Spikerush and other native plants have become established in many areas previously impacted by torpedograss.

Hypothesis 2

The transport of pelagic water (TP > 100 ppm) into interior regions of the marsh where TP concentrations are often less than 15 ppm occurs most often at high lake stage. Eutrophication of the interior marsh will result in the loss of desirable vegetation such as spikerush and sawgrass and lead to the expansion of cattail and other non-desirable vegetation.

Rationale**:** The expansion of cattail into Moonshine Bay in the 1980s first occurred along open airboat trails and in Cochran's pass. These areas were connected to the littoral-pelagic interface and likely received periodic inputs of P rich water during periods of high lake stage. Since the 1990s, hundred's of acres of fragrant water lily also have become established along the lake's shoreline and at interior marsh sites including Moonshine Bay.

9.5 Water Supply and Flood Protection

The AT currently does not have guidance for the assessment of water supply and flood protection. However, Renken et al. (2005) have prepared a review of the impacts of anthropogenic development on the coastal ground-water hydrology in Southeastern Florida from the period 1900-2000. The following is a summary of the findings of this study and will served as an introduction to the problem of conducting assessments on this topic.

The urban and agricultural corridor of southern Florida lies between the Everglades and water-conservation areas to the west and the Atlantic Ocean to the east. The area, which includes eastern Miami-Dade, Broward, and Palm Beach Counties, has experienced explosive population growth (from less than 4,000 residents in 1900 to 5 million residents in 2000), and as such is subject to widely conflicting stresses on the environment. A highly controlled water-management system evolved during the 20th century largely to provide drained land for a rapidly expanding population. Reclamation of Everglades wetland areas provided the opportunity for westward expansion of agricultural, mining, and urban activities. Surface water is impounded in water-conservation areas that lie west of the protective levee system, partly to: (1) sustain an Everglades ecosystem, (2) keep overland sheetflow from moving eastward and flooding urban and agricultural areas, and (3) use for water supply.

Parallel environmental interests exist in coastal areas of the urban-agricultural corridor. Coastal residential and urban areas must be drained for flood control, whereas the underlying surficial aquifer system must simultaneously serve as the principal source for water supply, and ground-water heads must be maintained to prevent saltwater intrusion. Changes in predevelopment ground-water flow patterns and the associated reduction in ground-water discharge to coastal bays have altered salinity and affected the local ecology. Active since the early 1920s, extractive mining has increased considerably, largely to satisfy urban construction needs. The limited availability of limestone that meets construction requirements and simultaneous competition for land by both industries place both in direct conflict.

Surface- and ground-water systems were altered considerably by the construction of a complex system of canals and levees as well as by heavy municipal withdrawals. Between 1900 and 1948, uncontrolled canal drainage increased the rate of flow from the Everglades, reduced the extent of inundated land, and lowered ground-water levels. These canals failed, however, to transport the load imposed during flood events and worsened drought conditions through over-drainage of the surficial aquifer system. Drought and hurricane-related flooding provided the impetus for the 1949 establishment of the Central and Southern Florida Flood Control Project and District; canals were enlarged, conveyance structures and controls were installed, and protective levees were constructed. The southern Dade conveyance system was completed as the final phase of the project during the 1980s, and involved redirecting surface-water flow and controlling ground-water levels in southeastern Miami-Dade County.

Ground water represents the principal source of water for municipal supply in the tri-county area of Miami-Dade, Broward, and Palm Beach Counties and has increased from three well fields producing about 66 Mgal/d in 1930 to about 65 well fields producing 770 Mgal/d in 1995. West Palm Beach is the only large municipality that uses surface water for supply purposes. Miami-Dade County uses a centralized well-field infrastructure in which five large-capacity well fields withdraw the majority of the supply. A decentralized well-field infrastructure has been constructed in Broward and Palm Beach Counties, in which municipalities have relied on developing their own source of supply to meet local demand. On the basis of temporal analysis of well-field locations and production levels, there has been a historic shift from large well fields near the coast to more western facilities partly designed to mitigate saltwater intrusion.

Surface water is the primary source of water for cultivation of sugar, field, and row crops in much of Palm Beach County, particularly in the Everglades Agricultural Area; conversely Miami-Dade agricultural growers primarily rely on ground water withdrawn from shallow wells and conveyed using truck-mounted pump and spray irrigation systems. The agricultural industry of Broward County has been largely displaced by residential and urban development, despite once having been the Nation's primary winter producer of tomato, pepper, and bean crops, between the 1920s and 1940s. Broward County producers mostly relied on surface-water supplies until about 1960, when they converted to the use of ground water. Whereas agricultural activities in Broward County had become a minor factor in the county economy, cultivated lands expanded considerably in Miami-Dade and Palm Beach Counties between 1953 and 1988. Damage caused by Hurricane Andrew, which resulted in an agricultural financial loss exceeding $1 billion, appears to have contributed to the decline in cultivated lands in Miami-Dade County since 1992. Agricultural water use in the tri-county area increased from 505 Mgal/d in 1953 to almost 1,150 Mgal/d in 1988, declining to 764 Mgal/d in 1995.

