ANNEX F

C-111

EVERGLADES NATIONAL PARK

DRAFT
ENVIRONMENTAL EVALUATION FOR THE STRUCTURAL ALTERNATIVE PLANS FOR THE C-111 DRAFT GRR

SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS

United States Department of the Interior

NATIONAL PARK SERVICE
Everglades National Park
and
Dry Tortugas National Park
40001 State Road 9336
Homestead, Florida 33034-6733

IN REPLY REFER TO:
L54

Colonel Terrence C. Salt
District Engineer
U.S. Army Corps of Engineers
P.O. Box 4970
Jacksonville, FL 32232-0019

Dear Colonel Salt:

I am writing this letter to transmit the enclosed follow-up materials that your staff had requested at the PRC meeting in early February, in support of the Draft C-111 General Reevaluation Report. I have also included the Park's general comments on the recently added Alternative 6A, as requested in your February 14, 1994 fax transmission. The first document includes a summary of the natural features of the C-111 study area, a brief discussion of past water management problems, and the justification for our focus on re-establishing more natural hydrologic conditions in the Park, and specifically in the Rocky Glades. The second document is an appendix to our previously transmitted technical report (93-4), which presents the results of our more detailed assessment of the hydroperiod and water level changes in seven subbasins of the study area. The subbasin analysis using the results of the SFWMD's 1x1 model shows improvement in the hydrologic conditions in the Rocky Glades area under both Alternatives 4 and 6. We have also provided a more detailed description of the structural plan that we envisioned for proposed Alternative 8, and a comparison of this alternative and 6A.

The structural components for Alternative 6A are similar to the Park's proposed plan for northern Taylor Slough and the Rocky Glades, and should provide the potential for significant improvements in water deliveries in these areas of the Park. While there are still substantial differences in the areas of the Frog Pond and the lower C-111 basin, we believe that all of the major components necessary for a workable plan have been reviewed with your staff. The Park strongly supports moving forward immediately into the public review process. We remain committed to working with your staff in the next phase of detailed planning, and anticipate that the remaining issues can be resolved, including the development of operational criteria for the project.

Sincerely,

Richard G. Ring
Superintendent

The Natural Features of the C-111 Study Area

Figure 1 is a map of the natural physiographic features of the C-111 basin and the eastern portion of Everglades National Park. The generalized land units are taken from a soil association map prepared by the University of Florida and the USDA (Leighty et al. 1954), and are used here to define the landscape characteristics of the study area. An excellent summary of the physiographic features of the lower Everglades, Florida Bay, and the Florida Keys is presented in a U.S. Fish and Wildlife Service report prepared in 1982 (Schromer and Drew 1982). The soil descriptions indicate that under natural conditions essentially all of this area, except the higher elevated Atlantic Coastal Ridge, was subjected to seasonal flooding due to low ground surface elevations and the close proximity to the Everglades. At Tamiami Trail, the concave depression that shaped the "River of Grass" is constricted, forming a narrow southwesterly trending arc of continuous wetlands which define the Shark Slough drainage. Shark Slough represents the southern extension of the Everglades trough, which originates outside of the Park in the wetlands of Water Conservation Area 3B. To the northwest of Shark Slough, the bedrock of the Everglades rises gradually into the sandy marl prairies of the Big Cypress basin. This area extends well south of Tamiami Trail, forming the transitional and short hydroperiod marshes to the west of the L-67 extension canal. These marl prairies occur on slightly higher bedrock elevations, and were originally only seasonally inundated. Today they are substantially wetter due to the diversion of flows away from the Northeast Shark Slough flow-way and into western Shark Slough.

To the southeast of Shark Slough is a large area of transitional (less than 3 months hydroperiod) and short hydroperiod (3 to 5 months hydroperiod) wetlands referred to as the Rocky Glades. Maximum inundations occurred after the peak of the rainy season, and formed a natural buffer separating the deeper Everglades marshes from the higher elevated, and drier areas along the Coastal Ridge. During the wet season, the Rocky Glades would receive runoff from the western portion of the Coastal Ridge, while additional surface water would spill over from the expanding Shark Slough wetlands. The shallow soils and exposed limestone bedrock in the Rocky Glades make it an important area of direct recharge to the underlying aquifer, which supplies groundwater flows to the adjacent eastern developed areas as well as the downstream Everglades. The Rocky Glades are significant hydrologically, since the southern portion of this area drains to the southeast, where it forms the headwaters of the Taylor Slough watershed. The marl soils in upper Taylor Slough extend eastward, covering much of the Frog Pond, and northward along the western flank of the Coastal Ridge. Under natural conditions, this region captured wet season runoff from the western Coastal Ridge and directed it westward into Taylor Slough, where it would be slowly released into the downstream marshes and Florida Bay. Construction of the L-31N, C-111, and L-31W levees has isolated much of the historical contributing area to Taylor Slough, and excess wet season runoff from this region is now rapidly drained via the canal systems eastward to Biscayne Bay or

