CERP restoration goals and strategies for the Greater Everglades Wetlands. These pertain to the effects of hydrology on 1) interior gradients of water quality (i.e., rates of change of a parameter over distance) and the resulting distribution of soil nutrients; 2) coastal gradients of flow, salinity, and nutrients; 3) wetland landscape pattern and extent; and 4) trophic levels of food chains supporting higher vertebrates. Additional species-specific premises relate to the American alligator, the American crocodile, and the Cape Sable seaside sparrow. Monitoring and assessment associated with each of these premises is dependent on the South Florida Hydrology Monitoring Network (Section 3.5).

Figures 3-6 to 3-12 illustrate the linkages of ecological premises to CERP hypotheses, monitoring components, and key uncertainties and supporting research. Supporting research is generally linked to monitoring components, in which case research supports the interpretation of monitoring results. In some cases, supporting research originates directly from a CERP hypothesis, and research will be required to develop an appropriate monitoring component. These linkages are indicated by a red arrow. The resulting monitoring components and supporting research for the Greater Everglades Wetlands are listed in Table 3-1 and described in detail in the following sections. The list of research topics includes those identified during the development of the current version of the MAP. This list has yet to be prioritized, and it is anticipated that additional research topics of equal or higher priority will be identified in the future, including those related to water quality.

The process used to develop the monitoring plan for the Greater Everglades Wetlands Module, and all of the other modules, is described in Section 2.0, Development of the CERP Monitoring Plan and Adaptive Management Program. The strategy for prioritizing and implementing monitoring components and research topics is discussed in Section 5.0, Implementation Strategy for the CERP Monitoring and Assessment Plan.

3.1.2.1 Interior Gradients of Flow and Water Quality (Figure 3-6)

Ecological Premise: The pre-drainage Greater Everglades Wetlands system was characterized by hydrologic inputs (primarily from direct rainfall) and by extended hydroperiods. Natural conditions were characterized by oligotrophic conditions with low phosphorus and sulfur concentrations in surface waters having defined zones of low or high conductivity as compared to present conditions. An overriding expectation of CERP is that it will restore hydroperiods by providing freshwater inflows and restored hydropatterns to the Greater Everglades Wetlands without increasing nutrient loads or subjecting more of the system (particularly the more pristine areas) either to elevated concentrations of surface water phosphorus, nitrogen, and sulfur or to constituents that alter the natural zones of conductivity in the freshwater regions, thereby improving overall water quality throughout the wetland system.

CERP Hypothesis: The restoration of hydrology toward Natural Systems Model (NSM) conditions (a simulation of the pre-drainage Everglades) will result in the following:

- Maintenance or reduction of nutrient (phosphorus and nitrogen) loads from inflow structures and phosphorus and nitrogen concentrations in surface water and soils in the open marsh at levels that do not expand zones of eutrophication in Greater Everglades Wetlands and halt the loss of Everglades landscape patterns (i.e., spread of cattail) and the breakdown in aquatic trophic relationships

- No increases or expansion of sulfate/sulfide concentration gradients into near pristine areas so that aquatic fauna and flora are not subjected to sulfide toxicity and ensure that mercury methylation in the system is not exacerbated (as described in Section 3.6)
- Maintenance of a soft water, low conductivity surface water in the Arthur R. Marshall Loxahatchee National Wildlife Refuge and hard water, higher conductivity water in the remaining freshwater Everglades

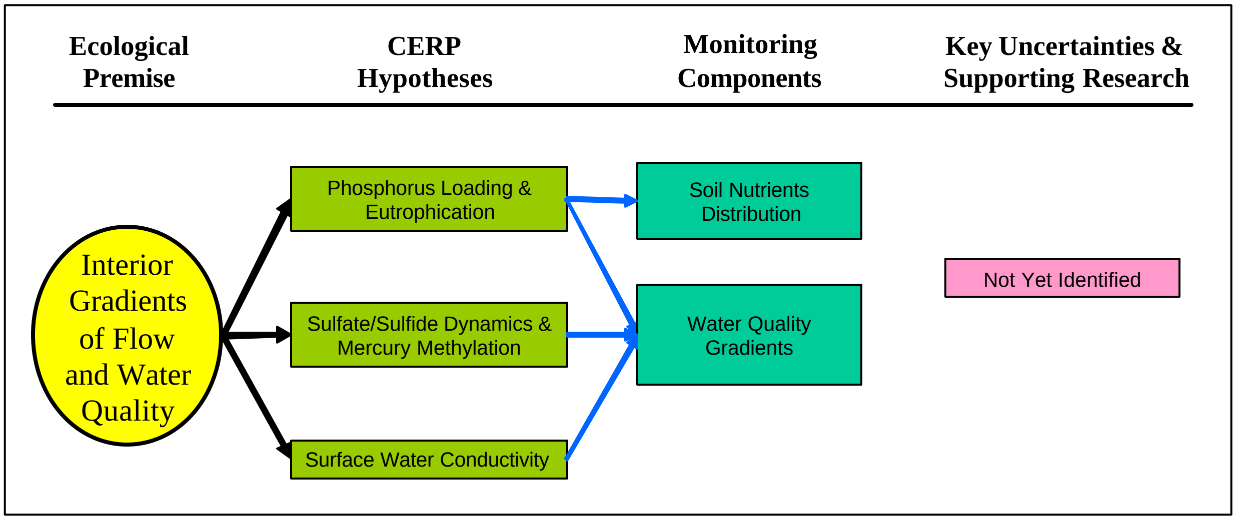

Figure 3-6: Diagram Depicting Relationships between the Ecological Premise, CERP Hypotheses, Monitoring Components, and Supporting Research for Interior Gradients of Flow and Water Quality in the Greater Everglades Wetlands

Adaptive Management Question: Will the restoration of NSM conditions achieve these objectives? If not, how and to what extent do we modify the physical structure and hydrology of the system to create desired trends toward pre-drainage water quality conditions? Will increased freshwater flows to the remaining Everglades bring higher or lower nutrient loads?

3.1.2.2 Coastal Gradients of Flow, Salinity, and Nutrients (Figure 3-7)

Ecological Premise: Pre-drainage hydrological conditions in the southern Everglades produced prolonged pooling of fresh water just upstream of the mangrove estuaries and prolonged patterns of freshwater flow into the mangrove estuaries. The freshwater pooling and inflow supported a wide salinity gradient, including a broad oligohaline zone, in the mangrove estuary. The freshwater inflows also provided nitrogen inputs that supported a highly productive estuarine transition zone without stimulating algal blooms in the downstream receiving estuaries.

CERP Hypotheses: The restoration of hydrology toward NSM conditions will result in the following:

- Prolong the pooling of fresh water in the region upstream of the southwest Florida shelf mangrove estuary, including the fertile crescent, and in the Craighead Basin region upstream of the Florida Bay mangrove estuary

- Expand the width and extend the seasonal duration of the oligohaline zone in the mangrove estuaries of the southwest Florida shelf, Florida Bay, and Biscayne Bay
- Slow the inland expansion of the "white zone" interface of marine and freshwater environments in coastal wetlands of Biscayne Bay and northeast Florida Bay
- Control nutrient inputs to Florida Bay and southwest Florida shelf that promote eutrophication and phytoplankton blooms
- Provide freshwater inflows, nitrogen inputs, and nutrient mixing to sustain a high-productivity salinity transition zone in the mangrove estuaries of the southwest Florida shelf

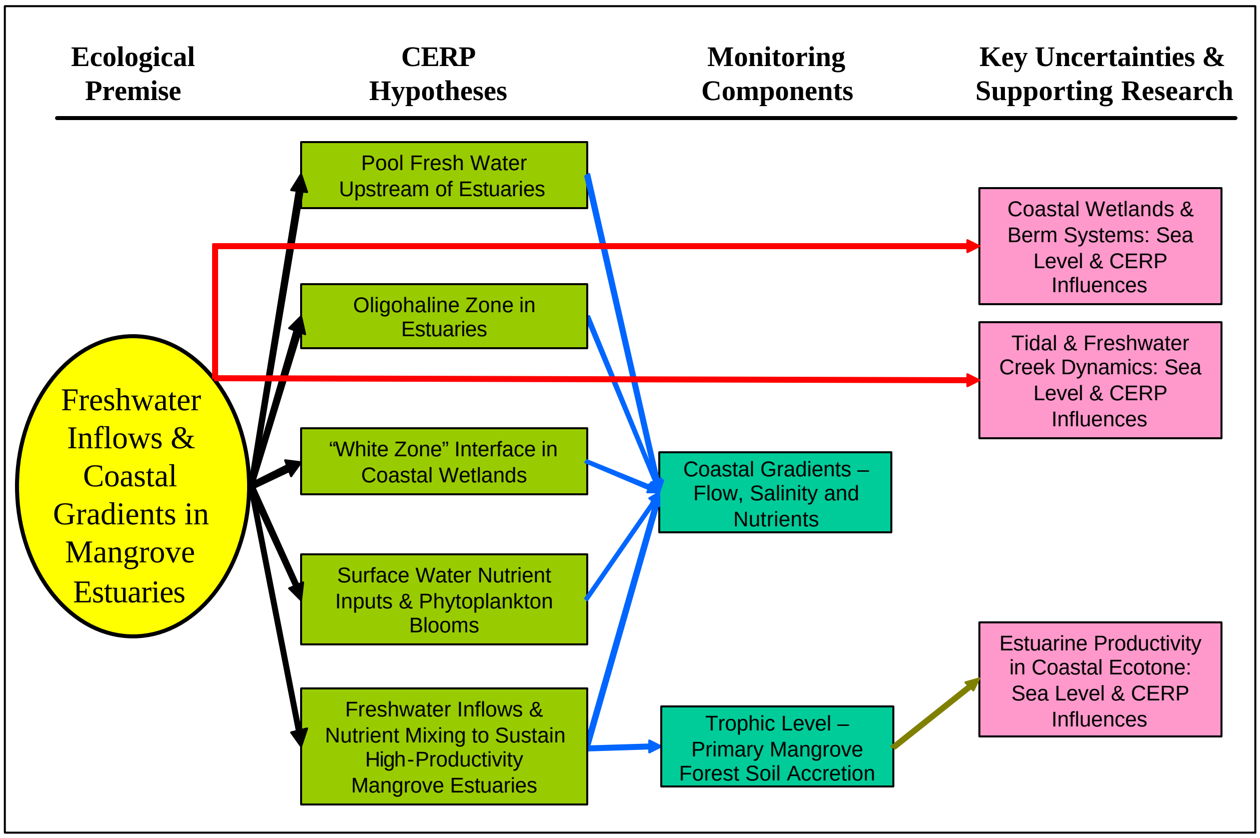

Figure 3-7: Diagram Depicting Relationships between the Ecological Premise, CERP Hypotheses, Monitoring Components, and Supporting Research for Coastal Gradients of Flow, Salinity, and Nutrients in the Greater Everglades Wetlands

Adaptive Management Question: Will the restoration of NSM achieve these objectives? If not, how and to what extent do we modify the physical structure and hydrology of the system to provide desired freshwater flow and salinity patterns in the coastal mangroves and basins of the southern Everglades without stimulating additional algal blooms in Florida Bay?

3.1.2.3 Wetland Landscape Pattern and Extent (Figure 3-8)

Ecological Premise: The loss of pattern and directionality in Everglades wetland landscapes has been caused by altered hydrologic conditions in combination with eutrophication.

CERP Hypotheses: The restoration of hydrology toward NSM conditions will result in the following:

- Sustain spatial extents and patterns of ridges and sloughs and the health of tree islands given the altered conditions now existing and restore patterns, where possible, through hydrologic restoration toward NSM conditions, in the ridge and slough landscape

- Achieve the above ridge and slough restoration objectives through hydrologic restoration without having negative impacts on vegetation communities due to excessive nutrient inputs and eutrophication

- Provide hydrodynamic conditions that will sustain patterns of tidal creeks in the mangrove estuaries

- Restore slough habitat in the southern Everglades while maintaining short hydroperiod, tussock-forming plant communities in the adjacent marl prairies

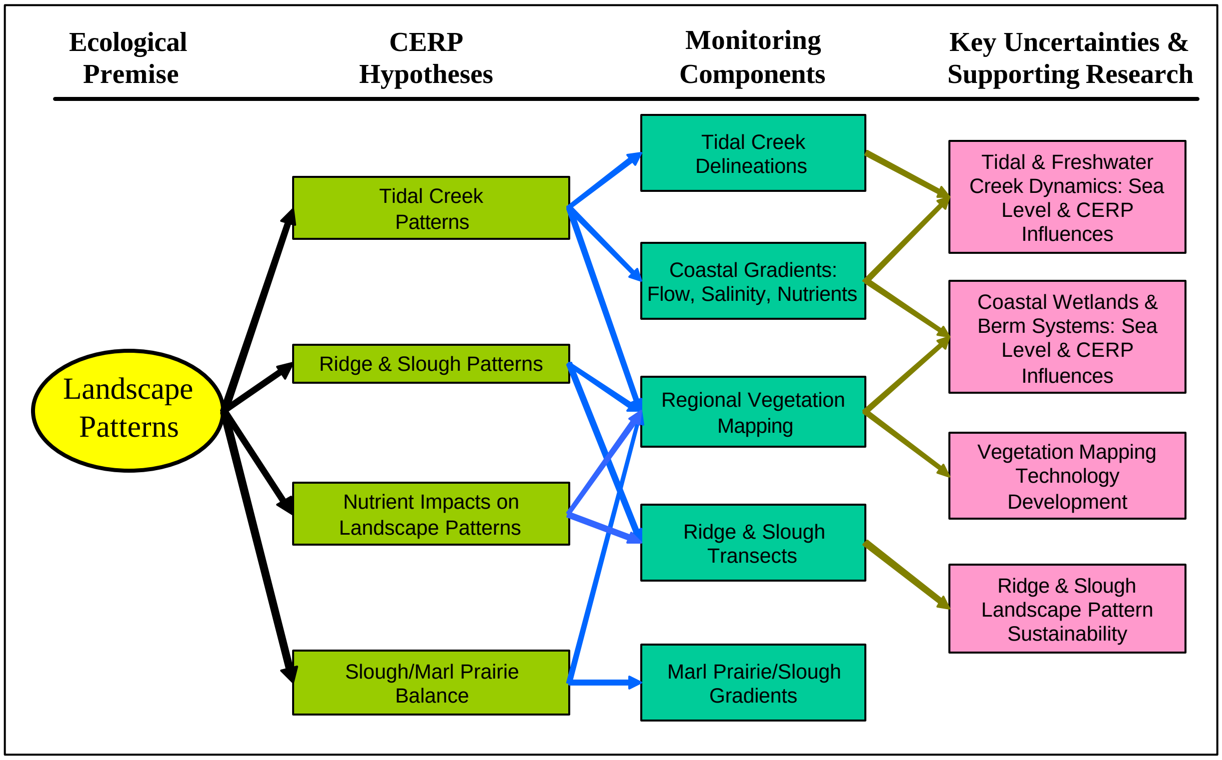

Figure 3-8: Diagram Depicting Relationships between the Ecological Premise, CERP Hypotheses, Monitoring Components, and Supporting Research for Wetland Landscape Patterns in the Greater Everglades Wetlands

Adaptive Management Question: Will the restoration of NSM conditions achieve these objectives? If not, how and to what extent do we modify the physical structure and hydrology of the system to restore pattern and directionality in Everglades landscapes?

3.1.2.4 Trophic Levels of Food Chains Supporting Higher Vertebrates (Figures 3-9, 3-10, and 3-11)

Ecological Premise: Reproduction of higher vertebrates that are dependent on aquatic food webs is food limited due to altered hydrologic and water quality conditions in the Greater Everglades Wetlands. As a result, the foraging distributions and nesting patterns of wading birds have been altered due to the redistribution of high concentrations of prey organisms.

CERP Hypotheses: The restoration of hydrology toward NSM conditions will result in the following:

- Enhance periphyton community characteristics and mangrove forest soil accretion rates as regional indicators of the functional bases of Everglades food webs
- Restore the density, seasonal concentration, size structure, and taxonomic composition of marsh fishes and other aquatic fauna to levels that support sustainable breeding populations of higher vertebrates
- Shift the distribution of high density populations of marsh fishes and other aquatic fauna from artificially-pooled areas (the Water Conservation Areas) to the restored pools in the southern Everglades
- Shift the foraging distribution of wading birds in response to expected trends in the density, distribution, and concentration of prey organisms
- Reestablish wading bird nesting colonies in the coastal regions of the southern Everglades and increase the numbers of nesting pairs and colony sizes in response to desired trends in populations of prey organisms
- Increase the nesting success/survival rate of wading birds in response to desired trends in populations of prey organisms

Adaptive Management Question: Will the restoration of NSM conditions achieve these objectives? If not, how and to what extent do we modify the physical structure and hydrology of the system to restore aquatic food webs that support reproducing populations of higher vertebrates and to shift the foraging distribution and nesting of wading birds to energetically sustainable breeding populations?

