Benefits Anticipated from the 1995 Water Regulation Schedule for Water Conservation Area 1: Review and Analysis

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Executive summary

A water regulation schedule is a tool used to guide management of water levels in impounded areas such as lakes, reservoirs, or marshes. Typically, a regulation schedule has water level thresholds which vary with time of year and trigger discharges (a.k.a., regulatory releases) or inflows. Regulation schedules are designed to attain specific goals often related to water supply, flood protection, and ecological needs. Here, the purposes of a specific water regulation schedule change to Water Conservation Area 1 (WCA-1) are reviewed and their attainment assessed. Such analyses assess the success of previous regulation schedule change and support future improvements in water management.

WCA-1 was established in the late 1940s, early 1950s as one of five water conservation areas (WCAs) in Palm Beach, Broward, and Miami-Dade counties. The original design for the WCAs was an attempt to accomplish multiple objectives related to water supply, flood protection, and enhancement of fish and wildlife habitat. In 1951, the Loxahatchee National Wildlife Refuge (now Arthur R. Marshall Loxahatchee National Wildlife Refuge), was established as an overlay of WCA-1 through a license agreement between the Central and Southern Florida (C&SF) Flood Control District (precursor to South Florida Water Management District, SFWMD) and the U.S. Fish and Wildlife Service, coupled with the Migratory Bird Conservation Act of 1929. The Refuge consists of WCA-1 and 2,550 acres of fee title lands that includes managed impoundments and cypress swamp (USFWS 2000).

The vegetation communities in WCA-1 (hereafter referred to as the Refuge interior) are shaped by interactions of water depth, duration of standing water (hydroperiod), frequency of dry-outs, water flow, and water quality. Areas that have deeper water for longer duration tend toward aquatic communities such as open water or sloughs. Areas that have shallower water for shorter duration or dry out more often tend toward communities such as sawgrass and brush. A mosaic of natural communities is important for providing habitat for the wide range of species that use the Refuge interior (USFWS 2000).

There have been four water regulation schedules since the establishment of WCA-1. The current schedule has been in effect since 1995. Section 2.04 of the "Preliminary Finding of No Significant Impact and Environmental Assessment - Water Conservation Area 1 Water Regulation Schedule Modification" (USACE 1994) established the anticipated benefits and ecological rationale for the 1995 regulation schedule change. Here, the original purposes (anticipated benefits) of this change from the 1975-1994 water regulation schedule to the current schedule (1995-2005) are reviewed and attainment of those benefits analyzed. Specific objectives of this analysis are to:

1. Describe the ecological rationale for the proposed changes as they relate to the stated purposes;
2. Describe the hydrological and ecological measures that could be used and the expectations for them if the anticipated benefits were achieved;
3. Describe, where possible, what has been achieved;
4. Provide a synthesis of what has been achieved.

Six anticipated benefits were described in the Environmental Assessment (EA):

1. Allow higher water levels during wet years in the northern portion of the Refuge;
2. Increase the hydroperiod of interior marshes of the Refuge such that dry-out does not occur on an annual basis;
3. Increase the proportion of the interior marsh of the Refuge that serves as nursery areas for aquatic organisms;
4. Improve the timing of winter stage drawdown in the Refuge to benefit wading birds;
5. Restore conditions in the Refuge similar to those found when the area was used by snail kites for nesting;
6. Allow for the storage of a greater quantity of water within the C&SF system during wet and normal rainfall years.

Hydrological and ecological information were used to the extent possible to determine if the anticipated benefits have been achieved. The focus of the analysis was the approximately 60% of the Refuge interior above and including an elevation of 15.0 feet NGVD because the purposes of the regulation schedule change focused on the northern portion of the Refuge interior. Elevation in the Refuge interior ranges from approximately 17.0 feet NGVD in the north to 12.0 feet in the south.

Hydrologic conditions in the Refuge interior from 1995-2005 are consistent with the purposes of the change to the current water regulation schedule in 1995. Many of the anticipated hydrological benefits listed in the EA have been achieved (see Summary of conclusions for details). Generally, there are higher water levels, longer hydroperiods, and a lower frequency of dry-outs in the more northern parts of the Refuge interior than occurred under the previous schedule. In addition, the timing of the start of the spring recession is earlier than it was under the previous schedule, and the rate of recession (as measured at the 1-8C gauge) is slower.

In most cases, it has not been confirmed that the hydrological changes have resulted in the desired ecological changes because monitoring was not established to track changes. It is likely that the increases in hydroperiod and average water depths in the north have at least slowed, if not reversed, the trend of conversion of sawgrass to brush. In addition, it is likely that the changes in frequency of dry-outs and the number of years between dry-outs have been beneficial for fish and apple snails.

Associated with these hydrological changes observed between the two regulation schedules, which focused on improving conditions in the north part of the Refuge interior are conditions that may be less desirable for the southern or central part of the Refuge interior. Higher water levels and longer hydroperiods in the northern Refuge interior result in higher water levels and longer hydroperiods in the southern part of the Refuge interior. These conditions could result in conversion of marsh to open water and could cause stress to tree islands. Another unintended consequence of current water management is a reduction in inter-annual variability in hydroperiod. Although the regulation schedule allows for water level management between the upper and lower bounds of the schedule lines, in general, water levels have been managed near the top of the schedule. The result is that inter-annual variability in hydroperiod is now lower than it was under previous schedules. The consequences of this are not known; however, natural variation at a range of spatial and temporal scales is important for shaping ecosystems including the Everglades (DeAngelis and White 1994).

It is likely that the upper and lower bounds of the current regulation schedule are appropriate for maintaining hydrological conditions to support key Refuge resources. The challenge is to develop operational rules that will allow for maximizing conditions for key indicators. Some indicators and targets are discussed in this document. Additional work is needed to clearly articulate the future desired conditions for the Refuge, what indicators will be used to track progress toward achieving those conditions, what the targets are for those indicators are, how those indicators will be monitored, and what strategies other than water management, such as prescribed fire, can be used or are necessary to obtain the desired ecological conditions. This document and the summary of the Water Management Breakout Session held at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop (Appendix 4) provide a starting point for these discussions.

Summary of conclusions from analysis of the six benefits listed in the WCA-1 water regulation schedule modification EA (USACE 1994).

Benefit 1 - Allow higher water levels during wet years in the northern portion of the Refuge.

Ecological Rationale *Reverse the trend of invasion of sawgrass by brush and of conversion of wet prairie to sawgrass. Bring 20,000 acres of marsh in the northern quarter of the Refuge back into productive marsh condition. Avoid yearly dry-outs.*

- There is not sufficient existing information on vegetation changes to address fully whether the desired ecological benefits described in the ecological rationale have been achieved.
- Average monthly stages in the marsh and canal are statistically significantly higher from 1995-2005 than from 1975-1994.
- Average monthly marsh stages are possibly high enough to contribute to the desired changes of halting conversion of wet prairie to sawgrass and sawgrass to brush; however, insufficient data exist to evaluate this with confidence.
- Retrospective analyses and current monitoring are necessary to further evaluate whether vegetation changes have occurred, whether they are the ones desired, and how much of the change has been (or continues to be) caused by the change in the regulation schedule.

Benefit 2 - Increase the hydroperiods of interior marsh so dry-out does not occur annually

Ecological Rationale *The desire was to have larger populations of aquatic organisms and to increase protection against drought by having greater year round water storage. Avoid yearly dry-outs.*

- Although hydroperiods (both annual and growing season) were longer at all three elevations from 1995-2005 compared to 1975-1995, only increases in hydroperiod at elevation above 16.0 feet are likely to have been ecologically significant. Hydroperiods in other areas changed by less than two months and were already within the current target ranges of 9 to 12 months.
- Hydroperiods in the more northern areas of the Refuge interior with higher elevation currently favor wetter communities compared to conductions under the previous regulation schedule. This is consistent with the objectives of the schedule change.
- Hydroperiods have been longer and water depths greater from 1995-2005 than from1975-1994 but have not resulted in a reduction in the frequency of dry-out at elevations above 16.0 feet.
- At 15.5 feet, frequency of dry-outs has decreased to one in every three years from one in every two years. The latter is within the range of once every three to five years (33% to 20% of the time) believed to be desirable and is consistent with the purposes of the regulation schedule change.

Benefit 3. Increase the proportion of marsh habitat that serves as nursery areas for aquatic organisms

Ecological Rationale *Increase aquatic productivity.*

- Except at the higher elevation of 16.0 feet, number of years between dry-outs was greater from 1995-2005 than from 1975-1994 and is closer to the current target of dry-outs no more then once every three to five years.
- Except at the higher elevation of 16.0 feet, percentage of years with at least three years between dry-outs has increased. This should be beneficial to aquatic fauna.
- Percentage of time when spring water depths were above the minimum threshold for apple snail egg laying is higher from 1995-2005 than from 1975-1995. This should contribute to increased apple snail density.
- Insufficient faunal density data exist to evaluate whether changes in hydrology have resulted in changes in fish or apple snail densities or distribution.
- Additional ecological monitoring is necessary to evaluate fully whether the desired ecological benefits described in the ecological rationale are being achieved.

Benefit 4. Improve timing of water stage drawdown in the Refuge to benefit wading birds.

Ecological Rationale *The assumption is that the intent was to provide foraging and nesting conditions for wading birds over the January-June period. Slower recession rate in the spring would benefit wood storks and other wading birds (also migratory waterfowl).*

- The current schedule dictates an earlier start to the spring recession, which should contribute to favorable conditions for wading bird foraging and nesting.
- Spring canal recession rate during 1995-2005 on average was lower (-0.03 feet compared to -0.10 feet per week, based on average monthly values) than from 1975-1995 which should benefit wading birds and other Refuge resources.
- Marsh recession rate as measured at the 1-7 was not different during the two periods. It is not clear how recession rate at the 1-7 relates to recession rates in the rest of the marsh.
- Additional monitoring (and analysis) of wading birds, aquatic fauna and hydrology are necessary to understand fully finer scale changes in recession rate that might occur under different water management operations.

Benefit 5. Restore conditions in the Refuge similar to those found when the area was used for kite nesting.

Ecological rationale *Provide habitat suitable for snail kite nesting.*

- Snail kites have nested sporadically in the Refuge since its establishment in 1951. There was a higher frequency (percentage of years) of nesting from 1995-2005 than from 1975-1995.
- There is not enough information to assess if the increase in frequency of nesting was a result of changes in hydrology and vegetation within the Refuge interior, or a result of other factors such as regional hydrologic conditions or regional population size. Because

snail kites are a semi-nomadic species and their nesting in one area is related to conditions in other areas using site specific trends in nesting without considering regional patterns can be misleading.

- Duplicating (spatially and temporally) natural hydrological regimes and processes for maintaining appropriate vegetation and apple snails is probably the best strategy for providing snail kite habitat in the Refuge.

Benefit 6. **Allow for storage of a greater quantity of water during wet and normal rainfall years**.

Ecological rationale A*void yearly dry-outs.*

- Based on the stage storage curve and average stage at the 1-7 water storage should have increased by 50,500 acre-feet. This has benefited Refuge resources by decreasing the frequency of dry-outs in some areas.

Additional information that would improve assessment of whether the benefits described in the WCA-1 water regulation schedule modification EA (USACE 1994) have been achieved.

Information needs are not in order of priority and are based on information that could led to better assessment of the benefits listed in the 1994 EA. Some of these needs also could be appropriate for assessment of effects of future water management operations depending on what performance measures are selected for future monitoring and assessment.

- Remote sensing could be used to develop a retrospective analysis of past and current vegetation patterns and where there have been changes over time. It will be important to be able to show where vegetation classes have changed, as well as to what class they have changed.
- A base line (current conditions) vegetation map that can be used to track changes in location and amount of shrub/brush, sawgrass, wet prairie, and slough in the future. (completion of SWFMD vegetation map from 2003/2004 imagery may provide this).
- A mechanism for tracking changes in the above communities on three to five year intervals to answer the question: Are there changes in the location and extent of the target communities? A broad scale approach such as the above vegetation map combined with on the ground field sampling at a finer scale (such as 100 acre vegetation plots or transects that have been used historically) that targets areas where change might be expected to occur should provide the most useful information.
- Linking vegetation changes (from retrospective and current analysis) to hydrological patterns to address the question: Are changes in amount and location of target communities correlated with hydrology?
- Development and application of hydrological models at a fine enough scale (a grid size no greater than 0.31 mile (500 m) in width) to relate hydrology to vegetation.
- Current aquatic fauna studies should be evaluated to determine how they could best provide information on overall distribution and density of fish and apple snails in the Refuge interior. The investigators of the three studies identified above should be contacted to discuss their methods, whether their data can be interpolated for specific Refuge purpose, and what additional information should be collected.
- Yearly monitoring for fish and apple snails if the above studies will not address Refuge specific needs to link aquatic fauna densities with hydrology.
- There is no way to recreate data on historic aquatic faunal communities; however, habitat suitability models linked with population dynamic models and hydrologic models could be used to hind cast densities of aquatic fauna as a way to evaluate current and past schedules. Calibration and validation of aquatic fauna models will require surveys at hydrologically diverse sites within the Refuge interior.
- Analysis of average weekly recession rates and reversals in relation to patterns of wading bird foraging and nesting in the Refuge interior and in a regional context (Data from the wading bird foraging and nesting SRF may be sufficient to address this).
- Hydrological models that provide the ability to examine recession rates throughout the Refuge interior.
- Monitoring of wading bird foraging and nest success.

- Linkage of wading bird foraging and nest success with information on aquatic fauna (i.e. typical wading bird food) density and distribution, vegetation, and hydrology.
- Better understanding of linkages between snail kites, apple snails, vegetation, and hydrology.
- Regular systematic surveys for snail kite nests coupled with evaluation of apple snail densities where kites are foraging.

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1. Introduction

The Arthur R. Marshall Loxahatchee National Wildlife Refuge is in part an overlay of Water Conservation Area 1 (WCA-1). WCA-1 (referred to as the Refuge interior) is managed under a water regulation schedule for multiple purposes of flood protection, water supply, and wildlife habitat. Since the establishment of WCA-1, there have been four water regulation schedules. Changes to the water regulation schedules have been primarily for the purposes of improving ecological conditions in WCA-1. The latest water regulation schedule went into effect in 1995. The primary objective of this document is to review the purposes of the change from the previous (1975-1994) schedule to the current (1995-2005) schedule as outlined in section 2.04 of the "Preliminary Finding of No Significant Impact and Environmental Assessment- Water Conservation Area 1 Water Regulation Schedule Modification" (USACE 1994) and:

1) Describe the ecological rationale for the proposed changes as they relate to the stated purposes;
2) Describe the hydrological and ecological measures that could be used and the expectations for them if the anticipated benefits were achieved;
3) Describe, where possible, what has been achieved;
4) Provide a synthesis of what benefits have been achieved.

1.1 Background

Water Conservation Area 1 (WCA-1) was established in the late 1940s as one of five water conservation areas (WCAs) in Palm Beach, Broward and Miami-Dade counties. The original design for the WCAs was selected to accomplish seven objectives (Light and Dineen 1994):

1) receive and store agricultural runoff from the Everglades Agricultural Area (EAA),
2) prevent water accumulated in the system from overflowing into urban and agricultural areas (flood protection),
3) recharge regional aquifers and prevent salt water intrusion,
4) store and convey water supply for agricultural, municipal and industrial use, and natural system requirements in Everglade National Park (ENP),
5) enhance fish and wildlife and recreation,
6) 6), receive regulatory releases from Lake Okeechobee, and
7) dampen the effect of hurricane-induced wind tides by maintaining marsh vegetation in the system (Light and Dineen 1994).

As early as March 1946, Everglades Drainage District and U.S. Fish and Wildlife Service (FWS) discussed the establishment of a wildlife refuge in the Loxahatchee marsh (Johnson 1974). In 1951, a license agreement between the Central and Southern Florida (C&SF) Flood Control District (precursor to South Florida Water Management District, SFWMD) and FWS, coupled with the Migratory Bird Conservation Act of 1929, authorized the establishment of Loxahatchee National Wildlife Refuge (now Arthur R. Marshall Loxahatchee National Wildlife Refuge) as an overlay of WCA-1. The Refuge consists of 141,374 acres within WCA-1 and 2,550 acres of fee title lands outside of WCA-1 that include managed impoundments and cypress swamp (Figure 1, USFWS 2000, USFWS 2002).

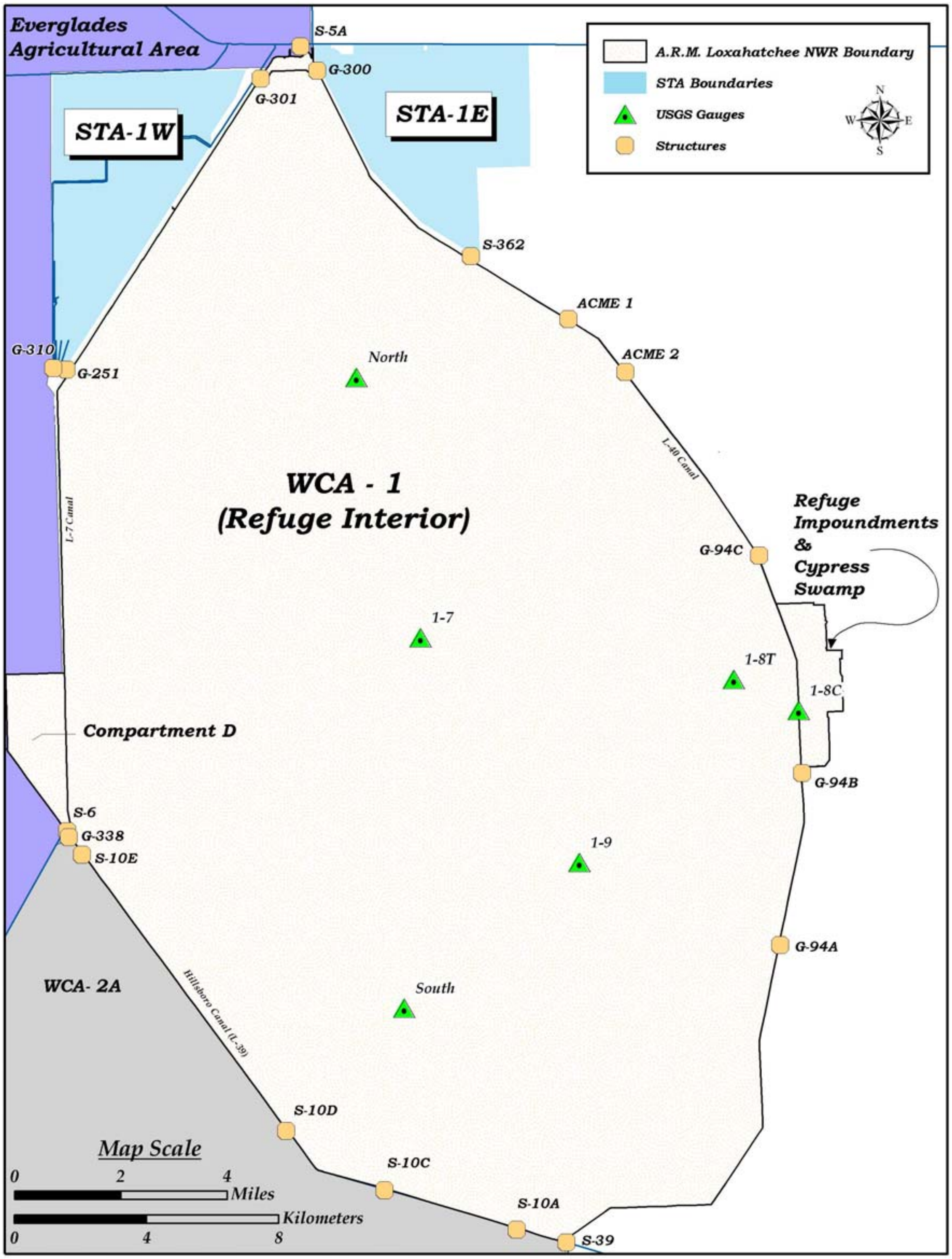


Figure 1. Arthur R. Marshall Loxahatchee National Wildlife Refuge includes WCA-1 and 2,550 acres of fee title lands (Refuge impoundments, cypress swamp, and compartment D). One canal (1-8C) and three marsh water level gauges (1-8T, 1-7, 1-9) are used for tracking water levels for compliance with the WCA-1 water regulation schedule. Two additional USGS gauges, North and South were installed in 2001 and could be used in the future