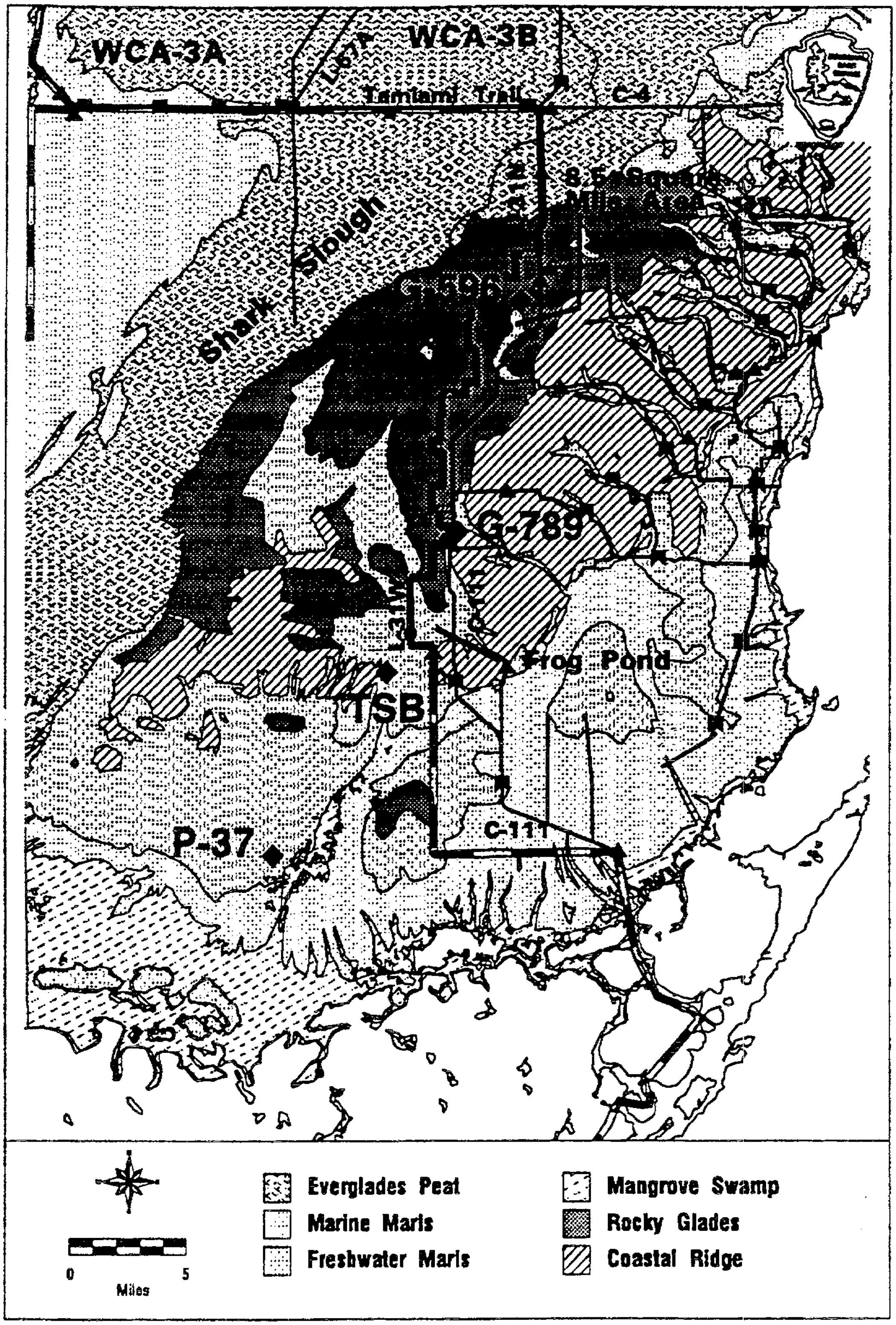

Figure 1. Map of the Natural Physiographic Features in the C-111 Study Area.

southward into the lower C-111 basin. These changes are a major reason for the long-standing conflicts over water management in this area and continue to contribute to the drainage problems in the eastern wetlands within Everglades National Park.

The lower C-111 or Eastern Panhandle basin is part of the Southeast Coastal Glades, which are underlain by a mixture of freshwater marls in the areas adjacent to the Coastal Ridge. Near the coast, these freshwater marls transition into marine marls (Leighty et al. 1954). Under natural conditions, the lower C-111 basin received the bulk of its runoff from the southern portion of the Atlantic Coastal Ridge. These surface and groundwater flows constitute the primary source of freshwater inflows to the northeastern portion of Florida Bay. Today much of the southern Coastal Ridge has been developed, and a significant portion of this natural runoff has been diverted eastward into Biscayne Bay. In the mid 1960's, when the C-111 canal was constructed, it formed a breach between the Coastal Ridge and the marl prairies. This has allowed wet season runoff from northern Taylor Slough (and at times runoff from Northeast Shark Slough) to be transferred into the lower C-111 basin. At the same time the natural marsh sheetflow was altered by the lower C-111 levees impounding water to the north of the canal which led to overdrainage of the marshes south of the canal. The southward diversion of runoff from the areas north of the Frog Pond increased freshwater inflows into the lower C-111 marshes and downstream Florida Bay during the 1980's, but the source of most of this water is drainage of the upstream wetlands (Northeast Shark Slough and the Rocky Glades) within the Park. Thus, the water draining from these areas is transferred through the canal system and re-introduced into the wetlands at a lower point. Recent acquisition by the State of a large tract of the marsh lands north of the lower C-111 basin has led to increased pressure to reintroduce surface water inflows as far north as possible. This has the benefits of maximizing natural marsh sheetflow, and mitigating damaging freshwater releases into the downstream estuaries during periods of high wet season runoff.

Past Hydrologic Changes in Southwestern Dade County

The earliest C&SF Project construction in southwestern Dade County began in 1951, with the completion of the L-30 levee and the northern portion of the L-31N levee. These levees were originally built as part of the Eastern Protective Levee System, to protect the expanding developed areas of the Lower East Coast from Everglades flooding. This levee system also established the land use plan for western Dade County, by defining the limit of flood protection. The original plan of improvement for southwestern Dade County also anticipated that the majority of the low-lying areas east of the L-31N and C-111 levees and adjacent to the Everglades would be developed for seasonal agriculture (U.S. Army Corps of Engineers 1961). This plan called for gravity drainage of an area of 227 square miles of southwestern Dade County using a system of 12 primary canals.

Although the Corps recognized that the natural drainage in the western portion of the Coastal Ridge was to the southwest (into Taylor Slough), gravity drainage primarily to the east and south (into Biscayne Bay, Barnes Sound, and Florida Bay) was found to be most practical, particularly with the continuing pattern of declining groundwater levels in the Coastal Ridge.

Runoff from the east of L-31N and north of Homestead was to be drained eastward into Biscayne Bay via six proposed canals (C-101 through C-106). The area south of Homestead was to be drained southward into Florida Bay and Barnes Sound via six proposed canals (C-107 through C-112). During project review, the National Park Service wrote correspondence to the Corps concurring with the plan for eastern Dade County, but requested that the area west and northwest of Homestead be drained westerly into Taylor Slough, to reduce the drainage effects of the C&SF Project improvements. The National Park Service and the Fish and Wildlife Service also objected to the southerly extension of the proposed C-109, C-110, C-111, and C-112 canals to tidewater, and requested that the canals be terminated at the one-foot contour to promote sheetflow, and reduce the effects of direct freshwater inflows to the downstream estuaries.

The 1961 plan was modified in the South Dade County GDM (U.S. Army Corps of Engineers 1963) so that the L-31N canal would be used "to provide southerly drainage to ENP in Taylor Slough for the westerly portion of south Dade County". The L-31W canal was specifically added as part of the 1963 GDM so that during the design storm approximately 28 square miles of land adjacent to the C-102 and C-103 canals would be drained westward into Taylor Slough. The first proposed operating criteria for the southern reach of the L-31N canal would have allowed wet season canal stages to rise as high as 6.5 feet to promote the discharge of water into Taylor Slough via the L-31W canal. Water would then spill overbank from the L-31W canal into Taylor Slough. Under flood conditions, up to 500 cfs would be discharged into the L-31W canal and pass southward via S-175, to maximize Taylor Slough inflows.

Prior to construction of the C&SF Project the farming practices in this region had adapted to the natural cycle of Everglades flooding and drying. Land preparation and planting would begin after wet season water levels naturally receded. Agricultural practices were thus in tune with the natural variability in seasonal rainfall and water levels. By the late 1960's and early 1970's, construction of the L-31N, L-31W, and C-111 canal systems reached completion, and the optimum canal operational stages were lowered in response to expanding agricultural and urban development into the lower-lying areas of western Dade County (Van Lent et al. 1993). During the 1980's, agricultural practices in the region began to change, in part due to a lower than normal decade of rainfall. Grove crops, which require low ground water levels throughout the year, expanded into the western portions of the basin. In addition, economic pressures forced south Dade farmers to plant their row crops earlier in the season to compete with growers from other areas. Both of these changes prompted additional demands to lower canal operational stages to increase groundwater storage potential so there would be a readily available area to absorb the stormwater runoff, thereby reducing the risk of flooding of the root zones.

