Chapter 6: Hydrologic Needs – Effects of Hydrology on the Everglades Protection Area (EPA)

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SUMMARY

This chapter discusses the multidisciplinary approaches currently in place to manage the hydrologic patterns of the Everglades Protection Area (EPA). The primary focus of this chapter is on the hydrologic trends and ecological assessments in the EPA in relation to the 2001 drought. Much attention has been given to the lowest-recorded Lake Okeechobee water levels in Florida history. Low lake levels led to water supply restrictions for urban and agricultural regions. Plans were developed to alter (i.e., lower) the Water Conservation Area (WCA) regulation schedules for the next dry season to reduce the Lower East Coast's (LEC's) dependency on Lake Okeechobee for water supply. However, the trends in the EPA were not as dramatic as in Lake Okeechobee, partly because the previous year had above average water levels due to Hurricane Irene and partly because this year's rainfall pattern in the Everglades was not significantly lower than the 32-year historic average. Despite a general reduction in rainfall in the WCAs of 23 percent and an average reduction of structure inflows to the WCAs of 45 percent, compared to the 32-year historic average, average weekly water levels in the WCAs were 0.4 to 0.7 feet higher than average. This apparent disconnect between water levels and rainfall appears to be due to water conservation and active management to hold water in the WCAs, but may also be due to the lag time between low rainfall and its expression as low water levels in specific regions of the Everglades. Therefore, the full impact of the 2001 drought may not be felt until the 2002 dry season.

These hydrologic trends can be expressed as rapid alterations to the biogeochemical processes in the Everglades or as slow alterations to the biomass and community structure. Tree islands are one of those slow components of ecological and cultural significance. In our continuing efforts to understand tree-island function and structure in relation to hydrology, this chapter presents new information on their creation and link to groundwater hydrology. A theory behind the development of tree islands is that nutrients released from a small island head (as a function of hydroperiod) will leach downstream (as a function of surface and groundwater flows) to form a nutrient-rich substrate for island head and tail expansion. Preliminary data collected over one growing season show that, in general, porewater nutrients are highest on the head of tree islands. The exchange of nutrients between the porewater and surface water has yet to be established. However, preliminary data show that nitrogen and phosphorus concentrations in the porewater were over 100- and 20-fold higher, respectively, than the overlying surface water, indicating an upward flux.

Groundwater studies on and around tree islands are a new research effort designed to provide long-term information for the Comprehensive Everglades Restoration Plan (CERP), short-term information on the function of groundwater for tree island succession and health, and the establishment of minimum flows and levels (MFLs). This groundwater program will document, for the first time, tree island depositional environments, groundwater levels, horizontal and vertical groundwater gradients and groundwater chemistry. It is hypothesized that the productivity and health of tree islands are linked to groundwater movement and chemistry. The work accomplished to test this hypothesis includes the construction of monitoring wells, collection and study of geologic and water samples, and installation of instrumentation for long-term collection of water-level and weather data. The data collected from these well stations will provide baseline hydrologic information before the CERP-driven decompartmentalization of WCA-3 and will document subsequent changes to hydrologic conditions after decompartmentalization is achieved.

Water level, muck fire, wading bird habitat and general ecological risk-assessment models were developed as tools for assessing current and predicted 2001 drought effects within the WCAs, Wildlife Management Areas and Everglades National Park (Park or ENP). Using the Environmental Protection Agency's REMAP data and the South Florida Water Management District (District or SFWMD) Stormwater Treatment Area (STA) Receiving Areas Monitoring & Research and Threshold Program data as a basis, formulae were created to estimate the current and predicted ecological conditions in the Everglades that may have occurred as a result of the drought. Overall, it was a good year for the ecosystems in the Everglades. Several muck fire hazard index marsh sites went beyond the critical water-level threshold. Fortunately, the numerous fires that occurred throughout the Everglades were restricted to healthy surface burns and didn't result in damaging muck fires. All the wading bird colonies successfully fledged young this nesting season, though some colonies were more successful than other ones.

Wildlife continues to be a critical aspect of CERP, routine water management, and the establishment of hydrologic needs. The estimated number of wading bird nests (excluding Cattle Egrets, which are not dependent on wetlands) in South Florida in 2001 was 38,647. This number is down only 5 percent from last year, which was one of the best years in a decade. Individual species showed very different responses to the drought. The White Ibis, Snowy Egret, and Wood Stork nested in higher numbers than average, whereas there were many fewer nests than usual for other heron and egret species. Scientists speculated that nest failure of Great Egret nests in WCA-3 was the result of both drought conditions and, ironically, a rainfall event in April that caused water levels to increase quickly. As a result, the nest numbers in 2001 might be slightly liberal. This pattern differs from 2000, when the high nest numbers also were accompanied by apparently good nesting success. Three species-groups met the numeric nesting targets proposed by the South Florida Ecosystem Restoration Task Force; however, the Wood Stork barely did so. Two other targets for the Everglades restoration are an increase in the number of nesting wading birds in the coastal Everglades and a shift in the timing of Wood Stork nests to earlier in the year. The 2001 nesting year showed no improvement for a shift in colony locations but there was improvement for the timing of stork nesting.

INTRODUCTION

Previous reports have focused on the ecological, biological and geological knowledge of the Everglades in relation to historic drainage and current hydrology. Last year's report on hydrology focused on Water Year 2000 hydrologic patterns in relation to Hurricane Irene, the Interim Structure Operation Plan (ISOP), biological processes, the Everglades Landscape Model (ELM) and the process of using regional conceptual models for the development of restoration performance measures.

This year's report will focus on the hydrologic trends and ecological assessments, in relation to the 2001 drought, including an overall assessment of wading birds and tree islands in WCA-3. Much attention has been given to the lowest-recorded Lake Okeechobee water levels in Florida's history. Concerns for water supply led to numerous water restrictions throughout South Florida. The trends in the EPA were not as dramatic as elsewhere, partly because the previous year had above-average water levels and partly because this year's rainfall pattern in the Everglades was not significantly lower than average.

HYDROLOGIC TRENDS

Historic hydrologic trends, detailed in previous reports, explained how drainage of the Everglades was able to reduce water tables up to 9 feet, reverse the direction of surface water flows, alter vegetation, create abnormal fire patterns and induce high rates of subsidence. These changes were initiated by lowering of Lake Okeechobee levels beginning in 1883 and were exacerbated by construction between 1910 and 1920 of four major canals (Miami, North New River, Hillsboro and West Palm Beach). Other significant hydrologic alterations included the levee around Lake Okeechobee and construction of the Tamiami Trail. The initiation of the Central & South Florida (C&SF) Project for Flood Control in 1947 created a system of levees and borrow canals, essentially complete by 1963, which created a highly compartmentalized landscape. This allowed water levels to be raised, reducing peat oxidation and fires within what are now the WCAs, but eliminating uninterrupted overland sheetflow and sloughflow through the Everglades. In addition to eliminating virtually all but the structure-related flows, compartmentalization has induced ponding in the southern regions of each WCA, increased the frequency and intensity of peat/muck fires in northern regions of WCAs and created a hydrologic environment dominated by flows along levee edges, in borrow canals and through water control structures.

Despite these extensive alterations, the District attempts to sustain a more natural hydroperiod throughout the Everglades by following distinct wet and dry seasons and by using a rainfall-driven formula for water deliveries to Everglades National Park. The recent hydrologic trends, summarized below, compare Water Year 2001 with a 32-year average of observed data and a 31-year average of NSM[1] output. A Water Year begins May 1 (the start of the wet season) and ends April 30 (the end of the dry season).

[1] NSM: Natural Systems Model. A 2 x 2-mile grid hydrologic model that is used to estimate the water depths for the pre-drainage Everglades and thus estimate water-depth targets for restoration. However, many other criteria were used to set restoration targets for the CERP, which is being designed to mitigate ponding in the southern regions of WCAs and excessive drying in northern regions of WCAs.

WCA-1

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge or WCA-1) was below average and below the Natural Systems Model (NSM) targets during Summer 2000 (**Figure 6-1**). This appears to be due to the lag effects of the Lake Okeechobee drawdown in Spring 2000 and the relatively low summer rainfall amount. The usual trend for WCA-1, both observed and estimated by NSM, is to reach minimum low water in mid-May, followed by an increasing water-level trend until October or November. Instead, water levels continued to drop past mid-May, then increased rapidly toward the end of the wet season (October) due to intensive precipitation and high structure inflows from the Everglades Agricultural Area (EAA) (**Figure 6-1**). After the October 2000 deluge, the rain and structure inflows indicated very little activity. As a result, water levels dropped precipitously and eventually went below ground elevation in April 2001.

A summary of the hydrologic trends in WCA-1 (**Table 6-1**) indicated a significant deviation from the normal managed inflows from the EAA to WCA-1. The average weekly 2001 structure inflows to WCA-1 decreased by 32 percent. At the same time, average weekly rainfall decreased by 21 percent. Despite these reductions the depth was 0.05 feet greater than the 32-year historic average. The low rainfall and inflows were indicative of the drought and its management, respectively. However, the average water depth appears to be due to water conservation, specifically a lack of structure outflows.

WCA-2A

The 2001 water-depth trend in WCA-2A (**Figure 6-2**, **top**) was similar to the A.R.M. Loxahatchee National Wildlife Refuge (**Figure 6-1**). Both areas experienced a 2.5-ft rise in water depth over a two-month period, and both saw a rapid decline in water depth from November to April. The difference was that rates of depth change, both up and down in WCA-2A, was a lot more dramatic than in WCA-1. Water depths in WCA-2A were generally unchanging and were similar to NSM levels during June, July and August, but quickly exceeded the NSM and historic averages in October. This increase appears to be related to rainfall (**Figure 6-2**, **middle**) and a big pulse of structure inflows to prevent urban and EAA flooding in October (**Figure 6-2**, **bottom**). The decline during the dry season produced dry soil by March, two months before the typical May drydown. This trend would have continued had it not been for a fortuitous 6-inch rainfall in late March (**Figure 6-2**, **middle**). This rain was enough to rehydrate the soils for an additional month before WCA-2A went dry again.

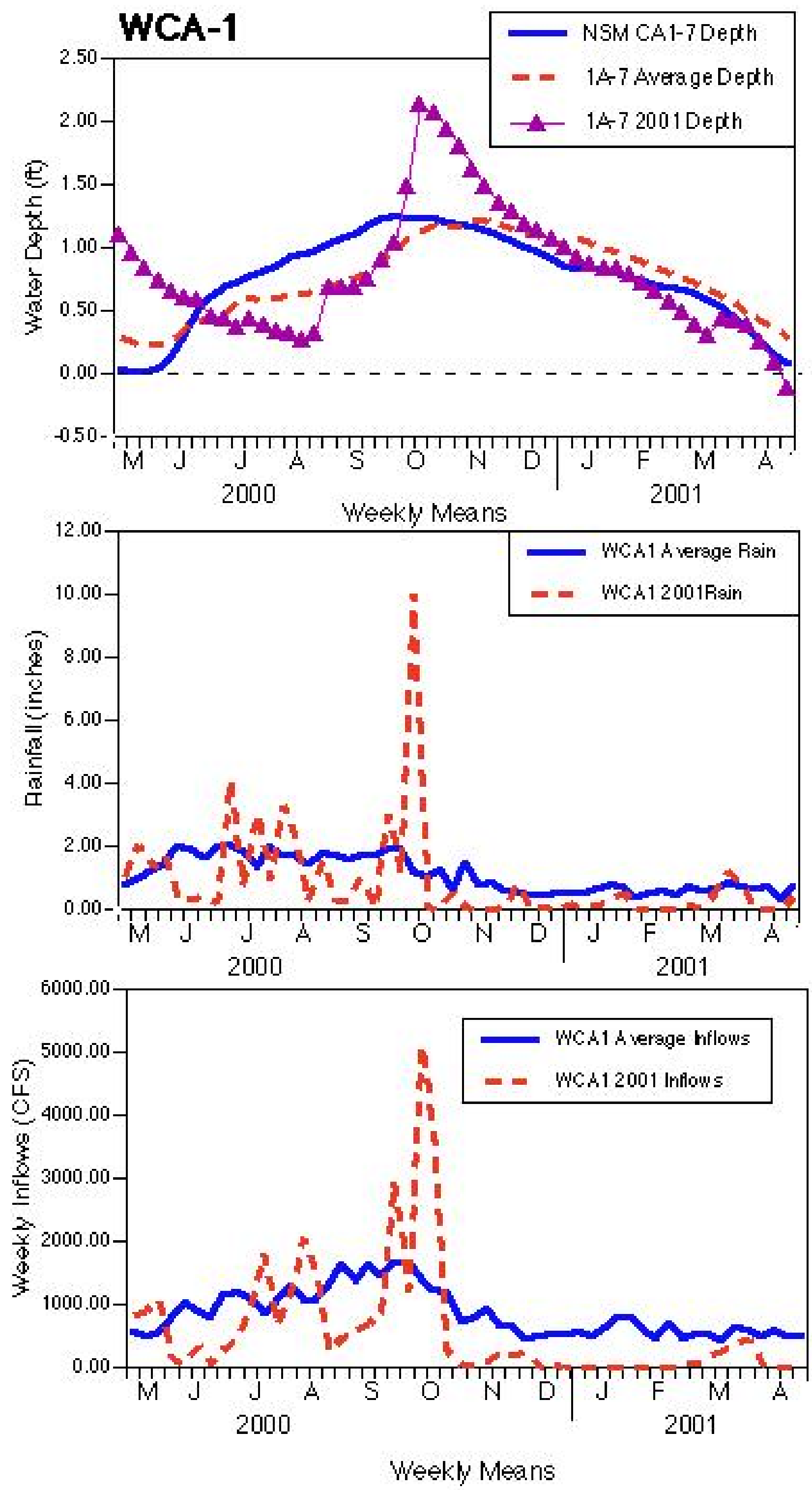


Figure 6-1. Average weekly water depth (Top), rainfall (Middle), and structure inflows (Bottom) for WCA-1. Average values are from May 1, 1970 until April 30, 2001. The NSM average water depths (Top) are based uon the 1965 to 1990 base climate condition.