WCA-1, which will be referred to here as the Refuge interior, consists of 141,374 acres of Everglades marsh with thousands of tree islands. With the exception of the higher elevated tree islands, most areas are inundated for at least a part of the year. Sloughs and alligator holes are the deepest water areas and tend to hold water throughout the year except during very dry years. Wet prairies are shallower than sloughs, (in the Refuge interior by about 0.33 feet, (Table 1 and Appendix 1), but also have an extended hydroperiod and generally hold water for all but one or two months of the year. Sloughs and wet prairies generally support aquatic floating, emergent, and submerged vegetation. Dominant floating vegetation includes the white water lily, floating heart, and spatterdock (Gunderson 1994). Emergent vegetation consists mainly of spikerush, pickerelweed, maidencane, arrowhead, and cattail. Submerged vegetation is mostly comprised of various bladderwort and ludwigia species. The submerged vegetation provides structure for attached periphyton. Sawgrass stands are another freshwater marsh community and are slightly drier than wet prairies (by about 0.27 feet Table 1 and Appendix 1). Sawgrass strands occur in three forms. The first two forms are found throughout most of the marsh where sawgrass occurs on elevated ridges or at the fringe of tree islands. The western and southern portions of the Refuge interior contain very large expanses of sawgrass studded with pockets of wet prairie and slough; this form is more typical of the central Everglades. Tree islands are another major community type scattered throughout the Refuge interior. These islands are generally 1-3 feet higher than surrounding land elevations and are considered one of the signature features of the Refuge (Brandt et al. 2002, Brandt et al. 2006). Tree islands perform an important ecological role by providing habitat for a wide range of plant and animal species (Brandt et al. 2003). As in other parts of the Everglades, invasive and exotic species have impacted Refuge communities. Cattails are the primary native nuisance species. As of 1990, approximately 6,000 acres in the southwestern portion of the Refuge were cattails (Richardson et al. 1990). More current estimates of cattail cover and distribution do not exist; however, it is obvious that cattails are expanding (Childers et al. 2003). Melaleuca and Old World climbing fern are the two predominant exotic invasive species in the Refuge interior impacting over 60% of the area (Woodmansee et al. 2005).

Table 1. Average difference in water depth between different vegetation communities in the Refuge interior based on water depths taken on the same day in adjacent communities. Differences in depths reflect differences in surface elevation. Data are from Richardson et al. 1990 and Jordan 1997 (see Appendix 1 for additional details). Increasing water depths by >0.16 feet has the potential to slow the conversion of sawgrass to brush while an increase in >0.27 feet also could contribute to a community shift from sawgrass to wet prairie.

Vegetation community	Difference between water depth/ elevation (feet)	Standard Deviation	n
Slough-Wet Prairie	0.33	0.29	92
Wet Prairie-Sawgrass	0.27	0.20	143
Sawgrass-Brush/Shrub	0.16	0.10	5
Slough-Sawgrass	0.61	0.32	94
Slough-Shrub	0.73	-	1

Interactions of water depth, duration, timing, flow, and quality help to shape vegetation communities in the Refuge interior (Brandt 2001, Richardson et al. 1990, Hangenbuck et al 1974). As described above, areas that are deeper for longer duration tend toward aquatic communities such as sloughs or open water, while those that are drier tend toward communities such as sawgrass and brush. A mosaic of natural communities is important for providing habitats for the wide range of species that use the Refuge interior (see USFWS 2000). Historically (i.e., pre-drainage), water level and hydrological patterns were predominately dictated by rainfall and overland sheet flow. During the dry season (November-May), water level in the marsh would recede, concentrating aquatic fauna and providing foraging habitat for wading birds. In dry years, only sloughs and alligator holes might hold water. In the wet season, the marsh would re-flood allowing re-colonization of fish and other aquatic fauna. In addition to yearly cycles of wet and dry, the Everglades experiences natural longer term cycles of regionally wet (flood) and dry (drought) conditions. Major floods and droughts occur on a time scale of once every 11 to 13 years (Gunderson 1992). These inherent fluctuating conditions, both on a yearly time scale, and longer time scales are important for maintaining Everglades plant and animal communities.

Water regulation schedules are a tool for use by water managers to manage water levels in an impounded area such as a lake or water conservation area. A regulation schedule is a rule curve that gives guidance on how to operate under varying seasonal requirements and water levels. To the extent possible, conditions are managed “between the lines” and with consideration to any specific conditions that require inflows or outflows. When the levees were completed to form WCA-1 in the early 1960s, such a regulation schedule was established by the U.S. Army Corps of Engineers (USACE) for WCA-1. Regulation schedules typically have water level thresholds that trigger discharges (regulatory releases). In areas with multiple uses, regulation schedules may be designed to balance competing objectives. Because of the elevation gradient in WCA-1 from north to south (ranging from approximately 17 feet NGVD in the north and 12 feet in the south), and the fact that the area is circumscribed by levees and associated borrow canals, it is challenging to manage for ecologically appropriate water level in all parts of WCA-1 at the same time. As a result, there have been four regulation schedules for WCA-1 since 1960 to attempt to manage these challenges. The reasons for changes to the schedule have been to improve conditions for fish and wildlife by enhancing their habitats without sacrificing flood protection or water supply. The current regulation schedule has been in effect since 1995.

1.2 History of WCA-1 Regulation Schedule (Compiled by Susan Sylvester with additions by L.A. Brandt from Refuge narratives)

Four regulation schedules have been establish since initial regulation of water levels in WCA-1. The original schedule was developed by the USACE with minimal input from the Refuge. All evaluations for proposed regulation schedule changes were requested by the Refuge. In addition there have been four official deviations from the regulation schedule. One deviation was requested by the Refuge (1983), one was initiated by USACE in response to regionally high water levels and a need to protect Cape Sable Seaside Sparrow habitat in Everglades National Park (1998) and two were requested by SFWMD (2001 and 2005).

The gauges used for water regulation have changed since the first schedule (Figure 1). Prior to fall of 1967 (July 22, 1960 – Fall 1967), water levels in WCA-1 were regulated on the basis of stages observed at the 1-8 (1-8C, now designated USGS 263000080120001) gauge located in the L-40 borrow canal. In late 1967, water levels were regulated by the use of the 1-8 telemetry gauge (1-8T, now designated USGS 263050080145001) located in the Refuge interior west of the 1-8 canal gauge site. By 1975, the use of the 1-8T gauge as the only indicator gauge for management decision was discontinued. The 1-8C gauge was used for regulation for the first part of the year (January 1 – June 30). After July 1, when stage was rising, the average combined stage of the 1-7 (now designated USGS 263180080205001), 1-8T, and 1-9 (now designated USGS 262750080175001) gauges was to be used when it was lower than the 1-8C stage. An average of the three interior marsh gauge (1-7, 1-8T, and 1-9) stages was to be used during rising stages in the normal wet season was intended to prevent unnecessary regulatory discharges of water that was needed for ecological communities in the Refuge interior.

1.2.1 *July 1960 – June 1969* (Figure 2). Regulation of WCA-1 water levels officially began on July 22, 1960 when the newly completed spillway gates in Structure 10 were closed (Figure 2). The stage in the pool at the time was 13.5 feet NGVD. Within three months after closure, the stage in WCA-1 stood at 18.1 feet NGVD, approximating the peak standard project flood (SPF) stage for the area. Rainfall from Hurricane Donna (September 10, 1960) plus pumping inflow was responsible for a rise in pool level of 4.6 feet and a storage volume increase of over 400,000 acre feet (ac-feet). By May 1, 1961, the stage on the 1-8C gauge had dropped to 10.8 feet NGVD, a total stage change of nearly 12 feet having occurred within a 12 month period. This original schedule had a maximum pool regulation elevation of 17.0 feet. When stage went above the schedule line water was released. When stage was below 14.0 feet, only water supply releases were made.

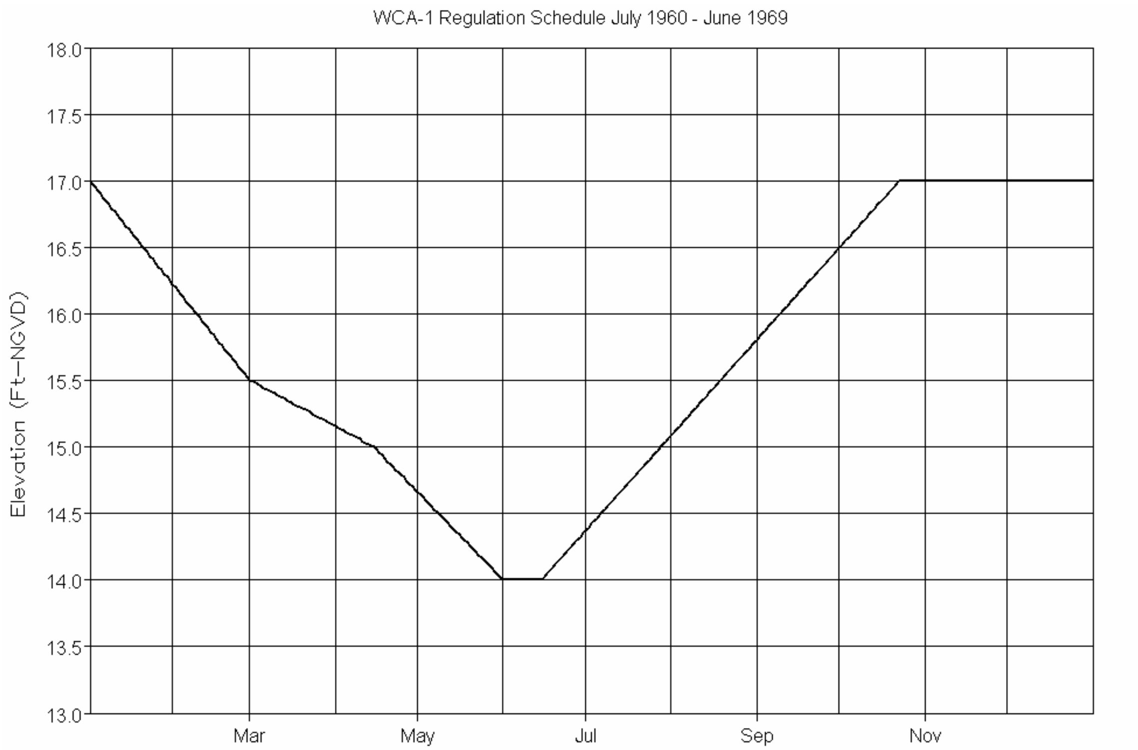


Figure 2. First water regulation schedule for WCA-1, July 1960-June 1969. See text for description

1.2.2 ***July 1969 – June 1975***. (Figure 3). The second regulation schedule retained a high level of 17.0 feet and substituted a low of 15.0 feet from mid-June through mid-August. This schedule change was made to reduce the frequency of occurrence of minimum stages below 11.0 feet-NGVD experienced in late May and early June, to increase minimum stages by an average of 1.5 feet, to reduce regulatory discharge requirements, and to provide an additional 1.3 feet of pool storage in June. During the six years this schedule was in effect, water levels in the dry season were held higher than 14.0 feet in most years, but large areas of marsh that previously had dried surficially during most dry seasons remained flooded most years. Such a condition was thought to be adverse to the maintenance of Everglades plant and animal communities because plant communities were believed to require drying for 30 or more days at least once every two to three years.

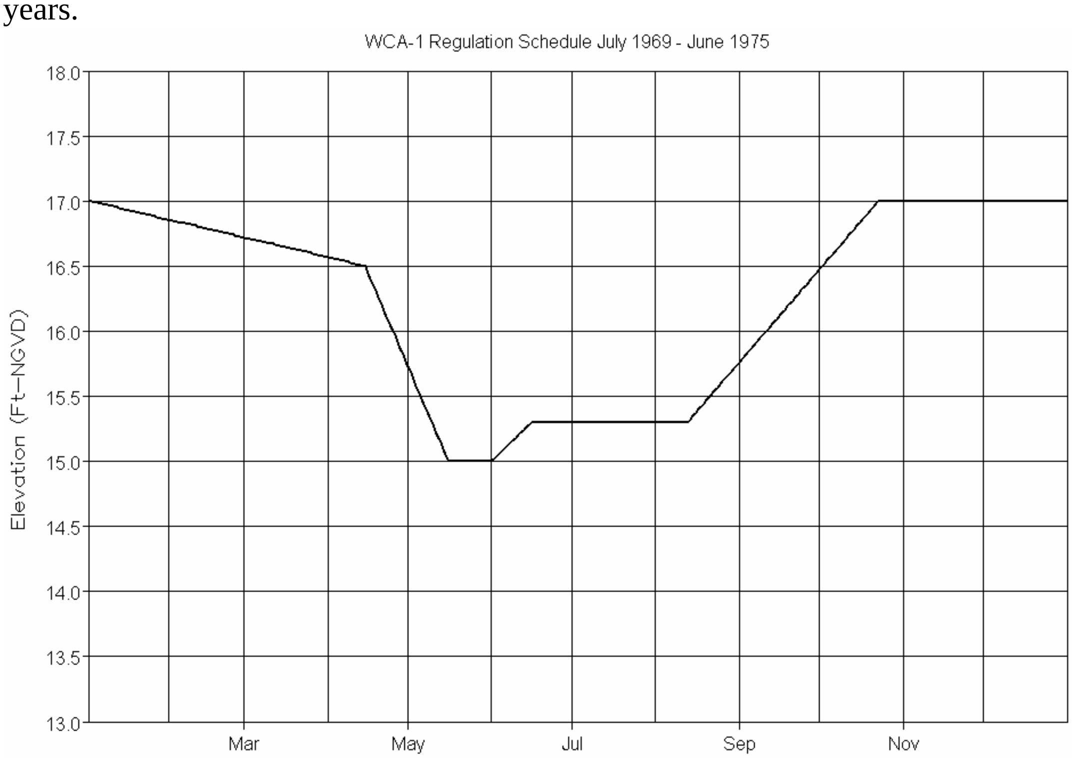


Figure 3. Second water regulation schedule for WCA-1, July 1969-June1975. See text for description.

1.2.3. ***July 1975 – April 1995*** (Figure 4). In October 1971 FWS and USACE initiated discussions to change the second schedule. It was believed that the previous schedule held water levels too high for regeneration of Tracey's beakrush, a food plant for water fowl) which needs 30-45 days of moist (not flooded) soil during the growing season (USFSW 1971). The third regulation schedule was implemented July 22, 1975. The purpose of the modification was to decrease the minimum allowable water levels during the dry season to allow for the majority of the marsh to dry-out for no less than 30 days every two to three years (USFWS 1991). Other references in the Refuge narratives described this schedule as having the intent of drying out 50% of the marsh once every two to four years (USFWS 1993). The schedule allowed a low regulation elevation of 14.0 feet instead of 15.0 feet and the use of the average of several gauges (1-9, 1-8T, and 1-7) during July – December if marsh stage was greater than canal stage (1-8C). The adopted schedule contained regulatory zones. Under this schedule, when water stage in WCA-1 was in Zone A, releases up to the maximum capacity at S-10 and S-39 could be made when agreed to by the USACE and SFWMD. In Zone B, discharges up to the maximum at S-10, based on the 30-day forecast could be made. If the WCA-1 stage exceeded 14.0 feet during the period March 1 through May 30, the 14-foot elevation criterion was disregarded, and an alternate Zone B (shown by the dashed line) defined Zone B for that year. Water levels were allowed to rise in Zone C if the WCA-1 stage was at or below 14.0 feet for at least 30 days. When WCA-1 stage was in Zone D, only releases for water supply were made. Regulatory releases up to the maximum practicable could be made through S-39 and S-5A (S) when agreed to by the USACE and SFWMD. A minimum water level of 11.0 feet was maintained in the perimeter canal around WCA-1. At the low level of 11 feet, water needs of the east coast areas were met by transferring water from Lake Okeechobee through WCA-1. There was no provision for replacement water to be brought in from Lake Okeechobee to maintain water levels at environmentally beneficial levels in the Refuge interior during water supply releases.

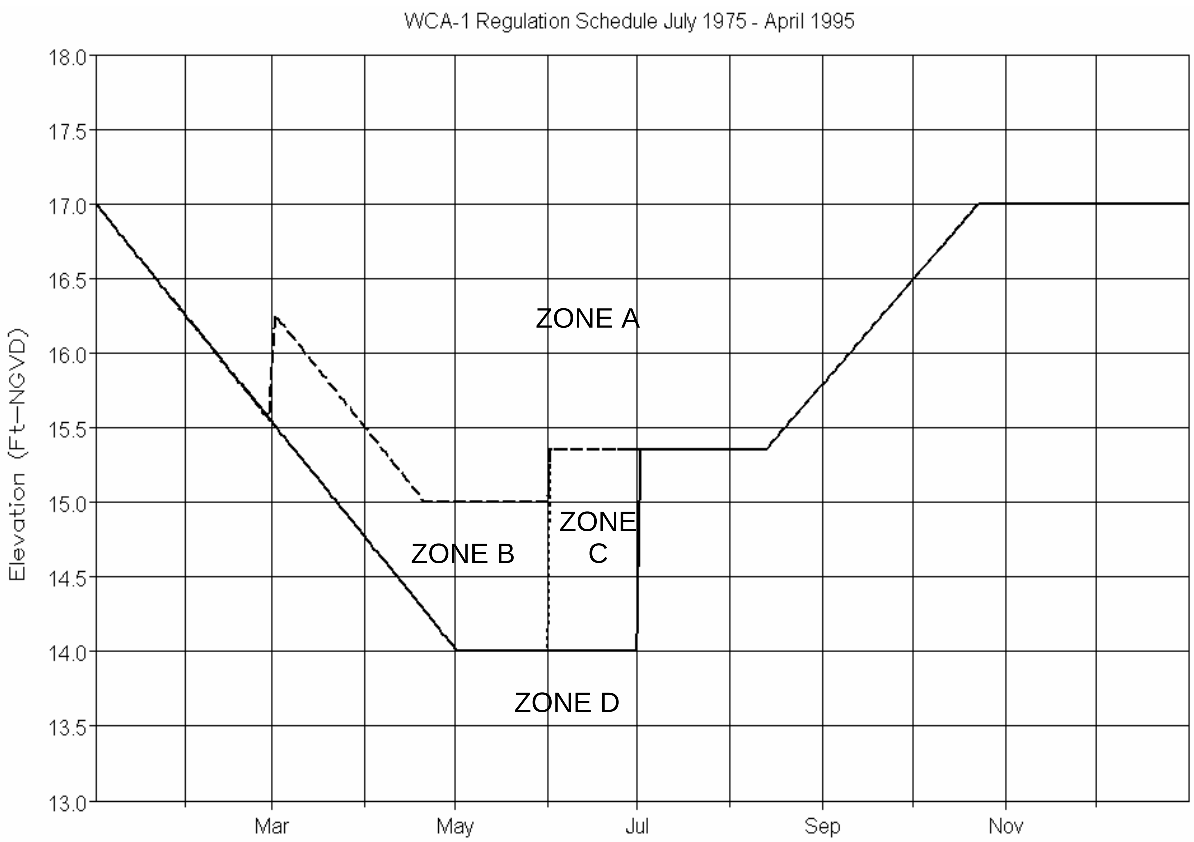


Figure 4. Third water regulation schedule for WCA-1, July 1975-April 1995. See text for description.