The surficial aquifer system, the principal source of ground water in southeastern Florida, is a wedge-shaped, eastward thickening sequence of limestone, quartz sand, shell, and terrigeneous mudstone of Pliocene to Holocene age. The prolific Biscayne aquifer, a sole-source aquifer, is the most transmissive of three separate aquifers that comprise the surficial aquifer system. Transmissivity of limestone-rich areas is greater than 1,600,000 square feet per day but decreases to 54,000 square feet per day where the surficial aquifer system mostly consists of sand; yields of 1,000 to 7,000 gallons per minute are reported from some wells completed in the cavernous part of the surficial aquifer system.

Well fields have been constructed farther inland during the latter part of the 20th century because of coastal saltwater intrusion. Competition between agriculture, the Everglades ecosystem, and mining interests ultimately limits construction of new well fields along the western margin of the urban corridor.

Unlimited utilization of unconfined freshwater aquifers is no longer permitted under current State regulatory authority. It is reasonable to assume that an expanded, widespread use of the Floridan aquifer system for multiple and conflicting uses will eventually result in unforeseen hydrologic consequences. Competition for the Floridan aquifer system as a water resource has become dramatically apparent during the last decade or more. The Upper Floridan aquifer is targeted as the major new source for potable supplies, either through direct withdrawals, brackish and shallow aquifer blending operations, reverse osmosis (RO) withdrawals, and aquifer storage and recovery (ASR). A large network of ASR wells is being evaluated for Everglades restoration purposes if regional hydrologic and local geotechnical, hydraulic, and water-quality issues can be resolved.

Alternatively, the Lower Floridan aquifer is used for purposes of municipal and some industrial, and reverse-osmosis concentrate wastewater disposal. Increased demand for the limited brackish-water resources of the Upper Floridan aquifer has placed deep well wastewater injection under increased surveillance, because there is concern that a stressed Upper Floridan aquifer will promote upward leakage of buoyant municipal wastewater injectate from the Lower Floridan aquifer.

More than 20 Class I injection wells were operating in the Broward, Miami-Date, and Palm Beach area by 2000, injecting treated wastewater into the Boulder Zone at depths of 2,000 to 3,000 ft below NGVD 1929. As a wastewater management option, Lower Floridan aquifer deep well injection has been under increased environmental, regulatory, scientific, and public review in recent years. Florida's Counties and municipalities are increasingly challenged to ensure safe disposal wastewater or its reuse. In 2002, more than 277 MGD were being injected in the tri-county area. Proposed EPA regulations allow continued wastewater injection in Lower Floridan aquifer wells showing evidence of upward leakage if operators can provide adequate protection. But public and environmental activists have expressed concern that injected wastewater will eventually commingle with shallower ground water used for public supply purposes. Monitoring wells near some deep well injection facilities in Miami-Dade, Broward, and Palm Beach County indicate wastewater has migrated upward from the wastewater injection zone into overlying strata. Traditionally, the risk of effluent leakage has been considered to be greatest through or around the outside of the injection well itself (Talbot 1972). However, an EPA (2003, pg. ES-11) report states that evidence of deep injection well mechanical failures is lacking, concluding that efficacy of overlying confining units are in question. The current understanding of the fate and transport of the wastewater plume migration and its cumulative impact on the existing physical system is poor. The general, but unproven assumption has been wastewater becomes diluted and rendered safe biogeochemically.

Few data are available to accurately document the predevelopment conditions within the surficial aquifer system; the water table probably subtly reflected the Atlantic Coastal Ridge topography. Peat and muck deposits, an important predevelopment component of Everglades surface- and ground-water hydrology, functioned as a storage reservoir to a water column that extended upward from the underlying aquifer and maintained a higher water table that prolonged the hydroperiod and restricted movement of a coastal saltwater interface. Surface-water stage within the adjoining Everglades was sufficient to allow water to discharge through traverse glades areas, and shoreline and submarine springs discharged freshwater.