Table 6-1. Average water depth, inflows from water control structures, and total rainfall (inches) for Water Year 2001 in WCA-1, in comparison to the long-term observed data. Gauge and structure locations are shown in previous Everglades Consolidated Reports.

	CA1-7 Water Depth (ft)	Structure Inflows (CFS)	S5A_R Rainfall (in.)
Weekly Average (1970–2001)	0.75	856	1.09
Weekly Average (2001)	0.80	584	0.86

A summary of the hydrologic trends in WCA-2A (**Table 6-2**) indicated a significant deviation from the "normal" managed water depths. The historic average depth for WCA-2A has been 1.34 feet. However, the average depth for 2001 was only 0.78 feet. It is interesting to note that the NSM predicted average weekly depths (**Figure 6-2**, **top**) were more inline with the actual 2001 depths than the historic average. Evidence that WCA-2A water levels may have been managed higher than needed can be found in previous Consolidated Reports that discuss the loss of tree islands. The difference between historic and 2001 water depths was mostly due to the 64-percent reduction in structure inflows. Average weekly rainfall decreased by 19 percent.

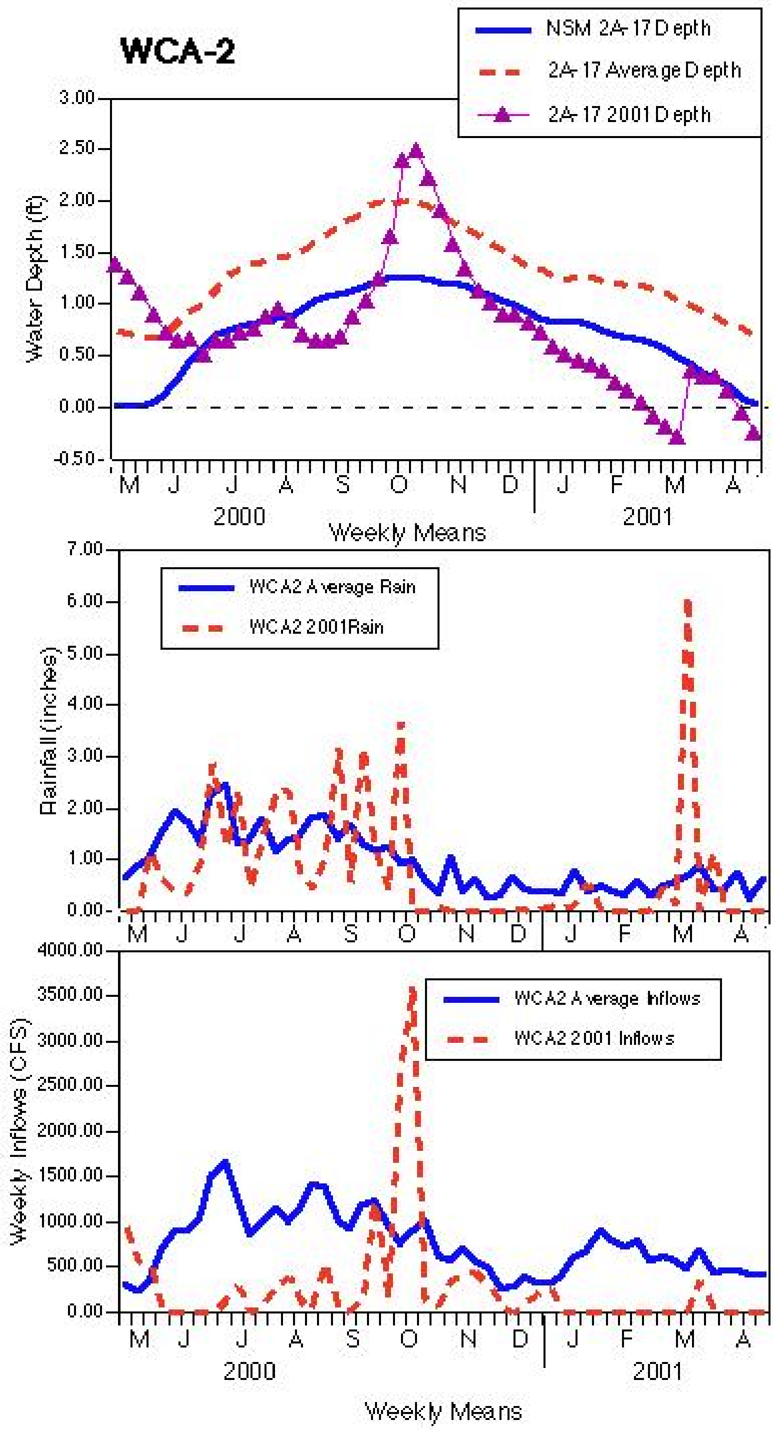


Figure 6-2. Average weekly water depth (Top), rainfall (Middle), and structure inflows (Bottom) for WCA-2A. Average values are from May 1, 1970 until April 30, 2001. The NSM average water depths (Top) are based on the 1965 to 1990 base climate condition.

Table 6-2. Average water depth, inflows from water control structures and total rainfall (inches) for water-year 2001 in WCA-2A, in comparison to the long-term observed data. Gauge and structure locations are shown in previous Everglades Consolidated Reports.

	2A-17 Water Depth (ft)	Structure Inflows (CFS)	S7_R Rainfall (in.)
Weekly Average (1970 – 2001)	1.34	771	0.95
Weekly Average (2001)	.78	281	0.77

WCA-3A

Despite a lack of data in fall 2000 due to gauge repair, the 2001 water depth in northern WCA-3A was very similar to the average historic and observed water levels (**Figure 6-3**, **top**). However, major water-depth deviations occurred during the 2001 dry season, when water levels hit zero (ground level) in February and never recovered, as they did in WCA-2A due to a spring rainfall pulse (**Figure 6-3**, **middle**). Historically, this site did not go dry until March, and according to NSM, water depths during predrainage conditions did not reach zero until April. The reason for the lack of any early indication of drought can be found in the rainfall and inflow patterns. Unlike the other WCAs, WCA-3A saw typical wet-season rainfall patterns (**Figure 6-3**, **middle**) and typical volumes of structure inflows (**Figure 6-3**, **bottom**). The early drydown in WCA-3A appears to be related to the early onset of the dry season, a lack of structure inflows from November through April and a general lack of rain.

Although the seasonal hydrologic regime in WCA-3A did not deviate much from the average (**Figure 6-3**, **top**), a summary of the hydrologic trends in northern WCA-3A (**Table 6-3**) indicated a relatively large deviation from the "normal" managed structure inflows and average rainfall. The average weekly 2001 structure inflows to WCA-3A decreased by 40 percent. At the same time, average weekly rainfall decreased by 30 percent. Despite these reductions, the depth was 0.07 feet greater than the 32-year historic average (Note: average was based on 40 weeks of data per year shown for 2001 in **Figure 6-3**, **top**. Based on trends in WCA-1 and WCA-2A, these missing data were likely below average.). The low rainfall and inflows were indicative of the drought and its management. However, the relatively higher average weekly water depth compared to historic averages appears to be due to area-specific rainfall patterns (**Figure 6-3**, **middle**) and active management to hold water in the WCAs (Note: the low structure inflow to Everglades National Park in 2001 [**Table 6-4**] was due in part to this water conservation).

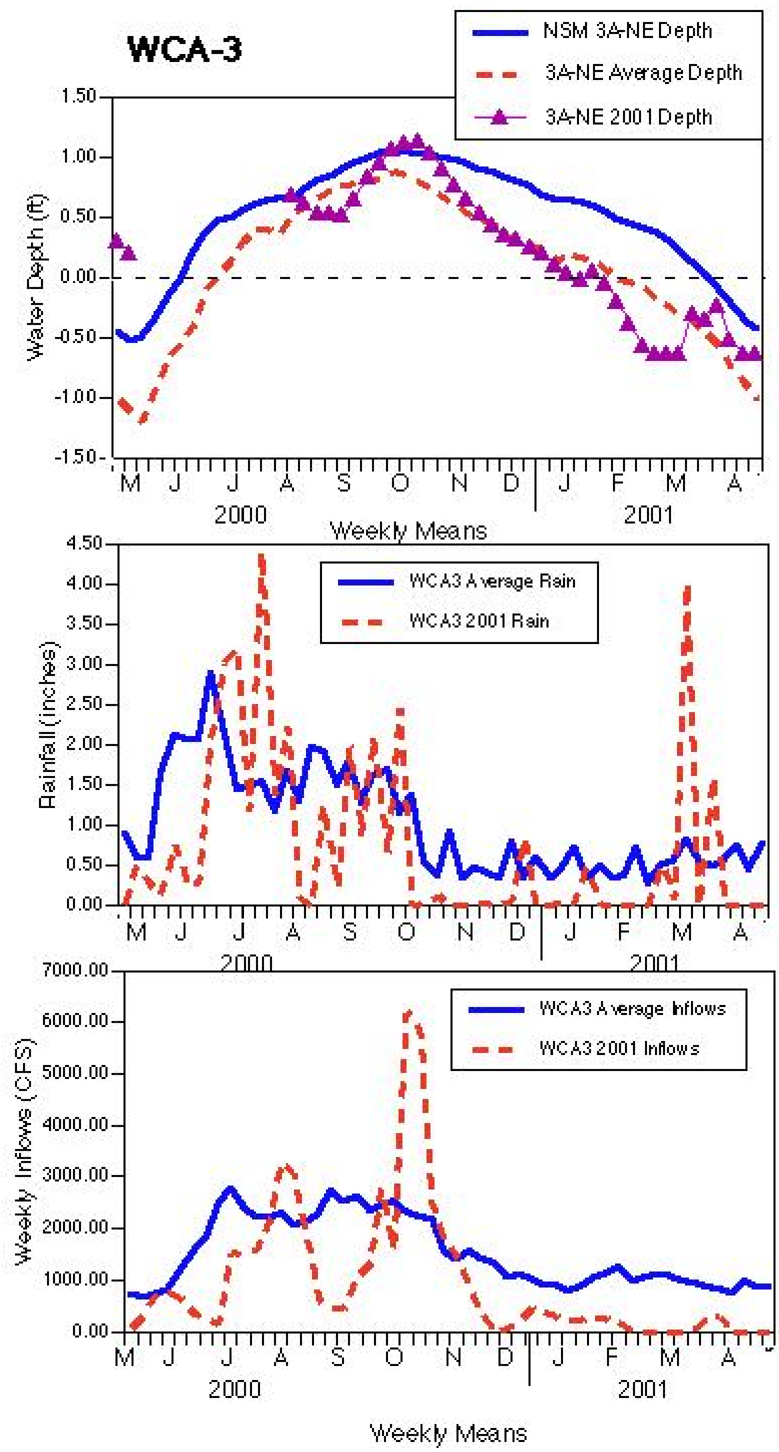


Figure 6-3. Average weekly water depth (Top), rainfall (Middle), and structure inflows (Bottom) for northern WCA-3. Average values are from May 1, 1970 until April 30, 2001. The NSM average water depths (Top) are based on the 1965 to 1990 base climate condition.

Table 6-3. Average water depth, inflows from water control structures, and total rainfall (inches) for water-year 2001 in WCA-3, in comparison to the long-term observed data. Comparisons are based on pairing of weekly data. Gauge and structure locations are shown in previous Everglades Consolidated Reports.

	3A-NE (n=40) Water Depth (ft)	***Structure Inflows (CFS)***	***3A-S_R Rainfall (in.)***
Weekly Average (1970– 2001)	0.15	1558	1.02
Weekly Average (2001)	0.22	936	0.72

Table 6-4. Average water depth, inflows from water control structures and total rainfall (inches) for water-year 2001 in Everglades National Park in comparison to the long-term observed data. Gauge and structure locations are shown in previous Everglades Consolidated Reports.

	P33 Water Depth (ft)	***P34 Water Depth (ft)***	***Structure Inflows (CFS)***	***Flamingo Rainfall (in.)***
Weekly Average (1970– 2001)	0.97	0.14	1153	0.90
Weekly Average (2001)	1.10	0.39	486	0.60

EVERGLADES NATIONAL PARK

Two water-depth stations in Everglades National Park (ENP or Park), P33 and P34, are used in each ECR because they are considered representative of slough and marsh, respectively (**Figure 6-4**). The ENP showed a significantly different hydroperiod than WCA-1 and WCA-2A and a similar hydroperiod to WCA-3. Though water levels during the wet season in Shark Slough (**Figure 6-4**, **top)** were much less than the targets set by the NSM, they were, nevertheless, higher than the 32-year historic average. A similar hydrologic pattern was observed in the adjacent marshes (**Figure 6-4**, **bottom**). However, the 2001 depths were slightly greater than the historical average, and for the most part, were similar to the NSM target. In all likelihood, this can be attributed to area-specific rainfall, as in WCA-3.

Rainfall patterns in the Park were similar to that in WCA-3 (**Figure 6-5**, **top**). Rainfall amounts were typical for the wet season and lower than average during the dry season, except for two significant "drought busters," one in March and another in April. A summary of the hydrologic trends in Northern Everglades National Park (**Table 6-4**) indicated a below-average rainfall and a relatively large deviation from the "normal" managed structure inflows. The average weekly 2001 structure inflows to WCA-1 decreased by 58 percent (**Figure 6-5**, **bottom**). Despite this reduction, the depths at P33 and P34 were 0.13 and 0.25 feet greater than the 32-year historic average, respectively. The low inflows were indicative of the drought and its management. However, the relatively higher average weekly water depth in comparison to historic averages was probably due to high rainfall in October and area-specific rainfall patterns.