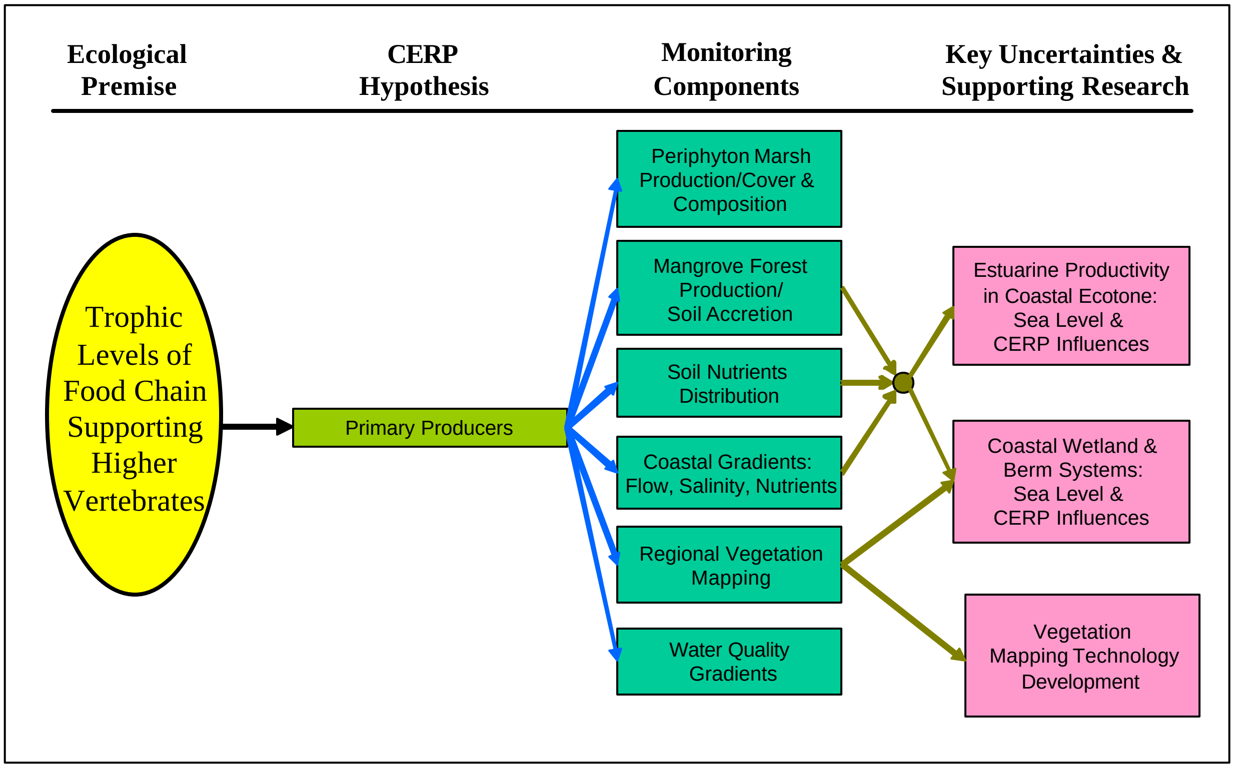

Figure 3-9: Diagram Depicting Relationships between the Ecological Premise, CERP Hypothesis, Monitoring Components, and Supporting Research for Primary Producer Trophic Levels of Food Chains Supporting Higher Vertebrates in the Greater Everglades Wetlands

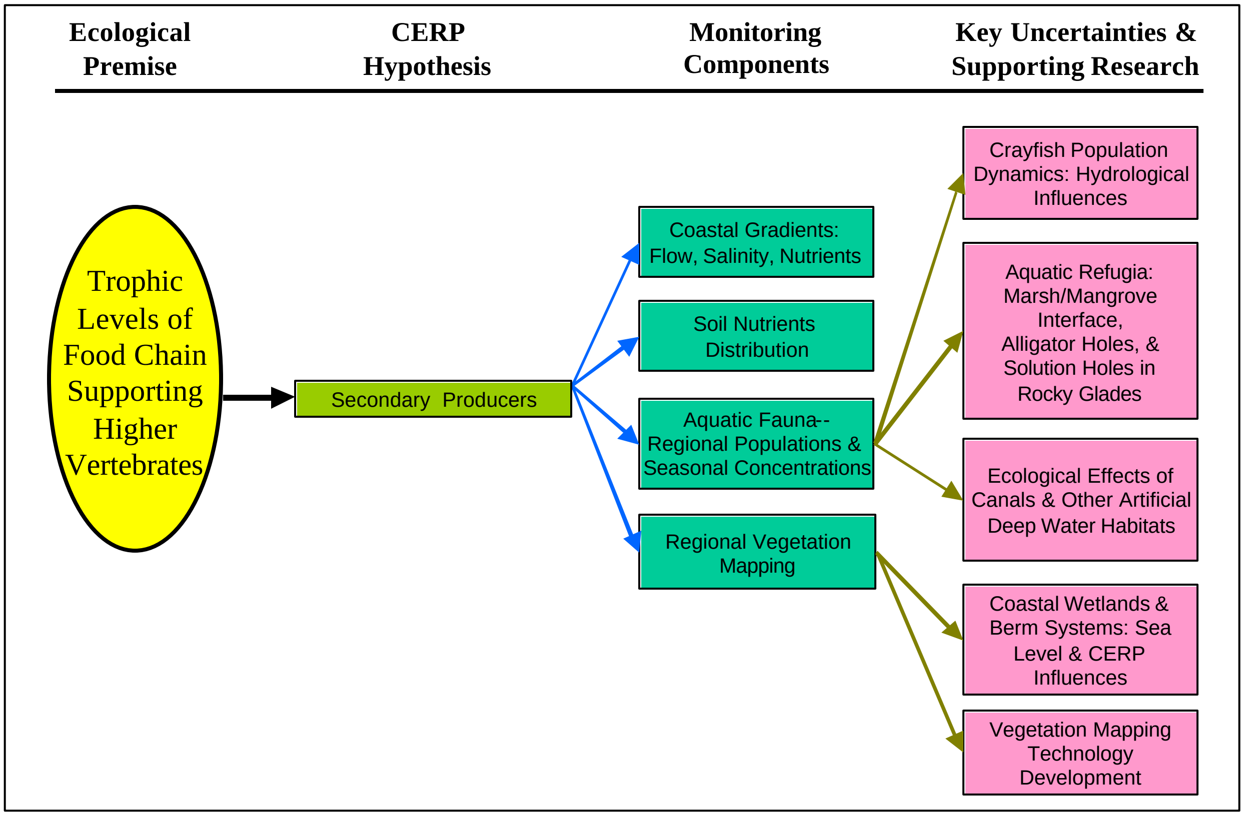

Figure 3-10: Diagram Depicting Relationships between the Ecological Premise, CERP Hypothesis, Monitoring Components, and Supporting Research for Secondary Producer Trophic Levels of Food Chains Supporting Higher Vertebrates in the Greater Everglades Wetlands

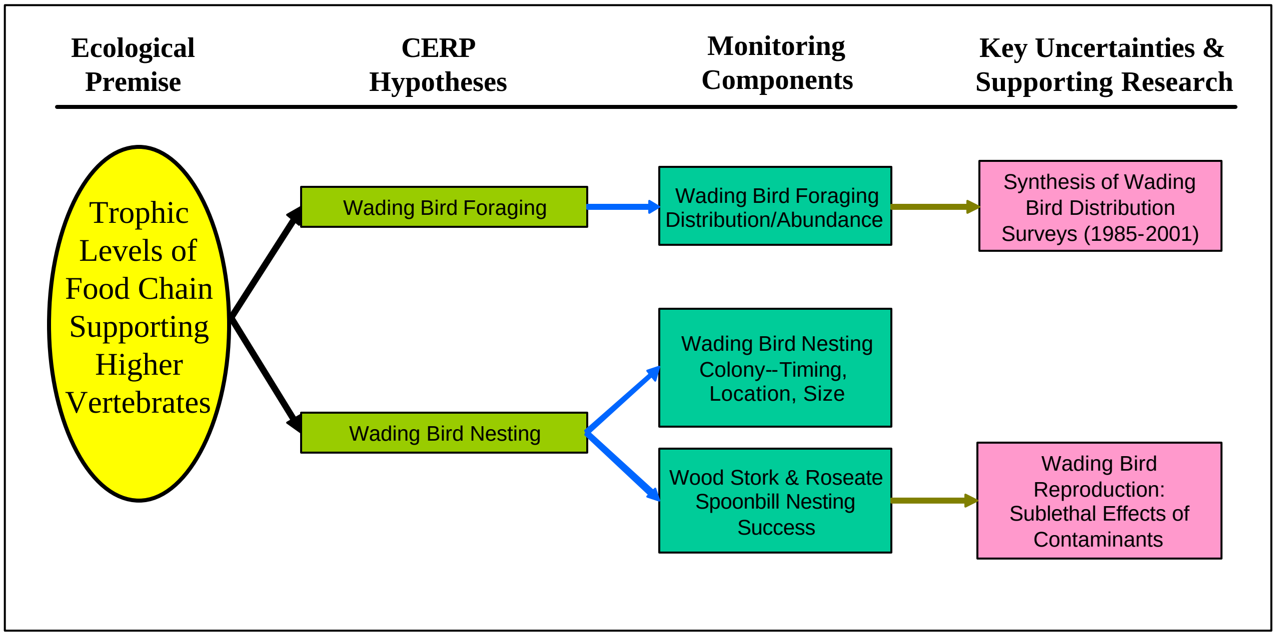

Figure 3-11: Diagram Depicting Relationships between the Ecological Premise, CERP Hypotheses, Monitoring Components, and Supporting Research for Wading Birds as Upper Trophic Level Consumers in the Greater Everglades Wetlands

3.1.2.5 American Alligator (Figure 3-12)

Ecological Premise: The distribution and reproduction of American alligator populations have been reduced as a result of altered hydrologic conditions and the reduced abundance and accessibility of prey organisms that accompany the hydrologic alterations.

CERP Hypotheses: The restoration of hydrology toward NSM conditions will result in the following:

- Expand the distribution of reproducing alligators and alligator holes to the southern marl prairies and restore the keystone role of alligator holes as drought refugia for aquatic fauna in that region
- Provide salinity regimes that are favorable for expansion of populations of reproducing alligators into the mangrove estuary
- Sustain current populations of reproducing alligators in the ridge and slough landscape

Adaptive Management Question: Will the restoration of NSM conditions achieve these objectives? If not, how and to what extent do we modify the physical structure and hydrology of the system to restore populations of the alligator in regions where they were formerly abundant by reestablishing both their wetland habitat requirements and the abundance and accessibility of their prey?

3.1.2.6 American Crocodile (Figure 3-12)

Ecological Premise: Growth and survival rates of juvenile American crocodiles have declined as a result of detrimental salinity ranges in coastal wetlands and tidal creeks of Biscayne and Florida Bays due to altered freshwater inflow regimes.

CERP Hypothesis: The restoration of hydrology toward NSM conditions will provide freshwater inflows and salinity regimes that will increase the growth and survival of juvenile crocodiles.

Adaptive Management Question: Will the restoration of NSM conditions achieve these objectives? If not, how and to what extent do we modify the physical structure and hydrology of the system to restore beneficial salinity ranges that will improve juvenile crocodile growth and survival rates?

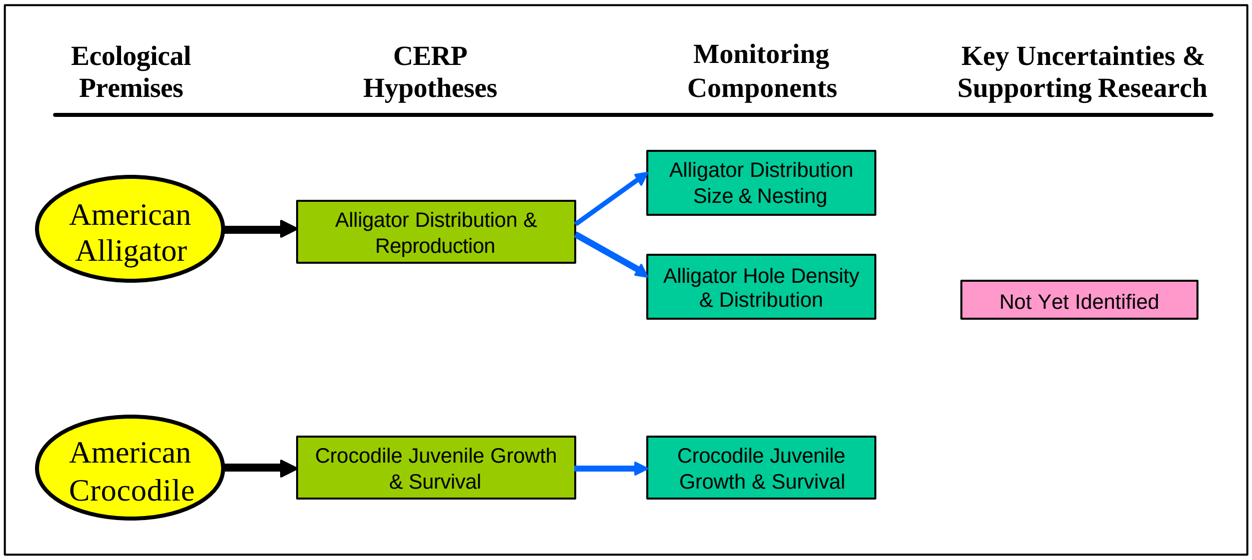

Figure 3-12: Diagram Depicting Relationships between the Ecological Premises, CERP Hypotheses, Monitoring Components, and Supporting Research for the American Alligator and American Crocodile in the Greater Everglades Wetlands

3.1.2.7 Summary of Monitoring Components and Key Uncertainties and Supporting Research

Table 3-1 summarizes the monitoring components and key uncertainties and supporting research for the Greater Everglades Wetlands Module. The section of this document where each monitoring component is discussed is provided in the second column of Table 3-1 for reference.

The systemwide assessment performance measures are being published in a separate document, the Performance Measure Documentation Report (RECOVER In prep). Each MAP monitoring component has at least one corresponding performance measure. For reference, the performance measure identification number or numbers are provided in the last column of Table 3-1.

Table 3-1: Summary List of Monitoring Components and Key Uncertainties and Supporting Research for the Greater Everglades Wetlands

Monitoring Components	MAP Section	Performance Measure Number
Interior Gradients of Water Quality	3.1.3.1	GE-A14 GE-A16 GE-A17
Regional Distribution of Soil Nutrients	3.1.3.2	GE-A15
Coastal Gradients of Flow, Salinity, and Nutrients	3.1.3.3	GE-A12
Landscape Pattern – Vegetation Mapping	3.1.3.4	GE-A2
Landscape Pattern – Marl Prairie/Slough Gradients	3.1.3.5	GE-A5
Landscape Pattern – Ridge, Slough, and Tree Island Mosaics	3.1.3.6	GE-A3
Landscape Pattern – Tidal Creek Delineation	3.1.3.7	GE-A4
Trophic Level – Primary – Periphyton Mat Cover, Structure, and Composition	3.1.3.8	GE-A10
Trophic Level – Primary – Mangrove Forest Soil Accretion	3.1.3.9	GE-A11
Trophic Level – Secondary – Aquatic Fauna Regional Populations	3.1.3.10	GE-A6
Trophic Level – Secondary – Aquatic Fauna Seasonal Concentrations	3.1.3.11	GE-A6
Trophic Level – Wading Bird Foraging Distribution and Abundance	3.1.3.12	GE-A7
Trophic Level – Wading Bird Nesting Colony Location, Size, and Timing	3.1.3.13	GE-A8
Trophic Level – Wood Stork and Roseate Spoonbill Nesting Success	3.1.3.14	GE-A8 GE-A18
American Alligator Distribution, Size, Nesting, and Hole Occupancy	3.1.3.15	GE-A9
American Crocodile Juvenile Growth and Survival	3.1.3.16	GE-A13
Key Uncertainties and Supporting Research		
Coastal Wetland Landscapes and Berm Systems: Sea Level and CERP Influences	3.1.4.1	
Tidal and Freshwater Creek Dynamics: Sea Level and CERP Influences	3.1.4.2	
Productivity in Coastal Ecotone: Sea Level and CERP Influences	3.1.4.3	
Ridge and Slough Landscape Pattern Sustainability	3.1.4.4	
Technology Development: Vegetation Mapping	3.1.4.5	
Crayfish Population Dynamics – Hydrological Influences	3.1.4.6	
Aquatic Refugia – Coastal Ecotone, Alligator Holes, and Solution Holes	3.1.4.7	
Ecological Effects of Canals and Other Artificial Deep Water Habitats	3.1.4.8	
Synthesis of Wading Bird Distribution Surveys 1985-2001	3.1.4.9	
Sub-Lethal effects of Contaminants on Wading Bird Reproduction	3.1.4.10	

3.1.3 Monitoring Components

3.1.3.1 Interior Gradients of Water Quality

The overall objective of water quality monitoring is to evaluate the impacts to the water quality in the Greater Everglades Wetlands system over time as a result of the altered routing, timing, quantity, and quality of fresh water entering the system and the resulting changes to the ecological indicators. Assessment performance measures have been developed for surface water nutrient and sulfate/sulfide concentrations as well as conductivity. The performance measures for total phosphorus concentrations in peat soils and periphyton mat production and composition are closely linked to water quality influences in this system. A nutrient loading assessment performance measure is currently being considered and developed by the REstoration COordination and VERification (RECOVER) Water Quality Team.