1.2.3.1 *1983 Deviation*

10 January 1983 – 31 December 1983: As early as 1980, there were comments in Refuge narratives that "…interior water levels have lost the highs and lows that are essential for maintaining Everglades habitat…" FWS suggested a change in 1981 to force low water level in the spring on a more regular basis. In 1983, by request of the FWS the USACE implemented a modification to the regulation schedule. The FWS expressed a need for an earlier recession of water levels to 14.0 feet, the normal lower limit for the WCA-1 regulation schedule. The purpose was to promote the potential for a complete drying to the interior of WCA-1, which seldom occurred under the 1975 regulation schedule. The change was implemented to improve bottom conditions and help wading bird populations. Various discussions on the schedule

continued through the 1980s. In 1986, FWS asked the SFWMD to drop the water levels one month earlier to get 60 days of dry-out in April and May instead of May and June.

1990 Change. In 1990, the floor of the regulation schedule was changed from 11.0 feet to 13.0 feet.

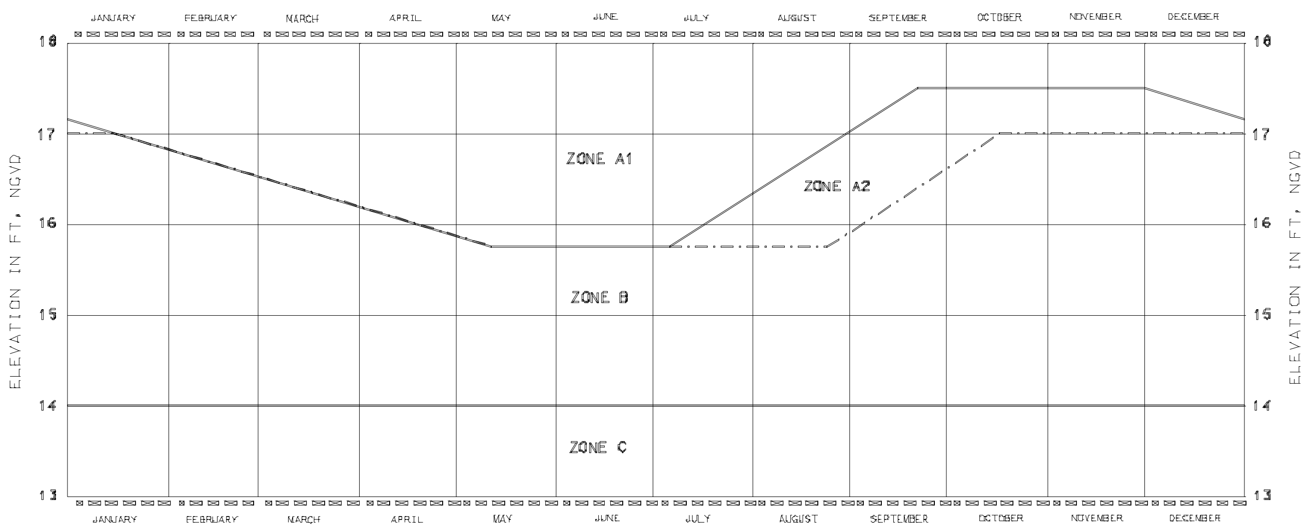
1.2.4 ***May 1995 – Present*** (Figure 5). In 1990, FWS initiated formal discussions with SFWMD and the USACE for changing the regulation schedule. It was believed that the third schedule had dried out the marsh more than was desired, resulting in vegetative communities being converted to drier types with loss of productive marsh habitat. Additionally, drying out the marsh every year or so was believed to be causing significant reduction in populations of aquatic vertebrates and invertebrates. Information collected by the Florida Fish and Wildlife Cooperative Research Unit indicated that the north end of the Refuge interior had experienced an increase in brush since the 1970s (USFWS 1989), which was likely a result of succession to woody species because of low water levels.

The fourth and current regulation schedule was implemented in May 1995. The current regulation schedule is intended to produce favorable impacts on wetland fish and wildlife resources, including species listed under provisions of the Endangered Species Act (see Section on anticipated benefits). This schedule was established to achieve the benefits of:

1) Allowing higher water levels during wet years in the northern portion of the Refuge;
2) Increasing the hydroperiod of interior marshes of the Refuge such that dry-out does not occur on an annual basis;
3) Increasing the proportion of the interior marsh of the Refuge that serves as nursery areas for aquatic organisms;
4) Improving the timing of winter stage drawdown in the Refuge to benefit wading birds;
5) Restoring conditions in the Refuge similar to those found when the areas was used by snail kites for nesting;
6) Allowing for the storage of a greater quantity of water within the C&SF system during wet and normal rainfall years.

In this schedule, the maximum stage varies between 15.75 feet and 17.5 feet. Zone A1 is the flood control zone from January through June. When water levels rise into that zone, water is released through the S-10s. From July through December, attempts are made to maintain water levels within Zone A2. Water levels in WCA-1 could be allowed to reach 17.5 feet in this zone when water is available. These decisions would be linked to rainfall and to water level in Lake Okeechobee, and would be controlled by releasing water from the S-10s and S-39 when agreed to by the USACE and SFWMD. When more water is needed, either for WCA-2A or other parts of the C&SF project, releases would be made from WCA-1 if the Lake Okeechobee level is a foot or more lower than the WCA-1 stage. If the Lake Okeechobee stage is higher, releases from WCA-1 would be preceded by an equivalent volume of inflow from the Lake. Zone B, the water supply zone, varies between 14.0 feet and the bottom of Zone A. When WCA-1 water levels are within this zone, water supply releases are made from WCA-1 as needed, if the Lake Okeechobee level is a foot or more lower than the WCA-1 stage. If the Lake Okeechobee stage is higher, releases from WCA-1 would be preceded by an equivalent volume of inflow from the

Lake. In Zone C, the drought zone, when water levels drop to 14.0 feet or less, there would be no net release of water from WCA-1. Any water supply releases would be preceded by an equivalent volume of inflow from Lake Okeechobee.



ZONE	RELEASES
A1	UP TO MAXIMUM AT S-10 (AND S-39 WHEN AGREED BETWEEN CORPS AND SFWMD). WATER SUPPLY RELEASES AS NEEDED.
A2	S-10 RELEASES BASED ON CORPS FORECASTS. WATER SUPPLY RELEASES AS NEEDED. IF LAKE OKEECHOBEE STAGE IS ABOVE WCA-1 STAGE OR NO MORE THAN ONE FOOT BELOW WCA-1 STAGE, THEN WATER SUPPLY RELEASES FROM WCA-1 MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW.
B	WATER SUPPLY AS NEEDED. IF LAKE OKEECHOBEE STAGE IS ABOVE WCA-1 STAGE OR NO MORE THAN ONE FOOT BELOW WCA-1 STAGE, THEN WATER SUPPLY RELEASES FROM WCA-1 MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW.
C	NO NET RELEASES FROM WCA-1. ANY WATER SUPPLY RELEASES MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW.

DATES	USE GAGE	CONDITIONS
1 JAN – 30 JUN	1-8 CANAL	ALL
1 JUL – 31 DEC	1-8 CANAL	EXCEPT AS NOTED BELOW
	AVG. 1-7, 1-8T, 1-9	DURING RISING STAGES WHEN CANAL STAGE EXCEEDS AVERAGE.

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
WATER CONSERVATION AREA NO. 1
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
DATED: 03 MAY 1995

Figure 5. Fourth and current water regulation schedule for WCA-1, May 1995 - Present. See Text for description.

1.2.4.1 *Deviations to the current schedule*

January 1, 1998 – December 31, 1998 (Figure 6): In response to regionally high water levels and concern that increased flows into Everglades National Park (ENP) would jeopardize the endangered Cape Sable Seaside Sparrow, the USACE requested a deviation to the regulation schedules of WCA-1, WCA-2, and WCA-3 (USACE 1998). The Refuge supported the need to protect Cape Sable Seaside Sparrow habitat in ENP by holding more water in the Refuge, but cautioned that the action could affect wading bird nesting and potentially tree islands. The deviation for WCA-1 included maintaining water levels at 17.5 feet in December and January, creating a Zone A3 where minimal releases were made through the S10s (maximum practical release were through S-39 and S-5A south as downstream capacity allowed), and eliminating the need for preceding inflows for water supply releases in Zone B from January-May. The result was that water levels from January-May 1998 were 0.5 to 1.0 foot higher during 1998.

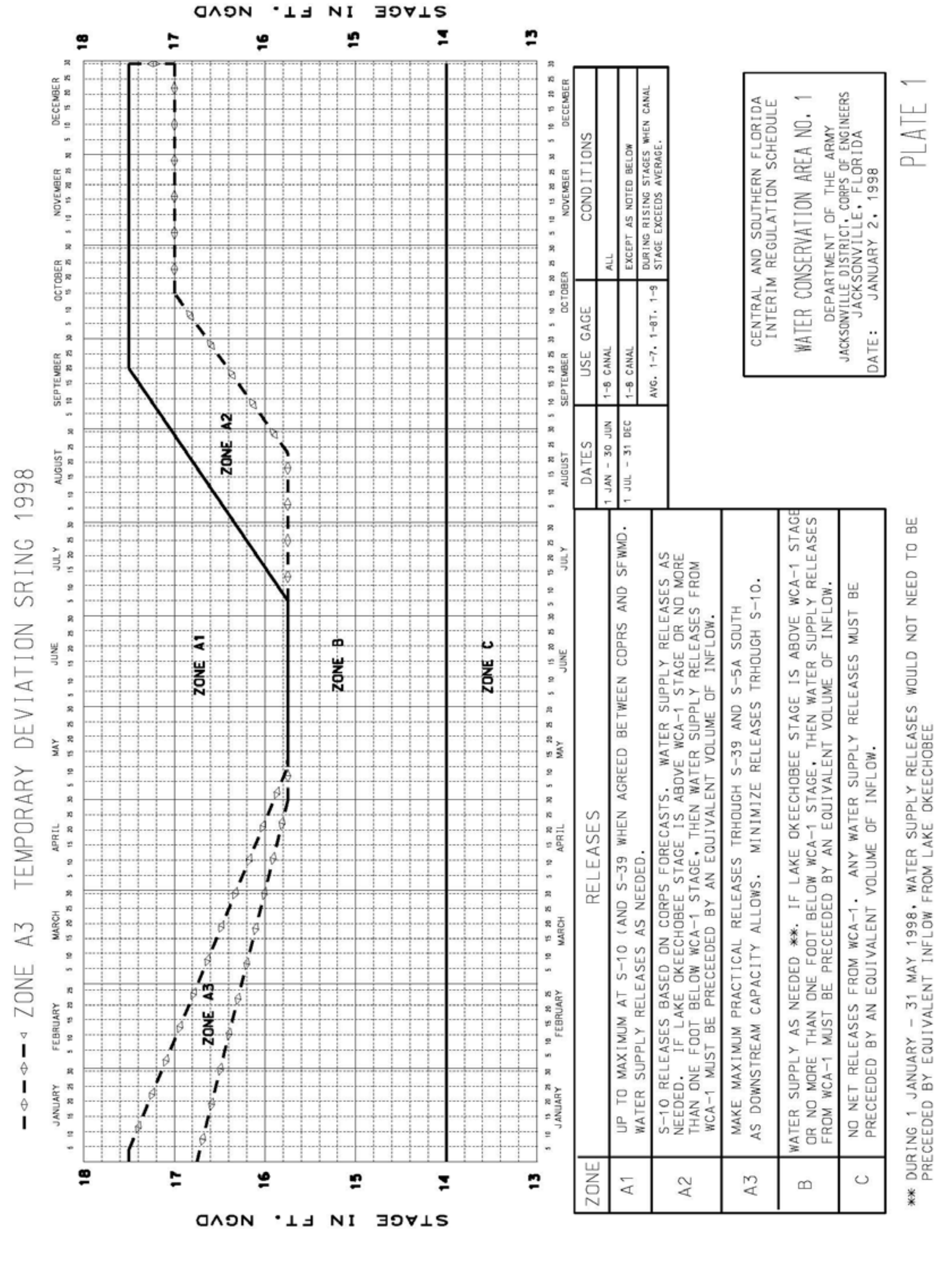


Figure 6. Temporary deviation to the WCA-1 water regulation schedule during 1998.

April 1, 2001 – December 31, 2001 (Figure 7): This temporary deviation was requested by SFWMD because of regionally dry conditions. The primary purpose of the deviation was to postpone water supply conditions that would necessitate SFWMD implementation of Phase III water use restrictions for urban and agricultural water users within the Lower East Coast Service area. The floor was lowered from 14.0 feet to 11.0 feet from June 1 to August 1. From April 20 (14.0 feet) to June 1 a linear water level deviation line would extend down until it reaches the 11.0 foot level on about June 1. The floor elevation line would remain at 11.0 feet until August 1 at which time it would increase linearly to return to 14.0 feet by October 1.

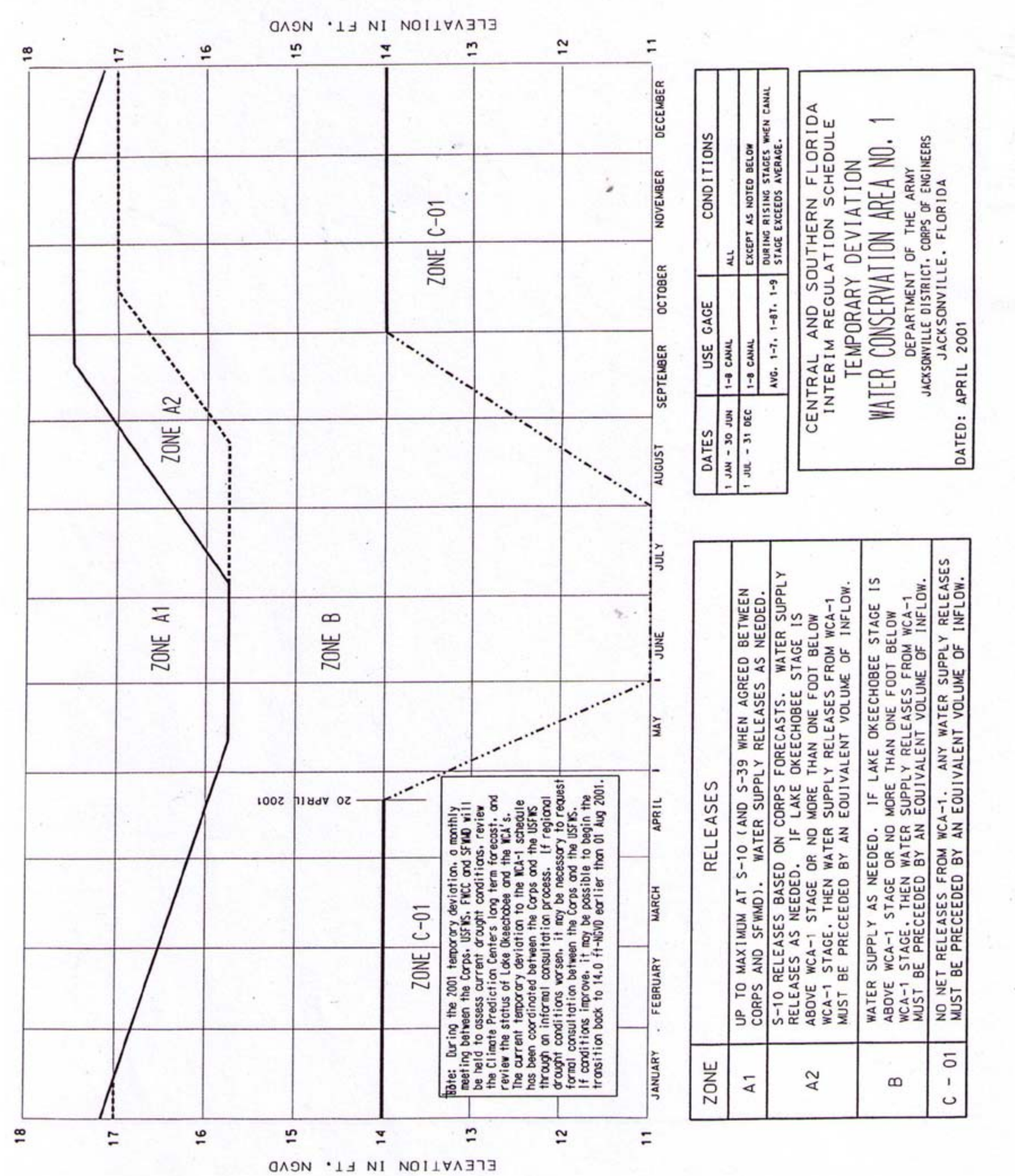


Figure 7. Temporary deviation to the WCA-1 water regulation schedule during 2001.

April 22, 2005-July 31, 2006: This temporary deviation was requested by SFWMD in 2005. The goals of the deviation were to reduce the unnecessary phosphorus load to the Refuge and to reduce the stress on STA-1W from treating the preceding inflows as required by the WCA-1 regulation schedule (USACE 2005). The deviation removed the requirement for preceding water supply deliveries with an equal volume of water when stages were in Zones A2 or B. The deviation included a “trigger” that would revert operations back to the existing regulation schedule (after discussion among USACE, SFWMD, Refuge, and Lake Worth Drainage District staff) if recession rate, as measured by the 1-9 and 1-8T gauges, was greater than 0.2 feet per week. This recession rate was selected to ensure that the deviation did not result in a recession rate that was unfavorable for wading birds.

2. Anticipated benefits of 1995 water regulation schedule

In this section, each of the six proposed benefits listed in the Finding of No Significant Impact and Environmental Assessment for the 1995 Water Regulation Schedule modification (USACE 1994; hereafter referred to as the EA) was examined and when possible, an ecological rationale for the benefit defined. An attempt was made to convert those rationales into measurable objectives for both hydrological and ecological conditions. Because the EA did not include measurable objectives, some assumptions had to be made concerning the scope, intent and magnitude of the expected benefits. Once a measurable objective was defined, a search of Refuge narratives and other files was conducted to determine if there were any data that could be used in evaluation of the objective. When data existed (primarily for hydrology), an analysis was conducted. Each anticipated benefits section includes a discussion of hydrological measures and expectations, hydrological evaluation, ecological measures and expectations, an ecological evaluation, additional information needs to better address if the anticipated hydrological and ecological benefits were achieved, and a summary.