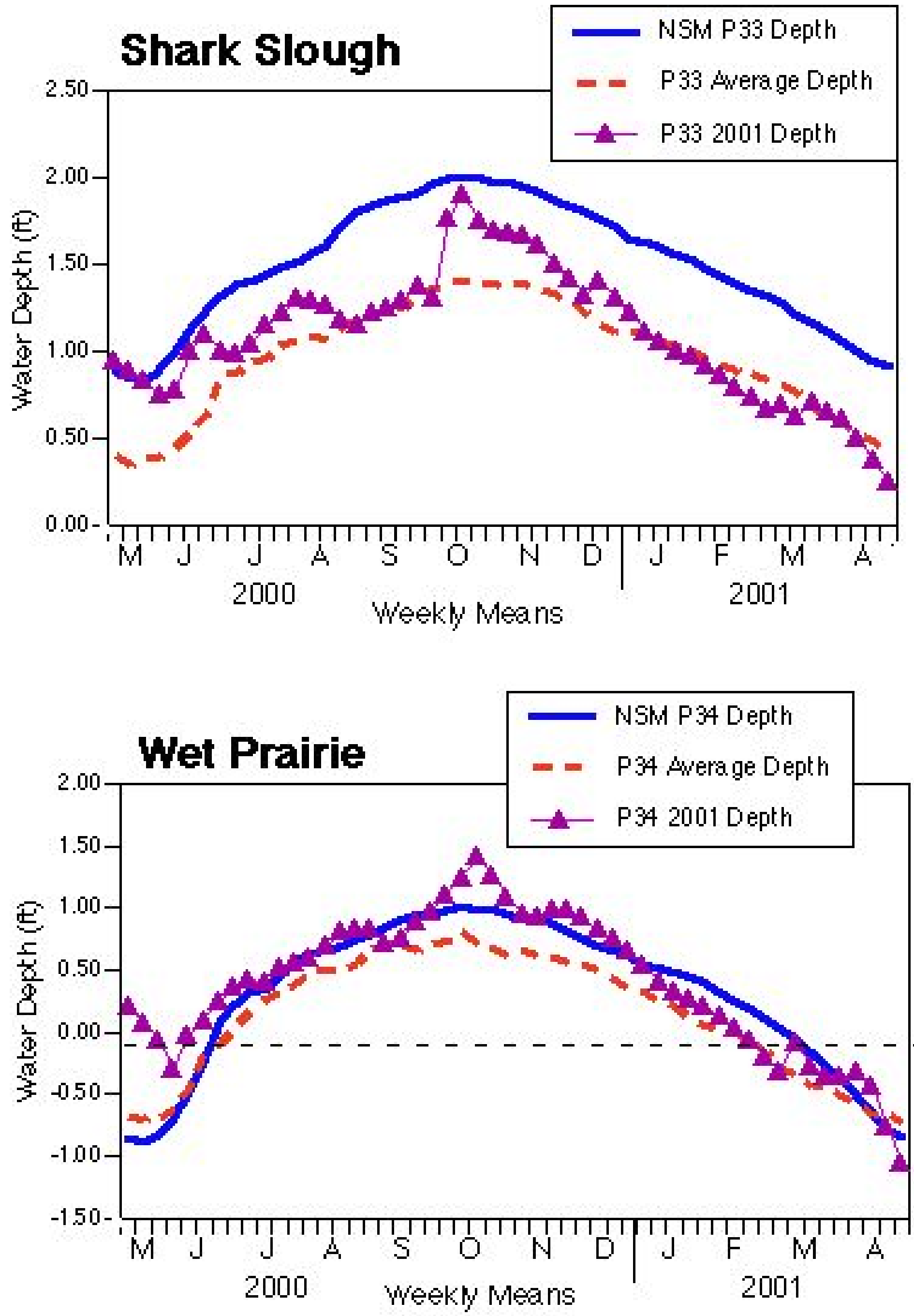


Figure 6-4. Average weekly water depth in the northern part of Shark Slough (Top) and in a wet prairie habitat east of Shark Slough (Bottom) in Everglades National Park. Average values are from May 1, 1970 until April 30, 2001. The NSM average water depths (Top) are based on the 1965 to 1990 base climate condition.

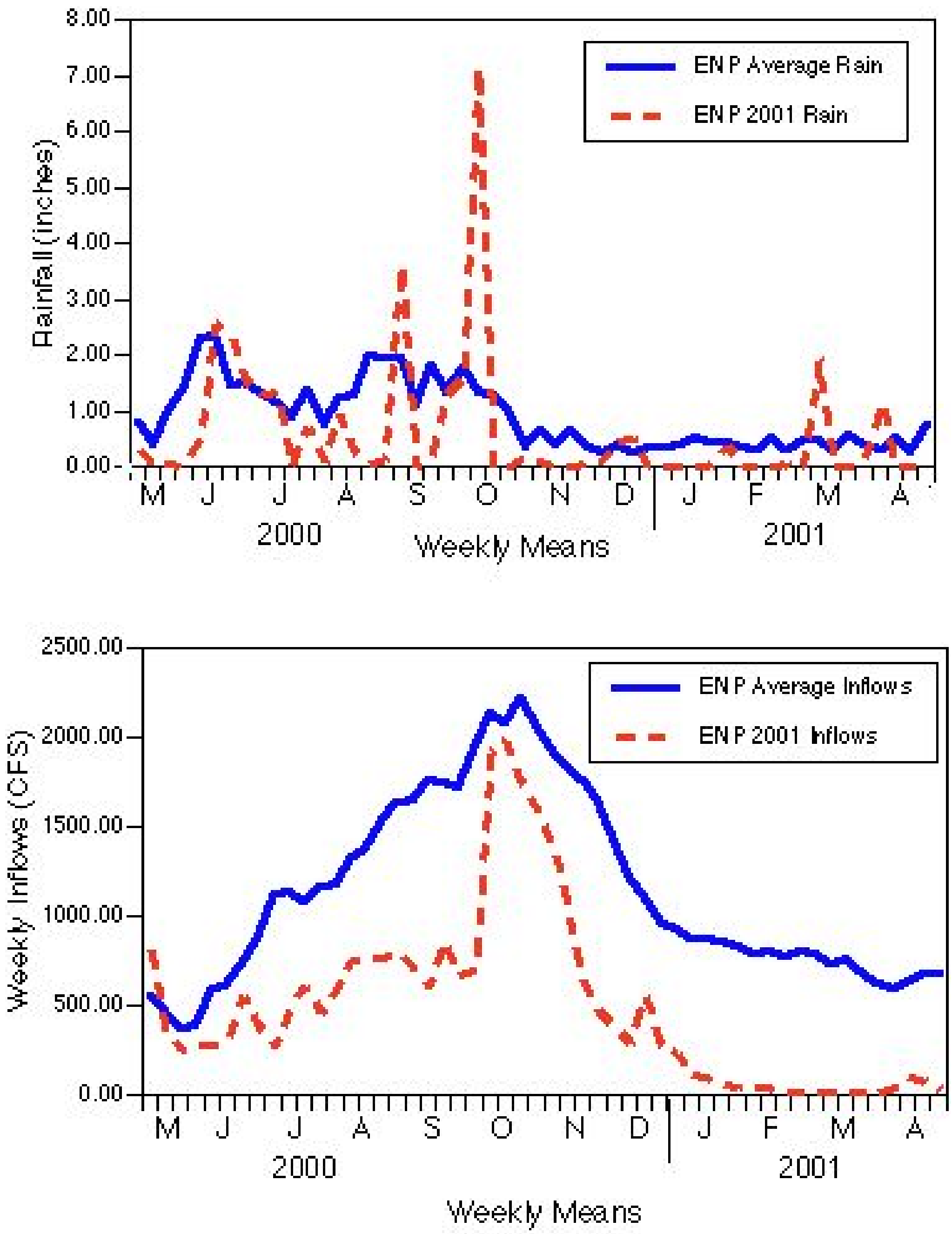


Figure 6-5. Average weekly rainfall (Top), and structure inflows (Bottom) for Everglades National Park. Average values are from May 1, 1970 until April 30, 2001.

THE 2001 DROUGHT

Much attention has been given to the lowest-recorded Lake Okeechobee water levels in the Florida history. Low lake levels led to water supply restrictions for urban and agricultural regions. Plans were developed to alter (i.e., lower) the WCA regulation schedules for the next dry season to reduce the LEC's dependency on Lake Okeechobee as a water supply.

A chronology of drought and water-management actions (**Figure 6-6**) provides an understanding of how climate, the environment, and water supply plans can interact to shape policy and ecology. Green boxes indicate environmental actions, blue boxes indicate water-management actions for water supply, and yellow boxes indicate the climate variables. In October 1999, concern for the ecology of Lake Okeechobee was focused on the fact that the lake remained above 13 feet 99 percent of the time during the past six years. After the District approved a managed lake recession to bring water levels down, the wet season returned with the driest four-month period on District record. As a result, Lake Okeechobee stayed relatively constant at 12 feet for a long period of time, and a wet-season peak in October 2000 was barely noticeable. The dry season of 2001 became a cascade of water-management decisions to minimize economic impacts. A new record-low lake level of 8.97 feet was reached on May 24, 2001.

GROUNDWATER AND SURFACE WATER INTERACTIONS ON AND AROUND TREE ISLANDS

Groundwater studies on and around tree islands is a new research effort designed to provide long-term information for CERP, as well as short-term information on the function of groundwater for tree-island health and the establishment of minimum flows and levels (MFLs) for tree islands. The next two sections are designed to provide an idea of the scope of this new program. Construction of monitoring wells for groundwater and surface water interaction investigations are almost complete. They will provide long-term information on spatial and seasonal changes in groundwater levels, horizontal and vertical groundwater gradients, surface water levels, hydroperiods and groundwater chemistry. The data collected from these well stations will provide baseline hydrologic information prior to the CERP-driven decompartmentalization of WCA-3 and will document subsequent changes to hydrologic conditions after decompartmentalization is achieved.

The first phase of well construction at tree islands 3AS3 and 3BS1 in Water Conservation Area-3 was completed in late 1999. A report was published in 2001 describing the construction of eight dual-zone monitor wells and the subsurface geology around those two tree islands (Bevier and Krupa, 2001). Drilling for a third set of wells in northern WCA-3A will be completed by the end of 2001.

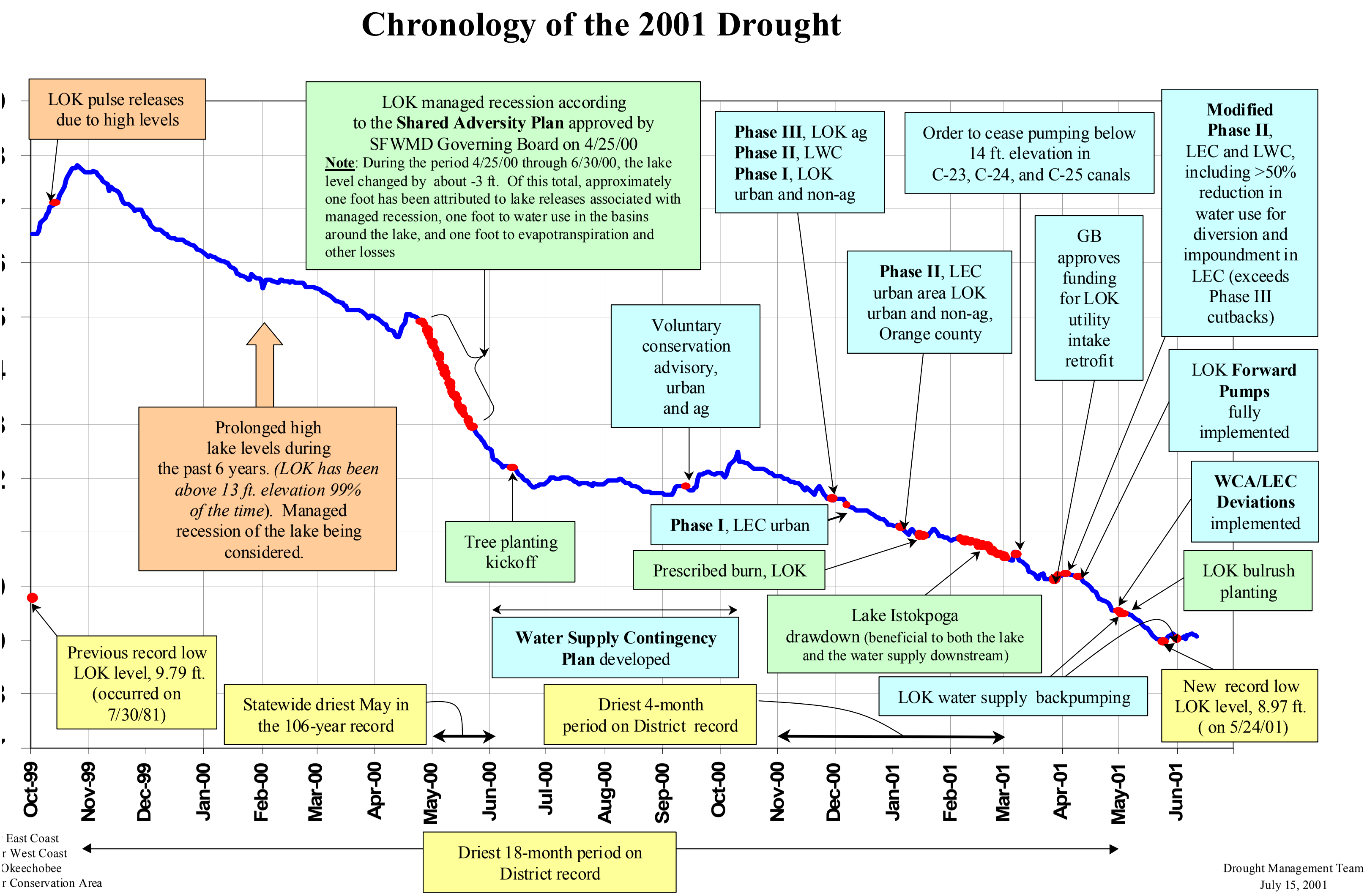


Figure 6-6. Chronology of 2001 Drought

TREE ISLAND HYDROGEOLOGY

Tree islands are linked to hydrogeology because the islands sit on limestone outcroppings and the tree roots penetrate the limestone. However, no one has examined this linkage and its role in the biogeochemical cycles of the Everglades or the health of tree islands. Below are some basic facts that were learned this past year. Cores obtained from tree islands contain sediments from the Miami Limestone and the Fort Thompson Formation (Fish and Stewart, 1991). The Miami Limestone and the Fort Thompson Formation are considered to be part of the Biscayne Aquifer (Fish and Stewart, 1991). The Biscayne Aquifer is one of the most permeable water-bearing units in the world and is designated a sole-source aquifer in a *Federal Register* notice of 1979 (Reese and Cunningham, 2000). The sediments retrieved from the wells varied distinctly between WCA-3A (island 3AS3) and WCA-3B (island 3BS1). Samples obtained beneath the organic peat deposits on 3BS1 to depths of 35 feet were composed primarily of limestone. This limestone varied from massive and relatively impermeable to solution-riddled, extremely permeable and sandy. In contrast, all the samples from 3AS3 had only 5-to-10 feet of limestone underneath the peat, below which was a fine, poorly sorted mix of quartz and carbonate sand and silt. This variation indicates a complex hydrogeology that may be linked to the surface biology.