The operational levels maintained in the L-31N, L-31W, and C-111 canals are also extremely important to the natural areas in the eastern section of the Park. These canals traverse the Rocky Glades and canal water levels largely control the magnitude of groundwater losses from the Northeast Shark Slough and Taylor Slough basins. The underlying limestone of the Rocky Glades is the most permeable bedrock found in South Florida, and minor reductions in canal water levels drain tremendous quantities of surface and ground water from the wetlands. Maintenance of higher surface and ground water levels in this area is pivotal to the restoration of flows throughout Northeast Shark Slough, Taylor Slough, and into the downstream estuaries of the Gulf of Mexico and Florida Bay. The immediate loss of stormwater runoff to tide during the rainy season and the continued drainage of the wetlands and stored groundwater into the dry season not only cause the loss of natural hydroperiods in the uplands, but also cause a drastic reduction of freshwater flow into the downstream estuaries during the remainder of the dry season. The resulting reduction in groundwater levels further aggravate the problem when the early spring rains arrive, rainfall must first fill up the depleted groundwater regime before surface water flow can resume, and transport freshwater into the downstream marshes and estuaries.

The Impacts of Water Management in the Rocky Glades

The impacts of water management changes in the Rocky Glades most likely date back to the beginning of drainage activities in the Everglades watershed. Unfortunately, little hydrologic information exists for the pre-drainage Everglades. Figure 2 shows water level hydrographs for two long-term monitoring stations in the Rocky Glades, which were installed in the late 1940's and mid 1950's (see Figure 1 for locations). Even with this late start, the plots indicate that the transitional wetlands in these areas were routinely subjected to short periods of seasonal flooding until approximately 1962, when the L-29 levee was completed, enclosing WCA 3B. Table 1 provides a brief summary of the water level and hydroperiod changes that have occurred in the Rocky Glades area. Prior to 1962, average wet season water levels exceeded 6.9 feet at the G596 gage, and exceeded 5.80 feet at the G789 gage. After 1962, average October water levels dropped by 1.2 to 1.5 feet at these gages. Similar reductions have occurred in average water levels during the late dry season. The reduced water levels have had a profound affect on hydroperiods in the Rocky Glades. Prior to 1962, surface water inundations occurred on average, 13 to 14 percent of the time. After 1962, surface water inundations occurred less than 1 percent of the time. More importantly, groundwater levels have become so low that much of the Rocky Glades has water levels several feet below the ground surface throughout the year. Under these conditions, rainfall rarely raises water levels to the point where

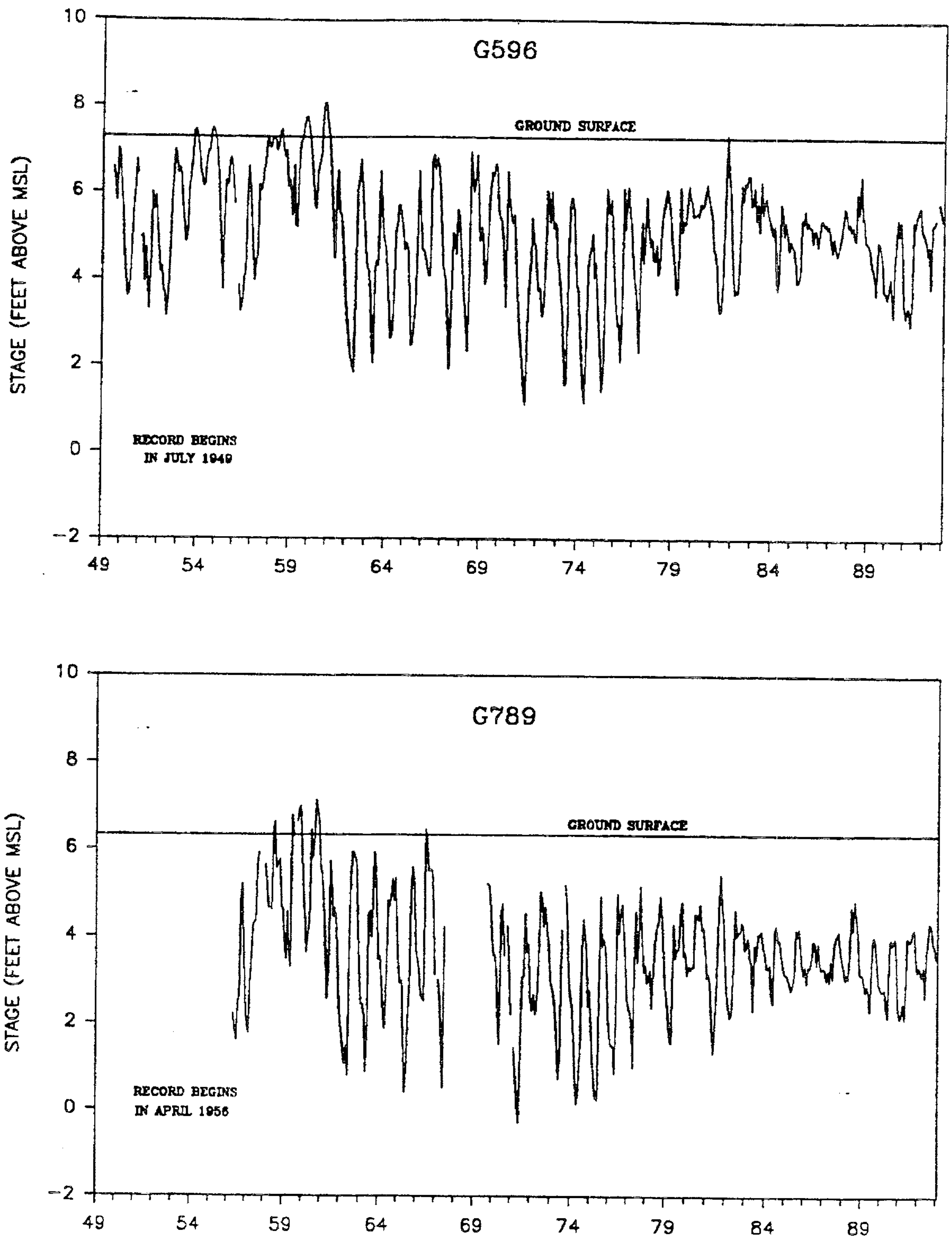

Figure 2. Water Level Hydrographs for two Long-Term Monitoring Stations in the Rocky Glades (see Figure 1 for site locations).

Table 1. Brief Summary of the Water Level and Hydroperiod Changes in the Rocky Glades. Key Stages are 6.0 feet at G596 and 5.0 feet at G789.

	PRE-1962		POST-1962	
SITE NAME	AVERAGE OCTOBER WATER LEVEL	AVERAGE APRIL WATER LEVEL	AVERAGE OCTOBER WATER LEVEL	AVERAGE APRIL WATER LEVEL
G596	6.93	4.96	5.71	3.47
G789	5.82	3.22	4.35	2.03
SITE NAME	PERCENT GREATER THAN KEY STAGE	PERCENT GREATER THAN GROUND SURFACE	PERCENT GREATER THAN KEY STAGE	PERCENT GREATER THAN GROUND SURFACE
G596	57	13	11	<1
G789	41	14	7	<1

surface water flows are produced, so the Rocky Glades have lost much of their ability to contribute flows to the Taylor Slough watershed, except under extreme rainfall events.