Uncontrolled canal drainage and a lengthy drought in 1945-46 caused water levels to reach their lowest recorded levels, exacerbating municipal well-field saltwater intrusion problems. The modern-day water table largely reflects the hydrologic influence of numerous engineering features, including primary and secondary canal systems, gated control structures, levees, impoundments, pump systems, and the drawdown effects of the larger well fields. Ground-water movement is largely coastward and water levels are highest near the water-conservation areas, except locally in southeastern Palm Beach County and northeastern Broward County, where surface water is pumped from the Hillsboro Canal into secondary canals to artificially maintain water levels. Regional water-level comparison maps of the difference in “average conditions” show that improved drainage systems built during the 1950s lowered inland ground-water levels and increased land areas for urban and agricultural development.

Gated coastal canal structures are used to retard landward movement of saline water during the dry season through maintenance of stage higher than local water levels, inducing seepage into the aquifer. Management of canal stage has helped to increase ground-water levels in some coastal areas. Long-term canal coastal discharge appears to have declined, but coastal canal stage has been maintained gradually at higher levels, presumably to impede saltwater intrusion. Diminished coastal discharge is attributed to the rerouting of surface water to secondary canals, and induced recharge to the aquifer caused by increased municipal withdrawals.

Calcium bicarbonate water is dominant in shallow parts of the surficial aquifer system, whereas sodium bicarbonate and sodium chloride water are dominant in more deeply buried parts of the aquifer system or along the coast. Chloride concentrations generally are less than 100 mg/L at depths shallower than 50 ft, except in coastal areas and southeast of Lake Okeechobee. Chloride concentrations are less than 100 mg/L at the

150-ft depth in eastern Palm Beach County, eastern Broward County, and much of central and northwestern Dade County.

A broad zone of diffusion characterizes the saltwater interface in southeastern Florida in which the position of the interface is a consequence of three principal mechanisms: westward lateral movement of seawater within the surficial aquifer system, seepage from tidal canals, and upconing of relict seawater. Prior to 1945, uncontrolled drainage contributed considerably to lowering the water table of the surficial aquifer system along the Miami Canal. Water levels were lowered further by heavy municipal withdrawals, inducing tidal seepage into the aquifer system. Canal drainage contributed greatly to intrusion of the saltwater interface in Broward County, lowering ground-water levels with the subsequent landward movement of saltwater in the surficial aquifer system from the Atlantic Ocean. Well-field withdrawals and tidal seepage are an important, but less important, source of saltwater intrusion.

Predevelopment freshwater spring discharge in Biscayne Bay diminished considerably following the emplacement of canal drainage networks and the loss and compaction of inland peat deposits that formerly maintained higher water levels in the ecosystem, and stored excess surface water that helped to recharge the underlying aquifer. Changes in land use and water-management practices have greatly impacted the marine ecosystem of Biscayne Bay, resulting in increased nutrient loads and other pollutants, and increased turbidity. Prior to construction of the major canals, the salinity of the southernmost part of Biscayne Bay was much lower than normal marine salinity, especially near the coastline from Manatee Bay to possibly as far north as the Coral Gables Canal. The increase in salinity interpreted for both Biscayne and Florida Bays in the early 1900s through the 1970s is likely related to the increased development of the canal system and modifications in surface-water drainage. This is consistent with the progressive inland saltwater intrusion. Post-1940 water-management practices to control water discharge greatly affected the Biscayne Bay ecosystem by increasing the frequency, and particularly the magnitude, of salinity fluctuations. By altering the natural variability in freshwater discharge to Biscayne Bay, the natural cycles of the nearshore marine organisms were disrupted, resulting in biotic fluctuations similar to the frequency and magnitude of the salinity changes.

9.6 South Florida Hydrology Module

The Water Resources Development Act (WRDA) of 2000 authorized theCERP as a framework for modifications and operational changes to the Central and Southern Florida Project needed to restore the south Florida ecosystem. Provisions within WRDA 2000 provide for specific authorization for an adaptive assessment and monitoring program. A Monitoring and Assessment Plan (MAP) has been developed as the primary tool to assess the system-wide performance of the CERP by the RECOVER program. The MAP presents the monitoring and supporting enhancement of scientific information and technology needed to measure the responses of the South Florida ecosystem.

Restoration of the Everglades system depends on the restoration of the volume, timing, and distribution of sheet flow as simulated in the Natural Systems Model for the pre-drainage greater Everglades ecosystem. Compartmentalization has altered or eliminated sheet flow and impacted landscape characteristics, surface-water/ground-water interactions, ecological processes and water quality. An approach to facilitate interaction, feedback, and support among monitoring, modeling, and management components of the restoration is needed. Developing a reliable mechanism to facilitate comparisons among metrics of hydrology, species monitoring data, and model outputs is the key to making adaptive management decisions.

The goal of the South Florida Surface Water Monitoring Network in Support of the MAP Projects (known as EDEN, Everglades Depth Estimation Network) is to develop a single integrated network that provides real-time stage data across the greater Everglades landscape to guide large-scale field operations, to integrate hydrologic and biologic responses, and to support MAP assessments by scientists and PIs across disciplines all of which are founded on the hydrology.