According to the work conducted by Stober et al. (2001a,b,c), there are significant north to south water quality gradients from Lake Okeechobee to Florida Bay in total phosphorus, sulfate, and total organic carbon that affect eutrophication as well as mercury contamination throughout the Everglades. These gradients are also apparent in the soil quality. All of these factors are interrelated and can be potentially affected by CERP efforts to change quantity, quality, timing, and distribution of the agricultural and urban stormwater runoff and Lake Okeechobee releases to various portions of the Everglades. An extensive mix of non-CERP, CERP, and critical restoration projects are underway or are planned that will have a cumulative impact on water quality in this region. Some of these projects include Modified Water Deliveries to Everglades National Park, C-111, WCA 3 Decompartmentalization, Everglades Agricultural Area Storage Reservoirs, Western C-11 Water Quality Improvement, C-9 Stormwater Treatment Area/Impoundment, Hillsboro Site 1 Impoundment and Aquifer Storage and Recovery, Lake Belt In-ground Reservoir Technology, and the C-111N Spreader Canal.

Conceptually, a network with a mix of transects and fixed sentinel sites will be designed to capture the interior water quality gradients that characterize the various subregions of the Everglades. The water quality transect and sentinel site design that is preliminarily described below will be designed 1) to distinguish project-level monitoring from the regional monitoring strategies and 2) to integrate the water quality sampling design with soil (Section 3.1.3.2), periphyton (Section 3.1.3.8), and vegetation mapping (3.1.3.4), as well as with the stratified random sampling design for monitoring trophic levels (Section 3.1.3.10).

The water quality monitoring program will quantify water quality performance measures in two different areas of the Everglades. The first area will be under the direct and immediate influence of the flows from South Florida Water Management District (SFWMD) structures and is referred to as near-field, short response-time areas. The quantification of nutrient loads or flow-weighted mean nutrient concentrations entering and leaving the greater Everglades area will be evaluated using this existing network of inflow and outflow stations currently operated by the SFWMD (Figures 3-13 and 3-14). As various CERP components are brought on-line, additional structure monitoring stations will be added to the network. Structures to be monitored will include those that 1) historically/currently manage flows into, within, and out of the Greater Everglades Wetlands and 2) will manage inflows in the future. Many, but not all, such structures will be affected by CERP implementation; however, it is estimated that approximately 20 additional sites will be required over time to characterize the new flow pathways that will eventually be created or modified by the CERP. Monitoring of flow volumes through structures is addressed in the South Florida Hydrology Monitoring Network Module (Section 3.5), and methodology for measurements is described in the CERP Quality Assurance Systems Requirements (QASR) Manual (RECOVER 2003).

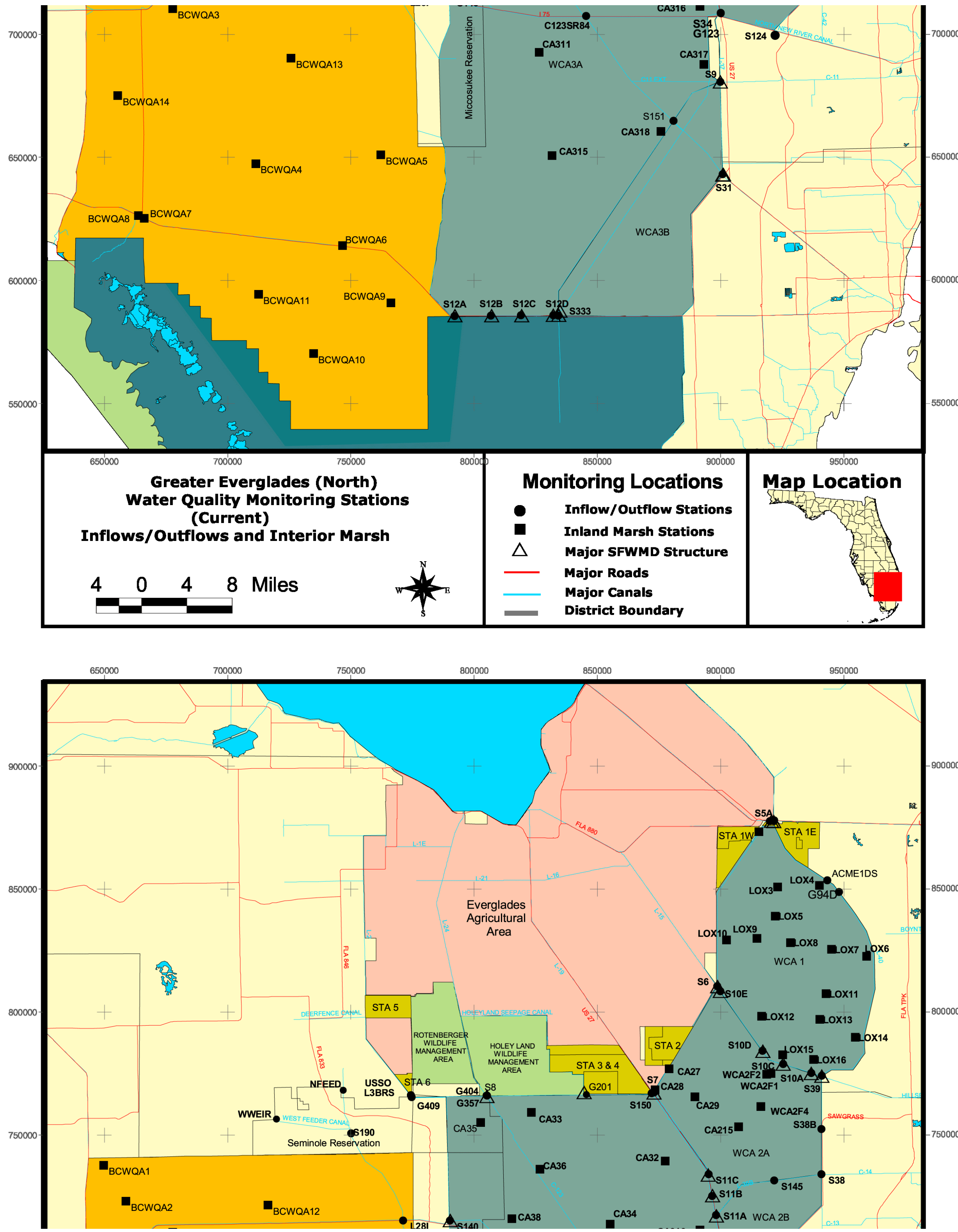

Figure 3-13: Greater Everglades (North) Water Quality Monitoring Stations as of September 2002 –Water Control Structures and Interior Marsh

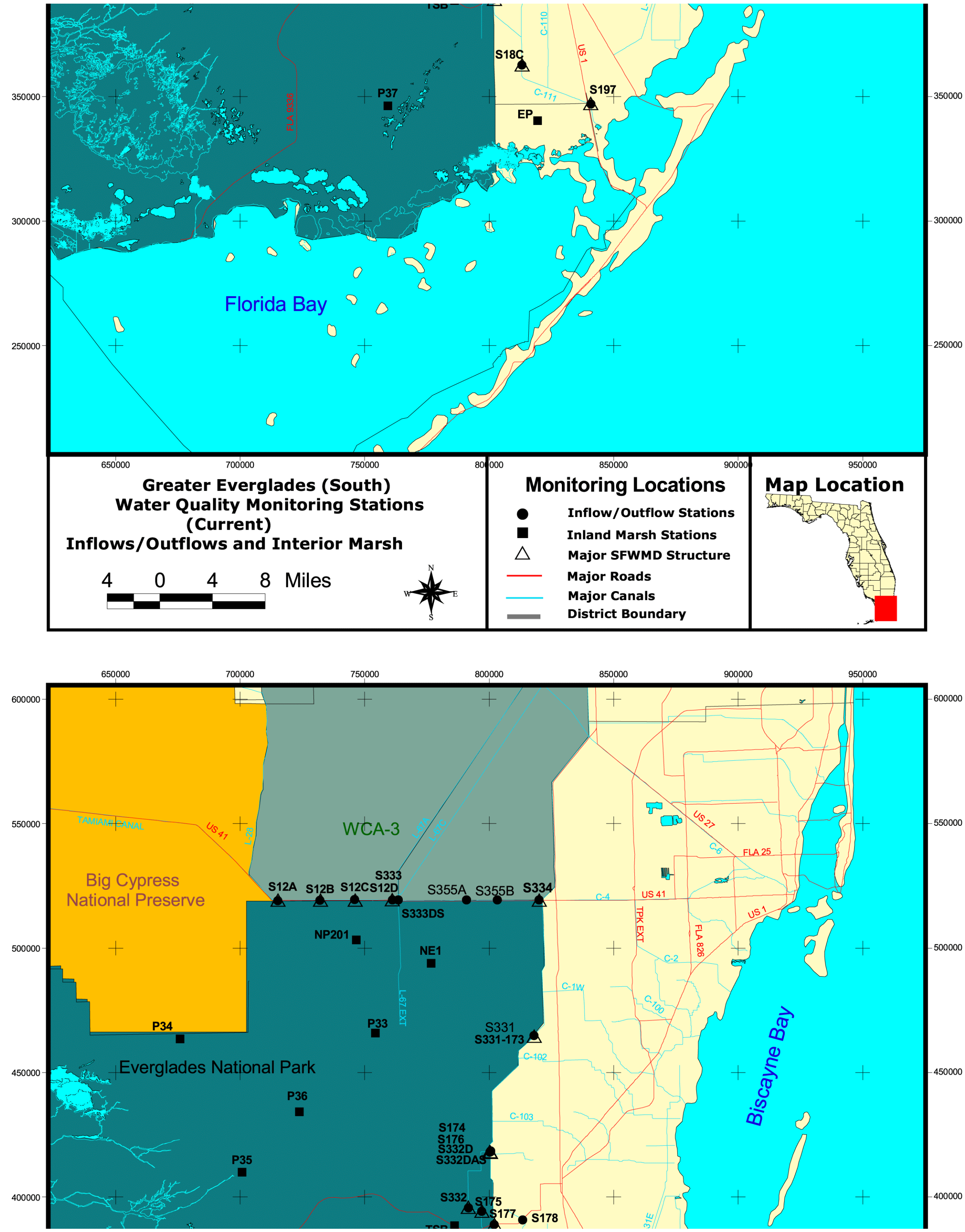

Figure 3-14: Greater Everglades (South) Water Quality Monitoring Stations as of September 2002 – Water Control Structures and Interior Marsh

The second distinct area will be under the delayed or indirect cumulative influence of multiple sources. These will be referred to as the far-field, long response-time areas that are located within the Greater Everglades Wetlands. For example, if nutrient or other contaminant loads are reduced at the inflows, there should a corresponding, longer-term response in the wetland systems. The existing network of far-field or marsh stations, shown in Figures 3-13 and 3-14, are primarily used to meet monitoring requirements under the 1992 Settlement Agreement/Consent Decree and the Everglades Forever Act and provide useful information for long-term trend tracking and a wealth of baseline information; however, this network is not necessarily structured or designed to address the documented water quality gradients and CERP-related scientific questions. RECOVER is proposing a monitoring design that calls for a suite of transects to be set up within current and expected hydrologic, nutrient, and habitat gradients that address several different but interrelated processes. Water quality and habitat gradients downstream of major inflow structures and along sheet flow paths that will be reconnected will be monitored to document potential water quality impacts resulting from the CERP. Monitoring water quality gradients will also help refine the regions of the Greater Everglades Wetlands for the stratified random sampling design based on eutrophication status.

Water quality monitoring in far-field, long response-time areas will consist of a mix of transects and fixed or sentinel sites distributed throughout the Greater Everglades Wetlands. Transect locations will be proposed to capture areas that are either currently impacted (geared to restoration) or where CERP plans significant changes to flows or depths (and nutrient loads) and thus are potential regions of ecological change. In addition, sentinel sites will be located to be representative of regionally significant ecotypes. Sentinel sites are intended to provide information for regions of interest either in impact areas or in reference, unimpacted regions. A number of the sentinel sites are existing fixed station monitoring sites with historical data. Transect alignments and sentinel sites will overlap with vegetation mapping cells and soil nutrient sites to the extent possible.

RECOVER intends to utilize the appropriate expertise to design and optimize a water quality monitoring network for the Greater Everglades Wetlands that will properly integrate with and complement the ecological and hydrological monitoring, adequately contribute to answering the CERP monitoring questions for this area, and be financially sustainable over the span of CERP implementation. Once the near-field and far-field monitoring program elements are finalized, they will be compared with the corresponding ongoing/current monitoring program elements (Figures 3-13 and 3-14) to identify opportunities for optimizing the number of sites, media, or frequencies of sampling or for reducing the number of analyses per sample.

Water quality parameters to be measured at near-field and far-field sites are listed in Tables 3-2 and 3-3, respectively. To estimate cost, approximately 65 near-field/water control structure monitoring sites and approximately 130 far-field or marsh stations are currently being used. The actual number of stations (whether new or existing) needed and sampling frequencies will be determined during the network design.

Physical parameters in the water column such as dissolved oxygen (DO), conductivity, pH, salinity, and temperature will be collected directly in the field on a monthly basis using water quality monitoring probes. Sampling for the other parameters will be conducted on a monthly basis using grab samples and subsequent laboratory analysis. The proposed monitoring program includes monitoring of additional core parameters, such as several major ions, total suspended solids, silicate, and calculated parameters, that will assist in interpreting monitoring results directly tied to the assessment of performance measures. Estimation of nutrient loading or flow-weighted mean concentrations requires the monitoring of water discharge (flow) and nutrient concentrations. Grab and flow-proportional autosampler assays will be conducted for surface water total phosphorus and total nitrogen concentrations at structures, along with the measurement of flow volumes. Such continuous monitoring equipment has already been deployed at some flow structures, but instrumentation of additional sites may be necessary. Surface water and sediment sampling methodologies, associated quality control requirements, and methods used for subsequent laboratory analyses are described in the QASR Manual (RECOVER 2003).

Table 3-2: Greater Everglades Water Quality Monitoring at Water Control Structures

Medium	Group	Parameters	Sites	Frequency	Collection Method
Water	Physical parameters	DO, conductivity, pH, temperature, turbidity, alkalinity, TSS, color, DOC	Approx. 65 sites	Monthly	Water quality probe and grab
Water	Nutrients	TP, TKN, TOC, NO_2, NO_3, NH_4, NO_{2+3}, SRP, SiO_2	Approx. 65 sites	Monthly and continuous	Grab and flow-proportional autosampler
Water	Other core parameters	Cl, SO_4, S^{-2}	Approx. 65 sites	Monthly	Grab
Water	Nutrients	Flow	Approx. 65 sites	Continuous	Flow recorder

LEGEND:

Cl - chloride
DO - dissolved oxygen
DOC - dissolved organic carbon
NH_4 - ammonium nitrate
NO_2 - nitrate
NO_3 - nitrite
NO_{2+3} - nitrate-nitrite
S^{-2} - sulfide
SiO_2 - silicate
SO_4 - sulfate
SRP - soluble reactive phosphate
TKN - total Kjeldahl nitrogen
TOC - total organic carbon
TP - total phosphorus
TSS - total suspended solids

Table 3-3: Greater Everglades Water Quality Monitoring at Marsh Stations (Transects and Fixed Stations)

Medium	Group	Parameters	Sites	Frequency	Collection Method
Water	Physical parameters	DO, conductivity, pH, temperature, turbidity, alkalinity, TSS, color, DOC, depth	Approx. 130 sites	Monthly	Water quality probe and grab: transects and fixed stations
Water	Nutrients	TP, TKN, TOC, NO_2, NO_3, NH_4, NO_{2+3}, SRP, SiO_2	Approx. 130 sites	Monthly	Grab: transects and fixed stations
Water	Other core parameters	Cl, SO_4, S^{-2}	Approx. 130 sites	Monthly	Grab: transects and fixed station

LEGEND:

Cl - chloride
DO - dissolved oxygen
DOC - dissolved organic carbon
NH_4 - ammonium nitrate
NO_2 – nitrate
NO_3 - nitrite
NO_{2+3} - nitrate-nitrite
S^{-2} - sulfide
SiO_2 - silicate
SO_4 – sulfate
SRP – soluble reactive phosphate
TKN - total Kjeldahl nitrogen
TOC - total organic carbon
TP - total phosphorus
TSS - total suspended solids

3.1.3.2 Regional Distribution of Soil Nutrients

The distribution of soil nutrients will augment water quality transects to delineate zones of eutrophication and to further refine the regions of the Greater Everglades Wetlands for the stratified random sampling design. Nutrient concentrations in surface soils provide indicators of site nutrient status that show less temporal variability than surface water phosphorus concentrations. Site nutrient status is a potentially important determinant of fish populations and will aid the interpretation of changes in regional populations of marsh fishes and associated fauna.