Wet season water levels show a further reduction in the early 1970's. The reduced water levels in the 1970's are thought to be a primary factor responsible for the increased agricultural and residential development throughout the low-lying areas of western Dade County. This has even allowed development to expand into the unprotected areas west of the Eastern Protective Levee System. This area remained relatively dry throughout the 1970's, as a result of a long period of lower than normal rainfall, the continued diversion of sheetflow away from NESS, and slightly improved drainage from the adjacent canals to the east. In spite of this, the agricultural and urban areas west of the L-31N canal are extremely susceptible to flooding, since the C&SF Project has no project features or provisions to provide flood protection in these areas.

In August and September of 1981, two extreme rainfall events produced extensive flooding in western Dade County. The unprotected areas of the East Everglades experienced surface water flooding for a period of several weeks. In June 1982, water levels in the adjacent L-31N canal were lowered, in an attempt to provide flood protection to the developed areas west of the L-31N canal. In mid 1983, after a period of high rainfall and continued flooding, the SFWMD began using the S-331 pump station to lower L-31N canal water levels to provide additional flood protection to the East Everglades Residential Area (8.5 Square Mile Area). This pump station was built as part of the South Dade Conveyance System, and was designed only for dry season water supply pumping. The SFWMD and the NPS have completed several hydrologic studies which show that the use of this pump station for flood protection has led to overdrainage of the Northeast Shark Slough wetlands, and may contribute to the flooding problems in the Rocky Glades agricultural area and the Frog Pond. In 1984, the Army Corps of Engineers, the SFWMD, and the NPS began a program of re-introducing surface water flows into the Northeast Shark Slough basin. As part of this program, the L-31N canal was further lowered, and strict operating criteria were established to limit NESS inflows during periods when the groundwater levels in the East Everglades are high. Hydrologic studies by the Corps, the SFWMD, and ENP have shown that throughout the NESS test, water levels in the East Everglades have remained below the pre-test levels. Even with these changes, the area remains subject to high groundwater levels and periodic flooding during extreme rainfall periods, because of low ground surface elevations, and its close proximity to the Everglades.

The Impacts of Water Management in Taylor Slough

Water level monitoring stations in the Taylor Slough basin were also installed well after the start of drainage activities in the Everglades. Figure 3 shows water level hydrographs for two long-term monitoring station in the Taylor Slough basin. The earliest monitoring data for the upper Taylor Slough area began at the bridge over Taylor Slough in late 1960. Monitoring began in the lower Taylor Slough area in early 1953. Table 2 provides a brief summary of the water level and hydroperiod changes at these two monitoring sites. The comparison in table 2 breaks the record based on the start of construction of the L-31N and C-111 canals in early 1965. Note that average wet season water levels at Taylor Slough Bridge and at P-37 show very little change. During the late dry season, water levels at the Taylor Slough Bridge have increased, as a result of supplemental water deliveries from the SDCS. Station P-37 shows no apparent water level or hydroperiod changes because it is located in the lower portion of the watershed, and the effects of local rainfall and its close proximatey to tide, overshadow the impacts of upstream water management.

Restoration Goals for the Rocky Glades and Taylor Slough

The wetlands throughout the Rocky Glades and Taylor Slough have experienced major changes in their original patterns of seasonal flooding and sequential drying as a result of reduced surface water inflows, the redirection of stormwater runoff to the eastern coastal canals, and the drainage effects of the canal system along the Park's eastern boundary. These hydrologic alterations have subsequently led to a reduction in the spatial scale of these wetlands, a loss of habitat heterogeneity, and declines in ecosystem productivity, that can be seen in many of the key plant and animal communities within the Park and adjacent natural areas. The current plan by the Army Corps of Engineers for Modified Water Deliveries to Everglades National Park is designed to address many of these

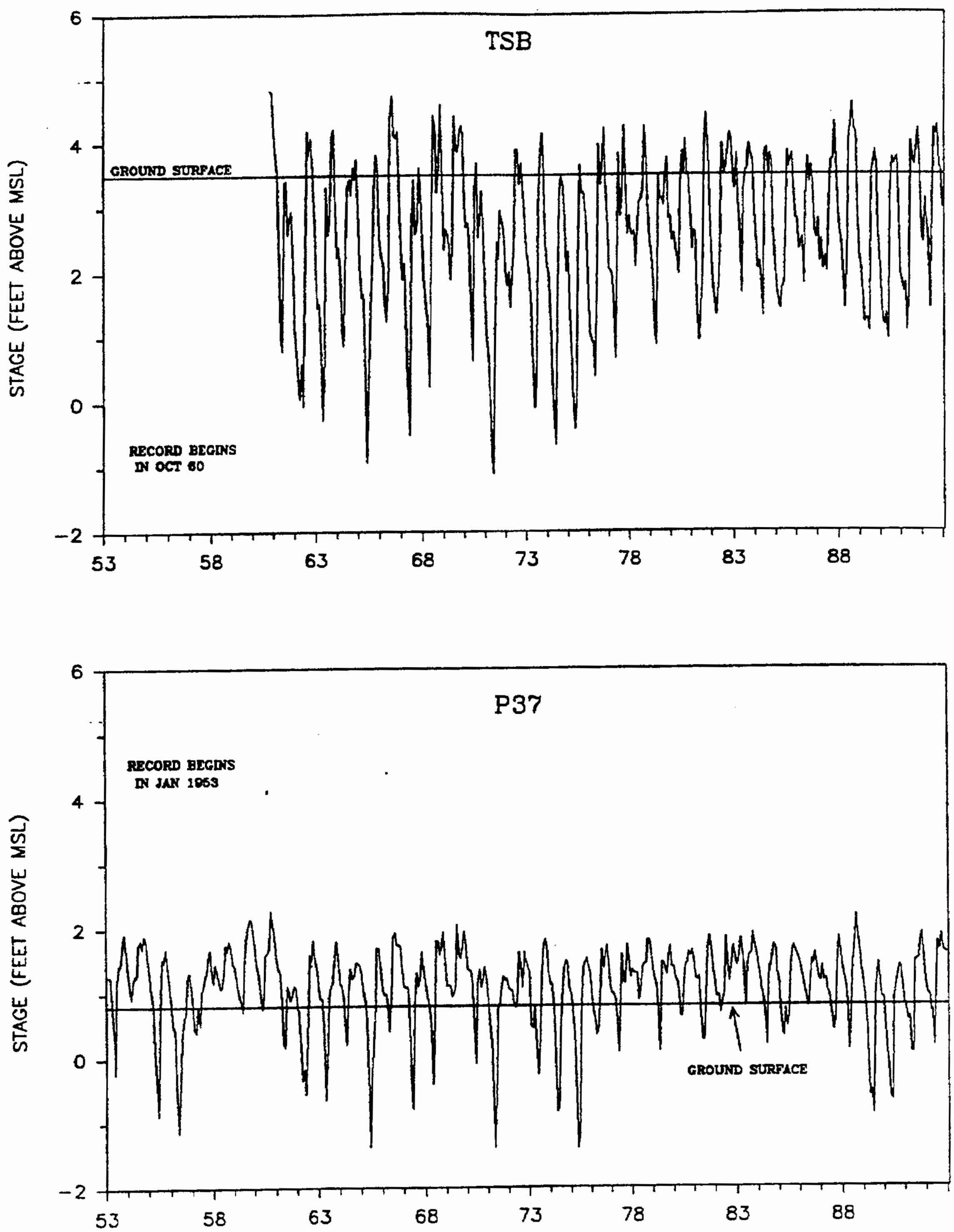

Figure 3. Water Level Hydrographs for two Long-Term Monitoring Stations in the Taylor Slough Basin (see Figure 1 for site locations).