The information is presented in the context of evaluating whether changing from the 1975 regulation schedule to the 1995 schedule has resulted in the benefits describe in the EA; however, all hydrologic changes observed may not be a direct result of the regulation schedule change. For example, periods of higher rainfall could result in greater water depths or longer hydroperiods in the absence of a regulation schedule change. Rainfall patterns are cyclical and wet years tend to follow wet years and dry years tend to follow dry years. Therefore, where in the cycle the periods of comparison are could influence hydrological patterns. Detailed evaluation of how rainfall patterns might be contributing to any differences observed in hydrology between the two time periods is beyond the scope of this document. Rainfall averaged 50.25±9.56 inches per year from 1975-9994 and 50.89±5.63 from 1995-2004.

Additionally, water depth, hydroperiods, and variances in water depth and hydroperiod may have been affected by deviations to the regulation schedule or changes in the locations of inflow and outflow locations. Detailed analysis of how those changes may have contributed to any observed changes also is beyond the scope of this document. The analyses in this document are presented as summaries of periods 1975 through 1994 and 1995 through 2005 with the assumption that the predominate difference between the hydrological conditions is because of changes in the regulation schedule, but with the knowledge that there are other confounding factors.

This document focuses only on the benefits and measures described in the EA. It does not discuss in detail the overall desired future conditions in the Refuge interior or whether the benefits (and ways of measuring them) presented in the 1995 document represent the optimum benefits on which to focus for future evaluations of Refuge conditions. It also does not discuss additional management actions, such as fire, that might help to achieve future desired conditions or if changes to the regulation schedule or water management operations have potentially affected water quality.

2.1 Methods used

Hydrologic data used in the analyses described below are primarily from four gauge stations currently maintained by USGS (1-8C, 1-8T, 1-9, 1-7, Figure 1). Data used were daily average values in feet NGVD. An assumption was made that for marsh gauges (1-8T, 1-9, 1-7) ground elevation at the gauge represents ground elevation of the surrounding slough. Additionally, it was assumed that there was a linear relationship between stage and depth when data were extrapolated to other elevations.

The 1-7 gauge (elevation of 15.0 feet NGVD) was used as the primary marsh indicator gauge with the assumption that higher stages in that area would result in higher stages in the north end. Actual data for this gauge are available for the entire period of record (1975-2005). Analysis also was performed using the 1-8C gauge as it is the primary regulatory gauge. On occasion, data from the other marsh gauges were used to supplement the analyses. In one analysis, a synthetic dataset (Waldon 2006) for an additional USGS gauge (North) was used in the analysis because actual data from the North gauge are only available since June 2001 on. Unless otherwise indicated, reference to years is based on the calendar year.

Elevation information was based on a contour map generated by Richardson et al. (1990) which indicates that approximately 61% of the Refuge is at elevation 15.0 feet NGVD or above, 34% of the Refuge is at an elevation of 15.5 feet or above; and 11% of the Refuge is at an elevation of 16.0 feet or above (Figure 8). The analyses presented in this document focus on the areas of elevation 15.0 feet and above because the primary purpose of the regulation schedule change was to improve conditions in the northern 20,000 acres of the Refuge interior. The northern 20,000 acres of the Refuge interior includes elevation contours from 15.4 to 16.3 feet with an average elevation of 15.8 feet NGVD.

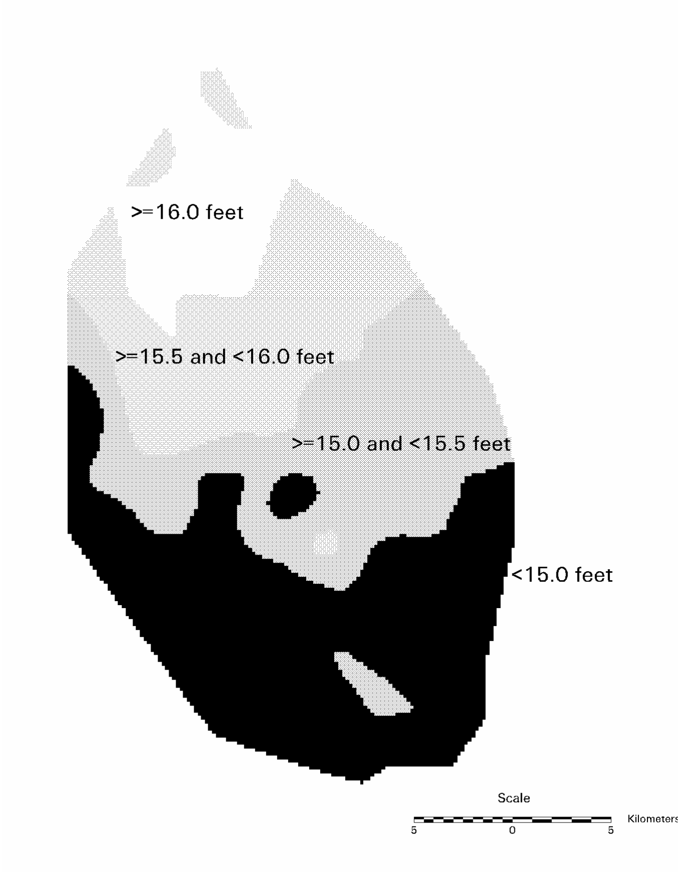


Figure 8. Elevation bands showing elevations ≥ 16.0 feet, ≥ 15.5 feet and < 16.0 feet, ≥ 15.0 feet and < 15.5 feet and <15.0 feet. The northern 20,000 acres of the Refuge interior has an average elevation of 15.8 feet NGVD with a range from 15.4 to 16.3 feet. Contours are from Richardson et al. 1990.

The periods of record used for these analyses are January 1, 1975 - December 31, 1994 for the previous regulation schedule and January 1, 1995 - December 31, 2005 for the current regulation schedule.

Data analysis consisted of a combination of visual inspection of graphs and tables, and when possible, statistical analysis. When data met assumptions of normality and homogeneity of variances (F test), t-tests or paired t-tests were used. When data did not meet those assumptions or were expressed as percentages a non-parametric Mann-Whitney U-test was used. A p value of < 0.05 was used to determine significance. Unless otherwise noted, averages are expressed plus or minus one standard deviation (S.D.).

2.2 Benefits listed in the 1995 Water Regulation Schedule modification EA

2.2.1 Benefit 1 - Allow higher water levels during wet years in the northern portion of the Refuge.

Ecological Rationale *Reverse the trend of invasion of sawgrass by brush and of conversion of wet prairie to sawgrass. Bring 20,000 acres of marsh in the northern quarter of the Refuge back into productive marsh condition. Avoid yearly dry-outs.*

2.2.1.1 Hydrological Measures

1) Average monthly water stage using 1-7 (marsh) and 1-8C (canal) gauges. Average monthly water stage using synthetic data for North gauge (marsh).
2) Number of years when stage went below ground surface at elevations (dry-outs) of 15.0, 15.5, 16.0 feet using 1-7 gauge data (also see discussion on hydroperiod for Benefit 2, section 2.2.2.1).

Hydrological Expectations

1) No specific target was listed in the EA for how much higher water level should be therefore a statistical analysis was performed (1995-2005 water levels should be higher than 1975-1994 water levels at 1-7 and 1-8C) with discussion as to whether the resulting differences in depth may be ecologically significant.
2) Percentage of years with dry-outs in the Refuge interior from 1995-2005 schedule should be lower than percentage of dry-outs from 1975-1994.

Hydrological Evaluation

1) Monthly average stage was statistically significantly higher during 1995-2005 than 1975-1994 for the 1-8C, 1-7 and synthesized North data (paired t-test, $t = -12.458$, -14.80, and -12.020; all $p<0.01$ for 1-8C, 1-7, and North, respectively). Seasonal pattern of fluctuations in average monthly stage is similar for all three gauges for the two time periods.

   Average monthly stage difference from 1995-2005 at 1-8C ranged from 0.63 feet (September) to 1.34 feet (April) higher than from 1975-1994 (Figure 9). Average stage difference between the two time periods at 1-8C was 0.85 feet ± 0.24 S.D (Figure 10).

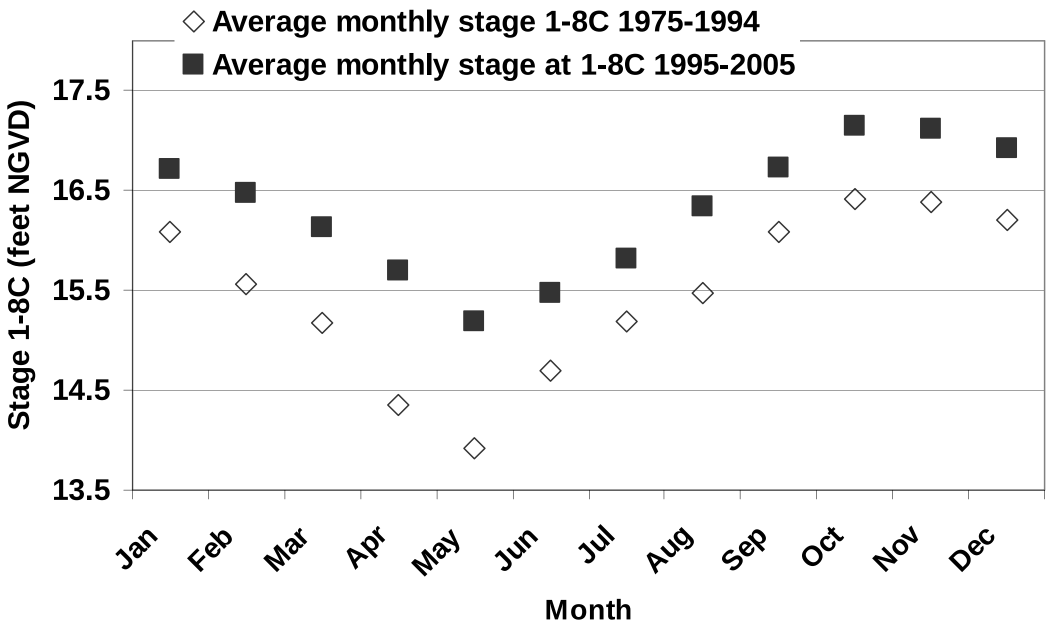


Figure 9. Comparison of average monthly stage at the 1-8C from 1975-1994 and 1995-2005.

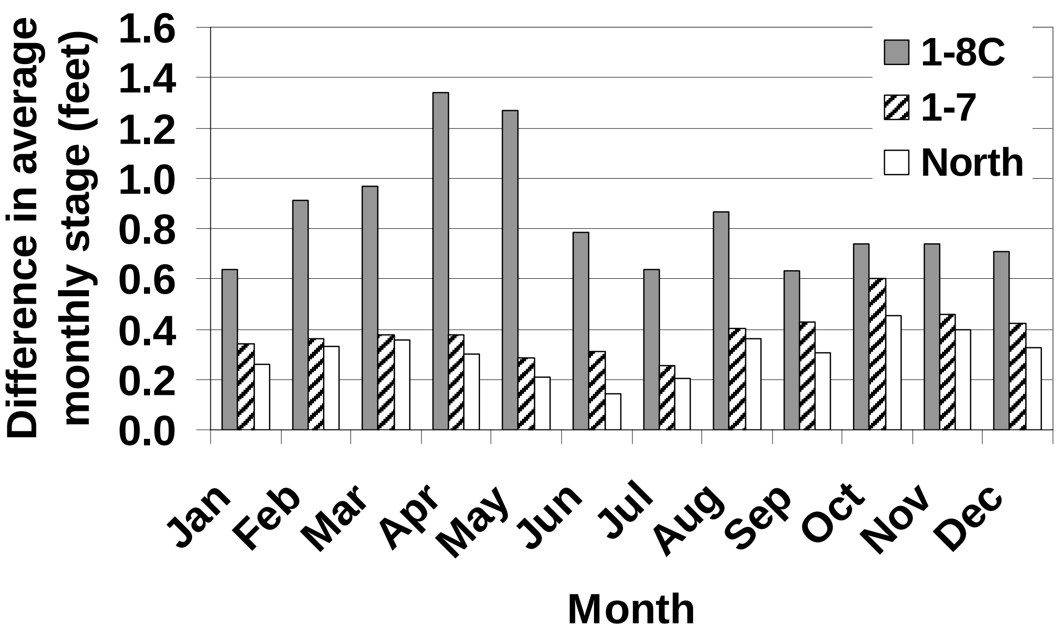


Figure 10. Difference in average monthly stage at the 1-8C, 1-7, and North (synthesized) gauges between 1995-2005 and 1975-1994.

Average monthly stage difference from 1995-2005 at 1-7 ranged from 0.26 feet (July) to 0.60 feet higher (October) than from 1975-1994 (Figure 11). Average stage difference between the two time periods at 1-7 is 0.38 feet ± 0.09. (Figure 10).

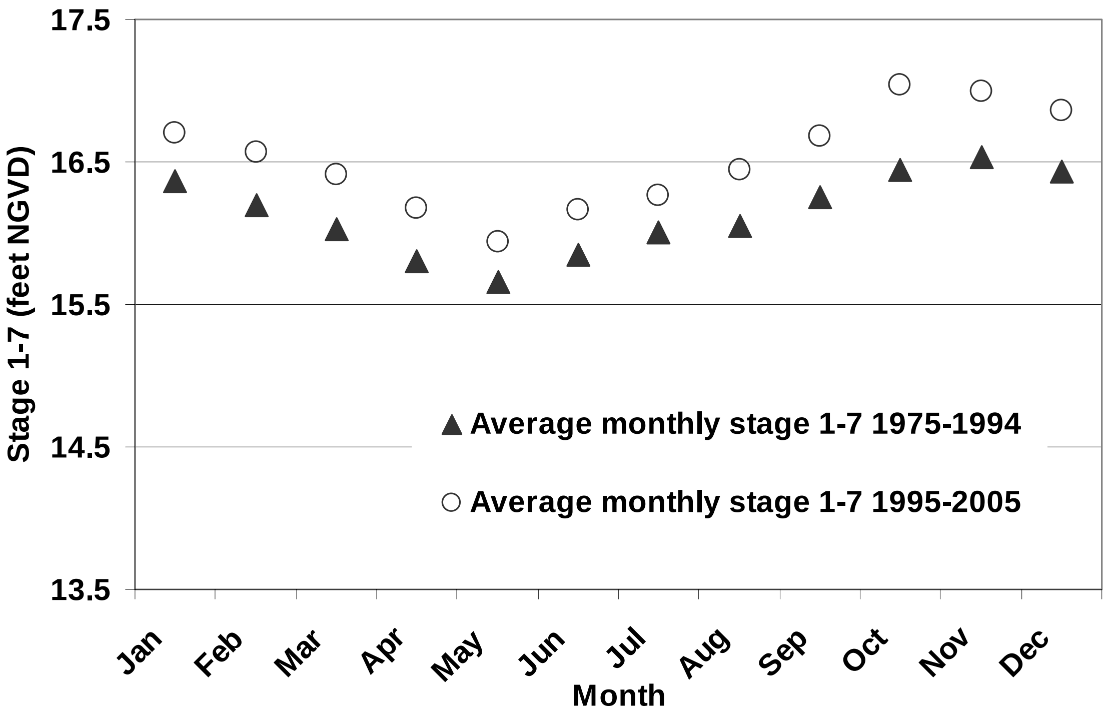


Figure 11. Comparison of synthesized average monthly stage at the 1-7 gauge from 1975-1994 and 1995-2005.

Average monthly stage difference from 1995-2005 at the North gauge (synthesized) ranged from 0.45 feet (October) to 0.14 feet (June) higher than from 1975-1994 (Figure 12). Average stage difference between the two time periods at the North gauge is 0.30 feet ± 0.09 S.D (Figure 10).

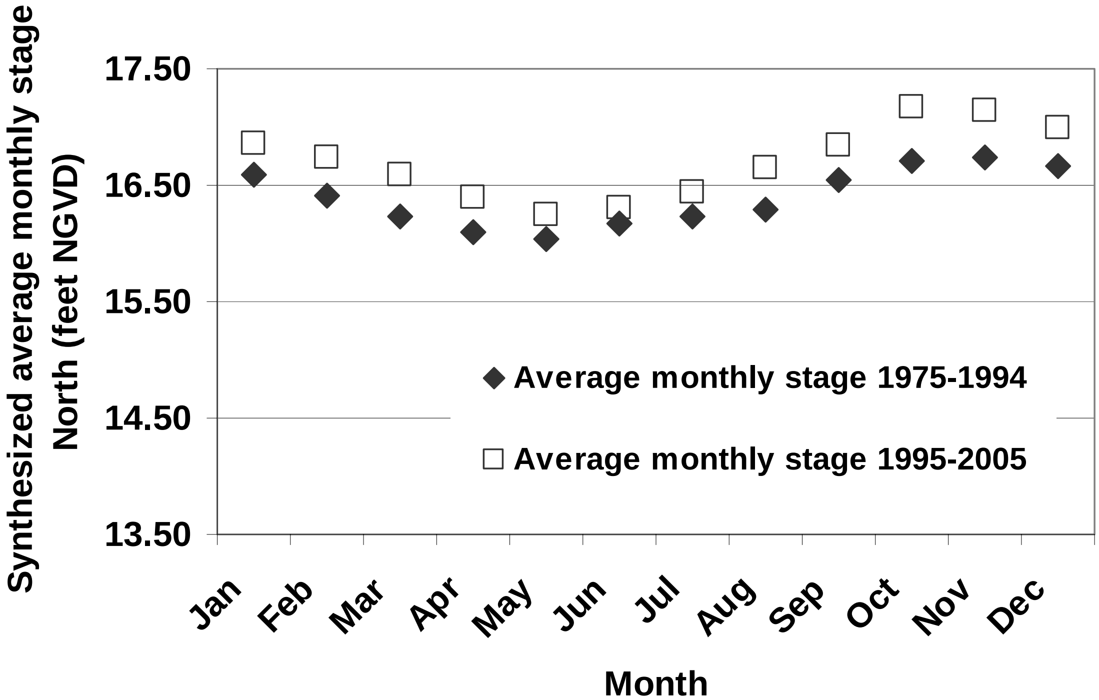


Figure 12. Comparison of synthesized average monthly stage at the North gauge from 1975-1994 and 1995-2005.

2) See Benefit 2, section 2.2.2.1

2.2.1.2 Ecological Measures

1) Acres of sawgrass, brush, and wet prairie in the northern 20,000 acres of marsh in 1975, 1995, and 2005. Expressed as percent of sample points or percent of total Refuge interior.
2) Acres of sawgrass converted to sawgrass/brush or brush in the northern part of the marsh (1975 to 1995; 1995 to 2005). Expressed as change in percent.
3) Acres of wet prairie converted to sawgrass in the northern part of the marsh (1975 to 1995; 1995 to 2005). Expressed as change in percent.

<u>Ecological Expectations</u>

1) Acres of brush in the northern 20,000 acres of marsh should decrease from 1995 to 2005.
2) Rate of conversion of sawgrass to sawgrass/brush or brush in the northern part of the marsh should be lower from 1995 to 2005 than from 1975 to 1995.
3) Rate of conversion of wet prairie to sawgrass in the northern part of the marsh should be lower from 1995 to 2005 than from 1975 to1995.

Ecological Evaluation

No specific data have been collected to address changes in ecological communities from 1995 to 2005. Two data sets provide information on conditions prior to the 1995 regulation schedule change. In the late 1960s and early 1970s, Hagenbuck et al. (1974) used a combination of ground transects and aerial photograph interpretation to understand relationships between water-level fluctuation and plant-community distribution. These data provided information and rationale for the change from the 1969 to 1975 regulation schedule (reducing water levels in the Refuge interior, especially during the dry season). In the late 1980s and early 1990, Richardson et al. (1990) conducted a study on the relationships of plant communities to water quality, quantity, and hydroperiod. They used satellite imagery to create a vegetation map and conducted field sampling at over 251 points. Both of these studies provide some information on the percentage of the Refuge interior in different community types, but neither of them provide information on conditions since the 1995 regulation schedule change. The discussion below refers to changes that occurred prior to the implementation of the current water regulation schedule.