A stratified random sampling design will produce maps of soil nutrient gradients across the Greater Everglades Wetlands (Figure 3-15). The model for the stratified random design will be based on that implemented in WCA 1 in the 1990s (DeBusk et al. 1994, Newman et al. 1997) with higher density strata based on current and anticipated soil, habitat, and flow gradients. Soil sampling locations will overlap water quality sites, vegetation mapping cells, and throw trap sites to the extent possible. The resulting sampling design will entail approximately 1,500 sample points to be sampled at five-year intervals corresponding to the years of vegetation mapping.

Surface soil (0-10 centimeters) and overlying floc will be collected from cores and analyzed for a standard suite of parameters including phosphorus and nitrogen concentration, bulk density, percent organic matter, and salinity using standard methods (USEPA 1983, 1986) that are documented in the CERP QASR Manual (RECOVER 2003). Figure 3-16 shows the spatial distribution of soil phosphorus concentrations based on the stratified random sampling design.

3.1.3.3 Coastal Gradients of Flow, Salinity, and Nutrients

Coastal gradients across the freshwater-marine interface of the mangrove estuaries of Florida Bay and the Southwest Florida shelf will be monitored to achieve the following:

- Track salinity gradients along historic flow paths that will be restored by the CERP and relate to freshwater flow volumes and sea level
- Delineate the boundaries of coastal regions for the stratified random sampling design
- Measure freshwater flow volumes and nutrient inputs into the high-productivity salinity transition zone of the mangrove estuary to support the evaluation of estuarine productivity in relation to freshwater inputs from the CERP
- Measure freshwater flow volumes and nutrient inputs from Greater Everglades Wetlands to Florida Bay and Gulf estuaries

Coastal gradients will be monitored along twelve transects extending from marine to freshwater conditions (Figure 3-17):

1. **Lostman's River.** Transect up Lostman's River, across the chain of bays, through the broad mainland mangrove fringe, and through Second (or Lostman's) Slough
2. **Broad River.** Transect up Broad River, through the broad mainland mangrove fringe, through the fertile crescent region, and into the marl wetlands below the Ochopee Marl Prairie
3. **Harney River.** Transect up Harney River, through the broad mainland mangrove fringe and the oligohaline wetlands, and into mid-Shark River Slough

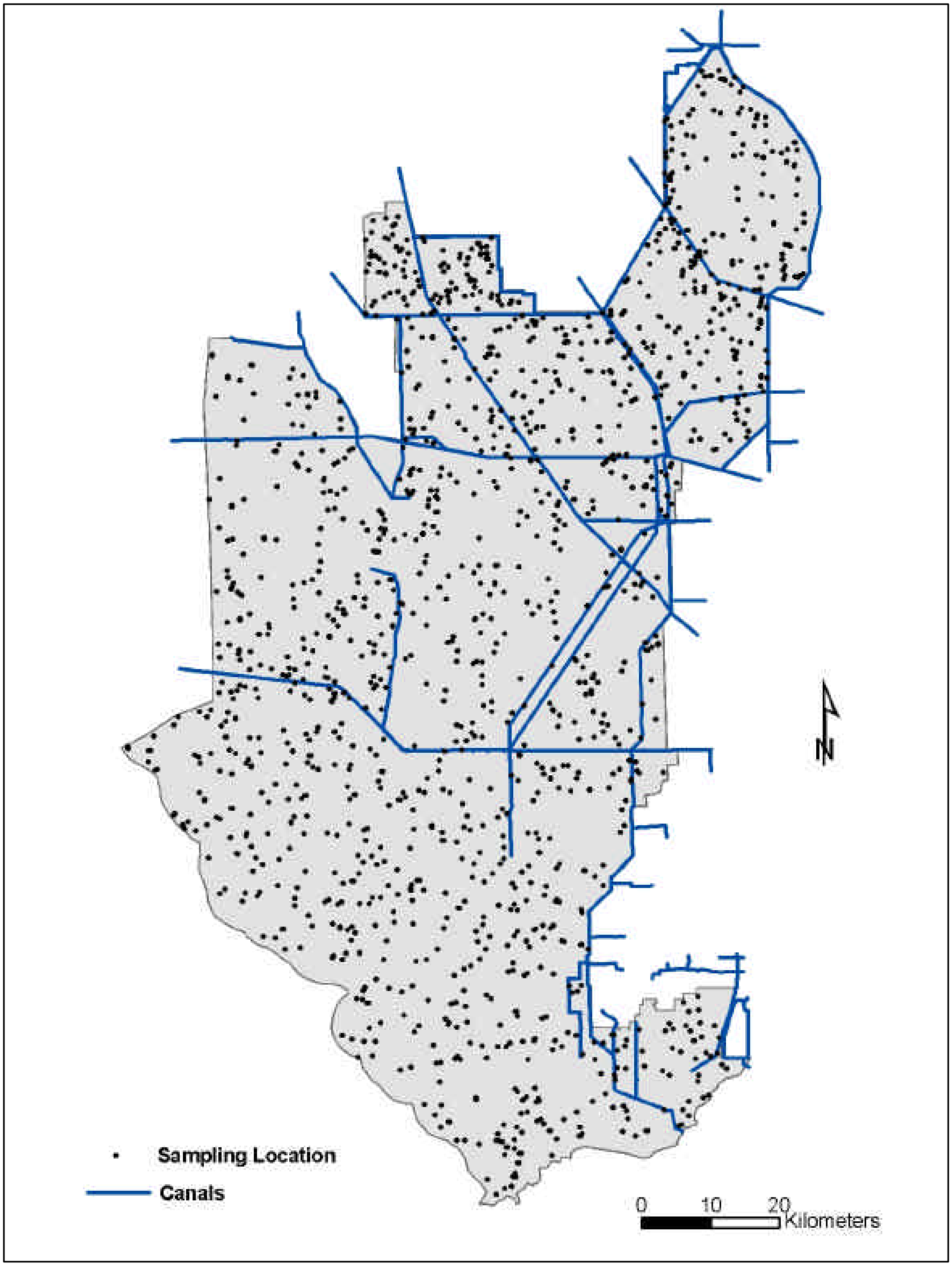

Figure 3-15: Stratified Random Sampling Design for Soil Nutrient Concentration Monitoring in Greater Everglades Wetlands

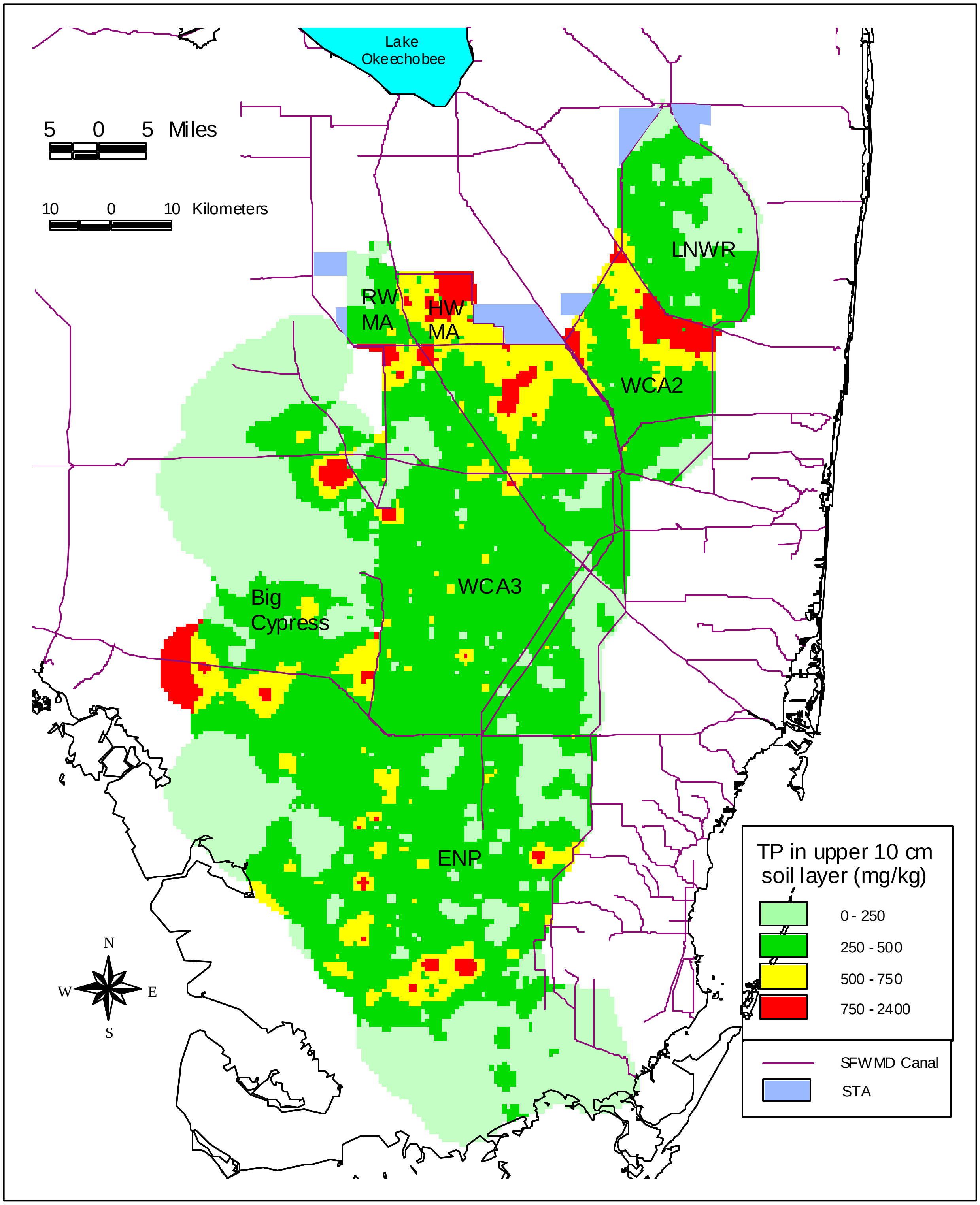

Figure 3-16: Spatial Distribution of Surface Soil (0-10 centimeters) Phosphorus Concentrations throughout the Everglades (Data sources: REMAP data from USEPA 2001, DeBusk et al. 2001, Smith unpublished data, Newman unpublished data)

4. **Ponce de Leon Bay.** Transect extending from Ponce de Leon Bay up Shark River into Shark River Slough

5. **North River.** Transect extending from the north shoreline of Whitewater Bay up the North River into mid-Shark River Slough

6. **McCormick Creek.** Transect extending from Terrapin Bay up McCormick Creek, through Seven Palm Lake, through Craighead Basin, and into Taylor Slough

7. **Little Madeira – Taylor Slough.** Transect extending from Little Madeira Bay up the Taylor River into Taylor Slough headwaters

8. **Joe Bay – C-111 Wetlands.** Transect extending from Trout Pass, through Joe Bay, through the dwarf mangroves, and through the East Perrine marl prairie to the location of the new C-111 spreader canal

9. **Barnes Sound – South Dade Wetlands.** Transect extending from Barnes Sound upstream into the pie-slice shaped area between US Highway 1 and Card Sound Road

10. **Card Sound – South Dade Wetlands.** Transect extending from Card Sound inland through the mangroves, oligohaline wetlands, and freshwater marl prairies of the South Dade Wetlands

11. **Biscayne Bay – L-31E – South Dade Wetlands.** Transect extending from near-shore western Biscayne Bay, west to levee L-31E, and ending just east of the Homestead Air Force Base

12. **Biscayne Bay – Black Point – South Dade Wetlands.** Transect extending from near-shore western Biscayne Bay through the Black Point coastal wetlands and westward to near the C-1 canal

Transects 1 through 8 will be adjusted to include seven existing salinity and stream flow monitoring stations at Trout, Taylor, and McCormick Creeks and along Shark, Harney, Broad, and Lostman's Rivers (Hittle et al. 2001, Patino et al. 2001). An eighth new stream flow monitoring station will supplement the existing salinity station at North River. Stream flow and salinity will be monitored using continuous recording stations at permanent, fixed platforms at the marine and oligohaline ends of Transects 1 through 8. Eight new continuous recording platforms at the upstream ends of these transects will supplement existing platforms at the downstream ends to provide continuous salinity records. Surface water will be collected at these sites using a flow proportioned automatic sampler and analyzed in the laboratory for phosphorus and nitrogen. Based on past studies by the SFWMD and Florida International University, composite sampling every three days (with four samples collected and pooled every 18 hours) is sufficient to capture nutrient pulses and smooth tidal variations, while at the same time minimizing laboratory costs. Conductivity, temperature, and flow meters at each platform will be needed in support of flow calculations and salinity monitoring. The monthly measurement of salinity and nutrients along the lengths of each coastal transect will supplement continuous flow, salinity, and nutrient records at the upstream and downstream ends. For Transects 9 through 12, where no flow channels exist, only monthly measurements will be made. Sediment elevation measurement stations along Transects 1 through 8, as described in section 3.1.3.9, will monitor soil accretion as an indicator of mangrove forest production as a function of flow, salinity, and nutrient inputs. As more advanced remote sensing techniques are developed during the next decade, the coastal gradient locations will be developed into belt transects to document changes and trends in substrate elevation, water quality, sediment characteristics, and vegetation.

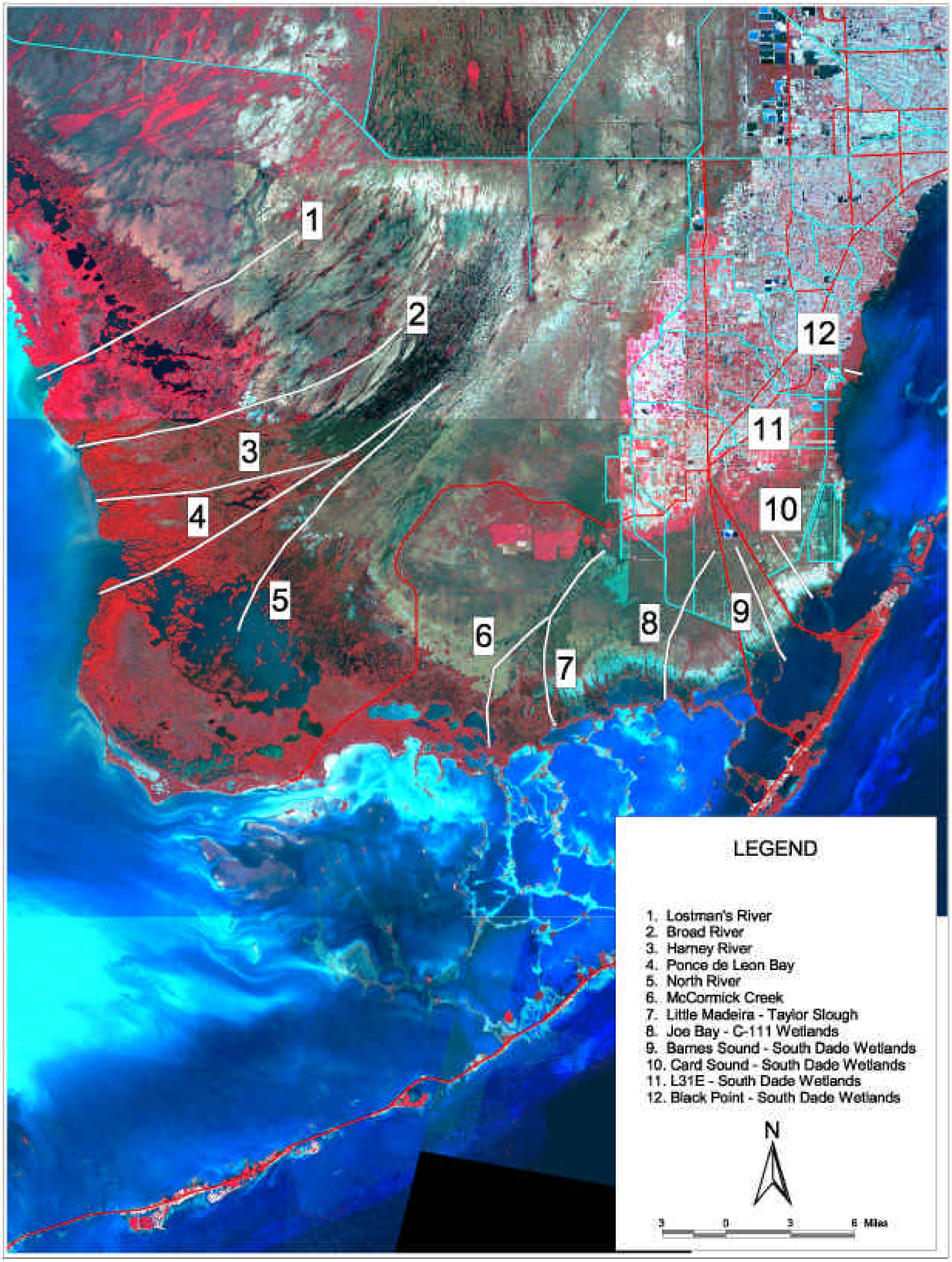

Figure 3-17: Coastal Gradient Transects of Flow, Salinity, and Nutrients for Monitoring Flow

3.1.3.4 Landscape Pattern – Vegetation Mapping

Vegetation mapping will monitor the spatial extent, pattern, and proportion of plant communities within major landscape regions of the Greater Everglades Wetlands. Specific landscape changes to be monitored that pertain to the CERP include the following:

- Changes in the extent and orientation of sloughs, tree islands, and sawgrass ridges as flow patterns, flow volumes, hydroperiods, and water quality are modified in the ridge and slough landscape

- Changes in the extent and distribution of cattail as flow patterns, flow volumes, hydroperiods, and water quality are modified in the ridge and slough landscape

- Changes in the extent and distribution of exotic plant communities

- Changes in the distribution and configuration of tidal creeks, salt marshes, and mangrove forests as changing flow patterns and volumes interact with sea level and salinity in the mangrove estuaries of Florida Bay and the Gulf of Mexico

- Changes in the distribution of plant communities in calcitic wetlands, including tussock-forming *Muhlenbergia* and sawgrass communities in the major breeding locations of the Cape Sable seaside sparrow, as hydrologic gradients change

- Changes in the distribution of plant communities of eastern Big Cypress with the removal of L-28 and hydroperiod restoration in the Kissimmee Billy Strand

Regional landscape patterns will be monitored using a combination of a transect and sentinel site sampling design (Section 3.1.3.1) and a stratified random sampling design (Section 3.1.3.10).