Water Levels and Gradients

Documenting surface and groundwater levels is expected to shed light on the seasonal and spatial shifts in hydrologic sources and sinks in the Everglades. It will produce a better understanding of the water budget and reduce uncertainties associated with the role of groundwater in the Everglades. It is apparent that rainfall is the greatest influence on both surface and groundwater levels around both tree islands. Large rainfall events clearly cause rapid increases in both surface and groundwater stage at the tree-island sites. However, there are slight differences in groundwater and surface water levels that may be due to island processes, the orientation of levees and canals or tree-island peat depths.

As part of the preliminary examination of hydrologic gradients around the tree islands, the direction of groundwater and surface water flow around island 3BS1 was plotted from May 2000 until June 2001. The direction of flow for groundwater was calculated by a linear regression program that took daily water levels for each 3BS1 well and determined the angle of the best-fitting plane surface through them. Surface water direction was determined in a similar manner, using daily surface-water values from gages at 3BS1, 3B-SE and S334.

It is apparent in **Figure 6-7** that surface water and groundwater around 3BS1 do not usually flow in exactly the same direction. Groundwater tends to flow in a more easterly direction, probably as a result of the regional groundwater gradient, which is influenced by urban and agricultural groundwater use to the east. Surface water around 3BS1 most often flows more to the southeast than groundwater, probably due to the influence of the S334 structure and the L-29 canal. Several large spikes appear in the data in response to rainfall events. During periods of high rainfall, both groundwater and surface-water gradients become flatter and the southerly component of flow is reduced. Therefore, the resulting gradient surface appears more easterly in direction and sometimes even northeasterly. At very flat gradients (i.e., very little difference in water level at compared stations), the accuracy of surveyed elevations becomes much more of a factor in gradient calculations.

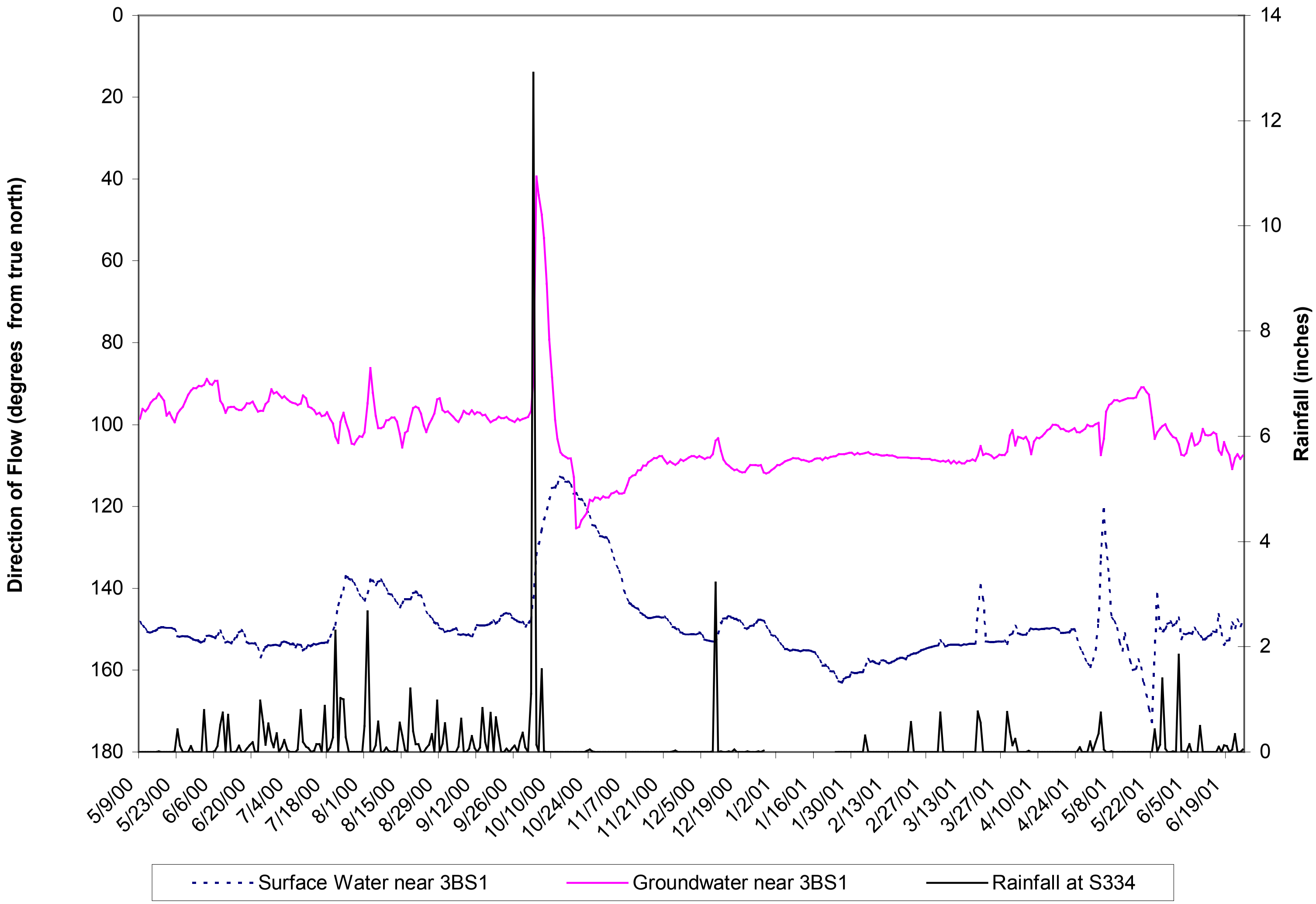


Figure 6-7. An analysis of flow direction around tree island 3BS1 in WCA-3B based on well water levels.

Tree Island Nutrients

Tree islands are narrow islands whose long axis runs more or less north-to-south.(i.e., upstream-downstream) Both their shape and orientation suggest that water currents have played a major role in their orientation and development. The two basic kinds of tree islands in the Everglades are floating pop-up, or battery, tree islands and fixed tree islands. Floating tree islands today are primarily found in the Loxahatchee National Wildlife Refuge, and occasionally in other areas with deep peats. Fixed tree islands are found south of the Refuge, that is, in WCA-2A, WCA-3A, WCA-3B and Everglades National Park.

Floating tree islands originate when a large piece of peat, known as a battery, detaches from the bottom during a period of high water and floats to the surface. This new island eventually becomes colonized by a variety of shrubs and trees.

The majority of fixed tree islands are believed to develop because of topographic highs in the limestone bedrock underlying the Everglades. These small bedrock pinnacles, or platforms, are associated with the "heads" of the islands. Heads are typically the highest, widest and most-upstream part of a fixed tree island. The tallest trees and shrubs are found on the head. Behind the head is the "tail," a long, linear mound of peat that forms behind the head. The elevation of a tail gradually drops from that of the head to that of the surrounding wetlands. The vegetation of the tail ranges from tall trees and shrubs immediately downstream of the head through ever-shorter and sparser shrub communities to a mix of tall sawgrass, ferns and cattail just before it becomes indistinguishable from the surrounding vegetation. This combination of head and tail gives fixed tree islands a characteristic elongated tear shape.

The movement of materials, both dissolved and suspended, by water currents and the effect of flow on primary production and litter decomposition rates are believed to be two primary mechanisms controlling the development of fixed tree islands. Two hypotheses, the hydrodynamic and chemo-hydrodynamic, have been proposed to explain the formation of tails. According to the hydrodynamic hypothesis, the tail develops due to litter from the head being deposited in its lee by water currents. According to the chemo-hydrodynamic hypothesis, the tail develops due to the release of nutrients from the head. These nutrients are leached from the head by surface water or shallow groundwater. This creates a plume of nutrients behind the head, resulting in better plant growth and the differential build up of peat in the plume area compared to nearby areas outside the plume.

Therefore, the determination of labile nutrient pools is an essential component in establishing tree-island development and sustainability. The majority of nutrient uptake on a tree island will occur via root uptake from the soils, with porewater providing the labile nutrient pool. Preliminary data collected over one growing season show that, in general, porewater phosphorus, chloride, calcium and sulfate have the highest concentration on the head of the tree island, while concentrations of DOC, Fe and nitrogen are highest on the near tail (**Figure 6-8**). The implications of this are unclear. However, preliminary data show that nitrogen and phosphorus concentrations in the porewater were over 100- and 20-fold higher, respectively, than the overlying surface water. A gradient this strong would indicate an upward flux. Data do not support any single hypothesis of tree-island formation at this time. Further comparisons of groundwater and porewater chemistry are needed to evaluate the degree to which nutrient cycling on tree islands is influenced by groundwater upwelling.

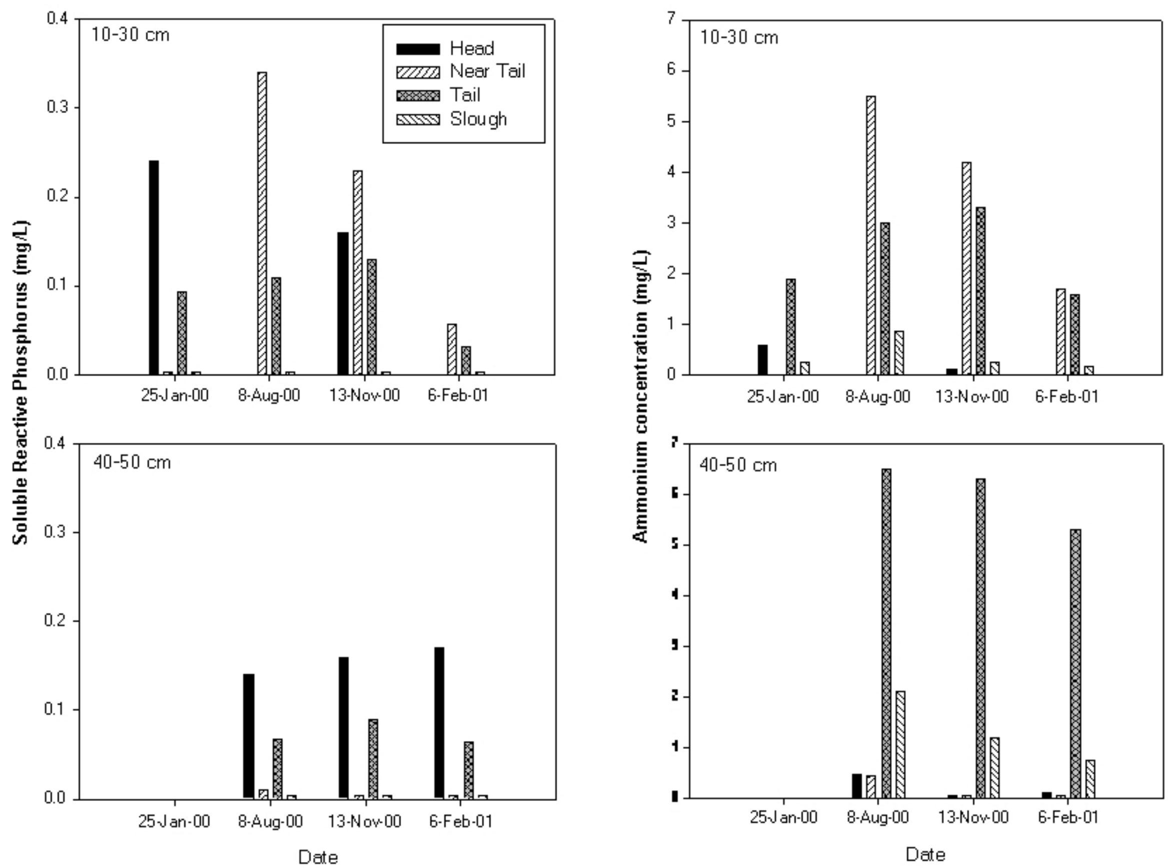


Figure 6-8. Biovailable phosphorus (left) and nitrogen (right) across tree island 3AS4 at two depths and for four different time periods indicate a general trend of decreasing nutrient availability downstream of the tree island head.

ECOLOGICAL TRENDS

WADING BIRDS

Previous Everglades Consolidated Reports have clearly demonstrated the significance of wading birds to the ecology and restoration of the Everglades. Previous reports have also demonstrated the hydrologic needs of wading birds relative to water depths and hydroperiods. Consequently, it is a matter of continuing to report on the wading bird population dynamics to see if trends make ecological and hydrologic sense. The information reported here represents a compilation of data collected by a variety of investigators monitoring wading bird nesting in South Florida (Gawlik 2000, Gawlik In Prep). The time-period covered by this report is the nesting season that began January 2001 and ended in the summer of 2001.

The estimated number of wading bird nests (excluding cattle egrets, which are not dependent on wetlands) in South Florida in 2001 was 38,647. This number is down only 5 percent from last year, which was one of the best years in a decade. The banner nesting in 2000 was attributed to increased nesting by white ibises, wood storks and snowy egrets, the three species that have declined most since the 1930s. In 2001 the number of wood stork and white ibis nests decreased slightly from 2000, and the number of snowy egrets increased. All were above average for the last decade.