Community classes from the point information from Hagenbuck et al. (1974) and Richardson et al. (1990) were merged to common classes (see Appendix 2 for list of classes used) of slough, wet prairie, sawgrass, brush and other. Percentage of the Refuge interior estimated to be in those classes based on the point data was compared between the two datasets (early 1970s and late 1980s). The biggest changes between the two datasets was observed in sawgrass which decreased by 12%, brush which increased by 8%, and other classes which increased by 5% (Figure 13). Cattail and open water accounted for much of the change in the other category. Examination of these two datasets provides information on rate of change across the entire Refuge interior prior to initiation of the current schedule (early 1970s to late 1980s), but do not provide any information on the spatial patterns of change (i.e. changes in the north) or which communities changed to which other different communities.

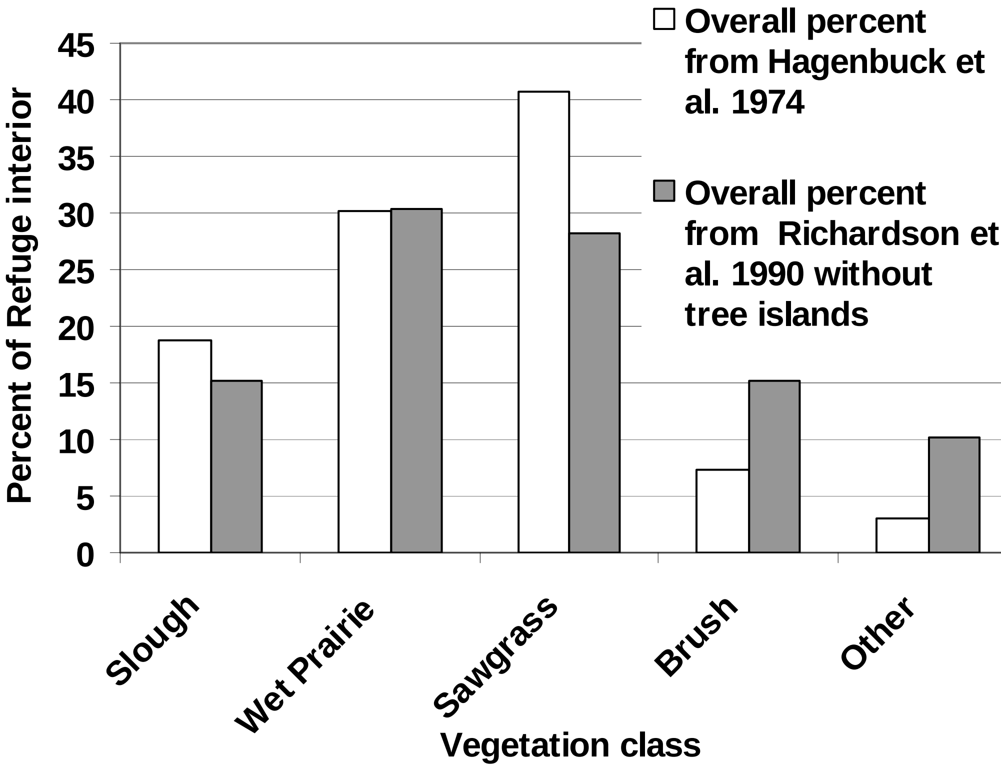


Figure 13. Estimated percent of the Refuge interior covered by each vegetation class based on point data from Hagnebuck et al. (1974) and Richardson et al. (1990). See Appendix 2 for grouping of original vegetation classes.

Hagenbuck et al.'s (1974) data could not be examined by location, but data from Richardson et al. 1990 was examined by location within the north, central, or south part of the Refuge interior. Relative percent cover of the vegetation classes in the north (north of 26 degrees 35 min), central (between 26 degrees 35 min and 26 degrees 28 min) and south (south of 26 degrees 28 min) were compared for the point data (data collected on the ground). The most notable differences are in the higher percent of brush and the lower percent of slough in the north compared to the other areas (Figure 14).

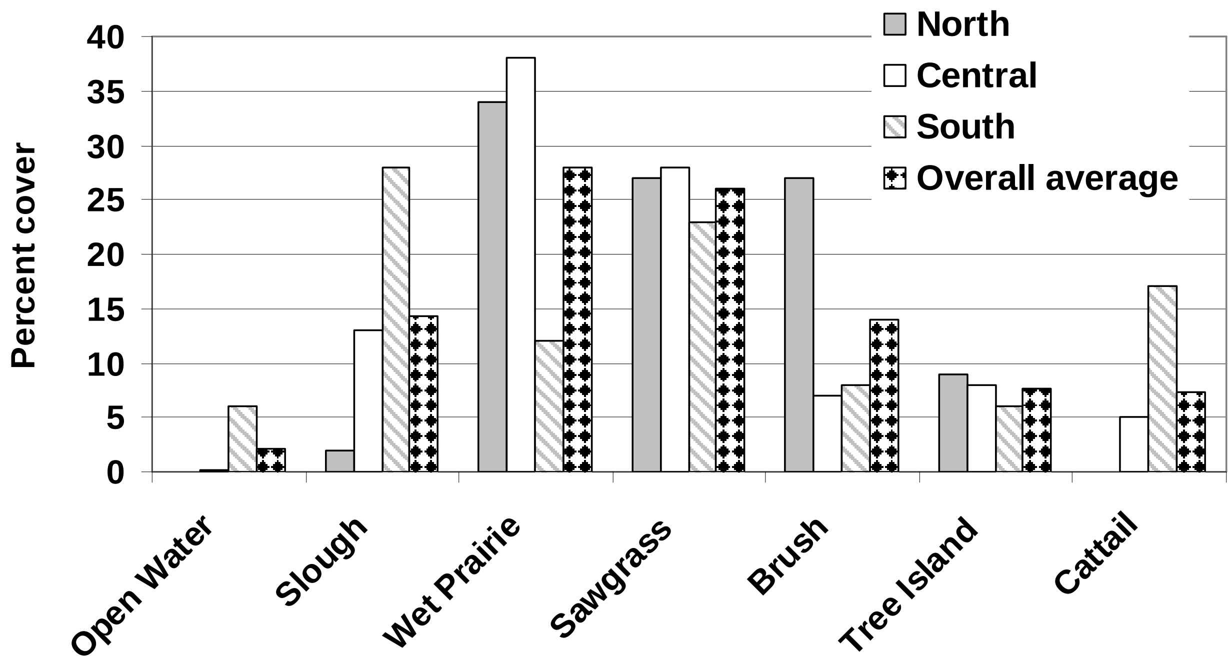


Figure 14. Percent cover of vegetation in 1987 in the north (49 points), central (135 points), and south (67 points) parts of refuge based on field data. Data are from Richardson et al. 1990.

The satellite image classification also was used to compare relative percent of each vegetation class in the north, central, and south parts of the Refuge interior. Based on an aggregation of classes in that map (see Appendix 2), the biggest difference between the north and other areas was a lower percent of wet prairie and sawgrass and a higher percentage of sawgrass/brush and brush than in the other areas (Figure 15).

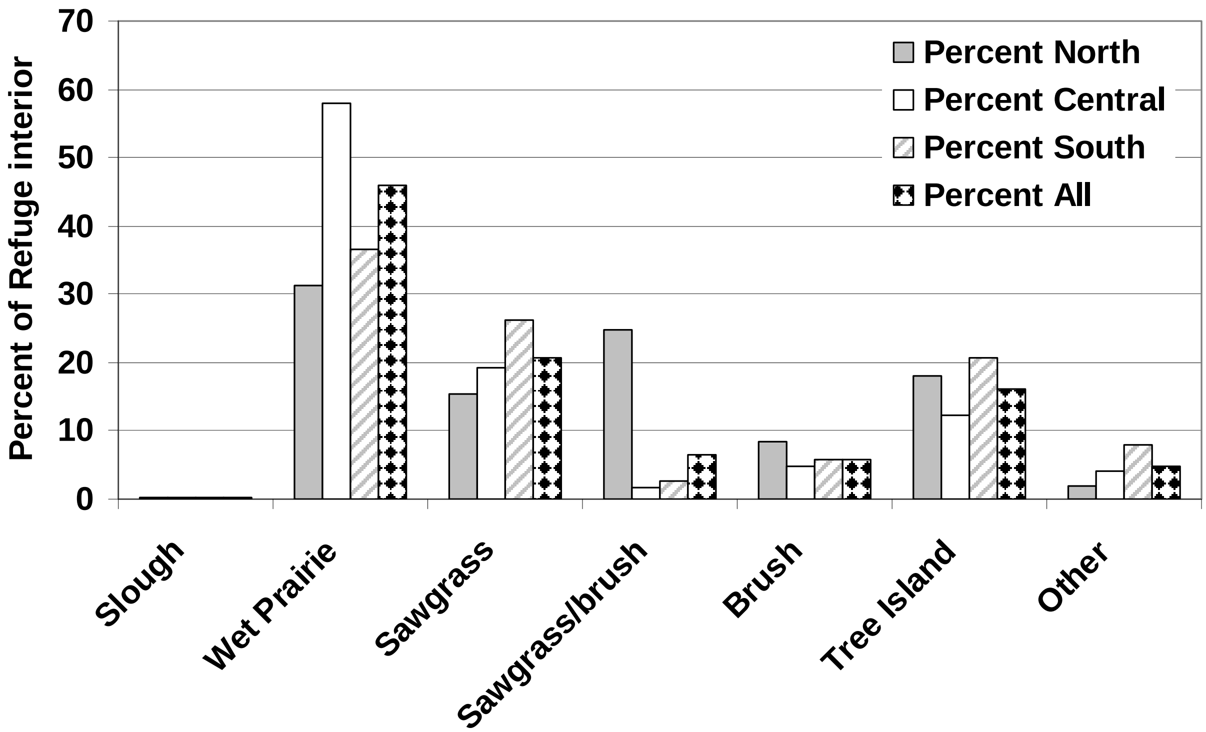


Figure 15. Percent cover of vegetation in the Refuge interior shown for the entire area and by North, Central, and South. Data are from a 1987 satellite image classification (Richardson et al. 1990). See Appendix 2 for grouping of original vegetation classes.

The data described above are some of the few sets of quantitative data available for vegetation throughout the Refuge interior. This information can provide a starting point for examining patterns of change; however, caution should be used in directly comparing results of the satellite image classification with other remotely sensed classifications (aerial photo interpretation, IKONOS data, etc) and ground data as each have their own limitations and biases and are not necessarily directly comparable. For example, it is more difficult to distinguish between slough and wet prairie from satellite image data than in the field; therefore, field results and classified image results for those classes individually may be different. An appropriate method may be to compare relative percentages of vegetation classes within each dataset and then compare those relationships among datasets. For example, for both sets of data from 1987 (point data and satellite image classification) the north part of the Refuge interior has proportionally more brush or sawgrass/brush than the rest of the Refuge interior. The expectation from the 1995 regulation schedule is that over time there should be less sawgrass/brush and brush in the north (assuming conversion to brush is reversible with just hydrologic changes), presumably moving toward percentages more similar to the central and south areas.

Analyses described in Appendix 1 using water depths taken on the same day in adjacent community types suggest that water depth differences (and hence elevation) of approximately 0.33 feet exist between slough and wet prairie and of approximately 0.27 feet between wet prairie and sawgrass. In addition, there is only approximately 0.16 feet difference in water depth (surface elevation) between sawgrass and brush (Table 1).

Based on the overall average changes in water depth at the marsh gauges (0.38 and 0.30 feet for the 1-7 and North gauges, respectively) and information on average differences in surface elevations between different vegetation communities (Table 1 and Appendix 1) it is likely that the greater average depths since 1995 could have contributed to shifts in vegetation in the north part of the Refuge interior. However, without past and current information on the extent and location of the different vegetation communities it is impossible to determine the extent and direction of change. Therefore, these measures cannot be evaluated fully at this time.

2.2.1.3 Additional information that would improve assessment

- Remote sensing could be used to develop a retrospective analysis of past and current vegetation patterns and where there have been changes over time. It will be important to be able to show where vegetation classes have changed, as well as to what class they have changed.
- A base line (current conditions) vegetation map that can be used to track changes in location and amount of shrub/brush, sawgrass, wet prairie, and slough in the future. (completion of SWFMD vegetation map from 2003/2004 imagery may provide this).
- A mechanism for tracking changes in the above communities on three to five year intervals to answer the question: Are there changes in the location and extent of the target communities? A broad scale approach such as the above vegetation map combined with on the ground field sampling at a finer scale (such as 100 acre vegetation plots or transects that have been used historically) that targets areas where change might be expected to occur should provide the most useful information.
- Linking vegetation changes (from retrospective and current analysis) to hydrological patterns to address the question: Are changes in amount and location of target communities correlated with hydrology?
- Development and application of hydrological models at a fine enough scale (a grid size no greater than 0.31 mile (500 m) in width) to relate hydrology to vegetation.

2.2.1.4 Summary

- There is not sufficient existing information on vegetation changes to address fully whether the desired ecological benefits described in the ecological rationale have been achieved.
- Average monthly stages in the marsh and canal are statistically significantly higher from 1995-2005 than from 1975-1994.
- Average monthly marsh stages are possibly high enough to contribute to the desired changes of halting conversion of wet prairie to sawgrass and sawgrass to brush; however, insufficient data exist to evaluate this with confidence.
- Retrospective analyses and current monitoring are necessary to further evaluate whether vegetation changes have occurred, whether they are the ones desired, and how much of the change has been (or continues to be) caused by the change in the regulation schedule.

2.2.2. Benefit 2 - Increase the hydroperiods of interior marsh so dry-out does not occur annually

Ecological Rationale *The desire was to have larger populations of aquatic organisms and to increase protection against drought by having greater year round water storage. Avoid yearly dry-outs.*

2.2.2.1 Hydrological Measures

1) Average yearly hydroperiod expressed as percent of year using the 1-7 gauge and extrapolating to 15.5 and 16.0 feet NGVD. Average yearly growing season (March 1-June 30) hydroperiod expressed as a percent using the 1-7 gauge and extrapolating to 15.5 and 16.0 feet NGVD.
2) Number of years when stage went below ground surface for at least one day at elevations of 15.0, 15.5, 16.0 feet using the 1-7 gauge data.

Hydrological Expectations

1) Average yearly hydroperiod and average yearly growing season hydroperiod at elevations of 15.0, 15.5 and 16.0 feet should be longer from 1995-2005 than from 1975-1994. There was no indication in the EA as to the extent of increase that would be ecologically relevant. Goodrick (1974) describes how species composition and vegetation biomass are influenced by hydroperiod. In his study in Water Conservation Area 3, hydrologic data accounted for difference in vegetation (slough or wet parairie) at two sites. Percent occurrence of dry season (April-May) water level below ground elevation was twice as great (60%) at the wet prairie site than at the slough site (30%). Stated differently, the April-May hydroperiod in wet prairie was 40% while the April-May hydroperiod in slough was 70%. In addition, Ross et al. (2003) found that in Shark Slough, Everglades National Park, that changes in hydroperiod of two months could result in changes in vegetation communities. Current annual hydroperiod targets for the Refuge include an average hydroperiod of 11 months (92%) with a range of 9-12 month (75-100%; U.S. Corps of Engineers 2006). 1995-2005 hydroperiods should be closer to those targets than 1975-1994 hydroperiods.

2) Percentage of years with dry-outs should be lower from 1995-2005 than from 1975-1994 at 15.0, 15.5 and 16.0 feet. The frequency of dry-outs should not be every year from 1995-2005. The current target for frequency of dry down to surface (dry-out) is no more frequently than once every three to five years (33% to 20% of the time, respectively). These numbers are based on evaluation of patterns of dry-out throughout the Everglades (RECOVER 2006) Refuge narratives document numerous references to the need for the marsh to dry-out for 30-45 days during the spring for regeneration of beak rush. The schedule was changed in 1975 in part to allow the marsh to dry out for a minimum of 30 days every two to three years. A pattern that allows for dry-outs to occur on average once every three to five years may be appropriate (20-33% of the years dry-out). Hydroperiod and frequency of dry-out changes will be discussed in the context of these targets.

Hydrological Evaluation

Yearly hydroperiod (expressed as a percent) and growing season hydroperiod were calculated for each year based on the data from the 1-7 gauge. Approximations of hydroperiod north of the 1-7 gauge were calculated by counting the number of days 1-7 gauge reading was <15.5 feet and < 16.0 feet NGVD.

1) Average yearly hydroperiod from 1995-2005 is longer than from 1975-1994 at all three elevations; however, the differences are statistically significant only at 15.5 feet (Mann Whitney U test, z=-2.501, p=0.006) and 16.0 feet (z=-1.689, p=0.046; Table 2; Figure 16). Differences in hydroperiod between the two time periods ranged from 3% (< 1 month) at 15.0 feet to 23% (approximately 3 months) at 16.0 feet. At 15.5 feet, hydroperiod increased from about and 10 to 11 months to 11 to 12 months. Both ranges are within the current target of 9 to 12 months and this difference may not be enough to result in significant changes in vegetation communities. The change at 16.0 feet, 23% equates to a change in hydroperiod of approximately 2 to 3 months and probably does result in vegetation community change, though water depth also should be considered when assessing whether occurance of a change is likely.

Table 2. Average yearly hydroperiod (% ± S.D.) from 1975-1995 and 1995-2005 at elevations of 15.0, 15.5, and 16.0 feet NGVD. Hydroperiods based on data for the 1-7 gauge.

	15.0 feet NGVD	15.5 feet NGVD	16.0 feet NGVD
Mean 1975-1995 (range; months)	97% ±13 (41-100%; 5-12)	88%±21 (19-100%; 2-12)	63%±26 (0-96%; 0-12)
Mean 1995-2005 (range; months)	100%±0.3 (99-100%; 12)	99%±3 (89-100%; 11-12)	86%±12 (58-100%; 7-12)
Statistically different?	No	Yes z=-2.501; p=0.006	Yes z=-1.689; p=0.046
Ecologically different?	No	Maybe	Yes

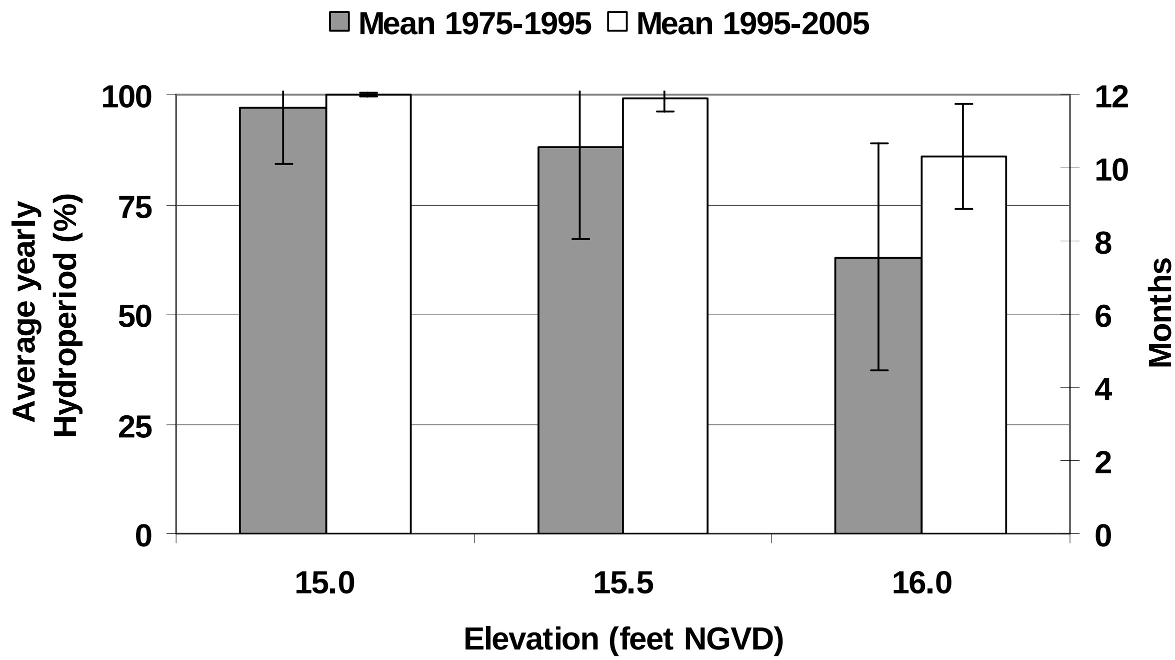


Figure 16. Average yearly hydroperiod (%) ±S.D. for elevation 15.0, 15.5, 16.0 feet NGVD based on data for the 1-7 gauge for 1975-1994 and 1995-2005.