Aerial photo-interpretation is currently the best tool available to produce dependable and accurate maps of the Everglades (Welch et al. 1995, Doren et al. 1999, Rutchey and Vilchek 1999, Richardson and Harris 1995). Aerial photography of the greater Everglades wetland system at a scale of 1/24,000 will be purchased at three-year intervals. Photography will be interpreted and ground-truthed to produce vegetation maps at three-year intervals for the randomly selected cells. Additional cells will be mapped to supplement the stratified random cells along the alignments of the coastal, marl prairie-slough, and WCA gradients that are described above. The vegetation classification scheme of Jones et al. (unpublished report) will be used to identify major plant communities that are defined by typical dominant species. An all-embracing, multi-decade vegetation mapping program will require appropriate resources and a dedicated group with a high level of commitment and stability.

3.1.3.5 Landscape Pattern - Marl Prairie/Slough Gradients

Hydrologic and plant community gradients will supplement vegetation mapping to document the potential trade-off between slough habitat restoration and the extent and quality of habitat in adjacent marl prairies in the southern Everglades. The goal is to maintain the short-hydroperiod, tussock-growth habitats in the marl prairies while restoring long-hydroperiod habitats in adjacent sloughs.

Two east-west vegetation transects will run through southern marl prairies and adjacent sloughs (Figure 3-18), traversing the three marl prairie nesting habitats for the major breeding populations of the Cape Sable seaside sparrow:

1. Lostman's Slough - Ochopee Marl Prairie - Shark River Slough – Southern Rocky Glades
2. Shark River Slough - Western Perrine Marl Prairie - Taylor Slough

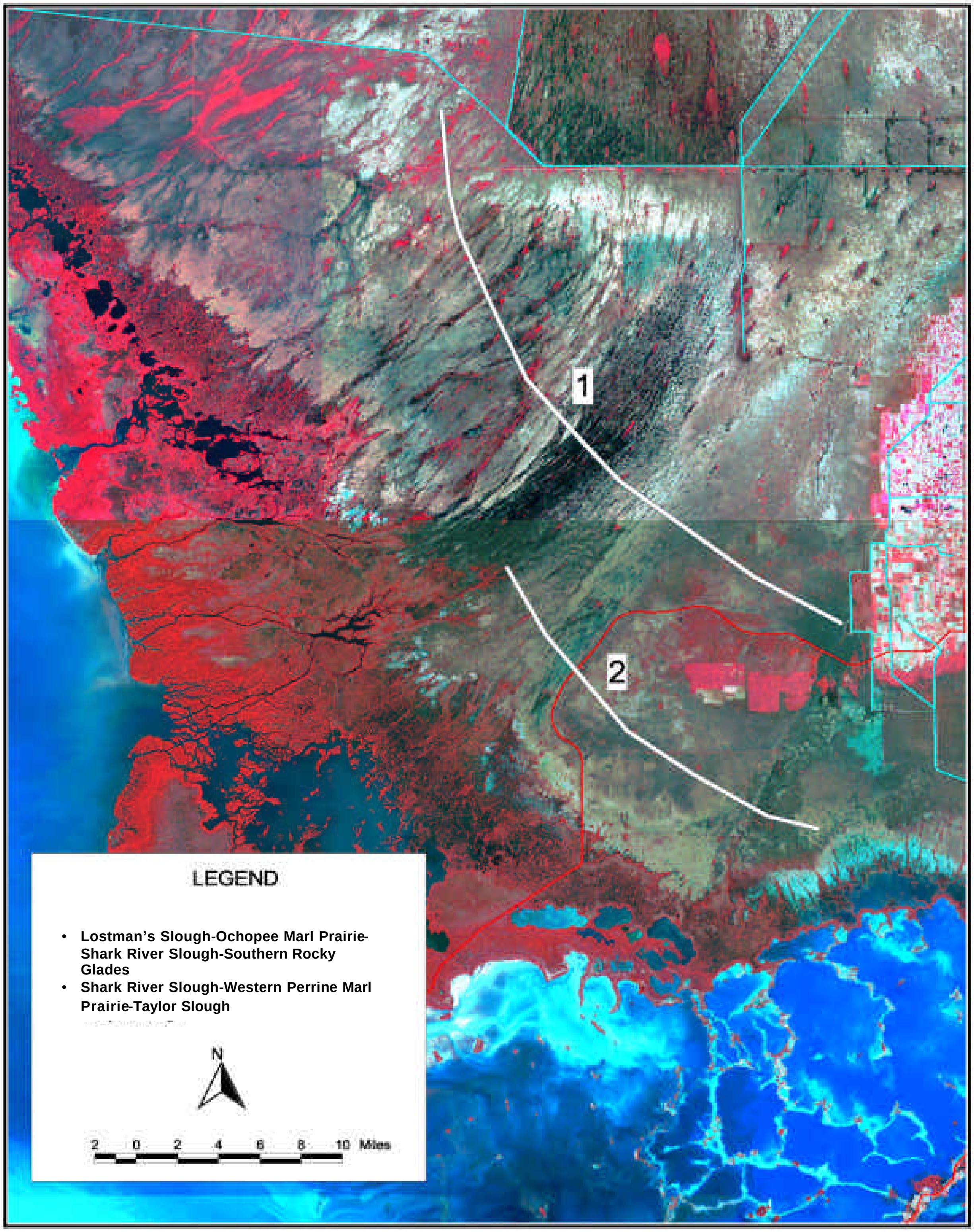

Figure 3-18: Marl Prairie/Slough Vegetation Transects Across the Southern Everglades

A preliminary monitoring design includes three replicate transects to be run through each of the marl prairies and into the adjacent sloughs. Plant community species composition, cover, and density will be monitored annually at approximately 100-meter intervals using a modified Braun-Blanquet technique (Braun-Blanquet 1964, Muller-Dombois and Ellenberg 1974, Peet et al. 1998) and at approximately 1,000-meter intervals in permanent 10x10-meter quadrants. The sampling design and frequency will be reviewed and refined during the development of a more detailed work plan for marl prairie/slough gradients.

3.1.3.6 Landscape Pattern – Ridge, Slough, and Tree Island Mosaic

A detailed sampling design for integrated sawgrass ridge, slough, and tree island landscape monitoring has yet to be completed. A preliminary sampling design includes ridge and slough transects perpendicular to the dominant flow vector to establish current microtopographic conditions. Additional transects are proposed for tree islands, running the length and width of each selected island from high and low island elevations. Tree island and ridge and slough parameters will be measured during the years of vegetation mapping. An initial set of parameters will include the following:

- Soil accretion
- Periphyton and flocculent characteristics in sloughs
- Macrophyte community characterization
- Tree island canopy cover
- Tree species richness
- Tree island tree and shrub species composition
- Surface elevation relative to water level and benchmark
- Soil depth to bedrock
- Bedrock elevation
- Tree species composition
- Tree seedling density and species composition
- Fern understory density and composition

3.1.3.7 Landscape Pattern - Tidal Creek Delineation

Channel bathymetry and volume measurements in representative tidal creeks of the mangrove estuaries of Florida Bay and the Gulf of Mexico will supplement vegetation mapping in cells and along coastal transects. The combined monitoring methodologies will be developed to delineate tidal creeks and to determine their status and evolution in relation to freshwater flow and sea level rise. The development of the tidal creek monitoring methodology is described under Section 3.1.4.2 Key Uncertainties and Research Topics in "Tidal and Freshwater Creek Dynamics: Sea Level and CERP Influences."

3.1.3.8 Trophic Level – Primary - Periphyton Mat Cover, Structure, and Composition

The monitoring of periphyton mats will track an important food base that supports the intermediate trophic level marsh fishes and macroinvertebrates in freshwater habitats of the Greater Everglades Wetlands. Periphyton mats will be sampled annually during the late wet season at the location of each throw trap sample and within each cell and each landscape unit when regional populations of marsh fishes are sampled, as described in Section 3.1.3.10. Periphyton sampling in landscape regions will overlap water quality transect alignments and sentinel sites to the extent possible. Annual sampling may be supplemented by seasonal sampling at sentinel sites.

Periphyton sampling methodologies are described in Noe et al. (2002) and Childers et al. (2001). The cover of floating, epiphytic, and benthic periphyton within each of the one-meter square throw traps will be visually estimated and archived using a digital photograph, after which biovolume will be measured, and a relatively homogenized subsample will be collected for laboratory analysis.

Periphyton will be analyzed for chlorophyll *a*, biomass, percent organic matter, and tissue phosphorus, nitrogen, and carbon using standard methods (USEPA 1983, Soloranzo and Sharp 1980). Periphyton will be analyzed for dominant algal species, indicator diatom species, and percent of mat biovolume consisting of non-filamentous blue-greens. Counts, identifications, and biovolumes of soft algal species will be determined using standard methods (Bahls 1993, Stevenson and Lowe 1986, Porter et al. 1993, Klemm and Lazorchak 1994). Diatom counts, identifications, and biovolumes will be determined using standard methods (Gaiser and Johansen 2000, Stevenson and Bahls 1999).

Periphyton biovolume, biomass, percent organic matter, chlorophyll *a*, and tissue phosphorus will be measured annually, and possibly seasonally, at selected sentinel sites. Tissue nitrogen and carbon analyses and species identifications will be conducted every three to five years to correspond with the years of vegetation photography.

3.1.3.9 Trophic Level – Primary – Mangrove Forest Soil Accretion

Mangrove soil accretion will be monitored as an indicator of mangrove forest production in relation to flow, salinity, and nutrient inputs. Mangrove soil accretion also provides a measure of coastal substrate elevation relative to sea level rise.

Mangrove soil accretion will be measured at fixed stations along Transects 1 through 8 of the coastal gradients of flow, salinity, and nutrients (Section 3.1.3.3, Figure 3-17). Sediment elevation measurement stations will be added to supplement existing stations of the United States Geologic Survey Global Climate Change project and the Florida Coastal Everglades Long-Term Ecological Research Program. Sediment elevation will be measured periodically at each station.

3.1.3.10 Trophic Level – Secondary - Aquatic Fauna Regional Populations

Understanding the effects of the CERP on the prey bases for wading birds and other higher consumers requires knowledge of the regional populations of fishes and associated aquatic fauna that are produced during each wet season and the distribution of those populations across the Greater Everglades Wetlands (Figure 3-19) (Gawlik 2002). The aquatic fauna that are anticipated to channel most of the energy from primary production to higher vertebrates under restored conditions include marsh fishes, crayfish, grass shrimp, and aquatic amphibians.

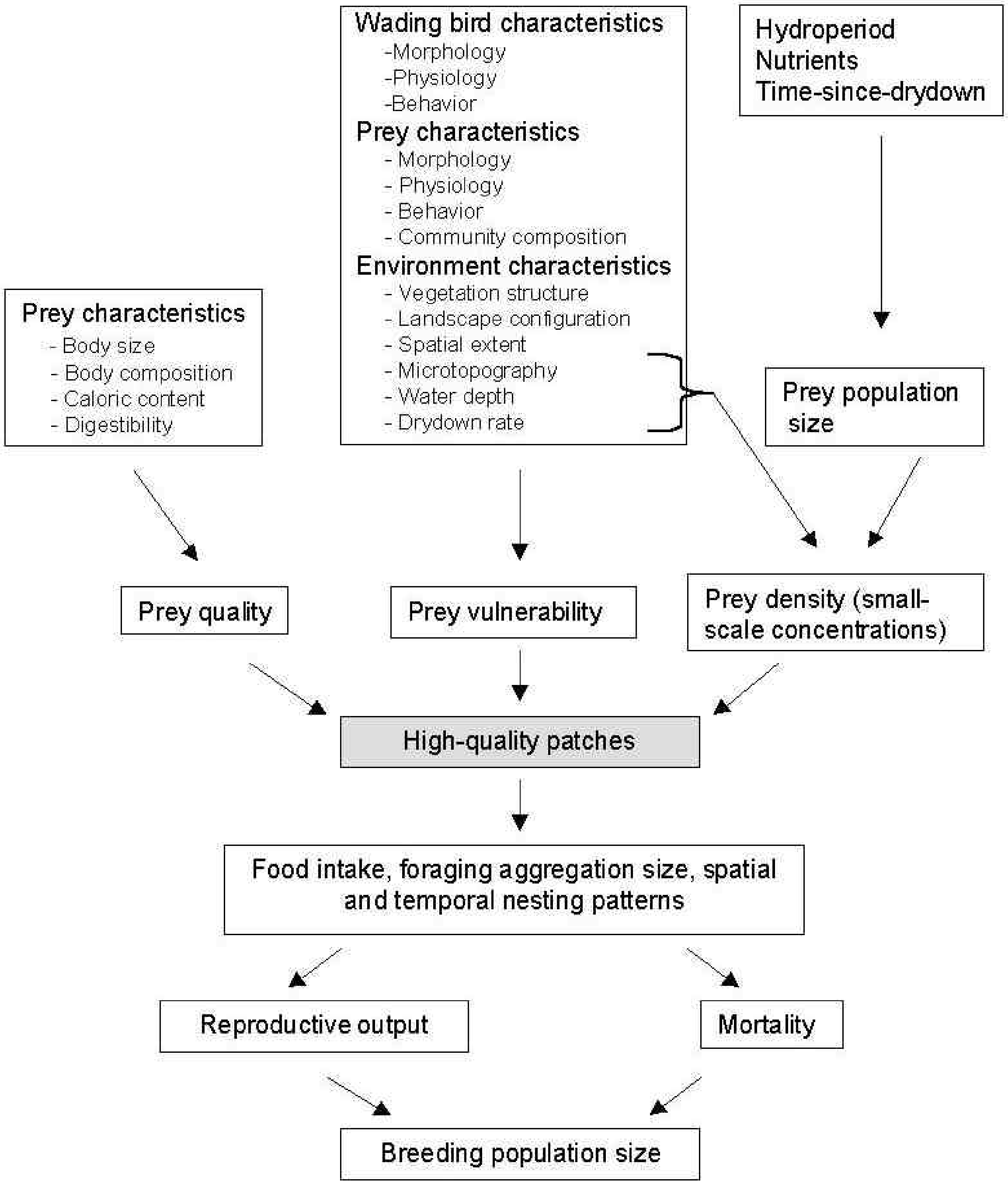

Figure 3-19: Everglades Prey-Availability Hypothesis

The regional population densities and distributions of marsh fishes and associated aquatic fauna will be monitored using a stratified random sampling design. The Greater Everglades Wetlands will be divided into landscape units (landscape subregions) representing distinct landscape patterns and/or management units. Figures 3-20 and 3-21 and Table 3-4 depict 52 such units that have been identified in the Greater Everglades Wetlands. Within each subregion, replicate cells will randomly be selected. The number and configuration of subregion, cell size, and number of replications are preliminary and will be revised during a more detailed statistical design of the sampling program. The stratified random approach will be designed to monitor system-level status and trends, trends within regions, and comparisons among regions (see Stoddard et al. 1998, Nusser et al. 1998, Dixon et al. 1998, Urquhart et al 1998, and Thompson 1992 for sampling design considerations).

Densities of marsh fishes, crayfish, grass shrimp, and aquatic amphibians will be monitored using one-meter square throw traps (Jordan et al. 1997, Chick et al. 1992, Kushlan 1981). Throw trap samples will be collected from the randomly selected sites within areas of sparse emergent macrophytes that will be delineated for each cell. These communities appear to be the most important habitats for marsh fishes and for wading bird foraging in the Greater Everglades Wetlands (Trexler et al. 2001, Loftus and Kushlan 1987). Parameters to be measured from throw trap samples include the density, species composition, and size class distribution of fishes and associated fauna. Electrofishing will supplement throw trap sampling at selected sites that are accessible by airboat to monitor fishes of larger size classes (Chick et al. 1999). Throw trap sampling is not effective in karst habitats, and this problem requires further development of sampling protocols. Drop trap sampling will be substituted for throw traps in estuarine areas where mangrove roots may prevent the use of throw traps (Lorenz et al. 1997).