Table 2. Brief Summary of the Water Level and Hydroperiod Changes in the Taylor Slough Basin. Key Stages are 3.0 feet at TSB and 0.8 feet at P-37.

	PRE-1965		POST-1965	
SITE NAME	AVERAGE OCTOBER WATER LEVEL	AVERAGE APRIL WATER LEVEL	AVERAGE OCTOBER WATER LEVEL	AVERAGE APRIL WATER LEVEL
TSB	3.83	0.54	3.71	1.24
P-37	1.67	0.24	1.62	0.25
SITE NAME	PERCENT GREATER THAN KEY STAGE	PERCENT GREATER THAN GROUND SURFACE	PERCENT GREATER THAN KEY STAGE	PERCENT GREATER THAN GROUND SURFACE
TSB	41	24	41	28
P-37	76	76	74	74

concerns through the re-introduction of sheetflow, and restoration of more natural water depths and hydroperiods in Northeast Shark Slough. This effort to re-establish higher surface water levels and longer hydroperiods in the deeper slough is crucial to increasing ecosystem productivity and maintaining adequate freshwater flows to the west coast estuaries, but these changes alone will not restore natural ecological function. Restoring more natural hydrologic conditions in the transitional wetlands of the Rocky Glades is also an essential component of this ecosystem restoration program. Without simultaneously raising groundwater levels and reinstating the historical seasonal inundations in the higher elevated prairies of the Rocky Glades, we will loose a key component of the natural diversity of habitats that are needed to sustain the wide range of animal species adapted to the natural Everglades Ecosystem.

Everglades National Park has developed a water management policy for Taylor Slough and the Rocky Glades that focuses on meeting a set of water level targets for the marshes in the northern portion of the Taylor Slough watershed. These weekly "average" water levels are based on their best estimate of the hydrology of the watershed in the 1930's and 1940's when the Park was established (Van Lent and Johnson 1993). The water level targets were designed to vary seasonally and annually in response to local rainfall, such that for any given week, half of the years will have water levels higher than this target, and half of the years will have water levels lower than the target. The weekly water level targets are calculated using an impulse response function, that is the mathematical relationship between rainfall and the average weekly stage for the period from 1933 through 1947. The plan would be implemented by adding up, or superimposing, the effects of all of the rainfall events over the previous 52 weeks,

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ENVIRONMENTAL EVALUATION FOR THE STRUCTURAL ALTERNATIVE PLANS FOR THE C-111 DRAFT GRR, SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS, DECEMBER 1993

John C. Ogden, William B. Robertson, Jr., Joe Carroll, Janet Ley, G. Thomas Bancroft, and Gerald Atmar

INTRODUCTION

This report provides a description of the process, and the results, from an effort to evaluate the environmental responses in the Taylor Slough and C-111 basins, and in eastern Florida Bay, to six proposed, alternative plans for structural modifications to the C-111, L-31N and L-31W water delivery systems.

ECOLOGICAL DEGRADATION OF THE TAYLOR SLOUGH AND C-111 BASINS

Although the timing and overall quantitative aspects of the biological degradation of the Taylor Slough/C-111 basins is poorly documented, it is well known that the region once maintained highly important wildlife habitat. We know, for example, that as recently as the 1940s and 1950s, Grossman's Slough (southwest of Grossman's Ridge) still supported a large, reproductively active population of American Alligators (G. Simmons, pers. observations). We also know that other sloughs in the headwaters east of Grossman's Ridge, including sloughs inside the present "8 1/2 sq. mile residential area", were important habitats for large numbers of migratory and wintering waterfowl and wading birds as recently as the late 1950s (D. Tabb and W. Robertson, pers. observations). Similarly, as recently as the late 1960s the headwaters of Taylor Slough and the East Everglades were important foraging habitats for Wood Storks from the now-abandoned Madeira Rookery in lower Taylor Slough (J. Ogden, pers. observations). Even the finger glades of Long Pine Key, now for the most part drained, were common feeding areas for Wood Storks in the 1940s and 1950s (E. Winte, pers. observations).

Loftus et al. (1992) suggest that the numerous rockland solution holes scattered throughout the higher elevation marshes that are characteristic of the Taylor Slough basin once were important refugia for fishes and aquatic invertebrates. The loss of these refugia due to regionally lowered ground water levels, mainly since 1962, has critically reduced the prey base necessary to support many larger vertebrates. The overall impression of long-time observers with respect to these basins is that the numbers for all species of larger aquatic animals, including otters, alligators, pied-billed grebes, anhinga, all wading birds, mottled ducks, and limpkins, have been substantially reduced during the past 30 years.

Aside from these qualitative observations, some quantitative studies support the same conclusion regarding the ecological degradation of the Taylor Slough and C-111 basins. A review of Wood Stork nesting patterns in the Park has shown that a relatively abrupt change in the timing of colony formation, one that has proved to be detrimental to colony success, occurred beginning in 1969-1970 (Ogden 1994). This change in timing of nesting coincided with the time when maximum water levels at a key station in northern Taylor Slough (G-789) declined to below ground surface (Van Lent and Johnson 1993). The number of sampling stations occupied by singing Cape Sable Sparrows in the Taylor Slough headwaters declined from 49 in 1981 to 12 in 1993 (Curnett and Pimm 1993). During the same period of years, habitat quality at 68 of the sampling stations in the same area, including those with singing males, was potentially degraded due to increases in the amount of woody vegetation in the marshes. The combination of reduced water depths and shortened annual hydroperiods are considered to be one of the primary environmental change that can result in invasions of woody vegetation into marshes (Kushlan et al. 1982).

The number of Roseate Spoonbills nesting and feeding in northeastern Florida Bay and in the mainland estuaries in the lower C-111 basin, respectively, has declined sharply since the early 1980s (Powell et al. 1991). This decline in spoonbill reproductive effort in the northeastern Bay occurred concurrently with changes in water delivery schedules for C-111, which presumably altered depth and drying patterns below the lower portion of C-111.
Reviews of ecological data from northeastern Florida Bay have suggested that elevated salinities have had a range of adverse impacts in the northeastern Bay, including alteration of the species composition of aquatic grass beds and reductions in the number of juveniles for several species of sport fishes (Boesch et al. 1993, McIvor et al. 1994). These salinity increases have been due to the reduction in freshwater flows entering the Bay from Taylor Slough and other mainland creeks.