To address the needs of the MAP assessments, a real-time surface-water data network requires adequate spatial coverage that transmits data in every landscape unit in the greater Everglades including Water Conservations Areas (WCA1, WCA2, and WCA3), eastern Big Cypress National Preserve, and Everglades National Park. The water-level network consists of the existing network of stage gages operated and funded by others including SFWMD, National Park Service, US Fish and Wildlife service, the Corps and US Geological Survey. Additional water-level gages are installed to fill gaps in the existing data network. The assessment portion of the MAP assessments will require PIs to make rapid assessment of biological communities and their responses based on the hydrology in selected landscape units.

Currently, water level gages have different vertical datums and are served on multiple websites or not available real-time without special FTP transfers and pre-arrangements. Scientists and investigators in the greater Everglades have used a wide variety of methods with varying consistency and success to transfer hydrologic data from gages to their study areas. The EDEN project will provide consistent, document-able, and easily accessible real-time hydrologic data throughout the greater Everglades. Other geospatial data, such as soils and water quality data will be integrated with project hydrologic data on a website for access by scientists and managers.

The objectives of the EDEN project are to:

1) Relate water-level data at real-time stage gages to ungaged areas and, using ground elevation data, computed water depths throughout the greater Everglades.
2) Gain an understanding of microtopography as it relates to vegetation and use vegetation to define water depth differences.
3) Develop a "clickable" web-based GIS map to assess real-time water-level data for all gages by RECOVER agencies in the greater Everglades.

4) Develop a dynamic web-based GIS tool for access to user-specified hydrologic data for study sites, such as computed water depth, hydrograph recession rates, slope, and hydroperiod; including other GIS information such as soils, water quality parameters, rainfall, and periphyton densities.

Real-time hydrologic data, such as water depth, recession rates, day since last dry period, and water-surface slope, present investigators and managers with an opportunity for decision making and adaptive management not previously possible. Sufficient characterization of surface water hydrologic conditions aids in interpreting the water quality and ecological data in the wetlands. A hydrologic network must provide the necessary information to link changes in the physical components to changes in chemical and ecological components of the system. Therefore, the first step is the adequate baseline monitoring of hydrologic data before a fully integrated multidisciplinary assessment of the ecosystem can be accomplished.

Using the network of 200-250 existing and 23 new water-level stations in the greater Everglades, water levels will be extrapolated to ungaged areas based on hydraulics, statistical analysis, and water surface modeling. The network of high accuracy ground surface elevation data collected by the USGS over nearly the entire greater Everglades provides elevations at approximately 50,000 points on a 400-square-meter grid spacing. Subtraction of ground elevation from the real-time water level elevation provides computation of water depth throughout the greater Everglades.

Vegetation impacts ground elevation in response to varying flow conditions, differential sediment deposition and biologically-influenced processes. The 400-square-meter grid cells will be overlain by a mosaic of vegetation where vegetation is lumped into four major categories 1) slough or open water, 2) ridge or saw grass, 3) tree islands, and 4) other which includes all vegetation types that do not fit into the first three types. Differences in ground elevation, or microtopograhy, will produce varying vegetation-influences water depths, flow paths, and flow resistance.

Coupling EDEN's real-time data approach with biological models, such as ATLSS and others, can contributed to our evaluation of how well the simulated relationships driving both biotic and abiotic models reflect and anticipate real-world events. The integration of real-time data and modeling can provide timely feedback to refine and corroborate model rules, a process that now faces significant impediments due to time lags in availability of calibration hydrologic data.

Three web-based GIS data access sites will be developed and linked to provide users with access to real-time water level gage data, computed water depth and other hydrologic data, and existing GIS coverage that allow users to integrate biological response and seasonal changes to hydrology. The websites are described below and details of the website functions will be finalized based on input from GE module PIs.

- Website with "click-able" access to real-time water level data from 200 to 250 existing and 23 new stage gages with telemetry or radio transmission capacity and

NAVD88 datum corrections. The site will display daily hydrographs and ground elevation data by vegetation community.

- Website to access all relevant GIS data coverage from the greater Everglades from any published source including EPA's REMAP water quality data, SFWMD coverage of landscape units boundaries and soils data, and USGS vegetation data, to name a few. Additionally, a list of relevant publications documenting these data coverage will be retrievable by searchable attributes.
- Website for access to temporal and spatial water depth maps with user-specified capability to select areas, time periods, and associated GIS coverage. The interface will include algorithms and methods for calculation of additional hydrologic characteristics, such as recession rates, days since last dry period, number of dry events over time, and water level deviations.