Throw trap samples will be collected annually during the late wet season (September-November) to provide an estimate of the net production of marsh fishes and other fauna at the end of the wet season. This represents the prey base that is available for concentration and wading bird consumption as water levels recede during the dry season. Annual sampling may be supplemented by seasonal sampling at sentinel sites.

3.1.3.11 Trophic Level – Secondary – Aquatic Fauna Seasonal Concentrations

Understanding the effects of the CERP on marsh fishes as prey bases for wading birds also requires monitoring the concentration of the fishes in high-density patches where the birds can feed effectively as water levels recede during the dry season. There is a close relationship between high prey-availability patches and wading bird foraging patterns under experimental conditions, and it is hypothesized that there is a linkage between high prey-availability patches and foraging and nesting patterns in the ecosystem (Figure 3-19) (Gawlik 2002).

Seasonal concentrations of marsh fishes and associated fauna will be monitored to determine the following:

- The spatial distribution of maximum fish densities across the landscape
- The inter-annual variation of maximum fish densities among years
- The correlation between annual wading bird nesting and foraging patterns and maximum fish densities
- The correlation between annual hydrologic patterns and maximum fish density

Fish concentrations during the dry season will be monitored in the randomly selected cells in a selected subset of the landscape units where wet season fish populations are monitored (Figure 3-20, Table 3-4). The subset that is proposed includes landscape units representing contrasting fish populations, hydroperiods, and drying patterns (numbers refer to numbered areas on Figure 3-20):

- 7. Central WCA 1 Ridge & Slough
- 16. Central WCA 3A Ridge & Slough
- 29. Mid-Shark River Slough
- 36. Southern Rocky Glades
- 43. Fertile Crescent region of Coastal Oligohaline Wetlands
- 47. Central Florida Bay Oligohaline Wetlands

Each selected cell within a landscape unit will be examined monthly from January to May each year to determine the presence of a drying front, as indicated by a disconnected water surface. Drying fronts will be identified monthly from systematic reconnaissance flights to monitor wading bird foraging as described in detail in the next subsection. If a drying front is present within a cell, points will be randomly selected from that drying front every two weeks. If any of those points have target water-level conditions of disconnected surface water in sloughs, the slough or deep-water refugia nearest a given random point will be selected for throw trap sampling. Samples taken within each slough or deep-water refugium will include at least one in the estimated deepest point. A cursory look at drydown patterns for the South Florida Water Management Model indicates that for any month during the dry season, three to four landscape regions of the six considered for sampling will have cells that could potentially meet the drying front criterion. A one-year pilot study will be conducted to refine the logistics of sampling across such a large spatial area.

Table 3-4: Landscape Units of Greater Everglades Wetlands to be used for Stratified Random Sampling Design

Everglades Landscape Regions	Everglades Landscape Subregions
Lake Okeechobee Littoral Zone	1. Lake Okeechobee Littoral Zone Northwest 2. Lake Okeechobee Littoral Zone Southwest
Corbett/Pal Mar	3. Corbett/Pal Mar
Northern Everglades	4. Rotenberger 5. Holey Land 6. Northern WCA 1 Drained 7. Central WCA 1 Ridge & Slough 8. Southern WCA 1 Pooled 9. Northwest WCA 2A Drained 10. Northeast WCA 2A Cattail 11. Southern WCA 2A Ridge & Slough 12. WCA 2B 13. Northern WCA 3A Drained 14. Northeast WCA 3A S-11 Influence 15. Northeast WCA 3A Miami Canal Influence 16. Central WCA 3A Ridge & Slough 17. Southwest WCA 3A Dwarf Cypress/ Hammock 18. Southeast WCA 3A Pooled 19. Northern WCA 3B Drained 20. Southern WCA 3B Pooled 21. Pennsuco Wetlands
Eastern Big Cypress	22. Kissimmee Billy Strand 23. Mullet Slough 24. Dwarf Cypress 25. L-28 Cypress
Everglades Slough	26. Lostman’s Slough 27. Lower Lostman’s Slough 28. Northeast Shark River Slough 29. Mid-Shark River Slough 30. Southwest Shark River Slough 31. Taylor Slough
Southern Marl Prairies	32. Ochopee Marl Prairie 33. Western Shark River Slough Marl Transition 34. Eastern Shark River Slough Marl Transition 35. Northern Rocky Glades 36. Southern Rocky Glades 37. Western Perrine Marl Prairie 38. Craighead Basin 39. East Perrine Marl Prairie 40. Model Lands Marl Prairie 41. South Dade Marl Prairie

Table 3-4: Landscape Units of Greater Everglades Wetlands to be used for Stratified Random Sampling Design (Continued)

Everglades Landscape Regions	Everglades Landscape Subregions
Coastal Oligohaline Wetlands	42. Lostman's Slough Oligohaline 43. Fertile Crescent 44. Southeast Shark River Slough Oligohaline 45. Cape Sable Salt Prairie 46. Cape Sable Marsh Prairie 47. Central Florida Bay Oligohaline 48. Northeast Florida Bay Oligohaline 49. Barnes Sound/Model Lands Oligohaline 50. Biscayne Bay Oligohaline
Gulf Mangrove Wetlands	51. Lostman's Slough Mangroves 52. Shark River Slough Mangroves

3.1.3.12 Trophic Level - Wading Bird Foraging Distribution and Abundance

Experimental studies have demonstrated a close link between feeding aggregation size of wading birds and prey availability (Gawlik 2002). This relationship appears to be the mechanism that links fish populations and wading bird nesting patterns.

Wading bird distribution and abundances will be monitored with monthly systematic reconnaissance flights over the Greater Everglades Wetlands. These spatially explicit surveys have been conducted monthly from January to June since 1985 (Bancroft et al. 2002). They represent one of the most comprehensive and systematic databases available for evaluating biological responses to the Everglades restoration.

Systematic reconnaissance flights are designed as a means of recording variability in the numbers and spatial distribution of wading birds over time and linking them to variability in hydrology and other more static features of the landscape. The systematic reconnaissance flight protocol is a standard aerial transect counting technique employed within a systematic sampling design (Porter and Smith 1984, Bancroft et al. 2002). The systematic reconnaissance flights, which continue today, are conducted by the United States Army Corps of Engineers and Everglades National Park. These surveys cover the Water Conservation Areas, Everglades National Park, Big Cypress National Preserve, and other landscape units within the Greater Everglades Wetlands.

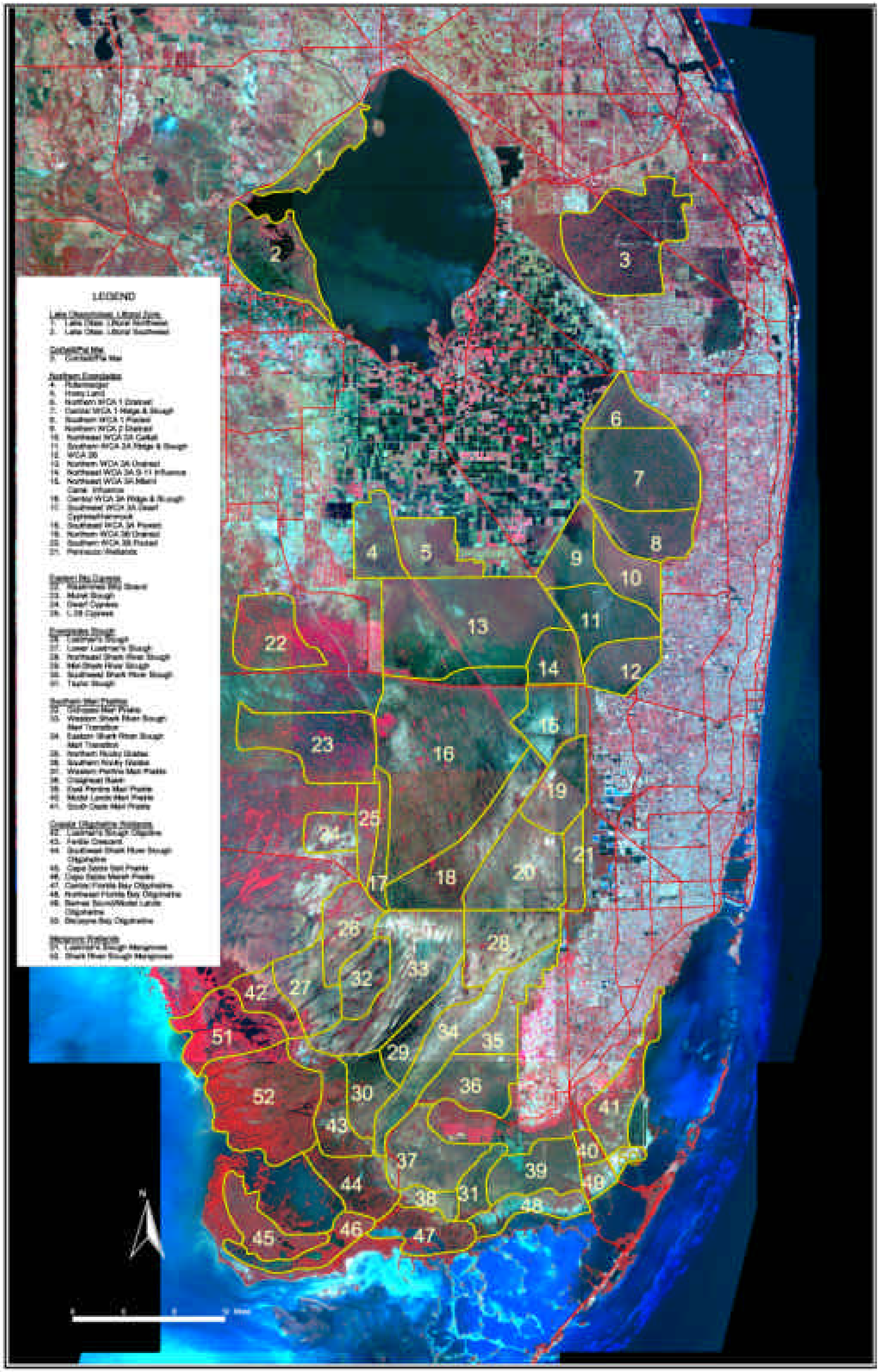

Figure 3-20: Landscape Units of Greater Everglades Wetlands to be Used for Stratified Random Sampling Design

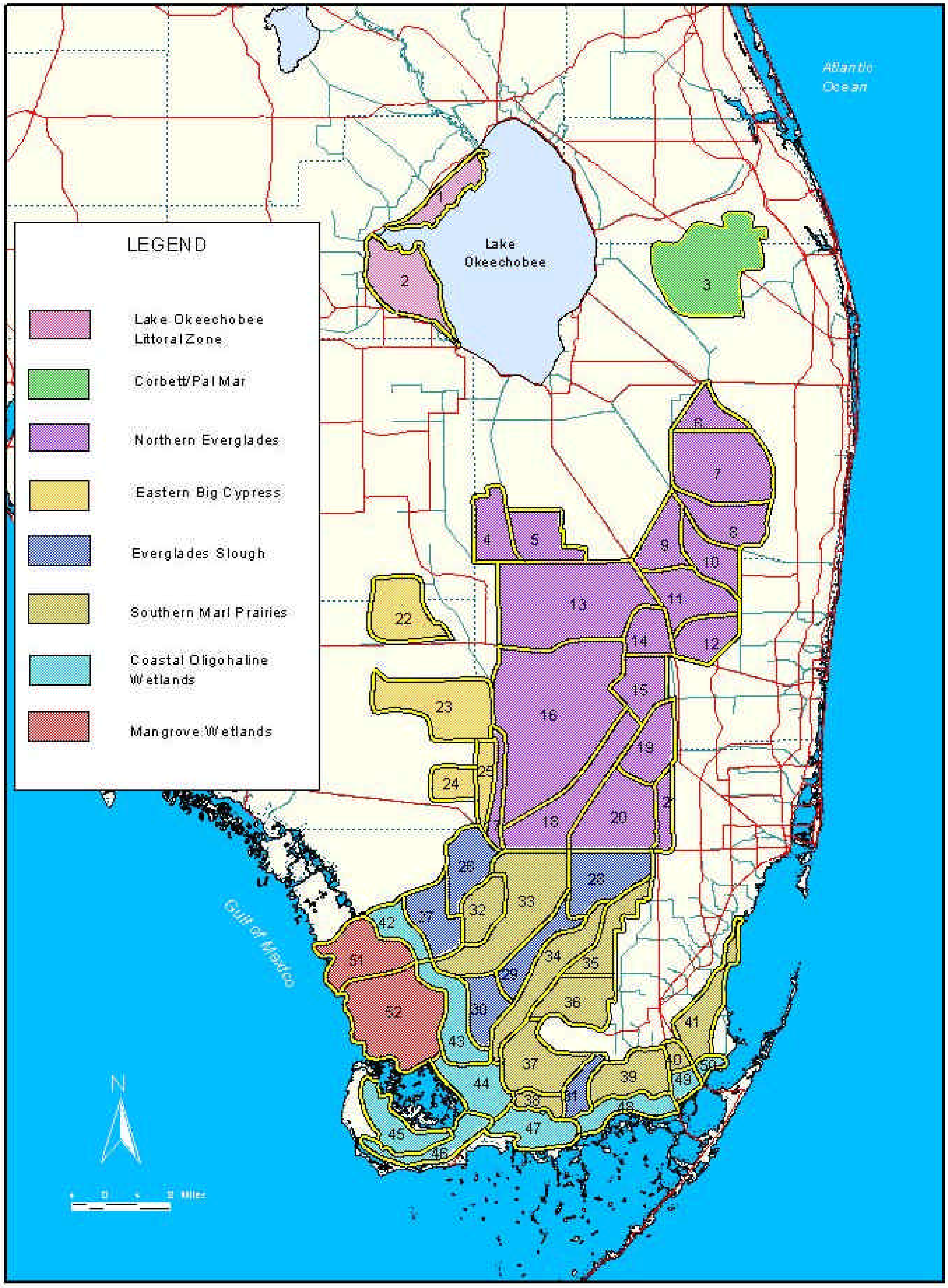

Figure 3-21: Landscape Subregions Aggregated into Regional Groups to be Used for Stratified Sampling Design

3.1.3.13 Trophic Level - Wading Bird Nesting Colony Location, Size, and Timing

A central prediction of the current Everglades restoration plan is that the return to natural flows and hydropatterns will result in large, sustainable breeding wading bird populations; return to natural timing of nesting; and restoration of nesting in the coastal zone. The timing, location, size, and productivity of wading bird nesting will be monitored over the geographic range of the Greater Everglades Wetlands. Monitoring methods will allow for comparison of historical and current information. The geographic regions monitored will include Florida Bay; mangrove estuaries and ecotone; freshwater marshes of Everglades National Park; Water Conservation Areas 1, 2, and 3; and Big Cypress National Preserve.

Nesting of six wading bird species will be monitored: wood stork, white ibis, roseate spoonbill, snowy egret, great egret, and great white heron. These are the species for which the best historical comparisons exist for one or more of the parameters of interest: range of trophic levels, prey sizes, and foraging techniques used (Ogden 1994, Frederick et al. 1996). Nesting will be monitored between January and late June of each year, with the exception of Florida Bay (November through June). However, there is the possibility that monitoring in the mainland areas will need to be expanded if wood storks begin nesting earlier than January. Evidence of early nesting (eggs or young) is likely to be discovered on January surveys, and timing of surveys will be adjusted accordingly.

The timing, location, and size of nesting events will be monitored using systematic aerial surveys followed by ground counts. Established techniques used in the freshwater marsh sections of the study area (Frederick et al. 2001) will be adapted to specific habitats in the Big Cypress National Preserve and the mainland mangrove estuary. Ground counts will focus on the largest colonies of each species based on the analysis of past years, which suggests that 90 percent of nesting birds are found on average in 3 to 33 colonies depending on the species (Frederick personal communication). Accuracy in aerial counts of large colonies will be improved through the use of aerial photography followed by later counts of those photos (Frederick et al. 2003).

Roseate spoonbill and white ibis nests in Florida Bay are generally located in dense red mangrove stands and are not generally visible from outside the colony. All islands that were previously reported to have had nesting colonies (Lorenz et al. 2001) will be surveyed monthly during the nesting season, and the number of nests will be counted. While traversing Florida Bay by boat, locations of roseate spoonbill and white ibis activity will be investigated for new nesting sites. The timing of colony surveys late in the incubation period and during mild climatic conditions and the limitation of time in an individual colony to less than one hour whenever possible will minimize impacts of surveys on colonies (Lorenz et al. 2001).

In order to use nesting effort and nesting success as criteria for ecosystem evaluation, the location of primary foraging grounds must be monitored for each colony group (Lorenz et al. 2001). In order to identify the direction of foraging grounds from nesting colonies, flight line counts similar to those described by Dusi and Dusi (1978) will be made at the two largest colonies in each colony group. Flight line counts will yield an estimate of the proportion of birds using general areas (e.g., eastern, middle, or western mainland sites; mainline keys; etc.). To get more specific foraging locations, individual birds will be followed using a fixed-wing aircraft from their nesting colonies to the first foraging location. Flight line observation and following flights will also greatly aid in identifying new colony sights locations throughout the bay.