These observations suggest that much of the ecological decline in this region has occurred since the 1960s. This time frame is consistent with the period of major alterations in the hydrology of the Taylor Slough and C-111 basins (Johnson and Fennema 1989, Loftus et al. 1992, Van Lent et al 1993, Van Lent and Johnson 1993). These authors show that significant lowering of water depths in the Taylor Slough headwaters began during the 1960s, and that by the late 1980s peak depths were 2 feet lower than the historical peaks. This magnitude of hydrological change has caused reductions in annual hydroperiods in upper portions of Taylor Slough of from 1 to 4 months, and has resulted in large areas of marshes no longer being flooded by surface water except during the wetter years.

ECOLOGICAL RESTORATION GOALS

Two basic assumptions underlie the ecological restoration goals for the Taylor Slough and C-111 basins and the downstream estuaries of northeastern Florida Bay. These are (1) that ecological restoration will for the most part only be achieved to the extent that hydrological restoration is achieved, and (2) that maximum restoration of ecological structure and function will require maximum recovery of the spatial extent and landscape heterogeneity of the system (Weaver and Brown 1993).

Specific ecological restoration objectives for the Taylor Slough and C-111 basins and Florida Bay are listed in the reports for sub-regions 7 and 8 in Weaver and Brown (1993). Four highly important, but representative, restoration objectives included in these lists should be emphasized here: (1) the recovery of keystone/indicator species, including pre-drainage wading bird nesting colony patterns, alligator reproductive patterns, and freshwater fish population movement and survival patterns, (2) the recovery of viable populations for all endangered and threatened species, (3) reestablish the upland freshwater source to mangroves and coastal wetland communities to restore their natural productivity and ecologically important detrital export to estuaries, and (4) the reestablishment of more natural spatial and temporal patterns of salinities in coastal estuaries.

Biological restoration of the Taylor Slough and C-111 basins also must be viewed as a companion endeavor with the Shark Slough restoration program. Although Taylor Slough and Shark Slough represent somewhat separate hydrological basins, their geographical proximity and complementary hydrologic systems support a single, dynamic wildlife community. Species with relatively large spatial requirements (Snail Kite, wading birds, etc.) are dependent on the combined habitat conditions in both of these basins for their survival. For example, the higher-elevation, short-hydroperiod marl prairies and the mainland estuaries, once much more extensive and/or more productive, served as essential early dry season foraging areas for Park-wide populations of wading birds.

ASSESSMENT PROTOCOL

Because environmental evaluations of the alternative structural plans for the C-111 project had to conducted in a period of approximately 8-10 weeks, and before species models for this purpose have been completed and tested, a more rapid evaluation process had to be developed. Our approach was to establish a small team of Everglades biologists/ecologists to (1) recommend the best evaluation process possible for the time frame available, and (2) conduct the environmental evaluations. The evaluation team consisted of John C. Ogden, chairman (NPS/EVER), Dr. William B. Robertson, Jr. (NPS/EVER), Joe Carroll (FWS/Vero Beach), Janet Ley (SFWMD/West Palm Beach), Gerald Atmar (COE/Jacksonville), and Dr. G. Thomas Bancroft (Natl. Audubon Society/Miami).

The evaluation team identified a series of ecological relationships that have been reasonably well demonstrated in the Everglades system, and for which some assessment of the alternative plans might be possible given the nature of the model output from the 1X1 hydrological model. The list of environmental relationships is presented below. For each of these ecological relationships, the team attempted to determine the number of 1X1 cells that showed improvement, degradation, or no change in habitat conditions, compared to the base condition, based on predicted changes in the hydrology in each cell.

The following ecological relationships were proposed for use in the evaluation of the alternative structural plans.

(1) Wood Storks. It has been shown that the timing of stork colony formation influences colony success rates, and that earlier colonies are more likely to be successful than are later forming colonies (Ogden 1994). It has also been shown that stork colonies in the park form earlier in years when extensive areas of the higher elevation, marl prairie marshes are flooded during the early dry season (November-December) than in years when these prairies are dry in these months. The evaluation will compare predicted changes in the number of cells located in the marl prairie portion of the study area that show surface water flooding during November and December. The preferred alternative will be the plan that shows the greatest increase in flooded cells for this region and these months.

(2) Roseate Spoonbill. Studies of spoonbill nesting patterns in eastern Florida Bay have shown that colony success is greatest when adult birds can find adequate feeding conditions in the mainland wetlands in the lower portions of the C-111 and Taylor Slough basins, especially during the nestling period from January through March (Bjork & Powell 1993). Ideal foraging conditions are created by extensive flooding early in the nesting season (Nov.-Dec.) followed by moderate, regional drying patterns through March. When drying is too slow, prey are not adequately concentrated; when it is too rapid, the adult birds are forced to fly greater distances to find adequate foraging sites. A preferred plan will be the one with the greatest number of cells in the lower basins flooded during November, and with 50-75% of these cells dry by end of March. A lower percentage of dry cells in March would indicate an inadequate drying rate, while a higher percentage would indicate a too-rapid drying rate, resulting in an unacceptably extensive drying of foraging habitats within range of the colonies.

(3) Cape Sable Sparrow. It has been shown that Cape Sable Sparrow nesting colonies only occur in marshes that lack even sparse amounts of woody vegetation (Werner 1975). Invasion of marshes by woody vegetation can occur

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where annual hydroperiods and/or water depths are reduced (Kushlan and Bass 1983, Taylor 1983). The preferred alternative will be the plan that shows the greatest increase in the number of flooded cells during the summer wet season (July-October), and following the sparrow nesting season (February-June; Werner 1975).

(4) American Alligator. It has been shown that the number of adult female alligators that initiate nesting during June each year is proportional to the area of surface flooding in the sloughs during the alligator pre-nesting, courtship period in April and May (M. Fleming unpublished data). Cells that occur in Taylor Slough will be compared for surface water patterns during the courtship months, with the preferred alternative being that plan which has the highest number of flooded cells for these two months.

(5) Freshwater fishes. It has been shown that increases in the length and spatial extent of uninterrupted, between-year hydroperiods results in increases in density and biomass of fishes (Loftus and Eklund 1994). The preferred alternative will be that plan that shows the largest number of cells in Taylor Slough with uninterrupted, inter-annual flooding.

(6) Freshwater fishes. It has been proposed that solution holes in the marl prairies are important refugia for fishes and aquatic invertebrates when the marshes in these areas lack surface water (Loftus et al. 1992). Data collected by Loftus suggest that when water levels drop more than 1 m. below ground level, that the presence of these aquatic animals in solution holes is much reduced. The preferred alternative will be the plan that has the fewest cells in the marl prairie regions with water levels that drop more than 1 m. below ground for one or more months during the year.