Nesting effort differed strongly among regions, but the pattern differed from the previous year's. In 2001, A.R.M. Loxahatchee National Wildlife Refuge (LNWR) supported the largest number of nests, whereas WCA 3 had fewer nests than usual. Water Conservation Area 3 supported only 38 percent of nests in the Everglades proper (WCAs, Everglades National Park, Florida Bay) in 2001, whereas it supported 81 percent of nests in 2000. In contrast, the Refuge supported 51 percent of the nests in 2001 and only 7 percent in 2000. The Park and Florida Bay collectively continue to support only about 10 percent of Everglades wading bird nests, a trend that must be reversed as part of the ecosystem restoration.

The switch in nesting effort between years in WCA-3 and the Refuge is almost certainly related to differences in hydropatterns. During the nesting season of 2000, water levels in WCA- 3 started out high and thereafter receded almost four feet so that about half of the area had surface water by the end of nesting. Also, most of the remaining surface water was shallow enough to provide foraging habitat. The strong, uninterrupted recession, starting with a wet system, resulted in a large nesting effort as predicted (Gawlik, in press). During that same year in the Refuge, water levels also started out high but never got very low, and there were several reversals in the drying pattern, resulting in considerable nest abandonment. In that area, there was very little wading bird nesting.

In contrast, during the nesting season of 2001, water levels in WCA-3A started out almost two feet lower than in 2000, and receded until almost all the area was dry. Nesting effort dropped considerably in 2001. A very different pattern occurred in the Refuge. During 2001, water levels in the Refuge started out slightly lower than in 2000, and water receded over two feet so that most of the remaining surface water at the end of the nesting season was shallow enough to provide foraging habitat. There was a corresponding increase in nesting effort in 2001.

Aerial wading bird distribution surveys in the WCAs indicated that abundances in 2001 were even higher than during 2000, which was 129 percent higher than in 1999, which was roughly three times that of 1998. This year continues a trend of more birds coming into the Everglades in the early dry season than have done so in the past.

Based on historic data collected during drought periods (1989 and 1990), our initial expectation was that most heron and egret species would have a low nesting effort, whereas white ibises, wood storks and snowy egrets had the potential to have a good nesting year. Total nest numbers are used as a measure of nesting effort for the restoration process, because past research in the Everglades has shown that they were correlated with nesting success (Frederick 1995) and they are considerably more cost-effective and easier to obtain. In addition, there is a good historic record of total nest numbers, whereas there is little data on nesting success. If we consider only total nest numbers, the 2001 data suggests our expectations were correct for the three species mentioned above, and we might have underestimated the response by the other herons and egrets.

Unfortunately, 2001 was noteworthy in that there was considerable nest failure, particularly for great egrets and for WCA-3. Scientists have speculated that nest failure was the result of drought conditions and a rainfall event in April that caused water levels to increase quickly (Gawlik, in prep.). There is some evidence that white ibis initiated courtship in WCA-3, in what traditionally has been the largest white ibis colony in the Everglades, but then moved to the Refuge, presumably because conditions there were more suitable. Because nesting success is not monitored system-wide, there are no precise estimates of overall nest success. Nevertheless, the most reasonable conclusion is that nest numbers in 2001 might be slightly liberal. This pattern differs from 2000, when the high nest numbers also were accompanied by apparently good nesting success, except in the Refuge.

Three species-groups met the numeric nesting targets proposed by the South Florida Ecosystem Restoration Task Force (**Table 1**); however, the wood stork barely did so. Two other targets for the Everglades restoration are an increase in the number of nesting wading birds in the coastal Everglades and a shift in the timing of wood stork nests to earlier in the year (Ogden, 1997). The 2001 nesting year showed no improvement for a shift in colony locations, but there was improvement for the timing of stork nesting.

Extreme hydrologic conditions favor one set of species over another in a given year depending on the species' feeding ecology and whether it is a wet or dry extreme (Gawlik, in press). It is likely that large differences in hydrologic conditions among years, which are common in South Florida, are necessary to maintain a diverse wading bird community.

Table 6-5. Numbers of wading bird nests in the Water Conservation Areas and Everglades National Park

Species	Base low/high	1994-1996	1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	Target
Great Egret	1,163/3,843	4,043	4,302	4,017	5,084	5,544	5,996	4,000
Snowy Egret/ Tricolored Heron	903/2,939	1,508	1,488	1,334	1,862	2,788	4,269	10,000-20,000
White Ibis	2,107/8,020	2,172	2,850	2,270	5,100	11,270	16,555	10,000-25,000
Wood Stork	130/294	343	283	228	279	863	1,538	1,500-2,500

EVALUATION OF THE 2001 DROUGHT

There is a critical need for making ecological and environmental science available to decision makers in timeframes required for both short-term and long-term water management. In response to urgent needs associated with the 2001 drought, the District's Everglades Division bridged expertise in ecosystem modeling and risk assessment with wading bird population ecology and geographic information systems. As you shall see in the sections to follow, this critical mass of information was integrated into indices of suitability and risk. The 2000-to-2001 drought affected all of South Florida and created unprecedented historical, below-normal water-level conditions in certain subregions. Under these conditions, either in combination with water supply operations or alone, water levels in the Everglades could have been drawn down below preferred levels for the biological components of the ecosystem. These drought conditions created situations that dictated striking a balance between water supply and environmental needs, which required protecting wellfields and conserving critical water supplies, while minimizing and mitigating for adverse impacts to the environment.

Ecological indices were developed to estimate current conditions in the Everglades and to predict impacts that might occur. Ecological analysis of various dry-season scenarios for deviations from the regulation schedules for Water Conservation Areas 1, 2A and 3A were performed.

Development of a Muck Fire/Bird Colony Suitability Hazard Index

This index consisted of estimated water levels at a series of hydrologic monitoring points measured relative to threshold values established for each monitoring point. For the muck fire index within the Everglades, soil surface was the threshold value. For the bird colony suitability index, a calculated colony reference stage was the threshold value (see Wading Bird Colony Suitability Index). These monitoring points were selected to provide coverage of the Everglades based on a set of gauges in current use (**Table 6-6**, **Figure 6-9**).

Table 6-6. Muck Fire/Bird Colony Suitability Hazard Index for Marsh Sites

Station Name	Last Reading	Stage	Muck Threshold	Bird Threshold	Index		Burn Hazard	WCA Location
1-7 gauge	5/15/01	15.18	15.40		-0.22	yellow		WCA-1
1-9 gauge	5/15/01	15.18	14.80	14.80	0.38	green		WCA-1
2A-159	5/15/01	11.31	12.20		-0.89	yellow		WCA-2A
2A-17	5/15/01	10.72	11.10		-0.38	yellow		WCA-2A
3-99	5/15/01	6.67	6.80	7.11	-0.13	red		WCA-2B
3A-NW	5/15/01	9.80	11.00		-1.20	red		WCA-3A
3A-NE	5/15/01	9.56	10.34		-0.78	yellow		WCA-3A
3A-2	5/15/01	9.30	10.10		-0.80	yellow		WCA-3A
3A-3	5/15/01	8.18	8.60		-0.42	yellow		WCA-3A
3A-S	5/15/01	8.66	9.00		-0.34	yellow		WCA-3A
3A-4	5/15/01	8.49	8.40		0.09	green		WCA-3A
3A-5	5/15/01	7.99	7.30		0.69	green		WCA-3A
3-76	5/15/01	5.72	6.32		-0.60	yellow		WCA-3B
3-71	5/15/01	6.33	6.52		-0.19	yellow		WCA-3B
Shark.1	5/15/01	5.53	6.23		-0.70	yellow		WCA-3B
3BS1W1	5/15/01	4.48	5.34		-0.86	yellow		WCA-3B
Holey1	5/15/01	10.53	11.00		-0.47	yellow		Holeyland
Holey2	5/15/01	9.70	10.75		-1.05	red		Holeyland
Roten.N	5/15/01	11.09	12.30		-1.21	red		Roten.
Roten.S	5/15/01	10.58	11.80		-1.22	red		Roten.
G-3273	5/15/01	3.64	7.00		-3.36	red		ENP
NP-205	5/15/01	2.80	5.86		-3.06	red		ENP
NP-44	5/15/01	1.87	5.02		-3.15	red		ENP
NP-46	5/15/01	-0.01	1.31		-1.32	yellow		ENP
E-112	5/15/01	2.44	3.24		-0.80	yellow		ENP
EVER4	5/15/01	2.15	1.80		0.35	green		ENP
NP-206	5/15/01	3.28	5.99		-2.71	red		ENP
RG-2	5/15/01	2.91	6.08		-3.17	red		ENP
NESRS2	5/15/01	4.45	5.62	5.50	-1.17	red		ENP
NP-67	5/15/01	1.10	3.41		-2.31	red		ENP
NP-38	5/15/01	0.21	0.85		-0.64	yellow		ENP
NP-36	5/15/01	2.90	3.23		-0.33	yellow		ENP
NP-33	5/15/01	5.10	4.87		0.23	green		ENP
G-620	5/15/01	4.20	6.83		-2.63	red		ENP
NP-201	5/15/01	4.46	6.17		-1.71	red		ENP

Green – current stage level is above the threshold **Yellow** – current stage level is below the threshold **Red** – current stage level is 1 foot below the threshold and muck fires are likely to occur. ENP station names G-3273, NP-205, NP-44, NP-46, E-112, EVER4, NP-206, RG-2, NP-67, NP-38, G-620, and NP-201 are located in marl forming wetlands and turn red at 1.5 foot below the threshold.
Note: Muck Threshold = Ground Elevation
Note: Bird colony suitability hazard index becomes red once stage level reaches the calculated colony reference stage threshold.

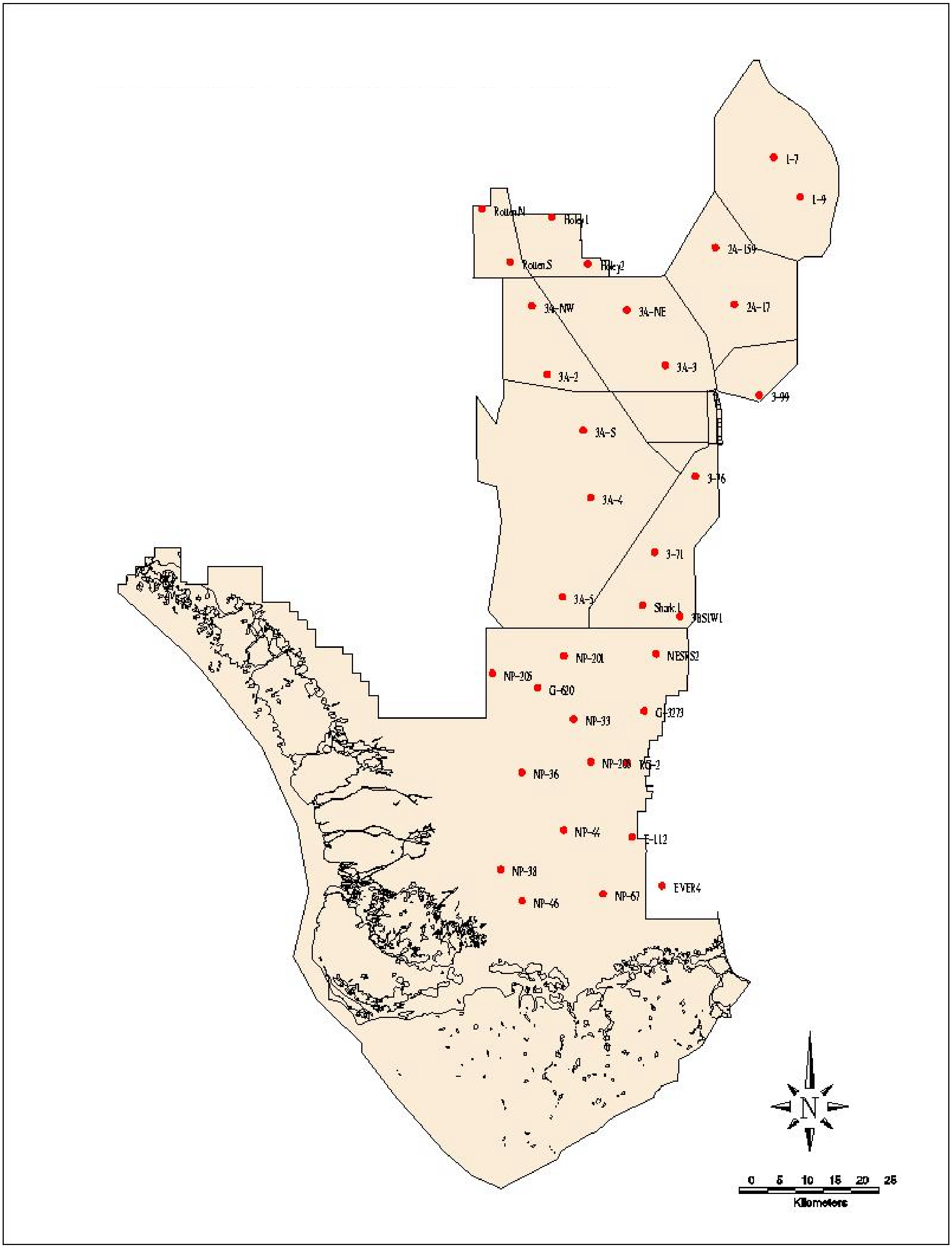


Figure 6-9. Drought Index Gauge Map

Wading Bird Colony Suitability Index

This year's drought in South Florida created a situation where water managers had to ensure that an adequate supply of water was available for human use, while minimizing impacts to the Everglades ecosystem. There was concern for all components of the ecosystem with special emphasis on wading birds, snail kites, exotic vegetation and peat fires. To aid managers with their task, District staff created a series of indices that formalized current knowledge of the effects of drought on these ecosystem attributes. The indices are compiled in Drought Ecological Impact reports that were updated monthly and are provided at: http://www.sfwmd.gov/curre/watshort/index2_sept.html Included in these indices were a wading bird foraging suitability index and a wading bird colony suitability index. This section describes the Wading Bird Colony Suitability Index.