Average annual hydroperiod is less variable from 1995-2005 than from 1975-1994 at all three elevations. This may be an artifact of operations within the schedule (managing to the top of the schedule) rather than a direct result of changing the upper and lower bounds of the schedule. Variability in hydrological conditions is an important factor in maintaining Everglades communities (Gunderson 1994, Holling et al. 1994) and this reduction of variation may have as much of an influence on vegetation patterns as the relatively small changes in hydroperiod observed at 15.0 feet.

Analysis of growing season (spring) hydroperiod followed Hagenbuck et al. (1974). They assumed that variation in emergent plant distribution in the marsh was largely regulated by inundation during the spring growing season. Spring growing season was defined as March 1 to June 30. Hagenbuck et al. (1974) estimated that areas with spring inundation (hydroperiod) of 80% or greater would be primarily slough, areas with 55% spring hydroperiod wet prairie, areas with 30% spring inundation sawgrass, and areas with 15% or less spring inundation brush and sawgrass.

Growing season hydroperiod was longer from 1995-2005 than from 1975-1994; however, only the 16.0 feet elevation growing season hydroperiod increase was statistically significant ($z=-2.077$, $p=0.019$; Table 3). Variation in growing season hydroperiod was statistically significantly different at 15.0 and 15.5 feet ($F=513.7$ and 12.8, respectively, $p<0.001$) from 1995-2005 compared to 1975-1994.

Table 3. Average growing season (March 1-June 30) hydroperiod (% ± S.D.) from 1975-1995 and 1995-2005 at elevations of 15.0, 15.5, and 16.0 feet NGVD. Hydroperiods based on data for the 1-7 gauge.

	15.0 feet NGVD	15.5 feet NGVD	16.0 feet NGVD
Mean 1975-1995 (range; months)	94%± 22 (0-100%; 0-4)	79% ±33 (0-100%; 0-4)	39%±34 (0-89%; 0-4)
Mean 1995-2004 (range; months)	100%± 0.9 (97-100%; 4)	97%± 9 (69-100%; 3-4)	67%±28 (0-100%; 0-4)
Statistically different?	No	No	Yes z=-2.077; -p=0.019
Ecologically different?	No	Maybe	Yes

Based on Hagenbuck et al.'s (1974) criterion growing season hydroperiod at 15.0 feet would favor slough during both time periods, while at 15.5 feet slough would be favored from 1995-2005 and slough and wet prairie from 1975-1994. At 16.0 feet, wet prairie would be favored from 1995-2005 and sawgrass from 1975-1994.

2) Number of years when there were dry-outs at 15.0, 15.5, and 16.0 feet for the two periods were calculated to address the question of whether annual dry-outs occurred and to quantify number of dry-outs at different elevations. From 1975-1994 parts of the marsh with an elevation of 16.0 feet or greater dried out every year (100%). From 1995-2005 the same area dried out 10 of 11 years (91%). At the lower elevations of 15.5 feet, dry-outs occurred in 9 of 20 years (45%) and 3 of 11 years (27%) from 1975-1994 and 1995-2005, respectively. At 15.0 feet, the frequency of dry-outs was 4 of 20 years (20%) and 2 of 11 years (18%).

   Hydroperiods have been longer and water depths greater from 1995-2005 than from1975-1994 but have not resulted in a reduction in the frequency of dry-out at elevations above 16.0 feet. At 15.5 feet frequency of dry-outs changed from a frequency of approximately one in every two years to one in every three years. The latter is within the range of once every three to five years (33% to 20% of the time) believed to be desirable. However, timing of the dry-outs and effects on aquatic fauna and vegetation (see section on aquatic fauna) also need to be considered. For example, three dry-outs have occurred since 2001 one in 2001, 2004, and 2005. Three or more years of dry conditions can change marsh communities (Wetzel 2001), if conditions were such that there was a dry-out at 15.5 feet in 2006 the pattern of dry-outs would be three years in a row and the long-term percentage of years with dry-out increases to 33% the top end of the range felt to be desirable. An additional dry-out in 2007 would increase the consecutive years of dry-out to four and percentage of years to 38%, a frequency considered undesirable.

2.2.2.2 Ecological Measures

1) Density and distribution of aquatic organisms. There was little information in the EA explaining which aquatic organisms were the target organisms. Here it is assumed that the reference was to fish that are typically food for wading birds, i.e., small fish that are

generally less than three inches in maximum adult length (Trexler et al. 2004) and apple snails, the primary food of the endangered snail kite.

<u>Ecological Expectations</u>

1) Density and distribution of aquatic organisms from 1995-2005 should be greater than from 1975-1994.

<u>Ecological Evaluation</u>

See anticipated benefit 3 (Section 2.2.3) for discussion of density and distribution of aquatic organisms.

2.2.2.3 Additional information that would improve assessment

- Development and application of hydrological models at a fine enough scale (a grid size no greater than 0.31 mile (500 m) in width) to relate hydrology and aquatic fauna distribution and abundance.
- See Section 2.3.3 for discussion of needs for density and distribution of aquatic organisms.

2.2.2.4 Summary

- Although hydroperiods (both annual and growing season) were longer at all three elevations from 1995-2005 compared to 1975-1995, only increases in hydroperiod at elevation above 16.0 feet are likely to have been ecologically significant. Hydroperiods in other areas changed by less than two months and were already within the current target ranges of 9 to 12 months.
- Hydroperiods in the more northern areas of the Refuge interior with higher elevation currently favor wetter communities compared to conductions under the previous regulation schedule. This is consistent with the objectives of the schedule change.
- Hydroperiods have been longer and water depths greater from 1995-2005 than from1975-1994 but have not resulted in a reduction in the frequency of dry-out at elevations above 16.0 feet.
- At 15.5 feet, frequency of dry-outs has decreased to one in every three years from one in every two years. The latter is within the range of once every three to five years (33% to 20% of the time) believed to be desirable and is consistent with the purposes of the regulation schedule change.

2.2.3. Benefit 3. Increase the proportion of marsh habitat that serves as nursery areas for aquatic organisms

Ecological Rationale *Increase aquatic productivity.*

2.2.3.1 Hydrological Measures

1) Number of years between dry-outs at 15.0, 15.5, and 16.0 feet.
2) Percentage of years with at least three years between dry-outs. Sampling in Everglades National Park and Water Conservation Area 3 has shown that fish densities decline when water level falls below ground surface and that it requires approximately three years of continuous inundation for small-bodied fish to fully recover to pre dry-down numbers (Trexler and Loftus 2001 in Trexler et al. 2004).
3) Percentage of time that water depth was >0.325 feet during peak apple snail egg laying (April through June). The life cycle of the apple snail is highly adapted to seasonal hydrological conditions. Eggs are laid between March and October with the peak of laying between April and June. If water depths during this period drop below approximately 0.325 feet (4 inches) reproductive output decreases because snails will settle in one spot and close the operculum to conserve moisture; hence they are no longer moving around to mate and lay eggs.

<u>Hydrological Expectations</u>

1) Average number of years between dry-outs should be greater from 1995-2005 than from 1975-1994.
2) Percentage of years with at least three years between dry-out and percentage of years when dry-out occurred more frequently than once every three years will be lower from 1995-2005 than for 1975-1994.
3) There is a higher percentage of days during the April through June period with water depths above 0.325 feet from 1995-2005 than from 1975-1994.

<u>Hydrological Evaluation</u>

1) Average number of years between dry-outs increased from 2.5 to 5.2; from 1.4 to 3.3; and from 0 to 0.1 at elevations of 15.0, 15.5, and 16.0 feet, respectively.
2) Percentage of years with at least three years between dry-outs was higher from 1995-2005 than from 1975-1994 at 15.0 and 15.5 feet but not at 16.0 feet (Table 4).
3) At all elevations, average percent of days in April-June when water depths were >0.325 feet was significantly higher from 1995-2005 than from 1975-1994 (Table 5; t-stat=-1.771, p=0.045; t-stat=-2.294, p=0.015; t-stat=-2.247, p=0.019 for 15.0, 15.5, and 16.0 feet, respectively).

Table 4. Percentage of years at different elevations with at least three years between dry outs.

Elevation (feet NGVD)	Percentage of years 1975-1994 when there was at least three years between dry outs	Percentage of years 1995-2005 when there was at least three years between dry outs	**Ecologically different?**
15.0	45%	64%	Yes
15.5	20%	55%	Yes
16.0	0%	0%	No

Table 5. Average percentage of days in April - June when water depths were >0.325 ft, the minimum water level for apple snail egg laying.

Elevation (feet NGVD)	1975-1994	1995-2005	**Statistically different?**	**Ecologically different?**
15.0	86%±29	98%±7	Yes t=-1.771, p=0.045	Maybe
15.5	53%±41	80%±26	Yes t=-2.294, p=0.015	Yes
16.0	8%±15	23%±19	Yes t=-2.247, p=0.019	No

2.2.3.2 **Ecological Measures**

1) Density and distribution of aquatic organisms. There was little information in the EA explaining which aquatic organisms were the target organisms. Here it was assumed that the reference was to fish that are typically food for wading birds, i.e., small fish that are generally less than three inches in maximum adult length (Trexler et al. 2004) and apple snails, the primary food of the endangered snail kite. Measures that can be used include number of fish or apple snails per m^2 and biomass of fish collected from throw trapping.

<u>Ecological Expectations</u>

1) Density and distribution of aquatic organisms as measured from throw traps should be greater from 1995-2005 than from 1975-1994.

<u>Ecological Evaluation</u>

1) There was one study on aquatic fauna (fish and decapods) conducted from 1990-1992 (Jordan 1996) that provides limited information on fish density during the 1975-1994 period in the Refuge. There are some references in Refuge annual narratives to apple snail egg cluster transects surveyed in the 1970s; however, detailed information and data are not available to accompany the observation of "lower numbers of egg clusters and snail densities (5-10 per hour of night searching) than in previous years" (USFWS 1972). No studies were set up to monitor aquatic fauna in response to the change in the regulation schedule. There are four more recent studies on fish and one on apples snails that can provide some information for future monitoring and evaluation.

Jordan (1996) conducted a study from 1990-1992 as part of his dissertation and in association with work conducted by Richardson et al. (1990). Jordan used throw trapping to collect data on fish density and biomass. He found an average overall density of fish of 26 fish per m^2. Habitat accounted for only 9% of the variation in density while 22% of the variation was accounted for by location. Highest fish density was in slough (42 fish per m^2), intermediate density in wet prairie (22 fish per m^2), and lowest density in sawgrass (14 fish per m^2). He did not observe an extended response to the dry-out that occurred in 1992 as densities returned to pre-dry-out numbers within two months.

Jordan's second study conducted in 2000-2001 under a Special Use Permit (SUP #41560-00014; Jordan 2000) looked at fish and decapods as health indicators of freshwater marshes. He again used throw trapping to collect information on fish density during July 2000, in wet prairies at six locations throughout the Refuge interior. On average, there were 23 fish per m^2 and fish densities ranged from 0 to 81 fish per m^2. Differences in fish density among sites appeared to reflect recent hydrological conditions; interior sites to the north had only been inundated for a few days, whereas southern sites probably had remained flooded during the 2000 drought. Density of fish collected from wet prairies in July 2000 was virtually identical to the 22 fish per m^2 measured during a 1990-1992 study. Jordan (2000) concluded that the mean density of fish in July 2000 was statistically indistinguishable from both the entire historical period and only the July events of the historical period.

Recently aquatic fauna studies have been initiated to monitor system-wide responses to the Comprehensive Everglades Restoration Plan (CERP). Currently, three of them include sampling for aquatic fauna in the Refuge interior:

- Aquatic fauna seasonal concentrations (Dale Gawlik, Florida Atlantic University (FAU), SUP#41560-03027).
- Establish pre-CERP reference conditions for fish, invertebrates, and periphyton (Joel Trexler, Florida International University (FIU), SUP # 41560-03031).
- Population dynamics of crayfish and hydrological influences in WCA-1 (John Volin and Mike Lott, FAU, SUP # 41560-05012).

These three studies have the potential to provide information that can help to evaluate the current status of aquatic fauna in the Refuge; however, for that to happen, the investigators should be brought together with Refuge staff to discuss their overall project objectives, methods, if their data could be used for Refuge purposes, and if not, what additional sampling is necessary to address Refuge specific questions.

Phil Darby (University of West Florida, (UWF)) initiated studies on apple snails in the Refuge in 2001 that continued through 2003 first under a SUP (#41560-01006), Florida Apple Snail Abundance & Recruitment along Hydrological Gradients in the Everglades and later as a Cooperative Agreement (#1448-40181-01-G-146). This study (Darby 2005) provides quantitative data on apple snail density in different habitats in the Refuge and Water Conservation Area 3A (WCA-3A). Overall, apple snails were consistently more abundant in wet prairie relative to slough, often by a factor of two to three. In general, Darby (2005) found lower apple snail density in the Refuge (mean by site of 0 to 0.22 snails per m^2; see Appendix 3) than in WCA-3A (0.08 to 1.40 snails per m^2). In some cases, there were not sufficient data (no snails sampled) from Refuge sites to conduct site-specific analyses on differences among habitats.

One of the purposes of Darby's study was to associate snail density to snail kite use. Snail kites were seen at only one site in the Refuge interior during this study and that site had the highest density of apple snails of all the sites sampled in the Refuge (0.22 snails per m^2). Based on observations in WCA 3A, minimum density of snails for snail kite foraging is 0.14 snails per m^2.

Although there are no historic data to compare Darby's (2005) data to, it appears from descriptions in the Refuge narratives that apple snails may not have been abundant in the Refuge since it was established. This may partially explain the limited snail kite nesting observed in the Refuge interior over the years (see Section 2.2.5.2).

2.2.3.3 Additional information that would improve assessment

- Current aquatic fauna studies should be evaluated to determine how they could best provide information on overall distribution and density of fish and apple snails in the Refuge interior. The investigators of the three studies identified above should be contacted to discuss their methods, whether their data can be interpolated for specific Refuge purpose, and what additional information should be collected.
- Yearly monitoring for fish and apple snails if the above studies will not address Refuge specific needs to link aquatic fauna densities with hydrology.
- Development and application of hydrological models at a fine enough scale (a grid size no greater than 0.31 mile (500 m) in width) to relate hydrology and aquatic fauna distribution and abundance.
- There is no way to recreate data on historic aquatic faunal communities; however, habitat suitability models linked with population dynamic models and hydrologic models could be used to hind cast densities of aquatic fauna as a way to evaluate current and past schedules. Calibration and validation of aquatic fauna models will require surveys at hydrologically diverse sites within the Refuge interior.

2.2.3.4 Summary

- Except at the higher elevation of 16.0 feet, number of years between dry-outs was greater from 1995-2005 than from 1975-1994 and is closer to the current target of dry-outs no more then once every three to five years.
- Except at the higher elevation of 16.0 feet, percentage of years with at least three years between dry-outs has increased. This should be beneficial to aquatic fauna.
- Percentage of time when spring water depths were above the minimum threshold for apple snail egg laying is higher from 1995-2005 than from 1975-1995. This should contribute to increased apple snail density.
- Insufficient faunal density data exist to evaluate if changes in hydrology have resulted in changes in fish or apple snail densities or distribution.
- Additional ecological monitoring is necessary to evaluate fully whether the desired ecological benefits described in the ecological rationale are being achieved.

2.2.4. Benefit 4. Improve timing of water stage drawdown in the Refuge to benefit wading birds.

Ecological Rationale *The assumption is that the intent was to provide foraging and nesting conditions for wading birds over the January-June period. Slower recession rate in the spring would benefit wood storks and other wading birds (also migratory waterfowl).*

2.2.4.1 Hydrological Measures

1) Timing of initiation of spring recession.
2) Rate of spring recession.

Hydrological Expectations

1) Spring recession should start in December instead of January or later.
2) Spring recession rate should be slower from 1995-2005 than from 1975-1994. No targets were identified for acceptable rate of recession.

Hydrological Evaluation

1) Timing of water stage drawdown on the regulation schedule was changed from starting in January (1975 schedule) to starting in December (1995 schedule; see Figures 4 & 5). In general, the earlier start to the recession was observed from 1995-2005. In addition, the slope of the top of the schedule line from January to June was changed from -0.175 feet/week to -0.075 feet/week.
2) Overall average recession at 1-8C from January through April (based on average monthly values) was -0.10 feet/week from 1975-1994 and -0.06 feet/week from 1995-2005. Average recession at 1-7 (based on average monthly values) was -0.03 feet/week during both time periods. Calculation of recession in this manor does not account for reversals that may occur because of rainfall or water management, but does show that, not surprisingly, changing the slope of the schedule line affected the canal stages more than the interior 1-7 stage. A greater change in the canal gauge was expected since that is the primary regulatory gauge (decisions are based on canal gauge stage) and canal stages tend to fluctuate more than marsh stages because of inflow and outflow through structures. It will be important to consider stages measured at marsh gauges in any further analysis of recession rate and wading birds because those gauges better reflect conditions experienced by wading birds.

2.2.4.2 Ecological Measures

Based on the assumption that changing the recession rate would provide better foraging and nesting conditions for wading birds, measures that could be used are:

1) Number and spatial extent of wading birds foraging in the Refuge interior from January-June,
2) Number of wading bird nests
3) Number of successful wading bird nests, and
4) Frequency of “good” nesting years (Crozier and Gawlik 2003).

Ecological Expectations

1) There should be more wading birds foraging in the Refuge interior from January-June from 1995-2005 than from 1975-1994.
2) Number of nesting wading birds should be greater 1995-2005 than from 1975-1994.
3) Number of successful nests should be greater 1995-2005 than from 1975-1994.
4) Number of "good" nesting years should be greater 1995-2005 than from 1975-1994.