(7) Estuarine fishes. Data have been collected that suggest that higher numbers and biomass of fishes during the dry season in the mainland estuary in the lower C-111 basin are associated with relatively deeper flooding during the later months (September-October) of the preceding wet season (J. Lorenz unpublished data). Based on the Lorenz data, the preferred alternative will be the plan that predicts the largest number of cells in the lower C-111 and Taylor Slough basins with surface depths greater than 0.5 feet of water during the late wet season months, September-October.

(8) Emergent aquatic plants. An earlier ecological assessment of the Taylor Slough basin has suggested that drying greater than 24-30 inches below ground surface results in stress to root systems of emergent aquatic plants (Tabb 1987). We propose to select a preferred alternative for this relationship by identifying the plan with the fewest cells showing subsurface drying greater than 30 inches for two or more consecutive months per year.

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(9) Periphyton. A review of periphyton community dynamics in the Everglades has suggested that areas with 1 to 5-7 month hydroperiods will be dominated by blue-green algal communities, while areas with 7 to 12 month hydroperiods will be dominated by diatom/green algal communities (Browder et al. 1994). This review also suggests that diatoms/green algae are more important in Everglades food chains, and that shifts in community composition due to shortened hydroperiods may have caused fundamental changes in productivity in Everglades marshes. The preferred alternative will be the plan that shows the largest number of cells with 7 to 12 month hydroperiods.

(10) Soil indicators. An earlier assessment of the ecology of the Taylor Slough basin suggested that the broad marl prairies should experience maximum hydroperiods that average 6-7 months, if these regions are to be ecologically healthy (Tabb 1987). A preferred alternative for this relationship will be the plan that produces the largest number of cells with 6-7 month hydroperiods in years with average rainfall.

This list of environmental relationships does not include eastern Florida Bay components because the 1X1 model does not extend as far south as the Bay or into the mainland estuaries immediately along the north shore of eastern Florida Bay. For this reason, and because no mathematical relationship between upstream water flows and northeastern Bay salinities has been developed, no quantitative evaluation of environmental responses in the Bay was possible for this report.

The environmental team based its evaluations on output from the 1X1 hydrological model, programmed to run with the current rainfall-based delivery formula and using the currently authorized operational criteria for optimum canal stages. For the environmental evaluations, the output from the model runs were processed by the EVER modeling team (R. Fennema et al.). These processed data consisted of separate sets of maps showing average annual water depths and annual hydroperiods for each 1X1 cell for Base conditions and for each alternative plan, for a wet year (1968-69), dry year (1973-74) and a normal rainfall year (1976-77). These data also were presented in summary tables, which included a monthly breakdown of the number of cells with surface water and the number of cells with annual hydroperiods in different depth classes, for each plan and year.

For the purposes of these environmental evaluations, three different subsets of the 1X1 cells were identified, representing three separate habitat types: marl prairies, central Taylor Slough, and the lower C-111 basin. The number of 1X1 cells in each of these habitat subsets were as follows: marl prairie (229), central Taylor Slough (78), and lower C-111 basin (86). End of month water depths for each cell in each subset, and for each of the three modeled years, were used in the final evaluations reported here. Only the subset of cells that was appropriate for the specific relationship being examined was used in each of these final evaluations.

RESULTS

Our evaluations are summarized below. For two reasons the team did not conduct environmental evaluations for all 10 of the ecological relationships identified in the above list. First, the post-processing of the 1X1 model output was unable to produce the hydrological data in all of the different formats required for these evaluations, in the time available for conducting these evaluations. Thus the team only was able to conduct five of the proposed evaluations, for the Wood Stork, Cape Sable Sparrow, American Alligator, Roseate Spoonbill and for the hydroperiod/freshwater fishes relationship. And secondly, because the hydrological data shown for the groupings of cells within each habitat subset were essentially identical, from an ecological perspective, both among the different alternative plans and between the Base condition and the alternative plans, the evaluation team was comfortable with the decision to produce an evaluation report for a sample of the ecological relationships representing each of the three habitat subsets of cells.

Marl Prairies:

1. Wood Stork. This evaluation compared differences in the areal extent of surface flooding in the marl prairies during the traditional months of colony formation, November and December. The preferred alternative plan would be the one showing the greatest increase, compared to the Base condition, in the number of flooded cells during these months in the marl prairies.

The combined two month total number (maximum 458 cells) of flooded cells during November and December for Base condition and for each plan are as follows (percentages are % increase compared to Base):

Base: Wet year= 298 cells; Dry= 250 cells; Norm.= 262 cells.
Plan 1: 306(1.0%); 254(1.6%); 271(3.4%): (cumulative 3 year increase: 2.6%).
Plan 2: 309(3.6%); 252(0.8%); 272(3.7%); (3.4%).
Plan 3: 333(10.6%); 270(7.7%); 302(13.3%); (10.5%).
Plan 4: 320(6.9%); 270(7.5%); 298(12.1%); (8.8%).
Plan 5: 323(7.8%); 259(3.5%); 293(10.6%); (7.5%).
Plan 6: 320(6.9%); 262(4.6%); 294(10.9%); (7.5%).

Plan 3 scored highest in all three years; Plan 4 scored 2nd highest, followed by

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plans 5 and 6. Although differences among plans 3, 4, 5 and 6 were not great, these four plans were stronger than plans 1 and 2. Thus it may be concluded that Plans 3 through 6 potentially can produce larger areas of early dry season foraging habitat for Wood Storks than can the other Plans or the Base condition, and therefore are more likely to improve stork reproductive effort in the southeastern Everglades.

2. Cape Sable Sparrow. Assuming that surface flooding in the marl prairies during the July through October wet season is an important control for woody plant invasion into sparrow nesting habitat, the plan showing the greatest increase in number of flooded cells, compared to the Base condition, would best benefit the sparrow. We scored each alternative plan for the cumulative, total number of cells flooded during these months (percentages are % change from Base):

Base: Wet year= 841 cells; Dry yr.= 688 cells; Normal yr.= 688 cells.
Plan 1: 846(0.6%); 704(2.3%); 707(2.7%); (cumulative increase= 1.8%).
Plan 2: 853(1.5%); 737(6.7%); 742(7.3%); (5.0%).
Plan 3: 856(1.8%); 758(9.3%); 766(10.2%); (6.9%).
Plan 4: 841(0.0%); 751(8.4%); 761(9.6%); (5.8%).
Plan 5: 854(1.6%); 758(9.3%0; 758(9.3%); (6.5%).
Plan 6: 844(0.4%); 748(8.1%); 753(8.7%); (5.5%).

Plans 2 through 6 show greater increases in total number of flooded cells during the wet season, than does Plan 1, and presumably would benefit sparrow habitat by having greater potential for controlling woody plant invasion into the marl prairie marshes. The strongest plans appear to be 3 and 5.

Taylor Slough:

3. American Alligator. The assumption is that the number of adult female alligators initiating nesting each June will be proportionate to the area of Taylor Slough that is flooded during the April-May courtship period. Thus the plan showing the largest increase in flooded cells in these 2 months should show the most improvement in nesting effort compared to Base. The combined April-May totals for Base and each Plan are as follows:

Base: Wet year= 102; Dry= 4; Norm.= 65; Cumulative total= 171.
Plan 1: 103; 6; 65; Total= 174.
Plan 2: 101; 3; 69; Total= 173.
Plan 3: 101; 2; 69; Total= 172.
Plan 4: 102; 3; 67; Total= 172.