Colonies are impacted when the surface water directly at the colony site disappears, thus providing access to mammalian predators and potentially causing abandonment of the colony (Rodgers, 1987; Frederick and Collopy, 1989). We reference the role of mammalian predators with some reservation because direct evidence for their impact is scarce. Nevertheless, regardless of the cause of abandonment, the relationship between colony abandonment and dry conditions appears in the literature and has been observed in the Everglades (J. Ogden, pers. comm.).

We only included colonies containing Wood Stork and White Ibis nests because they are species of top management concern whose populations have declined over the last several decades. The Wood Stork is a federally Endangered Species and the White Ibis is a Florida Species of Special Concern. Also, nesting data (Crozier et al., 2000) have shown that in years with drought conditions, few herons and egrets attempt to nest, whereas large numbers of Wood Storks and White Ibises may. Focusing attention on the species that have the best chance of success during drought years is the most prudent management strategy because there is at least some chance that they will nest successfully.

Colonies with Wood Stork or White Ibis nests located in the WCAs and northern ENP that were active in the 2000 breeding season, as well as any new colonies that were found during the 2001 breeding season, were monitored with aerial surveys from helicopters. Colonies were surveyed monthly between 16 March and 7 June to determine the number of Wood Stork and White Ibis nests in each colony. Six colonies were monitored in the WCAs and ENP (**Figure 6-10**).

Because the suitability of a nesting colony requires information on the surface water at a colony site rather than at a gage, the first step in the index development was to link surface water conditions at colonies with stage readings at gages. Colony locations were overlaid onto a 4km^2 grid of the WCAs and ENP. For each grid cell containing a colony, surface water estimates were obtained from aerial Systematic Reconnaissance Flights (SRF) wading bird surveys (Bancroft and Sawicki, 1995). SRF surveys provided monthly estimates (Jan through Jun) of surface water (wet - entire cell covered with water; transitional - only a portion of the cell covered with water; dry - no surface water present) from 1986 to the present. Surface water estimates were examined to determine times when cells with colonies were first recorded as dry following at least one survey when surface water was present. Stages (NGVD) were obtained for those dates from corresponding gages. The gages chosen were on telemetry (with the exception of 3A-SW), had data for the period of record, and were close to the wading bird colonies (**Figure 6-10**).

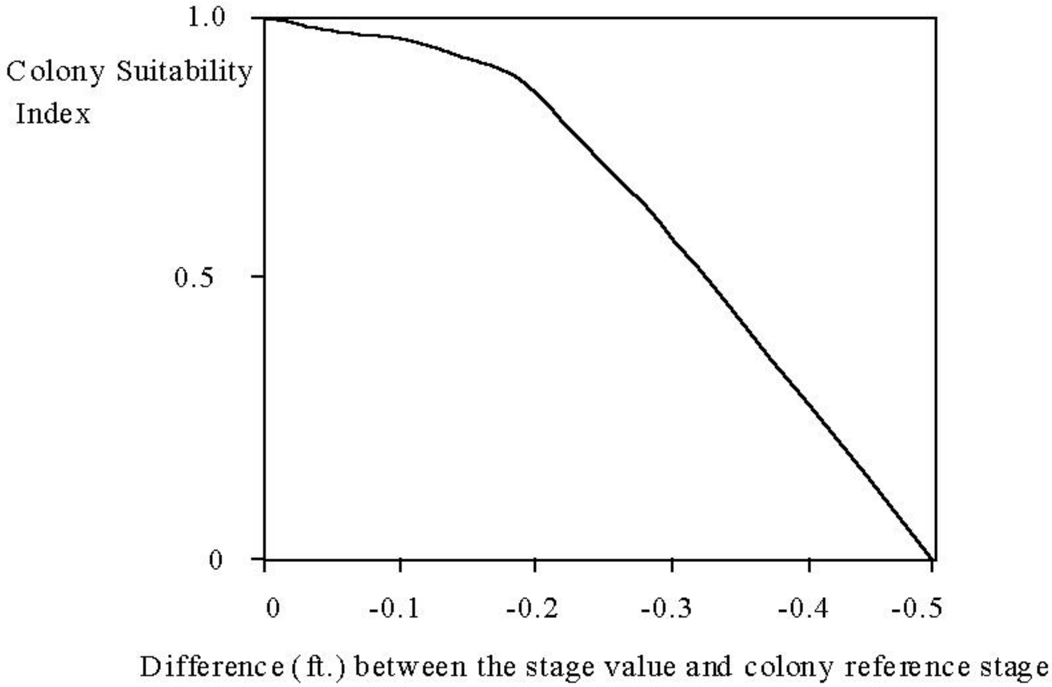


Figure 6-10. Location of Water Depth Gages (Cross-Hairs) and Wood Stork and White Ibis Colonies in WCAs and ENP

A mean stage was calculated and used to represent the average point at which a colony site was dry and colony site suitability began to decrease (hereafter termed the colony reference stage; **Figure 6-11**). The colony reference stage was 14.8 ft (gage 1-9) for colonies 01083 and 01084, 6.9 ft (gage 3-99) for the 2B Melaleuca colony, 7.9 ft (gage 3A-3) for the Alley North colony, 9.0 ft (gage 3A-SW) for the Crossover colony, and 5.5 ft (gage NESRS2) for Tamiami West colony. Initially, we chose 7.1 ft as the colony reference stage for 2B Melaleuca. But, this value was too high based on personal observations and we adjusted the value to 6.9 ft. The colony site suitability function (**Figure 6-11**) assumes that any amount of surface water produces a suitability of 1.0 (highly suitable). Suitability begins to decrease when water levels fall below the colony reference stage, and suitability decreases to 0 when stage drops to 0.5 ft below the colony reference stage. At that point, it is likely that the marsh surface will be completely dry and the colony will be abandoned.

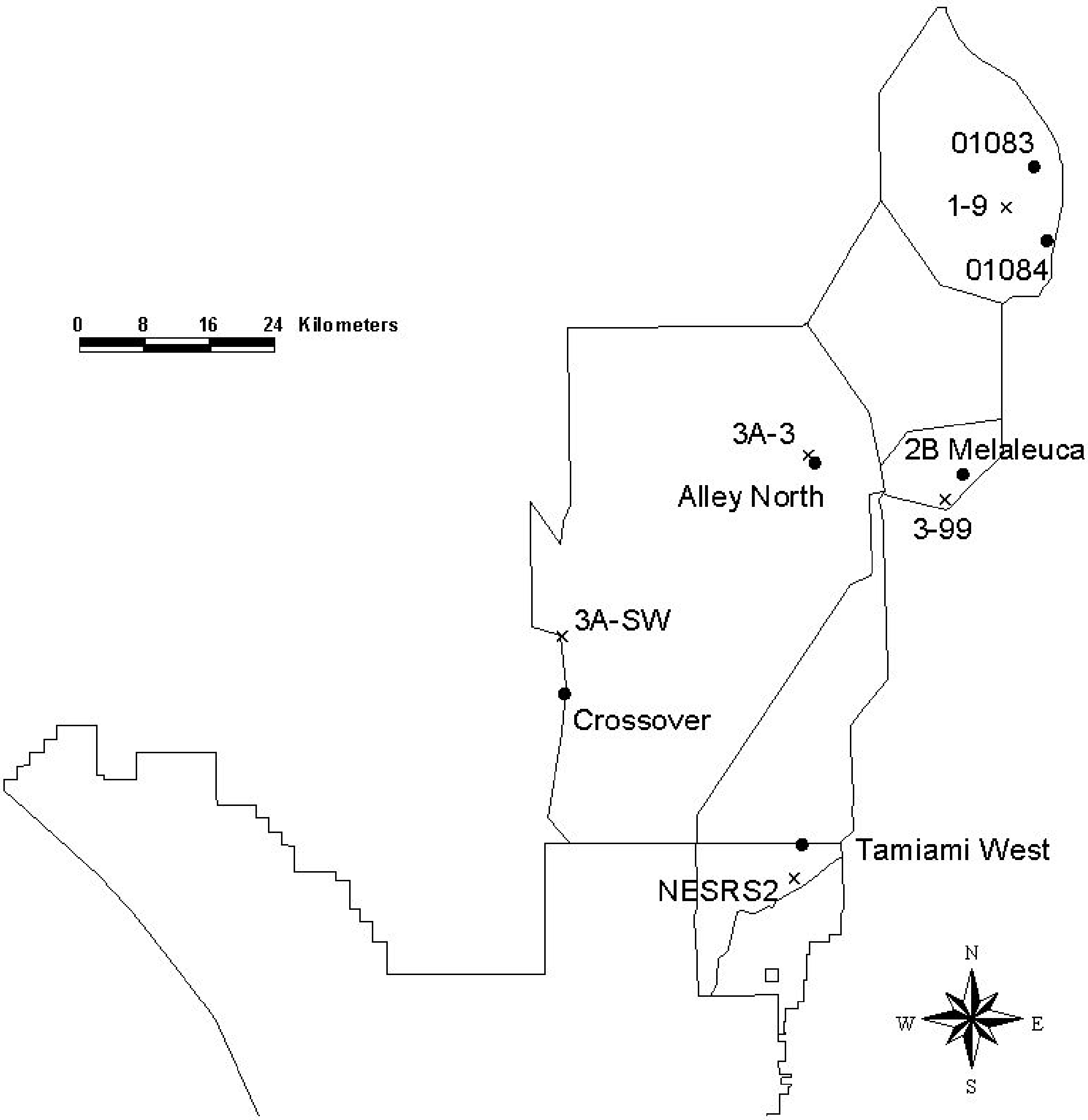


Figure 6-11. Colony Suitability Index as Function of Colony Reference Stage

INDEX VALIDATION

To validate the colony suitability index, the date the colony was predicted to go dry based on the suitability index (0.5 ft below colony reference stage) was compared with surface water observations made during monthly aerial surveys (**Table 6-7**). The suitability index accurately predicted when the 01084, 01083, and Crossover colonies would be unsuitable (i.e., no surface water present). It is likely that the index also accurately predicted when the Tamiami West colony went dry because the colony may have been predicted to be dry as early as 26 April (we do not have stage data for 26 Apr il- 11 May), but by 12 May the colony was already 0.5 ft below the point at which the suitability index = 0. We believe the 2B Melaleuca colony prediction may also have been accurate because although we never saw a lack of surface water at the colony on aerial survey dates (isolated pools were always present), it is probable the colony went dry between surveys. The colony suitability index was not correct for the Alley North colony. As a result, we have adjusted the colony reference stage for this colony to 9.3 ft based on the gage reading on 19 Apr when colony suitability was 0.

INDEX APPLICATION

We used the index to assess colony suitability (i.e., risk of abandonment) under different water management scenarios by comparing the index values calculated from predicted stages of the South Florida Water Management Model Position Analysis. These comparisons allowed us to focus our management actions on the colonies most in need of attention, and they provided some assessment of the relative effects of various water management scenarios.

As the drought progressed and the predicted suitability of the Tamiami West colony decreased to 0, managers were able to stay abreast of the situation. Personnel from various agencies began discussions on how to reduce the risk of nest abandonment to the largest colony of Wood Storks in South Florida. In the end, there was only a limited ability to slow the lowering of the water table under the colony, which was done by reducing flows out of the adjacent canal. Nevertheless, that action was taken and the colony ultimately fledged about 900 young storks, which were subsequently seen feeding nine miles west of the colony in the southern end of WCA3A. It is not known whether this management action played any role in the success of the colony. Tamiami West was unusual in that the storks were further along in the nesting cycle than those at Crossover colony, which failed as predicted. It may have been that the adults at Tamiami West were more hesitant to abandon their older young, highlighting the importance of early nest-initiation, which we use as a measure of restoration success. Also, Tamiami West was bisected by a small ditch that held surface water throughout the nesting period. Perhaps the presence of some water was enough of a stimulus to keep birds from abandoning.

Table 6-7. Validation of the colony suitability index based on stage values and surface water patterns from the 2001 dry season.

Colony	Colony Reference Stage (ft)	Date Colony Suitability Index = 0[a]	Date Surface Water = 0[b]	Colony Response
01084/01083	14.8	Never	Never	Both successful; some abandonment of 01083 by 19 Apr and of 01084 by 11 May
2B Melaleuca	6.9	30 Apr	Never	WOST abandoned between 19 Apr and 11 May. Some WHIB abandoned by 25 May
Alley North	7.9	Never	19 Apr	Abandoned by 19 Apr
Crossover	9	24 Apr	19 Apr	Abandoned by 19 Apr
Tamiami West	5.5	12 May[c]	19 Apr	Some abandonment by 11 May

[a] First date in the 2001 dry season that the stage minus the colony reference stage $\leq$ - 0.5 (i.e., the point at which the colony was predicted to be dry based on the colony suitability index).

[b] First date in the 2001 dry season that the colony was dry based on surface water observations made during monthly aerial surveys. Survey dates were 16 Mar, 19 Apr, 11 May, 25 May, and 7 Jun.

[c] Stage data missing between 26 Apr and 11 May.

Development of Models for Assessing Current and Predicted Ecological Risk

Data generated by the Environmental Protection Agency's REMAP program and the SFWMD STA Receiving Areas Monitoring & Research and Threshold programs provided a basis for complete spatial coverage of the Everglades Protection Area encompassing Water Conservation Areas 1, 2 and 3, the Rotenberger and Holeyland Wildlife Management Areas and Everglades National Park. Each model described below should be considered a work in progress and most likely will be revised as data are analyzed and validated.

PEAT-FIRE RISK-ASSESSMENT MODEL

The probability of peat fire (also known as muck fire) is influenced by biological and physical conditions. Seven factors were chosen based on their contribution to peat-fire potential. Data on each factor were grouped into categories, ranked on a scale of 1 to 5, assigned weights according to their relative importance in the process of burning and were combined in an equation to produce a single value for each site. These values were then ranked from 1 to 5 according to their magnitude. Below is a summary of each factor and how it contributes to the overall risk assessment.