Ecological Evaluation

Evaluation of wading bird foraging, nesting, and nest success patterns is outside the scope of this document. This question is one that should be answered in a regional context and extensive studies have been and are being conducted to help address this especially as related to CERP (Curnutt et al. 2000, Gawlik et al. 2004, RECOVER 2004). Wading bird nesting surveys were conducted in the Refuge interior from 1963-1971 and from 1984 to the present (Crozier and Gawlik 2003, and Refuge Annual Narratives). In addition, wading bird foraging and nesting data have been collected using Standard Reconnaissance Flights (SRF) since 1985 (Bancroft et al. 1994, Hoffman et al. 1994 and Jelks et al. 1992) conducted a study on response of wading birds to hydrology and vegetation in the Refuge interior during 1989-1991. Jelks et al. (1992) examined foraging patterns, nesting, and nest success. They found that the northwest third of the Refuge interior was not used to a great extent as a foraging area and that nesting in 1990 was limited to the southern part of the Refuge interior. Additional analysis of the long-term wading bird SRF data from 1985-2001 is underway by Dr. Mike Conroy at the University of Georgia Cooperative Fish and Wildlife Research Unit as part of RECOVER (Conroy 2003) and could help to provide a better understanding of relationships of water management and wading bird foraging and nesting in the Refuge interior.

2.2.4.3 Additional information that would improve assessment

- Analysis of average weekly recession rates and reversals in relation to patterns of wading bird foraging and nesting in the Refuge interior and in a regional context (Data from wading bird foraging and nesting SRF may be sufficient to address this).
- Hydrological models that provide the ability to examine recession rates throughout the Refuge interior.
- Monitoring of wading bird foraging and nest success.
- Linkage of wading bird foraging and nest success with information on aquatic fauna (i.e. typical wading bird food) density and distribution, vegetation, and hydrology.

2.2.4.4 Summary

- The current schedule dictates an earlier start to the spring recession, which should contribute to favorable conditions for wading bird foraging and nesting.
- Spring canal recession rate during 1995-2005 on average was lower (-0.03 feet per week compared to -0.10 feet per week, based on average monthly values) than from 1975-1995 which should benefit wading birds and other Refuge resources.
- Marsh recession rate as measured at the 1-7 was not different during the two periods. It is not clear how recession rate at the 1-7 relates to recession rates in the rest of the marsh.
- Additional monitoring (and analysis) of wading birds, aquatic fauna and hydrology are necessary to understand fully finer scale changes in recession rate that might occur under different water management operations.

2.2.5. Benefit 5. Restore conditions in the Refuge similar to those found when the area was used for kite nesting

Ecological rationale *Provide habitat suitable for snail kite nesting.*

2.2.5.1 Hydrological Measures
There was no information in the EA that explained in what years "…the area was used for kite nesting." Therefore, Refuge narratives from 1951-2005 were reviewed for occurrence and abundance of snail kite nests. Special focus was given to 1951-1990 to determine if there was a period of extensive snail kite nesting since the Refuge was established and prior to the initiation of discussions for the change in the regulation schedule. Based on records in the Refuge narratives, snail kites were known to have nested in the Refuge in 6 of the 39 years from 1951-1990 with the highest number of nests (11) in 1970 (Figure 17). Four of the other five years during that period when kites were documented to nest in the Refuge were 1972, 1974, 1975, and 1976; therefore, it is possible that the time period that was referenced in the EA was the early to mid 1970s or the reference could have been to pre-drainage conditions.

It does not seem that snail kite nesting was ever very high in the Refuge interior (Bennetts et al. 1994) and that the use of the Refuge interior for nesting is related to a number of factors including regional hydrological patterns, local conditions, and regional snail kite population size. If the desire is to provide suitable nesting habitat for snail kites, hydrological conditions should include those that are favorable for apple snail production. See hydrological measures that promote wet prairie over sawgrass and provide conditions suitable for apple snails. (Benefits 1, 2, and 3).

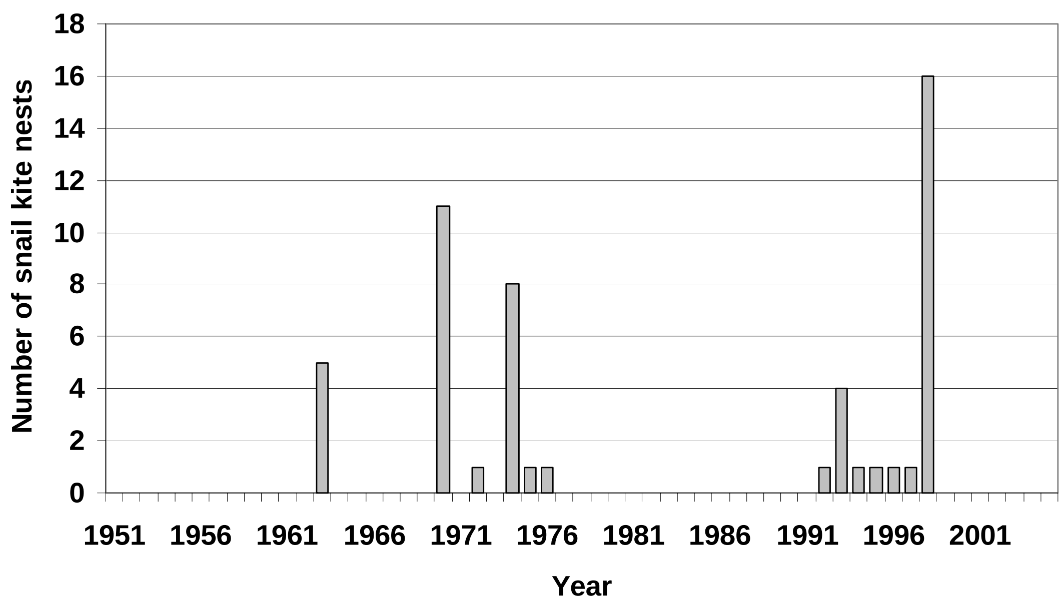


Figure 17. Number of snail kite nests reported in the refuge from 1951-2005. Information is from Refuge annual narratives.

<u>Hydrological Expectations</u>
See expectations for anticipated Benefits 1, 2, and 3 (Section 2.2.1, 2.2.2, and 2.2.3).

Hydrological Evaluation

There was no information in the EA that explained what years "…the area was used for kite nesting." which precluded making a direct comparison of hydrological conditions among years of high and low kite nesting. Additionally, patterns of snail kite nesting should be examined in a regional context, not only on an individual site basis, as kites are semi-nomadic and the importance of hydrology on snail kite population dynamics depends on food resources, vegetation structure, and climate (Bennetts and Kitchens 1997, Drietz 2000) across a broad spatial scale.

2.2.5.2 Ecological Measures

1) Frequency of snail kite nesting.
2) Number of successful nests per year.

Ecological Expectations

1) Frequency of years when snail kites nested in the Refuge from 1995-2005 than from 1975-1994.
2) Number of successful nests per year should be greater from 1995-2005 than from 1975-1994.

Ecological Evaluation

1) Based on data from Refuge narratives, snail kites nested in the Refuge twice during 1975-1994 (10% of the years) and seven times from 1995-2005 (64% of the years).
2) Evaluation on the number of successful nests could not be determined from the information available in the narratives; however, it was stated that all nests in 1995 and 1997 and six nests in 1998 failed.

The reoccurrence of snail kite nesting in 1992 after a 15 year hiatus was thought to be because of "…improved water levels" (higher water levels in the Refuge and surrounding areas). In addition, a statement was made in the 1998 Refuge narrative that the higher than normal water levels led to record snail kite nests in the Refuge.

Caution must be used in interpreting these individual year events to conclude that a specific yearly hydrological condition would result in increased snail kite nesting in the Refuge. Drietz (2000) showed that water level explained only a very small amount of the variation in nest success. Bennetts and Kitchens (1997) discuss hydrological requirements for snail kites in the context of a "window" that includes interactions among three temporal scales of hydrological regimes: water levels at nesting (availability of nest sites and food), hydrological regime in the previous few years (apple snail and vegetation), and longer-term hydrological regime that affects soil and vegetation. In addition, since snail kites are semi-nomadic, their choice to nest in the Refuge in any given year may be as much related to regional conditions and availability of suitable nesting areas as it is to conditions within the Refuge. Both Drietz (2000) and Bennetts and Kitchens (1997) stress the importance on protecting a network of wetlands and duplicating (spatially and temporally) natural hydrological regimes and processes (for maintenance of plant communities and apple snails) for long-term protection and management of snail kites.

2.2.5.3 Additional information that would improve assessment

- Better understanding of linkages between snail kites, apple snails, vegetation, and hydrology.
- Regular systematic surveys for snail kite nests coupled with evaluation of apple snail densities where kites are foraging.

2.2.5.4 Summary

- Snail kites have nested sporadically in the Refuge since its establishment in 1951. There was a higher frequency (percentage of years) of nesting from 1995-2005 than from 1975-1995.
- There is not enough information to assess if the increase in frequency of nesting was a result of changes in hydrology and vegetation within the Refuge interior, or a result of other factors such as regional hydrologic conditions or regional population size. Because snail kites are a semi-nomadic species and their nesting in one area is related to conditions in other areas using site specific trends in nesting without considering regional patterns can be misleading.
- Duplicating (spatially and temporally) natural hydrological regimes and processes for maintaining appropriate vegetation and apple snails is probably the best strategy for providing snail kite habitat in the Refuge.

2.2.6 Benefit 6. Allow for storage of a greater quantity of water during wet and normal rainfall years.

Ecological rationale *Avoid yearly dry-outs.*

2.2.6.1 Hydrological Measures

1) Average yearly water storage.
2) Percentage of years when dry-outs occur.
3) Number of years when stage went below ground surface at elevations of 15.0, 15.5, 16.0 feet using 1-7 gauge data.

Hydrological Expectations

1) Average yearly water storage will be higher from 1995-2005 than from 1975-1994.
2) Percentage of years with dry-outs should be lower from 1995-2005 than from 1975-1994 at 15.0, 15.5 and 16.0 feet.
3) Dry-outs should not occur every year from 1995-2005.

Hydrological Evaluation

Data from the 1-7 gauge were used to evaluate whether this benefit was achieved. Average stage over the two periods was calculated and water storage associated with those stages estimated from a stage storage curve (Figure 18). Average stage at the 1-7 gauge was 16.14 feet NGVD for the period 1975-1994 and 16.52 feet NGVD for 1995-2005.

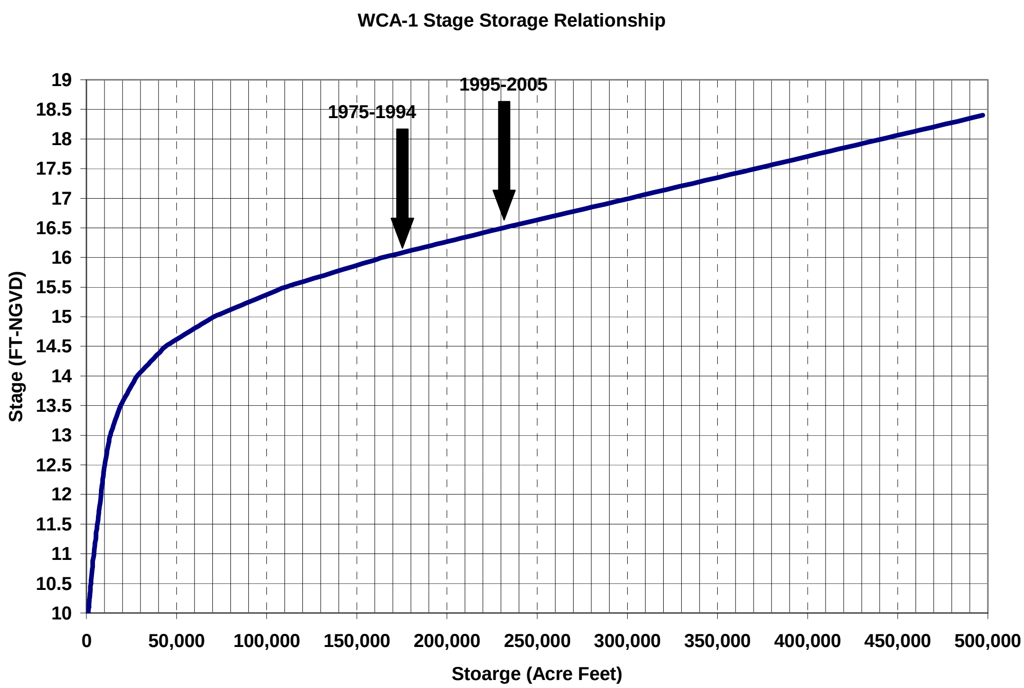


Figure 18. Stage storage curve for WCA-1. Left arrow indicates average stage 1975-1994. Right arrow indicates average stage 1995-2005. Curve produced by Susan Sylvester, U.S. Army Corps of Engineers, October 2003.

1) Approximate storage associated with the above stages is 184,300 and 234,800 acre-feet, respectively (Figure 18) a difference of approximately 50,500 acre-feet.
2) See anticipated Benefit 2 and 3 (Section 2.2.2 and 2.2.3) for discussion of dry-outs.
3) See anticipated Benefit 2 and 3 (Section 2.2.2 and 2.2.3) for discussion of dry-outs.

2.2.6.2 Ecological Measures

See anticipated Benefit 2 and 3 (Section 2.2.2 and 2.2.3) for discussion of dry-outs.

Ecological Expectations

See anticipated Benefit 2 and 3 (Section 2.2.2 and 2.2.3) for discussion of dry-outs.

Ecological Evaluation

See anticipated Benefit 2 and 3 (Section 2.2.2 and 2.2.3) for discussion of dry-outs.

2.2.6.3 Additional information that would improve assessment

- See Sections 2.2.2 and 2.2.3.

2.2.6.4 Summary

- Based on the stage storage curve and average stage at the 1-7 water storage should have increased by 50,500 acre-feet. This has benefited Refuge resources by decreasing the frequency of dry-outs in some areas.

3. Summary

Hydrologic conditions in the Refuge interior from 1995-2005 are consistent with the purposes of the change to the current water regulation schedule in 1995. Many of the anticipated hydrological benefits listed in the EA have been achieved. Generally, there are higher water levels, longer hydroperiods, and a lower frequency of dry-outs in the more northern parts of the Refuge interior than from 1975-1994 under the previous schedule. In addition, the timing of the start of the spring recession is earlier than it was under the previous schedule and the rate of recession (as measured at the 1-8C gauge) is slower.

In most cases, it has not been confirmed that the hydrological changes have resulted in the desired ecological changes because monitoring was not established to track changes. It is likely that the increases in hydroperiod and average water depths in the north have at least slowed the rate of conversion of sawgrass to brush, if not reversed the trend. In addition, it is likely that the changes in frequency of dry-outs and the number of years between dry-outs have been beneficial for fish and apple snails (Table 6).

Table 6. Summary of hydrological measures used to access if the anticipated benefits of the 1995 water regulation schedule have been achieved, which anticipated benefit they are associated with, and if the extent of hydrologic change observed from 1975-1994 to 1995-2005 is likely to result in an ecological change. In most cases this evaluation was based on best professional opinion. Y indicates likely to result in change, M indicates may result in change, N indicates probably won't result in change, ? indicates not enough information. Shading indicates that the change or condition may not be in the preferred direction (for change) or may not be the preferred condition.

Hydrological Measure	Anticipated Benefit	Ecological Indicator	Overall	15.0 feet	15.5 feet	16.0 feet
Average Monthly Stage	1, 5	Vegetation		Y	Y	M
# years when stage went below ground	1, 2, 5	Vegetation, fish, snail kites		N	Y	N
Average yearly hydroperiod	2, 5	Vegetation, snail kites		N	M	Y
Average growing season (Mar-Jun) hydroperiod	2, 5	Vegetation, snail kites		N	M	Y
# years between dry outs	3, 5, 6	Vegetation, fish, snail kites		Y	Y	N
% years with at least 3 years between dry outs	3	Fish		Y	Y	N
% of time in Apr-Jun depth >0.325 ft	3, 5	Apple snails, snail kites		M	Y	N
Timing of spring recession	4	Wading birds	Y			
Recession rate	4	Wading birds	?			

4. Unintended consequences

Associated with these hydrological changes observed between the two periods that correspond to the previous and current regulation schedules are conditions that may be less desirable for the southern or central part of the Refuge interior. The focus of the change to the regulation schedule was to improve conditions in the northern part of the Refuge interior. There was no discussion on the potential effects of those changes on the southern portion of the Refuge interior. Higher water levels and longer hydroperiods in the northern Refuge interior result in higher water levels and longer hydroperiods in the southern part of the Refuge interior. In parts of the Refuge interior, hydroperiods were 100% under the 1975 schedule and water depths favored slough community. An increase in those depths results in there being a greater likelihood of each year having a 100% hydroperiod, which over the long-term will convert slough to open water, and wet prairie to slough (Hagenbuck et al. 1974). Increased depths could be detrimental to tree islands, causing stress or mortality to trees and shrubs (Sklar et al. 2002, Heisler et al 2004), especially if depths are increased during the spring growing season. In addition, longer hydroperiods and increased depths can result in changes in the fish community from one dominated by small fish to one dominated by larger fish such as bass and blue gill (Trexler et al. 2004), which could subsequently affect (either positively or negatively) higher trophic levels (e.g., wading birds and alligators). In addition to contributing to changes in vegetation community types, changes in hydroperiod and depths can result in changes in biomass and percent cover of vegetation, which could in turn affect density and distribution of fish and selection of foraging sites by wading birds (Bancroft et al. 2002).

Godrick 1974 found that vegetation biomass at a wet prairie site that was dry for 6.5 months was three times as high as biomass at a wet prairie site that had been flooded for 28 months. In addition, under the dry conditions, Tracey's beak-rush and maidencane increased to 62% of the biomass, from 19.2% of the biomass under flooded conditions. Busch et al. (1998) also found a relationship between hydrology and vegetation biomass/percent cover. They found that average macrophyte cover had an inverse relationship with water depth, i.e. average percent cover was lower with increased water depths. Interactions of hydroperiod and water depth should be considered when determining appropriate hydrological conditions for the Refuge interior. Higher vegetation biomass/percent cover of wet prairie vegetation that may result from drier conditions may not provide the best conditions for wading bird foraging as it makes prey less accessible.

Another unintended consequence of current water management is a reduction in inter-annual variability in hydroperiod. Although the regulation schedule allows for water level management between the upper and lower bounds of the schedule lines, in general, water levels have been managed near the top of the schedule. The result is that inter-annual variability in hydroperiod (section 2.2.2.1) is now lower than it was under previous schedules. The consequences of this are not known; however, natural variation at a range of spatial and temporal scales is important for shaping ecosystems including the Everglades (DeAngelis and White 1994).

Taking advantage of the full range of hydrological conditions (increasing variability) provides flexibility in management and potentially hydrological benefits to the Refuge interior. Timing of low water level that coincide with timing of natural dry events (both annually and on a longer time scale) would help to move conditions toward a more natural (desirable) pattern. Marsh vegetation communities respond to hydrological changes on a scale of three to five years with conversions from drier to wetter communities happening over shorter time frames (two successive years of flooding will result in changes while it may take three successive years of dry conditions to result in change (Wetzel 2001)). In addition, marsh vegetation appears to be most sensitive during the spring growing season (Hagenbuck et al. 1974). Tree islands also are sensitive to hydrological conditions and, although specific flooding tolerances are not well known, it appears that somewhere between 60 and 300 days of flooding will cause stress or mortality to tree island vegetation (Heisler et al. 2004) depending on the species and water depth.