Any periodic surveys are likely to lead to underestimates due to asynchronous nesting and the possibility that nests may start and fail between survey dates. Comparing typical monthly survey schedules with a large sample of known nesting histories of individual nests shows that the monthly survey schedule that has been followed in the central Everglades since 1986 has been associated with a known correction factor, with annual variation in that correction factor of 26 percent above and below any annual estimate

(Frederick et al. In prep.) Therefore, the resulting nesting population estimates are likely to be associated with this level of error. However, estimation of this error rate is based on only 2 to 4 years of information on marked nests, depending on species. The database of individual nest histories will be expanded in order to refine the estimation of error associated with monthly surveys. This involves close monitoring of individual nests at one or more colonies throughout the nesting season in order to measure both duration and seasonal timing of nesting attempts.

3.1.3.14 Trophic Level - Wood Stork and Roseate Spoonbill Nesting Success

Success of nesting for wood storks and roseate spoonbills will be measured as the number of young produced per nest start. This provides at minimum a relative measure that can be compared among years. If measured at enough colonies, the absolute number of fledglings produced may be estimated. Historical information exists for this parameter in both species, and techniques for these measurements are standardized in both species (Ogden 1994, Bjork and Powell 1994, Lorenz et al. 2001).

For wood storks, helicopter censuses will be performed at one or more points during the nestling period, and numbers of large, standing young per nest will be counted. This yields young per successful nest. Young per nest start will be calculated by using the total number of estimated starts as the denominator.

For roseate spoonbills, the two largest colonies within each subregion of Florida Bay will be used to estimate nesting success for each group. Survey transects will be established in each of these colonies so that representative samples of nests can be monitored. On the initial visit, 25 to 50 nests will be marked with numbered plastic tags (unless a colony has less than 25 nests, in which case all nests will be marked), and the number of eggs per nest will be counted. Each colony will be visited approximately every ten days, and the contents of each nest will be recorded. Information on clutch size, duration of nesting, reproductive success, and cause of nest failure will be collected for each nest. Nests will be monitored until failure or until all surviving chicks reach at least 21 days of age. Chicks reaching at least 21 days of age will be considered a successful nesting attempt (fledged). Subsequent counts of flying young of the year at other colonies within the same group will be used to corroborate results from this method.

3.1.3.15 American Alligator Distribution, Size, Nesting, and Hole Occupancy

The American alligator will be monitored using three approaches in the Greater Everglades Wetlands, each to determine if populations are recovering in expected ways as CERP is implemented. Methodologies are described in Rice et al. (2004 in press).

The recovery of a healthy range of alligator size classes and condition throughout the system, including increased occupancy on mangrove creeks, will be monitored by surveys at the end of the wet season and throughout the dry season. Eye shine surveys of freshwater wetlands will be supplemented by aerial and ground surveys of coastal creeks during September and throughout the dry season. Alligators will be captured, weighed, and measured in October and March-April. Survey and capture locations will be a combination of fixed and randomly selected routes in regions and cells where landscape patterns and marsh fish populations are monitored. Capture areas and survey areas will not overlap during a given sampling period. Alligator parameters will include the number of alligators per kilometer, size class distribution, and body condition of alligators greater than one meter in length. Habitat parameters will include water level, temperature, salinity, and vegetation type.

The return of reproducing alligator populations to the southern marl prairies and mangrove estuaries, while maintaining alligator nesting in Shark River Slough, will be monitored by systematic reconnaissance flight surveys supplemented by aerial surveys and ground checks. Annual systematic reconnaissance flight surveys will be flown throughout Everglades National Park in July. Systematic reconnaissance flight methodology is described above for monitoring wading bird foraging. The number of alligator nests and the number of successful nests will be measured in addition to water level, salinity, and vegetation type.

Occupancy rate of alligator holes (with a goal of 75-100 percent occupation) and an increase in the number and distribution of alligator holes in areas of low density will be monitored by mapping alligator holes in combination with occupancy checks. The number and distribution of alligator holes will be mapped every three years in the regions and cells where landscape patterns and fish populations are monitored, using the aerial photography acquired for vegetation mapping. The number of mapped holes occupied by alligators 1.8 meters or longer will be monitored annually in a random sample of holes using helicopter and airboat surveys.

3.1.3.16 American Crocodile Juvenile Growth and Survival

American crocodile surveys will be conducted using methodologies described in Mazzotti and Cherkiss (2002). Surveys for crocodile nests will be conducted April through August in Biscayne Bay and Florida Bay from Crandon Park to Shark River. Nests will be monitored through incubation, and hatchlings will be captured, measured, and marked upon emergence. Surveys and captures of juvenile crocodiles will be conducted four times a year in the same areas (early nesting, late nesting, and twice in the winter dry season). All animals will be weighed, measured, sexed, and given an individual mark. Location (using a global positioning system), salinity, and temperature will be recorded at each capture.

3.1.4 Key Uncertainties and Supporting Research

3.1.4.1 Coastal Wetland Landscapes and Berm Systems: Sea Level and CERP Influences

<u>Justification</u>: With the projected future increase in the rate of rise in sea level over the coming century, dramatic changes in coastal landscapes of the Everglades are inevitable. It is critical to predict the resulting landscape changes in the lower Everglades because ecosystem restoration will succeed only by working in harmony with those inevitable changes. Ecological performance measures and project design features may require substantial modification given the projected changes resulting from this evaluation. It is recommended that the following research and evaluation be carried out early in the Everglades restoration program to permit its results to be incorporated into the restoration design and monitoring program.

<u>Project Description</u>: This project will include the following work activities:

- Determine the anticipated relative sea level rise over the next 50 and 100 years and select moderate and moderate-to-high scenarios to project the evolution of South Florida environments.

- Provide an integrated map of topography, sediments, and sediment influx/production for coastal and southern Everglades environments and assess the susceptibility of those sediments and environments to change due to rates of sea level rise, storm events, and changes in freshwater discharge and water level. Based on this information, define the sequences, patterns, and connectivity of environmental change in response to the anticipated sea level rise scenarios over the next 50 and 100 years.

- Develop understanding and consensus on the responses of lower Everglades environments and substrates to sea level rise and changes in freshwater discharge and water level through a series of workshops bringing together experts on sea level stress to wetland systems, substrates, and ecosystem dynamics.

- Forecast the type, extent and patterns of environmental change and changes in flow and flooding patterns in the next 50 and 100 years based on the sea level rise scenarios. Identify freshwater flow conditions that should optimize stability of coastal wetland systems. Test the feasibility of landscape model forecasting. Identify gradient transects most likely to reveal the areas most and least susceptible to environmental and substrate change in response to future sea level and freshwater discharges.

3.1.4.2 Tidal and Freshwater Creek Dynamics: Sea Level and CERP Influences

Justification: Many tidal creeks through coastal wetlands of the Everglades have disappeared entirely during the past century because they have been filled in with sediments and with the vegetation of surrounding landscapes. Reduced freshwater flow volume and rising sea level are probable contributing factors. In the course of Everglades ecosystem restoration, there are two critical changes anticipated that may greatly influence the character of channeled flow and, in turn, the pattern of freshwater and saline water movement: 1) changes in the freshwater flow volume, timing, depth, and hydroperiod and 2) changes in sea level and associated changes in flow and sediment loads during prevailing storm conditions. Restored freshwater inflow from the Everglades is expected to sustain and open watercourses through the estuary that will more closely resemble historic patterns, yet the causal factors of flow and sea level remain poorly understood. This project defines causes for instability in flow channels, determines rates and patterns of change that can be expected in response to changing influences, and defines monitoring criteria that can be used as early warning indicators for channel system instability.

Project Description: This project will include the following work activities:

- Define the different types of natural channel/creek systems and networks along the coastal zone from central Biscayne Bay to Lostman’s River. Determine the present and historical dynamic status and evolution of these systems. For channel systems with significant recent geologic and historical evolution, document the timing and assess the causes for observed changes.

- Select a suite of representative sites along freshwater and tidal channels for documenting and understanding stability and the evolution of channel form. These will include channels that are currently stable, enlarging, and constricting; channels cut through differing substrates and with differing margin topography; channels that have been filled because of presumed historical reduction in freshwater flow; and channels historically initiated through natural and human causes. For the selected channels, define and carry out a research program to determine the following:

  – Boundaries of hydrologic conditions necessary to maintain but not enlarge or constrict channel form

  – Nature and volume of sediment loads released in response to channel changes if stable flow conditions are exceeded

  – Rate and degree of channel constriction/infill in response to channel hydrology changes if stable flow conditions are not maintained

  – Influence of catastrophic event and post-event sediment redistribution on channel flow, stability, and evolution

- Input research results into workshops assessing effects of anticipated changing sea levels to evaluate anticipated changes in channel forms, changes in flow velocities, changes in sediment supply and load, and differing effects of catastrophic events in a time of rising sea level.

3.1.4.3 Productivity in Coastal Ecotone: Sea Level and CERP Influences

Justification: The salinity transition zone of the Everglades, along both the Florida Bay and Gulf of Mexico coastlines, is an ecotone of high productivity due to the retention of nitrogen that enters this region from the Everglades and phosphorus that enters from the Gulf of Mexico and Florida Bay. The estuarine productivity peak is hypothesized to have supported food webs that sustained the large colonies of wood stork, great egret, and white ibis that once nested in the ecotone region. The retention of nitrogen and phosphorus is also important in order to maintain water quality in the adjacent, more oligotrophic systems (the Everglades and Florida Bay) and to sustain soil accretion and thus minimize the effects of sea level rise. It is expected that implementation of the CERP will enhance productivity in the ecotone as a result of reduced salinity combined with the continued function of the transition zone as a "sink" for nitrogen and phosphorus. This study provides support to a comprehensive research program of the Florida Coastal Everglades Long-Term Ecological Research Program to address productivity in the estuarine ecotone in relationship to freshwater flow, sea level, and the associated variables of nutrient mixing and salinity.

Project Description: A series of simple experiments are proposed to provide information on the factors that control nutrient uptake, releases, and storage in the salinity transition zone:

- **Measure organic matter decomposition rates -** The release and uptake of nutrients during the decomposition of organic matter in the salinity transition zone is hypothesized to be tightly coupled so nutrients are retained. Rates of decomposition (leaching, carbon loss, and nutrient mineralization) will be measured for different sources of plant organic matter.

- **Measure belowground root production and decomposition -** Soil accretion in the transition zone may largely be a function of the production of decay-resistant root tissues. Production and decomposition rates will be estimated in transects through the salinity transition zone.

- **Measure controls of decomposition rates -** In order to understand the effect of restoration on the processes of organic matter decomposition and accretion in the transition zone, experiments on several factors that are likely to change in coming decades will be manipulated. These include salinity, wetting and drying patterns, and phosphorus and nitrogen concentrations.

- **Integrate with monitoring and modeling programs -** Results from these studies will help RECOVER understand the effects of restoration on central processes, such as the maintenance of patterns of productivity, water quality (including measurements of creek flow and nutrient loads), and soil elevation. All of these patterns will be monitored and are important components of any models of the region. Data from the proposed studies will be included in the refinement and further development of conceptual and numerical models.

3.1.4.4 Ridge and Slough Landscape Sustainability

Justification: An important restoration expectation for the ridge and slough landscape is to prevent further loss of tree islands and sloughs and to restore these features, if possible, through the restoration of sheet flow patterns, water depths, and hydroperiods that more closely resemble natural, pre-drainage hydrology (Science Coordination Team 2003). Sloughs have lost spatial extent and directionality and have been encroached by sawgrass, apparently as a result of a combination of reduced water flow and reduced depth.

Tree islands have experienced high-water stress and drowning, as well as burnout under low-water conditions. Hydrologic requirements for the sustainability of sloughs and tree islands have yet to be determined. Furthermore, in the current degraded system with widespread losses in peat elevation and depth, there is concern that the hydrologic conditions necessary to perpetuate sloughs and tree islands may be conflicting. The hydrological, geological, and ecological processes that control the origin and persistence of co-existing sloughs and tree islands must be understood to prevent their continued disappearance from the ridge and slough landscape. The role of climatic extremes, which produce peak flow velocities and depths at one extreme and peat-burning fires at the other, is critical to that understanding.

<u>Project Description</u>: The project description of a comprehensive research program to address ridge-slough-tree island mosaic sustainability has yet to be developed. The following ongoing and proposed research projects pertain to this question.

Processes Affecting Sheet Flow in Vegetated Wetlands of the Everglades

This project quantifies the magnitude, direction, and behavior of sheet flow in the major wetland communities of the Everglades. The external and internal processes that affect sheet flow behavior will be determined. Forcing mechanisms will include the immediate and long-term residual effects of fire on shallow surface-water flows. The project analyzes data from eight existing and two new flow monitoring stations located in the major wetland plant communities of the southern Everglades to provide the following information:

- Quantify, both temporally and spatially, the nature and behavior of sheet flows in vegetated wetlands
- Identify the external and internal processes that affect sheet flow behavior, both horizontally and vertically
- Contrast slough, spikerush, marl prairie, and tidal headwaters plant communities regarding sheet flow magnitudes and patterns
- Determine the effects of temperature on flow structure
- Determine forcing functions that govern the channeling of sheet flows from sloughs to the headwaters of tidal creeks
- Analyze data from flow monitoring stations in the Squawk Creek tributary headwaters of Everglades National Park to 1) quantify, both temporally and spatially, the effects that fires have on the nature and behavior of sheet flows; 2) identify the extent and duration of the residual effects of fires on external and internal flow-forcing mechanisms; 3) contrast flow magnitudes and directions in adjacent burned and unburned sites; and 4) investigate long-term recovery effects of vegetation regeneration on flow conditions.

Loxahatchee Impoundment Landscape Assessment

The Loxahatchee Impoundment Landscape Assessment (LILA) project defines hydrologic regimes that can sustain a healthy Everglades ridge and slough ecosystem. Specifically, this study quantifies the effects of water depth, hydroperiod, and flow rate on five of the seven CERP ridge and slough priority components: 1) wading birds, 2) tree islands, 3) marsh plant communities, 4) marsh fishes and invertebrates, and 5) peat soils. LILA also provides the public easy access to a site where construction work that is so much a part of the CERP is visibly producing restored tree islands, restored ridge and slough habitats, increased wildlife use, and an obvious example of the integration of science into the restoration process.

"Macrocosms" will be constructed so that they are a large enough to include ridges and sloughs, tree islands, and free ranging wading birds, but small enough to allow for control of their hydrologic regimes. These macrocosms will be used to measure the responses to hydrologic manipulations at several trophic levels of the CERP priority components of the ridge and slough system. Four replicate macrocosms that total 32 hectares in size will be constructed in two impoundments at the Arthur R. Marshall Loxahatchee National Wildlife Refuge. Each impoundment will be divided into two macrocosms, each containing tree islands, ridges and sloughs, and deep-water refugia (representing alligator holes). These macrocosms will be used to study how different hydrologic treatments that are controlled, replicated, and defined a priori affect the ridge and slough system. The tree island and ridge and slough responses will be measured by examining biogeochemical, vegetative, and physical parameters. The wildlife response will come from changes in the distribution, abundance, and behavior of free-ranging wading birds and native fish communities.

Tree Island Assessment

This project will evaluate how best to quantify the overall health of tree islands and then use this quantification to monitor the performance of the CERP. The vegetation structure, plant succession, soil quality, elevation change, and wildlife diversity will be assessed on six tree islands in WCA 3B, 12 tree islands in WCA 3A, and 8 tree islands south of WCA 3B in Everglades National Park.

Vegetation will be sampled primarily using two intensive 10-by-10 meter (0.01 hectare) plots at the head, two at the near-tail, and one in the tail of each tree island. In each sampling unit, presence of all tree species with diameter breast height greater than 2.5 centimeters will be tagged. Height and canopy cover will be recorded for each tagged tree. Nested subplots will be employed to obtain estimates of plant species number and co-occurrence at spatial scales less than that of the 0.01 hectare plot.

Soil samples will be collected on each island in year 1 of this program and again in year 5. In the near-tail of each tree island, a water depth recorder capable of hourly measurements of both surface and ground water elevations will be established.

A sediment erosion table will be used to measure wetland elevation change to an accuracy of plus or minus 1 millimeter. This device, in conjunction with feldspar marker horizons, will measure deposition by monitoring vertical soil/peat accretion or erosion on the head of each tree island.

Ridge and Slough Flows Study

This study will quantify hydrologic processes (water flows, sediment flows, water depths, vegetation communities, and geometry of man-made conveyance structures) under actual field conditions that will provide the data needed both for development of mechanistic models and for objective evaluation of alternative restoration scenarios. Specifically, meteorological and biological conditions that affect the carbon balance in and topography of sloughs will be measured, as well as the anthropogenic influences that may alter carbon accumulation in sloughs.