Stage. Water level is, for obvious reasons, of primary importance in determining the combustibility of vegetation and soils (Wade et al., 1980). Site-specific ground elevations were determined from topographic maps generated by the South Florida Water Management Model (Fennema et al., 1994). Site-specific stage levels were determined by extrapolation (assuming a flat pool) from the nearest stage recorder within a network of 33 gauges throughout the EPA. Site-specific water depths were then calculated as the stage of the nearest recorder, minus ground elevation of the site. These values were then ranked as shown below. The ranges take into consideration that: 1) capillary action from a subsurface water table will keep upper level soils moist; 2) soils will retain moisture for a considerable length of time following water level recession.

Classes	Rating
< -2 ft	5
-2 to -1.5 ft	4
-1.5 to –1.0 ft	3
-1 to -0.5 ft	2
-0.5 ft or above	1

Prior stages (cumulative drought effects). For each site, a value was calculated that represents the cumulative effects of dryout. In other words, the values characterize how long a site experienced water levels below ground and, therefore, how dry it had become. Sites were given a value of 0 if the water level was at or above the ground elevation, regardless of prior stages. If the water level was below ground level, a value of 1-(stage/ground elevation) was calculated for the site. Each of these values was then weighted according to its position in the drought period, with June values multiplied by five (fifth month of dry period) and February values multiplied by one (1st month of dry period). If a previously dry site became wet again, the value was automatically returned to 0. Site-specific cumulative dryout values were then calculated as the dryout index value for the present month, plus the sum of values from all previous months within the designated dryout period. These values were then ranked from 1 to 5 over their range.

Vegetation. It is well known that plant species vary in combustibility as a result of differences in tissue moisture content, structure and elemental composition. In this regard, sawgrass is extremely flammable compared to other Everglades plant species (Kushlan, 1990). Dead leaves of sawgrass remain in a standing position for long periods of time, and the live material has a low water content (S. Miao, personal communication). Accordingly, areas dominated by sawgrass were assigned a value of 5. Cattail (mainly *Typha domingensis*) has a much higher water content, but also accumulates large amounts of biomass, although dead leaves are less rigid and tend to fall into the water column rather than remain standing (personal observation). Wet prairie vegetation (e.g., *Panicum hemitomon, Sagittaria lancifolia, Eleocharis spp., Rhynchospora* spp.) is much shorter and thinner and tends to be comprised mainly of live tissues, with little standing dead biomass. As a result, this community does not carry fire well (Gunderson and Synder, 1994) and was assigned a lower risk value. Slough communities generally exist in areas with long hydroperiods and are dominated by water lily (Nymphaea odorata, Nymphoides aquatica) and spikerush (Eleocharis spp.) vegetation. This habitat is considered to be the least flammable of all Everglades emergent habitats.

Classes	Ranking
sawgrass	5
sawgrass/cattail	4
cattail/sawgrass	3
sawgrass/wet prairie	3
cattail	2
cattail/wet prairie	2
wet prairie	2
cattail/slough	1.5
slough	1
shrubs/tree island	2
slough	1

* dogfennel and mixed upland vegetation in the Rotenberger Wildlife Management Area were given a 5.

Burn history. Incidence of fire greatly influences susceptibility to burning for a certain period of time. In surface fires, the aboveground biomass of vegetation and litter layers on the ground are diminished; the extent to which is largely dependent on fire temperature, water depths and vegetation moisture levels. Rates of recovery from fire can be quite variable, since a myriad of environmental factors (such as soil nutrient levels) influence regrowth. By approximately two years, the standing biomass of sawgrass can reach pre-fire loads (Gunderson and Synder, 1994 and references therein). In contrast, wet prairie vegetation may require three years or more for complete recovery (Herndon and Taylor, 1986). However, it may take several more years to accumulate similar above- and below-ground fuel loads (Gunderson and Synder, 1994).

In contrast to surface fires, peat fires typically destroy all above-ground plant material and consume a portion of below-ground organic matter. Areas that have experienced peat fire may initially be slow to recover, since revegetation must occur via clonal growth from peripheral (unburned or surface-burned) plants or seed. However, this lag phase tends to be offset by an increase in vegetation growth in response to elevated concentrations of bioavailable phosphorus (P) (Smith et al., 2001; Smith and Newman, 2001).

Classes	Ranking
burn > 4 yrs ago	5
burn 3 to 4 yrs ago	4
burn 2 to 3 yrs ago	3
burn 1 to 2 yrs ago	2
burn < 1 yr ago	1

Soil TP. Phosphorus (P) is the primary limiting nutrient for Everglades vegetation and elevated levels of soil TP correspond with enhanced plant productivity and biomass (Davis, 1994; Miao and Sklar, 1998). For example, unimpacted regions of WCA-2A typically have soil TP concentrations of 400 mg/kg or less, while moderately impacted regions show variation from 400-700 ug/cm^2. In contrast, concentrations of 700 mg/kg and above are accompanied by major vegetation changes, frequently from sawgrass to cattail (Craft and Richardson, 1997).

Classes	Ranking
> 700 ug/cm3	5
600-700	4
500-600	3
400-500	2
< 400	1

Soil type. Peat soils contain a higher percentage of undecomposed organic matter than marl (also known as calcitic mud), which is comprised of hardened layers of periphyton-derived calcium carbonate (Gleason and Stone, 1994). Dried peat soils are more loosely packed (more airspace) and presumably more flammable than dense marl. Sandy soils tend to have the lowest organic matter content and therefore are less combustible. Peat, marl and sand soils were ranked 5, 3 and 1, respectively. Combinations of these soil types were given intermediate ranks.

Classes	Ranking
Peat	5
Peat/Marl	4
Marl	3
Sand	1

Bulk density. When peat dries out, oxidation, consolidation and compaction occur, resulting in decreased porosity and the irreversible loss of part of its water-holding capacity. In addition, peat burning can greatly alter the structure of soil so that its water-holding capacity is substantially reduced (Ewel and Myer, 1990 and references therein). Soil bulk density values reflect the process of drying and peat burning, and were therefore ranked over their range and included as an unweighted component of the final risk calculation.

Classes	Ranking
>0.4	5
0.3-0.4	4
0.2-0.3	3
0.1-0.2	2
<0.1	1

* Some factors were ranked 1, 3, 5, with no intermediate values in order to allow evolution of the model and further resolution/refinement.

Risk calculation:

Peat-fire risk = (burn-history rank*5) + (water depth rank*4) + (cum drought rank *4) + (veg type*3) + (soil TP*2) +(soil-type rank*1) + (bulk density rank*1)

The risk values calculated from the equation in **Table 1** for each site were ranked from 1 to 5 over the entire range of possibilities (i.e., highest and lowest possible risk values dictated by the equation) so temporal changes could be detected. The final index values were mapped using Arcview version 3.2. Sites were color-coded according to index value.

WADING BIRD HABITAT VALUE ASSESSMENT MODEL

Wading bird habitat values were developed using woodstork (*Mycteria americana*) and white ibis colony locations, colony nest numbers and species-specific foraging distances. Colonies of the wood stork and white ibis were given priority over other wading bird species because the wood stork is a Federally Endangered Species and the white ibis is a Florida Species of Special Concern. Also, these two species have shown dramatic population declines over the past 70 years (Ogden, 1994; Crozier et al., 2000). Finally, historic nesting data (Crozier et al., 2000) have shown that during drought years, few herons and egrets attempt to nest, whereas large numbers of wood storks and white ibis might. Focusing attention on the species that have the best chance of success during drought years is the most prudent management strategy.

Site value as assessed by water depth. The suitability of site-specific water depths for wading-bird foraging was calculated on a 0-to-1 scale. Water depths less than -0.33 ft (-10 cm; too low) or greater than 0.82 ft (25 cm; too high) were given a 0 value. For the range between -.33 and 0 ft (ground level), values were calculated as 1-(water depth/-0.33) so that increasing depths followed a slope from 0 to 1 (Dale Gawlik, personal communication). Over the range of 0 to 0.49 ft (15 cm), all water depths were assigned a value of 1 (i.e., highly suitable foraging conditions). Above 0.49 ft, values again declined according to the function (1-(water depth/0.82))/(1-0.49/0.82). These calculations essentially follow a modified bell curve, whereby foraging suitability is constant over an "optimal" range of water depths, but declines linearly beyond minimum and maximum thresholds. The final values were then ranked on a 1-to-5 scale over their range to ensure water depth carried equal weight when combined with other components of the assessment.

Calculated value classes	Ranking
0-0.2	1
0.2-0.4	2
0.4-0.6	3
0.6-0.8	4
0.8-1	5

Site value as assessed by distance from active colonies and weighted by colony size. One measure of the suitability of a foraging site is distance from a colony, with closer sites having a higher suitability. Distance thresholds that cause abandonment vary among species, stage of the nesting cycle and prey availability at foraging sites. Mean foraging distances for white ibises were estimated at 12 km and 9 km (Bancroft et al., 1990). Mean foraging distances for wood storks were estimated at 9 km and 13 km (Bryan and Coulter, 1987; Bryan et al., 1995). However, Kahl (1964) reported that wood storks can fly 32 to 40 km without expending large amounts of energy.

Distances of each map site from each woodstork colony were calculated and subsequently converted to a ranking. Associated with every site, therefore, were x number of distances from x number of colonies. Each of these distances was then scaled based on a foraging range of 0 to 34 km. Values exceeding this threshold received a rank of 0, whereas values within this range were transformed by the linear function y = 1-(distance from colony in km/34km). In this way, closer sites received higher values. Each distance-related rank value for a particular site was then multiplied by the number of estimated nests in the colony from which the distance was calculated. Nest numbers were updated on a monthly basis by helicopter survey. These nest-weighted values were added to obtain a number that identified a site's value as wading bird habitat based on the proximity to multiple colonies and the relative importance (size) of the colonies.

The same procedure was repeated with white ibis colony data using a foraging range of 0 to 18 km so that two separate species values were generated for every map site. Because woodstorks are listed as a Federally Endangered Species, however, they are perceived as more significant from the standpoint of environmental management. Accordingly, wood stork habitat values were multiplied by 3 and white ibis by 2, thereby giving more weight to the endangered species. These two values for each site were then added to obtain final numbers reflecting a combined species habitat value, which were ranked from 0 to 5 over their entire range.

Site value as assessed by recession rate. A rapid rate of receding water seems to produce good nesting effort (Kahl, 1964; Frederick and Spalding, 1994). When recession rate drops below 0.5 cm per day (0.16 ft/week), or when it reverses, nest abandonment can occur (Kushlan, 1976b; Frederick and Collopy, 1989a; Frederick and Collopy, 1989b). Recession rates were calculated from monthly stages and scaled according to a modified bell-curve function whereby rates less than -0.086 received a value of 0. Between -0.6 and -0.16, rates were converted to 1 (rate/-0.086). Between -0.016 and -0.007 optimum range, rates were given a value of 1. Between -0.05 and 0.05, the function y = -0.05*rate + 0.05. Rates above the 0.05 ft/wk threshold received 0 values.

Calculated value classes	Ranking
0-0.2	1
0.2-0.4	2
0.4-0.6	3
0.6-0.8	4
0.8-1	5

Integration of all components in assessing habitat value

To combine all the above aspects of wading bird habitat suitability, the water-depth-related rank and distance-related rank (weighted by nest numbers and species) for each map site were added. A time switch was incorporated into the calculation of distance-related (weighted by nest numbers) and recession-related habitat values so that these components are dropped from the overall habitat assessment beginning June 1, which approximates the end of nesting activity for these species.

Wading bird habitat suitability calculation:

Habitat suitability = (water depth-related rank*2) + (recession-related rank) + (distance adjusted by colony size-related rank*2)

GENERAL ECOLOGICAL RISK ASSESSMENT MODEL

Lastly, a more generalized index of habitat quality was created by averaging the peat fire and wading bird values (equal weights) for each site to give a more generalized, broader-scope risk assessment within the Everglades. Examples of the graphical output for these various assessment models can be found in **Figure 6-12.**

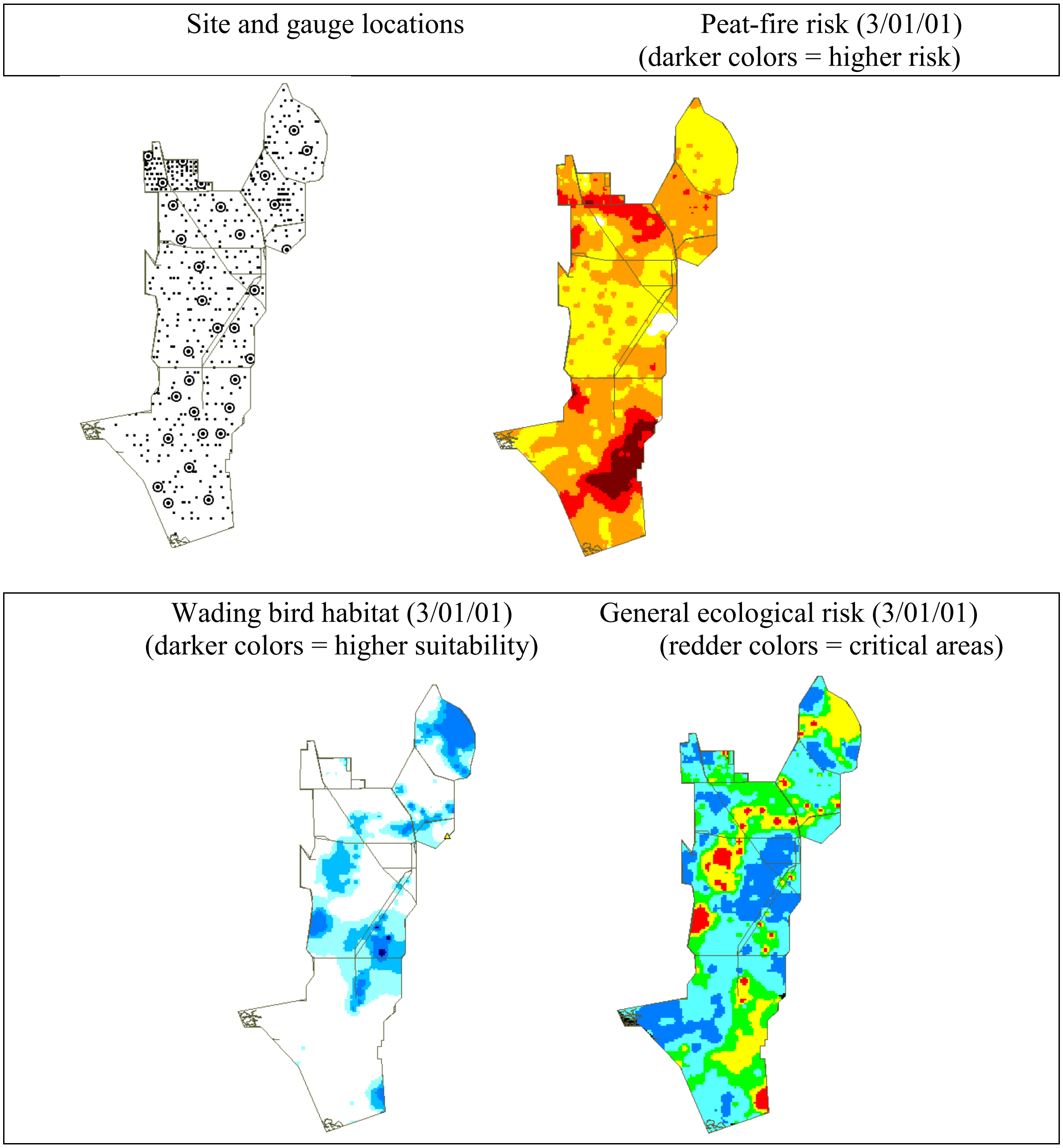


Figure 6-12. Output of the General Ecological Risk Assessment Model.