Information on timing of dry-outs and flood events should be incorporated into water management decisions. Historic Everglades communities experienced a wide range of hydrological conditions including floods and drought. Such conditions in any one year are not likely to have long-term lasting effects if they follow the natural climactic pattern, i.e., the conditions are not unusually high or low because of water management.

In addition to unintended hydrological effects, there may have been unintended water quality effects. It was stated in the EA that: "The proposed inflow/outflow modifications would not worsen existing conditions, and water quality improvement projects now underway are expected to insure that water management practices involving the project are brought into conformity…". However, implications of the altered water regime under the 1995 regulation schedule on transport of nutrients and other water-borne constituents from the canals to the marsh are not well understood. It is reasonable to speculate that, particularly in the more hydrologically isolated northern marsh, higher canal stages likely result in increased intrusion of canal water. Therefore, it is critical that in the future, review of environmental impacts (positive or negative) associated with changes in water management address both water quality and water quantity.

It is likely that the upper and lower bounds of the current regulation schedule are appropriate for maintaining hydrological conditions to support key Refuge resources. The challenge is to develop operational rules that will allow for maximizing conditions for key indicators. Some indicators and targets have been discussed in this document. Additional work is needed to clearly articulate the future desired conditions for the Refuge, what indicators will be used to track progress toward achieving those conditions, what the targets are for those indicators are, how those indicators will be monitored, and what strategies other than water management, such as prescribed fire, can be used or are necessary to obtain the desired ecological conditions. This document and the summary of the Water Management Breakout Session held at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop (Appendix 4) provides a starting point for these discussions.

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APPENDICES

Appendix 1. Summary of methods used to calculate water depth (elevation) differences between vegetation communities using data from Richardson et al. (1990) and Jordan (1996)

As part of data collection for development of their topographic map Richardson et al. (1990) collected water depth and vegetation community percent cover at 251 points spaced approximately 1 minute of latitude and longitude apart throughout the Refuge interior. Vegetation communities included aquatic, wet prairie, sawgrass, brush, cattail, and open water. Three water depths were taken in each community if it was present at the point. Samples were all taken within a three-day period in January 1987 when average water stage was maintained at about 17.0 feet, a flat pool condition.

The depth information in this data set was used to look at differences in water depth and hence elevation between vegetation communities. Only points that had more than one vegetation community were used. The difference between the average depth measurements between the two communities was calculated. For example if slough and wet prairie were present wet prairie water depth was subtracted from slough water depth to determine how much deeper slough was than wet prairie. Because the communities were adjacent to each other at the same point differences in water depth can be viewed as differences in ground surface elevations between the vegetation communities.

There was a large amount of variability in the differences; however, the data do illustrate that elevation differences of 4-8 inches can result in visible changes in vegetation community (Table 1). Micro-topography differences such as these, along with longer-term water depths shape what vegetation communities dominate the landscape.

Table 1. Average difference in water depth (elevation) between different vegetation communities in the Refuge interior based on water depths taken on the same day in adjacent communities. Differences in depths reflect differences in surface elevation. Data are from Richardson et al. (1990).

Vegetation communities	Difference between surface elevation (feet)	Standard Deviation	n
Slough-Wet Prairie	0.36	0.35	6
Wet Prairie-Sawgrass	0.27	0.21	57
Sawgrass-Brush/Shrub	0.16	0.10	5
Slough-Sawgrass	0.68	0.39	8
Slough-Shrub	0.73	-	1

Jordan (1996) collected similar data while examining vegetation community patterns and aquatic fauna. He visited random points throughout the Refuge interior during 1990-1992 and sampled slough, wet prairie, and sawgrass at each site. Because he sampled in the same area on the same day the information could be used in the same way that the Richardson et al. (1990) data were used. The results (Table 2) were similar to those from the Richardson et al. (1990) data (Table 1).

Table 2. Average difference in water depth (elevation) between different vegetation communities in the Refuge interior based on water depths taken on the same day in adjacent communities. Differences in depths reflect differences in surface elevation. Data are from Jordan (1996).

Vegetation communities	Difference between surface elevation (feet)	Standard Deviation	n
Slough-Wet Prairie	0.33	0.29	86
Wet Prairie-Sawgrass	0.28	0.20	86
Sawgrass-Brush/Shrub			
Slough-Sawgrass	0.61	0.31	86
Slough-Shrub			

The two datasets were combined to get the resulting table (Table 3) and graph (Figure 1).

Table 3. Average difference in water depth (elevation) between different vegetation communities in the Refuge interior based on water depths taken on the same day in adjacent communities. Differences in depths reflect differences in surface elevation. Data are from Richardson et al. (1990) and Jordan (1996).

Vegetation community	Difference between water depth/elevation (feet)	Standard Deviation	n
Slough-Wet Prairie	0.33	0.29	92
Wet Prairie-Sawgrass	0.27	0.20	143
Sawgrass-Brush/Shrub	0.16	0.10	5
Slough-Sawgrass	0.61	0.32	94
Slough-Shrub	0.73	-	1

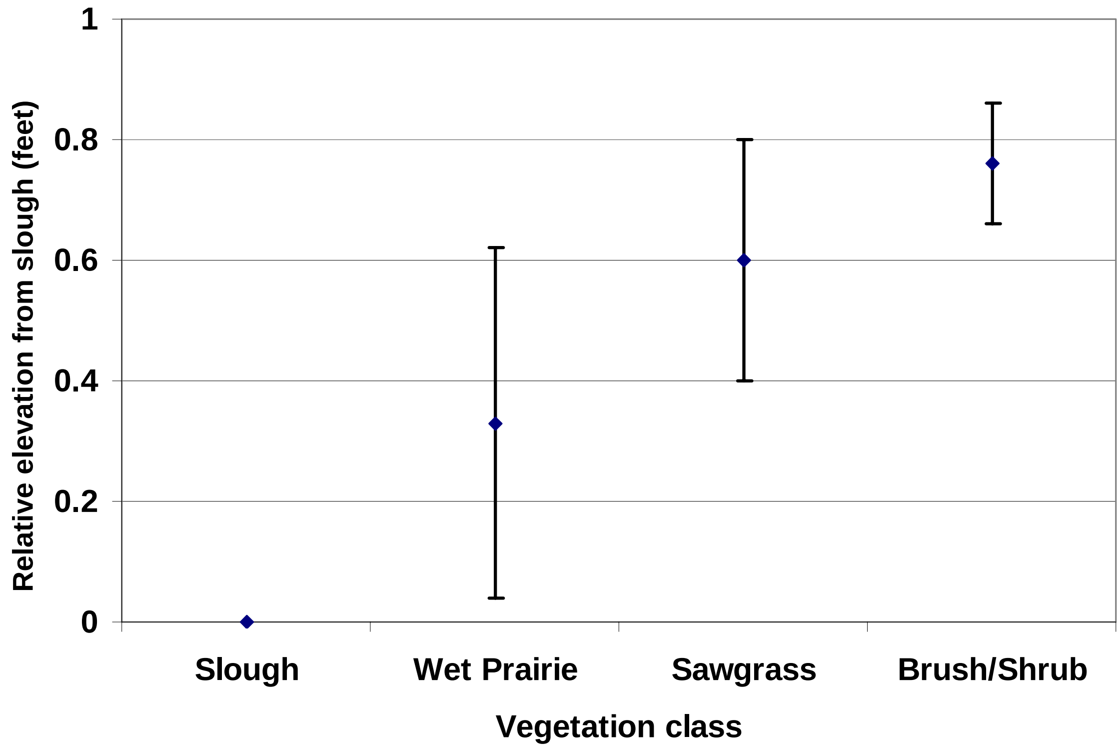

Figure 1. Relative depth (elevation) ±S.D. difference among vegetation communities in A.R.M. Loxahatchee NWR interior marsh. Data from Richardson et al. 1990 and Jordan 1996.

Appendix 2. Grouping of classes from Hagnebuck et al. (1974) and Richardson et a1.(1990) used for Review of Water Regulation Schedule document.

Hagenbuck et al. 1974 original class	Grouping for Regulation Schedule review document
Aquatic	Sough
Wet prairie	Wet prairie
Sawgrass	Sawgrass
Brush/sawgrass	Brush
Other	Other

Richardson et al. 1990 original class (see below for complete description)	Grouping for comparison to Hagenbuck et al. in Regulation Schedule Review document
1. Sawgrass	Sawgrass
2. Cattail	Other
3. Sawgrass	Sawgrass
4. Brush	Sawgrass/brush
5. Tree island	Not included
6. Wet prairie	Wet prairie
7. Tree island	Not included
8. Brush	Brush
9. Wet prairie	Wet prairie
10. Cattail	Other
11. Aquatic	Slough
12. Aquatic	Slough
13. Tree island	Not included
14. Tree island	Not included
15. Sawgrass	Sawgrass/Brush
16. Sawgrass	Sawgrass
17. Tree island	Not included
18. Cattail	Other

Vegetation Communities in Supervised Classification (Table 8 From Richrdson et al. 1990).

1. (Sawgrass) High density sawgrass (948 Acres, 0.7%) – very dense sawgrass with some occurrence of fern tussocks.
2. (Cattail) Sawgrass with invasion of cattail (2124 Acres 1.5%) – sawgrass mostly near the canal and with high incidence of cattail mixed in the sawgrass.
3. (Sawgrass) Sawgrass (18132 Acres, 13.0%) – primary sawgrass class occurring on all parts of the refuge including the vast sawgrass areas on the west side of the refuge.
4. (Brush) brush/sawgrass (21015 Acres, 15.7%) – primarily sawgrass with large amounts of wax myrtle. Some tree islands which may have been burned out previously are made up entirely of this class, particularly in the southern part of the refuge.

5. (Tree Island) Tree island (2387 Acres, 1.7%) – lower stature tree island community made up of a mix of wax myrtle, dahoon holly and red b ay. Occurs along edges of large tree islands with some smaller tree island made up entirely of this class.
6. (Wet Prairie) Wet prairie (46544 Acres, 33.4%) – largest area of the refuge. This class is the denser wet prairies occurring over all the refuge but the primary community type of the central portion of the refuge. This class may contain small tree islands smaller then 30 ft across and areas with small sawgrass strands.
7. (Tree Island) Tree island (867 Acres, 0.6%) – core of larger tree islands, larger stature trees made up primarily of dahoon holly and red bay with lesser amounts of wax myrtle than class 5.
8. (Brush) Brush (4771 Acres, 3.42%) – smaller brush clumps primarily in wet prairies.
9. (Wet Prairie) Wet prairie (9934 Acres, 7.1%) – sparser wet prairie community often with sparse sawgrass.
10. (Cattail) Cattail (1746 Acres, 1.3%) – cattail community close to the canal.
11. (Aquatic) Open water (282 Acres, 0.2%) – mostly identified as deep water along Hillsborough canal.
12. (Aquatic) Slough/very sparse wet prairie (272 Acres, 0.2%) – a small class, very similar to class 9 but a little deeper and/or less vegetated.
13. (Tree island) Willow/brush (1160 Acres, 0.8%) – predominately willow but with some mixed classification with wax myrtle brush areas.
14. (Tree island0 Brush/tree island (16467 Acres, 11.8%) – class of many of the smaller tree island with mostly wax myrtle, some sawgrass, occasionally dahoon holly and red bay.
15. (Sawgrass) Sawgrass/brush (2548 Acres, 1.8%) – mostly sawgrass with some invasion of wax myrtle, generally closer to canal than other sawgrass classes. A small class similar to class 4.
16. (Sawgrass) Sawgrass (6214 Acres, 4.46%) – slightly higher elevation sawgrass than class 3. Core of sawgrass ridges.
17. (Tree island) Willow (1167 Acres, 0.8%) – willow along canal edge, some misclassified floating aquatics along hillsborough canal.
18. (Cattail) Cattail (1856 Acres 1.33) – cattail further from the canal than class 10.

Appendix 3. Table 5 from Darby and Karunaratne 2005. Numbers of foraging Snail Kites and the apple snail densities (mean ± S.E.) in sites sampled in WCA1 (Refuge interior-highlighted), WCA3A, and A.R.M. Loxahatchee National Wildlife Refuge (LNWR) impoundments in 2003. Sites are in order of lowest to highest snail density.

Wetland	Site	Foraging Kites	Snail Density Mean ± S.E.		
WCA1	A	0	0.00	±	0.00
LNWR	IMC6	0	0.00	±	0.00
LNWR	IMC7	0	0.00	±	0.00
WCA1	D	0	0.01	±	0.01
WCA1	F	0	0.02	±	0.01
WCA1	KN3	0	0.03	±	0.02
WCA1	KN4	0	0.07	±	0.03
WCA3A	11	0	0.08	±	0.02
LNWR	IMC8	0	0.09	±	0.04
WCA1	E	0	0.09	±	0.06
WCA3A	3	0	0.10	±	0.06
WCA1	KN1	0	0.11	±	0.03
WCA1	KN2	0	0.11	±	0.03
WCA1	B	0	0.14	±	0.06
WCA3A	2	2	0.14	±	0.06
WCA3A	6	4	0.16	±	0.06
WCA3A	1	2	0.18	±	0.07
WCA1	C	2	0.22	±	0.06
WCA3A	14	14	0.25	±	0.04
WCA3A	5	4	0.30	±	0.09
WCA3A	15	7	0.45	±	0.08
WCA3A	13	8	0.72	±	0.09
WCA3A	12	1	0.78	±	0.09
WCA3A	16	15	0.97	±	0.09
WCA3A	10	12	1.40	±	0.16

Appendix 4. Excerpt from the Water Management Breakout Session from the **"**Summary of Arthur R. Marshall Loxahatchee National Wildlife Refuge 2004 Science Workshop". See Brandt 2005 for complete document.

Water Management Breakout Sessions

There were three water management breakout groups with 12-14 people each. An attempt was made to spread agency representation among the groups, but no attempt was made to spread out subject expertise. A facilitator and note taker were assigned to each group.

Facilitators:	**Note takers:**
Nick Aumen	Arturo Torres
Agnes McLean	Jocie Graham
Jim Smoot	Pam Pannozzo

Participants and facilitators were given the following information for the basis of discussion:

Objective: Develop a matrix of attributes that can be used as a guide for future water management decisions. Identify key science uncertainties related to those attributes.

Supporting information: Appendix 3- Biological indicators.pdf, Watermanagement.gif (presented as a poster to each group)

Focus questions:

What science do we need to help us make decisions on water management issues?

- What are we missing from the poster?
- What are our external constraints?
- For each area, what are the key things we need to know (drivers, stressors, ecological endpoints)?
- What are the specific studies needed to address the areas identified?
- Are they being done? By whom?

Each group approached the tasks assigned a little differently as was done in the general session. All groups prepared a list of things missing from the poster, external constraints, and some version of what the key things we need to know about the listed attributes. Less attention was given to the specific studies needed and all groups described needs in broad categories.

The attributes listed as missing from the poster can be grouped into 12 general categories (Table 3). Some topics also were listed as external constraints to water management. External constraints were grouped into one of six categories (Table 4). Needs generally fell into one or more of 17 different categories (Table 5).

The list of general categories of needs was reviewed to see if the need also had been listed as an existing study during the general session. Of the 13 general categories of needs (Table 5), there were ongoing studies identified that addressed eight (Alligators, Apple snails, Exotics, Models, Targets for water management, Tree islands, Wading birds, Water quality). In no case were all of the specific topics being addressed by ongoing studies.

In a number of cases, the general category was related to an overarching issue or refuge identified question (Appendix 2), but was not explicitly listed. For example targets for water management (Table 5) are something the refuge needs for addressing how do hydrologic conditions affect key refuge resources… (Appendix 2); however, there is no specific question in Appendix 2 that states this or suggests that paleoecology to understand historic ecology (Table 5, specific topic) is one of the key questions. This example illustrates how the information compiled here can be used as a starting point for discussions among researchers and managers. In general, the questions and issues listed in Appendix 2 are broader in scope than the specific topics identified in the workshop and further discussions are needed to make the linkages between the specific studies and management needs.

Comments from Evaluation and Lessons Learned

Most people who completed the evaluation form found the water management break out very useful and felt that it should be continued in future workshops. A lot of information on general needs was gathered through interactions of the participants. Some participants felt that more background information on the refuge and refuge needs would have enhanced the discussions. This session provided a good general framework of ideas for developing a matrix for water management, but additional work is needed to complete that task. Future topic break outs should have an introductory presentation providing background and objectives of the break out. Follow up workshops focusing on specific management questions should be scheduled to present the synthesis and take any needed next steps.

Table 3. General categories, and specific topics of items missing from the water management poster presented to the breakout groups at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop.

Category	**Specific topics**
Climate	Seasonal weather conditions and seasonal hydrology, extreme events, future weather conditions
Fauna	Fishes, macro-invertebrates, other aquatic fauna, occurrence and distribution, T&E species
Historic	What were historic conditions?
Hydrology	Surface/ground water interactions, natural or managed variability, water movement, effects of altered hydrology
Integration	Decision support system
Land Use	Surrounding land use changes and regional spatial dynamics, effects on water supply
Soil	Soil processes including accretion and vertical profiles
Unintended consequences	Unintended consequences
Vegetation	Vegetation patterns, marsh community composition and structure
Water management	Pathways of water delivery, managed variability, more control of water going out then in, topographic effects on management
Water quality	Soft water low conductivity system affected by hard water canal water intrusion
Water supply	Water supply current and future needs

Table 4. General categories of external constraints and specific topics identified in the Water Management Break out at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop.

Category	**Specific topics**
Available resources	Budget, time, resources
Climate/weather	Extreme weather events
Land use	Changes in land use and existing surrounding land use
Legal constraints	Consent decree (federal water quality), regulation schedule, flood protection, water supply, legal rights of the refuge to water
Physical configuration/design	Refuge is impounded, topography, more control of water out then in, STA design and flood protection
Politics	Politics-water supply and water quality

Table 5. General categories of needs and specific topics listed in the Water Management break out groups at the 2004 A.R.M. Loxahatchee National Wildlife Refuge.

Category	**Specific topics**
Alligators	Direct effects on nesting success; distribution, abundance, health/condition; indirect effects on condition; relationship between hydrology and nesting effort; relationship to hydrologic patterns
Apple snails	Distribution, production, availability, and short term variations; effects of extremes; historic distribution and abundance; relationship to water quality
Climate	Understanding of global climate change impacts
Communication	
Education	Pubic, legislators, higher management, other agencies
Exotics	Effects of local environmental conditions; effects of hydrology
Fire	Historic patterns; role of historic fires; effects of peat fires vs surface fires
Integration	Understanding how cumulative long-term impacts affect the refuge; decision support tools to weigh and mitigate conflicts; integration of effects of water management at different spatial, temporal, ecological scales; whole system vs single system management
Models	Comprehensive models at appropriate scales; Conceptual ecological model; Hydrodynamic model
Public support	
Social science considerations	Understanding current and future land use and water use requirements

Targets for water management	Paleoecology to understand historic ecology; water regulation schedule optimization based on what?
Tools	Decision support/integration tools
Tree islands	Impacts of hydrology on tree islands biological diversity; tree islands elevation relative to slough; need healthy, sustainable, achievable target; historic vs current state; tree islands hydroperiod; what is the target?
Trust resources	Migratory and other birds; snail kites
Wading birds	Effects of hydrology on nesting; effects of hydrology on prey; natural vs human induced effects; nesting; spatial patterns
Water quality	Ecological effects of hard water; effect of changing sources; effects of chloride; effects of P; effects of S; mobilization of P in canal sediment; pore water intrusion; relationship of canal stage, operation, and intrusion