The effects of sediment transport and water flows on marsh topography and habitat diversity will be measured using three parallel approaches: 1) continuous monitoring, 2) synoptic characterization, and 3) residual characterization. In particular, the threshold conditions (velocity, wind speed, temperature, bioturbation, etc.) needed to suspend and transport organic sediments (flocculent) will be quantified.

Effects of continuous, average flows and effects of infrequent, higher energy flows will be separated. Infrequent effects will be captured through continuous, automated monitoring of flows and sediment movement and of the meteorological driving forces at approximately 5-10 ridge and slough sites. The same autonomous monitoring stations transmitting continuous data back to SFWMD will also capture low energy, average flow effects. Synoptic studies of areas large enough to include 4 to 6 replicate ridges and sloughs will capture the variations in flow and sediment transport over representative portions of the ridge and slough landscape. The studies will include passive tracer monitoring (nonsorbing fluorescent dyes and/or lithium) and active sediment movement experiments in which flocculent layer movement will be artificially induced and monitored within sloughs and ridges. Residual studies will use before and after comparisons on either side of large meteorological events to further document sediment movement events and to act as a check on the continuous monitoring stations.

Fully Integrated, Multi-Scale Simulation Model(s) for Ecosystem Processes in Northern and Southern Everglades

As better temporal and spatial ecological data are becoming available, particularly in the southern Everglades, the Everglades Landscape Model (ELM) is being further evaluated and refined to best capture system dynamics in the southern and the northern extent of the system. Functional refinements include the following:

- Year 1: Complete version 3.0 refinement
- Year 2: Improve peat and marl soil responses to interactions of hydrology and nutrient dynamics
- Year 1, 2, and 3: Deploy fine scale ridge and slough implementations (including existing but unused sedimentation module) in 2 subregions of WCA 3A
- Year 1, 2, and 3: Incorporate simple net settling rate module for nitrogen transport and fate and further develop existing, process-based nitrogen module
- Year 1 and 2: Fully integrate data on topography and mangrove creek hydrography
- Year 1 and 2: Develop simple creek flow module based on existing canal module
- Year 2, 3, and 4: Enhance existing dynamics for mangrove (including dwarf) biomass and species responses to hydrology, salinity, and nitrogen and phosphorus interactions
- Year 1-5: Develop code and data-passing algorithms for enhanced collaboration with existing mangrove and seagrass modeling efforts

3.1.4.5 Technology Development: Vegetation Mapping

Justification: Many of the CERP projects are intended to directly affect vegetation mosaics and water quality characteristics in the Everglades wetlands. Currently, Everglades vegetation mapping is limited primarily to photo-interpretation of aerial photography, which is very time-consuming and costly but yields relatively accurate determinations of the cover vegetation. Water quality monitoring proposals using transects and grab samples are also costly. This project investigates the potential use of hyperspectral remote sensing technologies as a way to develop more cost-effective techniques for mapping Everglades landscape and water quality patterns. The anticipated results will be used to supply baseline information on the key attributes of the regional system, refine the calibration and validation of the simulation models, and provide quasi-real time performance measure assessments as the restoration plan proceeds.

Project Description: The specifics for a project description are still being developed.

3.1.4.6 Crayfish Population Dynamics – Hydrological Influences

Justification: Native crayfish species appear to represent an important intermediate trophic level and a major prey base for wading birds in Everglades food webs (Frederick and Collopy 1988, Gibbs 1993, Hart and Newman 1995, Jordan et al. 1996, Kushlan and Kushlan 1979, Lodge et al. 1994, Momot et al. 1978, 1984, 1995, Nystrom et al. 1996). The Everglades are the only large wetland system in the Western Hemisphere where the predominant wading bird (white ibis) feeds largely on crayfish. Large nesting colonies (super colonies) comprised mostly of white ibis form during years following major droughts when marsh fish populations are diminished and when crayfish may provide the prey base supporting the nesting birds. Numbers of nesting white ibis in the Everglades have plummeted during the last century, apparently as a result of diminished prey population density and availability. Knowledge of crayfish population dynamics in relation to hydrology is essential to understanding why large breeding populations of white ibis and other wading birds return or do not return to the Everglades upon the hydrologic restoration implemented by the CERP. Presently there is little information on the population ecology of the two Everglades crayfish species, as affected by hydrology and water management. The crayfish population dynamics research, in combination with trophic level and water quality monitoring, will provide the foundation for future research on the causal factors leading to the formation of wading bird super colonies (large nesting colonies of white ibis and other wading birds that form after major droughts).

Project Description: This project will include the following work activities:

- Compare the capture efficiency and selectivity of sampling gear and mark/recapture techniques to determine the most effective combination of sampling methods across the diversity of regions listed below. Test traditional capture methods including throw traps, drop traps, minnow traps, and Breder traps. Conduct literature survey of other applicable sampling methods and compare with traditional methods. Devise an optimal method or combination of methods to monitor crayfish populations as prey bases for wading birds in the Everglades.

- Determine the basic life histories and population dynamics of *Procambarus alleni* and *P. fallax* in relation to season and hydrology at selected sites in the Everglades. Provide quantitative estimates of population density, growth, survival, recruitment, and dispersal through monthly sampling in six regions: Coastal oligohaline wetlands in the fertile crescent region, Florida Bay oligohaline wetlands, mid-Shark River Slough, southern Rocky Glades, central WCA 3A, and central WCA 1. The duration of this study may need to be extended or revised to include a major drought year and the year following the drought. Crayfish research will be coordinated with the throw trap monitoring program to compare the population dynamics of crayfish with those of marsh fishes and grass shrimp.

The crayfish research is the first in a series of studies on the life histories and population dynamics of groups of aquatic fauna that appear to play important but little understood roles in aquatic food webs in the Everglades. The importance of amphibians as environmental indicators and their abundance in the Everglades make them likely candidates for future research priorities.

3.1.4.7 Aquatic Refugia – Coastal Ecotone, Alligator Holes, and Solution Holes

Role of Marsh-Mangrove Interface Habitats as Aquatic Refuges for Marsh fishes and Other Aquatic Animals

Justification: The freshwater marsh/mangrove ecotone of the southern Everglades is considered to be essential in achieving the restoration goals of the CERP. Reductions in freshwater flows to this region have been implicated in the loss of secondary production and the departure of historical wading bird colonies from coastal areas. Aquatic habitats in this region are the most heterogeneous in the ecosystem and the most naturally productive, even under current conditions. They are also among the least understood in terms of their ecological function. The pools and swales and small creeks that coalesce to form larger river channels are thought to provide protection for aquatic fauna from adverse dry season conditions, although rising salinity and predatory fishes may diminish the functions of these habitats as drought refuges. How aquatic animals respond to present-day conditions in the marsh/mangrove ecotone and how the CERP will affect conditions are questions that are meshed tightly with wading bird responses and the restoration of coastal nesting colonies. Information from these studies will be critical in testing hypotheses about the management and recovery of the freshwater marsh/mangrove ecotone and in planning adaptive assessment actions during the implementation and operation of the CERP.

Project Description: This project will include the following work activities:

- Determine the dynamics of population density and movement of marsh fishes and other prey organisms within creek channels and between marshes and channels in response to cycles of tide and climate. Determine the upstream hydrologic factors that affect those dynamics, including upstream water management, freshwater inflows, and hydroperiod.

- Determine the effects of salinity as a factor limiting the survival of marsh fishes and other prey organisms in tidal creeks and rivers, pools, and swales during dry seasons and drought years. How significant are salinity and drying pattern as factors limiting species richness and density during the following wet season?

- Determine if the refuges in the freshwater wetland/mangrove ecotone provide a source of colonists for long-distance dispersal into the sloughs and peripheral wetlands. Quantify the direction and degree of dispersal by fishes and other aquatic prey organisms from this region during the wet season under different hydrologic conditions.

- Focus on ecotones at the North, Shark, Broad, and Lostman’s Rivers’ drainages in the fertile crescent region that historically supported intensive wading bird foraging and nesting. Establish replicate stations of creek/pool and marsh habitats within each river’s drainage. Concentrate sampling during the dry season, especially as the marshes dry, with less frequent sampling during the wet season. Measure movement of fishes and other prey organisms to and from creeks to determine the temporal and spatial extent, direction, species composition, and size distribution of the individuals involved.

Role of Alligator Holes as Aquatic Refuges for Marsh Fishes and Other Aquatic Animals

Justification: An important restoration expectation of the CERP is to increase population densities of marsh fishes and other aquatic fauna that form the major prey bases for wading birds. The restoration of more natural hydrologic patterns is expected to increase prey populations due to prolonged hydroperiod and to increase survival rates in aquatic refuges during dry periods. Because alligator holes provide permanently flooded habitats when surrounding marsh areas dry in the main Everglades sloughs, they are considered to be important aquatic refuges. Alligators and alligator holes are expected to increase in distribution and density as more natural hydrologic patterns are restored, thereby increasing survival rates for aquatic fauna during droughts and sustaining higher population densities during wet periods. A key uncertainty is whether these deeper aquatic habitats serve as sources or sinks for aquatic animals during dry periods.

Project Description: This project will include the following work activities:

- Determine the relationship between the density of alligator holes and numbers of fishes and other aquatic fauna available to colonize surrounding wetlands following a drought.

- Measure the survival of fishes and other aquatic fauna in alligator holes during the dry season.

- Measure the characteristics of alligator holes that affect their quality as refuges, i.e., vegetation cover, alligator occupancy, etc. Determine which characteristics favor the survival of particular groups of aquatic species.

- Determine if the numbers of fishes and other aquatic fauna that take refuge in alligator holes are adequate to explain the numbers of colonists found in adjacent wetlands during the following wet season. Is there reason to suspect that long-distance dispersal from other refuges is an important factor in repopulation of wetlands?

- Analyze evidence from refuges that droughts foster predator release for small-bodied fishes and other aquatic fauna, resulting in population increases that support high wading bird nesting in subsequent years.

A research plan to address these questions will involve sampling of fishes and other important prey species in holes and surrounding marshes within major sloughs (Lostman's, Shark, and Taylor) in the dry season, using multiple methods to assess animal populations and their use of the habitats.

Role of Solution Holes as Aquatic Refuges for Marsh Fishes and Other Aquatic Animals in Karst Wetlands: Pilot Study of Remote Sensing/Surveying Methods for Estimating Refuge Characteristics

Justification: An important restoration expectation of the CERP is to increase population densities of marsh fishes and other aquatic fauna that form the major prey bases for wading birds. The restoration of more natural hydrologic patterns is expected to increase prey populations due to prolonged hydroperiod and to increase survival rates in aquatic refuges during dry periods. Dry season refuges are particularly important determinants of fish population densities in the rocky glades, where water levels typically drop below the ground surface each dry season and where the ground surface is underlain by a complex karst network of solution holes that may retain water during the dry season.

Aquatic animals such as fish and crayfish are known to move onto the surface of the rocky glades at high water for feeding and reproduction. The source of these animals is still uncertain but involves both long-distance dispersal and local movement from solution holes. Reduction in ground water levels in the rocky glades since the 1960s has reduced the number of solution holes available as refuges. An objective of hydrologic restoration of the CERP is to raise ground water level in the rocky glades to inundate more solution holes and increase the abundance of re-colonizing aquatic fauna during wet seasons.

To relate the dynamics of aquatic animals to the characteristics of solution holes, data are presently collected from a sample of holes of various depths and diameters in several areas of the rocky glades. To predict the consequences of regional increases in ground water levels on populations of marsh fishes and other prey species, however, it is necessary to extrapolate the data from the intensive, site-based studies to the greater rocky glades landscape. This requires measurement of the density of holes and their diameters and depth distributions. New technologies for remote sensing have recently been developed that may gather these physical data in a more rapid and cost-effective manner; however, these methods are untested in the rocky glades landscape.

Project Description: This project will include the following work activities:

- Conduct a pilot study to test alternative remote sensing methods to determine their resolution and accuracy in estimating hole density, areas, and depths in the rocky glades. Validate the methods by comparison to results from standard land surveying methods.

- Determine optimum study designs and survey methods to characterize the density, areas, and depth distributions of solution holes in the rocky glades in a spatially explicit manner.

3.1.4.8 Ecological Effects of Canals and Other Artificial Deep Water Habitats

Justification: Effects of canals on the physical and biological aspects of the Everglades ecosystem are widespread but, in some cases, poorly understood. They act as 1) corridors for the movement of nonnative animals and plants, 2) artificial deep water habitats for native and introduced aquatic predators in the dry season, and 3) refuges in which large native and introduced species achieve higher abundance than in natural deep-water habitats. During the dry season, those predators prey heavily on small marsh fishes and invertebrates that are attracted to the canals from adjacent wetlands. Since some canals will be filled by the CERP and a new set will be excavated, it is important to understand the consequences of this artificial habitat in light of restoration costs.

Project Description: This project will include the following work activities:

- Determine if canals act as sources of colonists after the dry season, as sinks for wetland production at the end of the wet season, or as both for different groups of animals

- Analyze the outstanding largemouth bass fishery in Everglades' canals in terms of the energy subsidy from adjacent wetlands, the effects on the ecology of adjacent wetlands, and the potential for a wetland-supported trophy fishery without canals given the lengthened hydroperiods that will result from CERP implementation

- Examine effects of canals on the distribution and abundance of the American alligator and alligator holes in adjacent wetlands

- Analyze canals as habitats and movement corridors for exotic fishes. Do canals result in higher colonization rates than wetlands? How far into wetlands do native and nonnative fishes move in relation to artificial habitats?

- Compare wetlands adjacent to filled canals before and after the canals are filled, in contrast to wetlands adjacent to canals that are unaffected. Sample two years before and three years after an infilling action

- Compare canals cut through natural wetlands with canals isolated from wetlands

3.1.4.9 Synthesis of Wading Bird Distribution Surveys 1985-2001

Justification: The decline of wading bird populations in the Everglades was one of the first and most visible signs that the Everglades ecosystem had been degraded. Currently, wading bird populations are used as an important indicator in the Everglades restoration effort. The CERP uses hypothesized relationships between wading birds and hydrology to shape hydrologic targets for the Everglades restoration. In addition, several performance measures based on wading birds will likely be used to gauge the progress and success of the Everglades restoration (e.g., the number of large flocks in the system, the number of nests in the system, the location of the nesting colonies, and the timing of nesting initiation). The results from this project will be used to fine-tune these hydrologic targets and performance measures to support the Everglades restoration.

Project Description: This project will include the following work activities:

- Determine the relative contribution of short- and long-term effects of hydrologic stressors and landscape variables on the variation and trends in wading bird feeding patterns and population sizes observed over the past 17 years

- Develop a wading bird performance measure based on relationships between wading bird spatial distributions, hydrology, and annual nesting effort

- Evaluate the systematic reconnaissance flight as a tool for wading bird monitoring

The primary data set consists of 17 years of spatially explicit aerial wading bird systematic reconnaissance flight surveys across the entire Everglades landscape with a suite of associated environmental variables. The ancillary data range from detailed observations on feeding behavior on experimental plots to long-term information on annual nesting patterns to data on habitat and hydrology.

The project will proceed in three stages: 1) collect the primary and ancillary data sets into a single data base, 2) perform an initial exploration of the assembled data sets, and 3) develop detailed empirical models and performance measures aimed at quantifying the effects of multiple hydrologic and landscape factors on wading bird populations.

3.1.4.10 Sub-Lethal Effects of Contaminants on Wading Bird Reproduction

Justification: Restoration of wading bird reproduction has been a centerpiece of the argument for restoring hydrology in the Everglades. However, the current nesting populations demonstrate reproductive anomalies that also appear to be consistent with contaminant effects. While reproductive failure is likely related to a hydrology-mediated problem with the production and availability of prey organisms, contaminants remain an important competing explanation. Thus, while hydrologic degradation may have been a primary cause of population and nesting declines, reproductive impairment due to contaminants may also be operating in the current, more polluted South Florida environment. Our lack of knowledge about the levels and specific effects of contaminants remains a key uncertainty in our ability to predict reproductive responses of wading birds.

Two major uncertainties have been identified in resolving effects of contaminants on wading bird reproduction in the Everglades. First is the identification of potential contaminants that might be of risk to the birds. Second, the effects of most contaminants on wading bird reproduction are poorly known, and the only useful information is that contaminants can have effects on reproduction in other bird groups.

Project Description: This project will include the following work activities:

- Conduct a survey of wading bird tissues for levels of possible contaminants, including regularly used pesticides, herbicides, heavy metals including mercury, polychlorinated biphenyls (PCBs), dioxins, and furans. The survey will be done via collection of pipped eggs or small young from Everglades nests. The survey may be the basis for a monitoring program at five-year intervals if contaminant levels appear to pose a risk to reproduction.

- Conduct aviary studies to experimentally investigate the effect of ecologically relevant concentrations of contaminants on willingness to breed, reproductive success, and other sub-lethal effects such as susceptibility to disease, parental behavior, endocrinology, and foraging behavior. Aviary studies will be conducted on breeding groups to include individual variation in stresses (planned food shortages, effects of normal dominance, disease) so that the mechanisms and patterns by which contaminant effects are manifested in the field can be inferred with confidence.

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