Results of Using the Developed Indexes and Risk Assessment Models

The developed indices and risk-assessment models were used to document and estimate the current and predicted ecological conditions in the Everglades that may have occurred as a result of the drought. In addition, the developed risk-assessment models were used as ecological analysis tools for evaluating various alternatives for Water Conservation Areas 1, 2A and 3A deviations for 2001 and 2002. The reports began in April 2001 and were updated monthly as the drought continued. Monthly versions of these documents can be found at the South Florida Water Shortage Alert Website (http://www.sfwmd.gov/curre/watshort/index2.html) under "Environment" and within the Drought Ecological Impact reports. The April 2001 report contains additional background information on how the ecological risk-assessment models were developed and used based on an initial set date of April 1, 2001.

Overall, it was a good year for the ecosystems in the Everglades when evaluating the ending dry-season conditions of May. Several muck fire hazard index marsh sites did go beyond the critical water level threshold of one foot below ground elevation. Fortunately, the numerous fires that did occur throughout the Everglades during this same time period were restricted to healthy surface burns and didn't result in damaging muck fires. All the wading bird colonies successfully fledged young this nesting season, although some colonies were more successful than others.

Drought conditions were still present at the beginning of the rainy season, especially when considering the low water levels in Lake Okeechobee. Several model runs based on past historical data show that conditions could be as bad or worse for year 2002 if above normal rainfall amounts don't occur in select regions of the system. Under these conditions the Everglades Drought Conditions reports will continue to be produced and utilized in evaluating the ongoing drought conditions.

DROUGHT EFFECTS ON FLORIDA BAY AND EVERGLADES TRANSITION ZONE

One of the important effects of the drought of 2000-2001 has been the impact on salinity in the lower Everglades and Florida Bay. Because much of the fresh water that normally supplies Florida Bay during the rainy season is exported as runoff and groundwater from upstream wetlands, drought conditions upstream have a direct effect on conditions in northern Florida Bay.

Using the Dataflow multi-parameter sampling system (Madden and Day, 1992), two high-resolution mapping surveys of Florida Bay and Transition Zone salinity were undertaken in the wet season of 2001. The salinity sensor used is an induction type temperature-compensated conductivity probe that was pre- and post-calibrated to a series of conductivity standards each day. Measurements were spot-checked by Hydrolab datasonde several times throughout each transect. On June 2-3, continuous transects were undertaken to map spatial patterns of salinity and other water quality parameters over an 800 square mile area of Northeastern and North Central Florida Bay. There was virtually no evidence of fresh water flowing from the Everglades, despite several heavy rains in the lower Everglades and Florida Bay for several days prior to sampling. The entire eastern Bay from Tavernier to Bob Keys north to Taylor River and East to Long Sound was found to be 34-36 PSU, approximately full strength seawater (**Figure 6-13**). In Lower Taylor Slough, salinity was 35 PSU as far as the upper chain of ponds, 5 km inland. Further upstream, Argyle Henry was 30 PSU. The lowest salinity measured in the entire Mangrove Transition Zone was 30 in the north end of Seven Palm Lake.

Waters from Madeira Bay through McCormick and Crocodile Point were hypersaline, ranging from 42-45 PSU; as transects continued west into Rankin Lake and Whipray Basin, salinities averaged 47 and frequently exceeded 50. The seagrass community in these areas appeared healthy from visual observations- lush beds of *Thalassia testudinum* and *Halodule* wrightii were observed. For comparison, in July 2000, salinity in the North Central Bay averaged 38-42, about 10 PSU lower, and in the Northeastern Bay, about 26-30, also about ten PSU lower. In June 1999, Central Bay salinities were also about 38-42, and Northeastern Bay salinities were 36-38 (AOML: Florida Bay Website http://www.aoml.noaa.gov/ocd/sferpm/salmaps.html).

Dataflow transects also showed DO to be low bay-wide: 4-to-6 mg/L; 3 in the mangrove zone. pH was also low in the mangrove zone (7.6 to 7.9) relative to the open bay, where pH averaged 8.3. Water temperatures were about 30° C throughout the transect area. In-vivo chlorophyll fluorescence indicated possible blooms in Whipray Bay and Rankin Lake. Water clarity was very high, with transparency, as measured by beam transmissometer, near 90 percent that of deionized water in all parts of the northern bay measured.

From July 12 through 14, a second comprehensive mapping effort was undertaken to compare with the June data (**Figure 6-13**). Despite very heavy rains in the watershed during the month of June, hypersaline conditions intensified in Florida Bay. The severity of the condition differed by region, but virtually all the eastern and central bay exhibited salinities above full-strength oceanic salinity of 36 PSU. The mangrove transition zone and creeks connecting the Everglades to the bay were also hypersaline, which is somewhat surprising given prior heavy rains locally and in the Southern Everglades. Observed Transition Zone salinities of 38-to-40 PSU were exceptional for these areas during the rainy season, when salinities are usually 5-to-15 PSU.

In the north central bay, salinities abruptly increased from 38 on the eastern side of the dragover to 45 on the western side of the dragover. Salinity further increased westward to 52 PSU, centered in Whipray Bay and Rankin Lake. The dramatic salinity difference between the eastern and central bay emphasizes the barrier to circulation between the two regions. Despite the June rains, mean salinity in North Central Florida Bay had increased by 2-to-4 PSU in the month between measurements. The central bay was also marked by high chlorophyll a (**Figure 6-14**), which may be affected by high salinities. Higher chlorophyll values exactly coincided with the region's extreme salinity.

Two additional points of interest regarding seagrasses were observed: (1) Thalassia plants appeared healthy and very green throughout the transect area in Trout Cove, Little Madeira Bay, Madeira Bay, Crocodile Point and Rankin Lake, and preliminary data show that the plants were productive; (2) The north central bay was marked by a high amount of seagrass wrack on the surface of the water. These large rafts of detached leaves, sometimes as much as 50 meters across and composed of tons of decomposing biomass, covered large areas of the central bay. The mats included Thalassia, Halodule and Syringodium leaf material. While no definitive cause can be attributed, it is noteworthy that the areas of highest observed wrack distribution coincided with the areas of most extreme hypersalinity. No major windstorms that could account for leaf loss had recently passed through the area. Summer leaf dihisis might account for the wrack, although none was observed in less saline eastern areas of the Bay. SFWMD mesocosm experiments in progress (Koch et al., unpub.) indicate that Thalassia plants are particularly stressed at even brief exposure (two days) to salinities above 50 PSU. While no cause-effect between the presence of wrack and high salinity can be attributed, these observations are being presented as points upon which to base further observation and study.

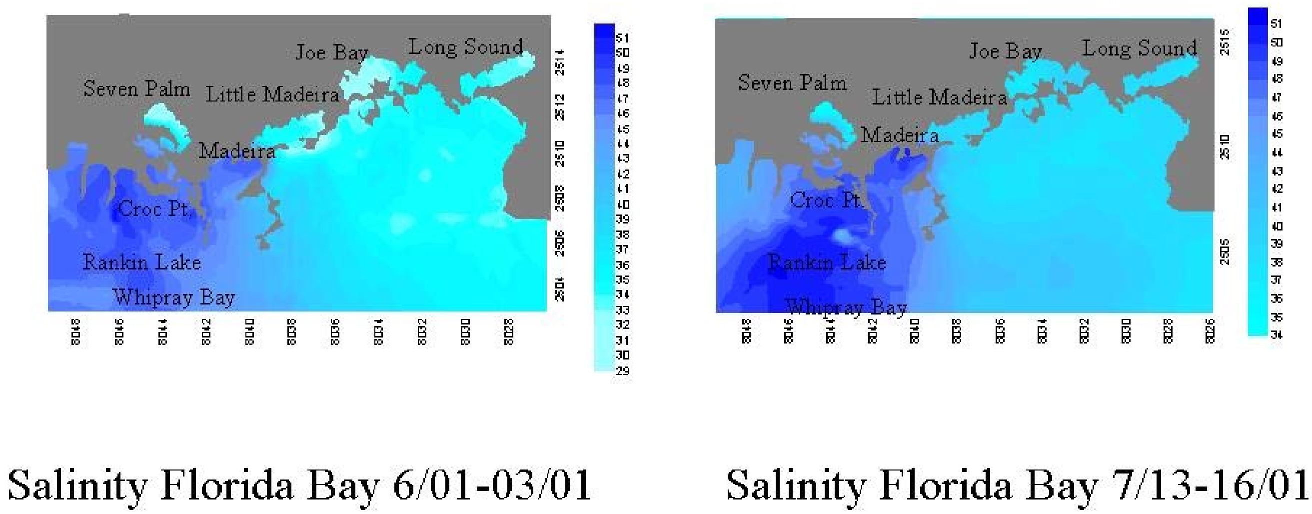
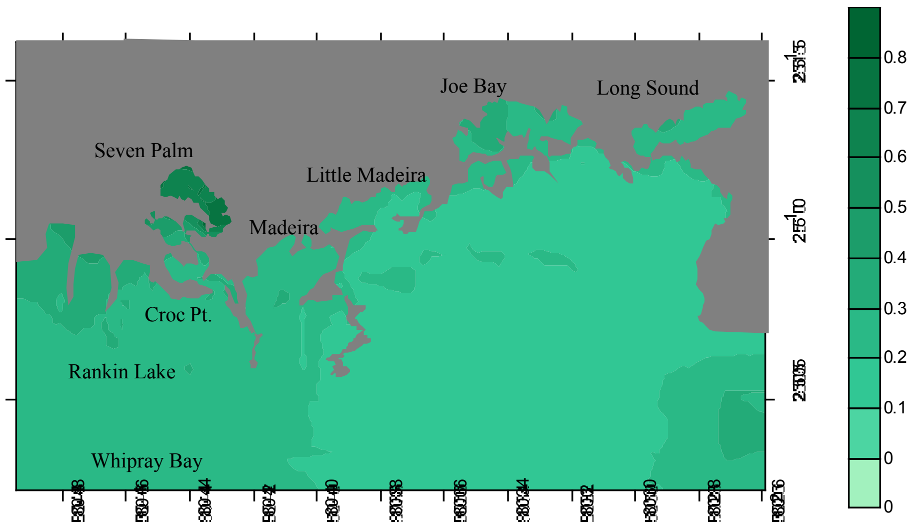


Figure 6-13. Comparison of Florida Bay salinity maps from synoptic Dataflow transects in early June and mid-July 2001.



Chlorophyll a Florida Bay 7/13-16/01

Figure 6-14. Synoptic map of in vivo chlorophyll a fluorescence in Florida Bay in mid-July, 2001. Scale is Relative Fluorescence Units, with 1=approximately 40 µg/L.

In the McCormick Creek complex, the only parcel of water below full-strength seawater salinity was observed (Seven Palm Lake waters ranged from 34-36 PSU). However, these waters were 4 PSU higher than that recorded in June. Downstream, in Middle and Monroe lakes, salinity quickly increased to above 40, then to 45 PSU in Terrapin Bay. In all areas of Long Sound, which receives water from the C111 Basin, salinity was 38 to 40, including near the channelized C-111 outflows of both branches of Highway Creek and Stillwater Creek. Neither channel was flowing. In all areas of Joe Bay, also supplied by C-111, and in the west by Taylor Slough, salinities were 38 to 40. From Davis Cove, Alligator Cove and Little Madeira northward through all lower Taylor Slough ponds to Pond 5, salinities ranged from 38-to-40 PSU, a remarkable departure from normal wet-season salinities. Despite observations of abundant propagule production by red mangroves in the Transition Zone, wilting leaves indicated probable salinity stress.

Dissolved Oxygen ranged from 6-9 mg/L throughout the eastern and central Bay, much increased from in June, though levels continued at 3 mg/L in the mangrove zone. Water clarity continued to be very high during the July survey, with transparency, as in the June survey, near 90 percent that of particle-free water.

No fresh water export to Florida Bay was observed from any area of the southern Everglades as of mid-July in the 2001 rainy season. The eastern-central Bay increased in salinity between early June and July, and in all areas along the Southern Everglades margin in eastern and central Florida Bay, there was no evidence of declining salinity. During southerly winds in July, hypersaline water was observed flowing into the Everglades at greater than 0.5 m per sec. The significant rains in the upstream basins through July were not sufficient to relieve the water deficit in the lower Everglades.

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