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Plan 5: 101; 3; 68; Total= 172.
Plan 6: 101; 4; 66; Total= 171.

This evaluation shows no difference among the different plans in the number of flooded cells in central Taylor Slough, and no difference between the plans and the Base condition.

4. Freshwater fishes. This evaluation assumes that the Plan that shows the fewest number of dry cells in Taylor Slough will be the Plan that most improves reproduction and survival among fishes. The hydrological evaluation of the 1X1 model output shows that the driest months occur in February, March, April and May, the months with the fewest flooded cells. For each Plan, the four month cumulative total of dry cells is compared with the cumulative total for the Base condition:

Base= Wet year= 96; Dry= 300; Normal= 202; Total= 598 dry cells.
Plan 1: 94; 297; 201; Total= 592.
Plan 2: 97; 302; 192; Total= 591.
Plan 3: 97; 301; 199; Total= 597.
Plan 4: 95; 297; 197; Total= 589.
Plan 5: 97; 304; 203; Total= 604.
Plan 6: 96; 297; 201; Total= 594.

This evaluation shows no meaningful difference among the six alternative plans in the number of dry cells, and no habitat improvement (reduction in dry cells) between Base and the plans.

Lower C-111 Basin:

5. Roseate Spoonbill. The evaluation for spoonbill habitat cells is based on information that shows that nesting success is reduced in years when extensive drying or flooding occurs during the months of the nesting cycle. Our assumption is that ideal foraging habitat is created when more moderate drying rates our, when between 50% and 75% of the cells that are flooded in November become dry by the following March. The following evaluation shows the percentage of cells that become dry between November and March. The preferred plans will be those that show more than 50% and fewer than 75% of the cells drying during this period.

Base: Wet year= 23.8% drying; Dry= 100%; Normal= 65.2%.
Plan 1: 18.8%; 100%; 65.7%.
Plan 2: 21.0%; 100%; 64.8%.

Plan 3: 13.6%; 100%; 66.7%.
Plan 4: 17.5%; 100%; 70.9%.
Plan 5: 25.0%; 100%; 68.7%.
Plan 6: 20.0%; 100%; 65.2%.

Neither the Base condition nor any of the plans are predicted to provide suitable foraging habitat during wet and dry years. The best wet year drying rate occurred under Plan 5. The Base condition and all plans provide suitable foraging habitat during the normal rainfall year, although the six plans show no meaningful improvement compared to the Base condition.

DISCUSSION

The results from these five environmental evaluations suggest that while plans 3-6 may provide greater ecological benefits, this type of evaluation does not reveal strong environmental benefits from any of the proposed plans. None of the plans are predicted to provide greater than 10% increases in the number of improved habitat cells. Even this low level of improvement may be of no ecological significance, in view of the assumed, but unmeasured, degree of error that is inherent in all models. More specifically, these evaluations show no changes in the numbers of improved habitat cells in the Taylor Slough and lower C-111 basins, and very modest improvements in the Marl prairies.

A more positive perspective is that alternative plans 3 through 6 show potential for habitat improvement in the marl prairies, the habitat type that appears to be most in need of restoration. Irrespective of the actual water depth values produced by the 1X1 model, the fact that the output for all of the alternative plans, especially 3-6, all show increases in the number of improved habitat cells strongly suggests that these plans potentially can meet the restoration targets set for this region, once improved delivery formula and operational criteria are in place.

The primary reason why these plans do not show strong environmental benefits is because they each have been modeled with essentially the same delivery formula and operational criteria. The different structural modifications being evaluated do no more than move a fixed amount of water around to different places in the Taylor Slough/C-111 basin. Thus each plan tends to improve habitat conditions in one location at the expense of habitat conditions in a different location. The fact that the model output shows much greater hydrological responses among the three different categories of rainfall years than among plans within a year shows that substantial increases in total, regional volumes of water will produce much greater numbers of improved habitat cells than will structural modifications alone.

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The environmental evaluation team agrees with the hypothesis that the initial focus for ecological restoration must be on achieving hydrological restoration (Weaver and Brown 1993). The test for this hypothesis requires that a strong, regional ecological monitoring program be developed to be implemented as an integral part of the C-111 project. The environmental evaluation team assumes that a more useful assessment of environmental benefits from the C-111 project will be produced once further structural improvements identified by the current hydrological evaluation of alternative plans are incorporated, and a set of alternative operational plans are modeled.

LITERATURE CITED

Hydrological Evaluation of the Proposed Alternatives for the U.S. Army Corps of Engineers' General Re-evaluation Report for the C-111 Basin

National Park Service
Everglades National Park
South Florida Natural Resources Center

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U.S. Department of the Interior
National Park Service
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1 Executive Summary

The restoration of Everglades National Park is possible only if the extent and duration of surface water inundations and surface water flows are brought back to more natural levels, resembling pre-drainage conditions. The Army Corps of Engineers C-111 General Re-evaluation process was designed to address flood control, environmental enhancement, and water management improvements in the C-111 basin. This report describes the predicted hydrological impacts on the water resources of the Park and adjacent areas caused by each of the structural alternatives proposed in the GRR process. The analysis relied entirely on output from the South Florida Water Management District's 1x1 version of the South Florida Water Management Model (Version 1.2), which was modified by the District and the Corps to simulate each of the alternatives.

- The Park's criteria for the evaluation of the structural alternatives focused heavily on the re-establishment of more natural surface water and groundwater levels in the wetlands of the C-111 basin. As proposed, all of the alternatives would provide only very modest improvements in ground and/or surface water levels in these natural areas. Most of the salient items offered in the alternatives provide for increased flood control and drainage for the eastern developed areas, but do little to address the continued environmental degradation of the natural areas west of the Eastern Protective Levee System.

- Alternatives 1, 2, 3, 5 and 7 provide increased flood control and water supply benefits by pumping into the main channel of Taylor Slough through large pumps located at a single location. In contrast, alternatives 4 and 6 use five moderate size pumps to spread water out over the wetlands of the Rocky Glades and northern Taylor Slough. The increased pump capacity in the headwaters and northern portion of the Taylor Slough basin provide for large increases in wet season flows through the Taylor Slough Bridge cross-section, but produce only modest additional flows into the downstream areas of Taylor Slough and Florida Bay.

- None of the alternatives significantly restore more natural conditions in the Eastern Panhandle watershed of the lower C-111 basin, however all plans degrade the spoil piles on the southern bank of the C-111 canal. Alternative 5 partially backfills the C-111 canal south of S-18C, and Alternatives 3 and 4 backfill the canal completely south of the confluence with C-111E. All, except Alternative 7, place plugs in C-109 and C-110, but do not backfill the canals. Additional flood control and water supply discharges to the Eastern Panhandle are proposed in all but Alternative 7. A new spreader canal (C-500E), aligned eastward from the confluence of the C-111E and C-111 canals, is added in Alternatives 1 through 6. This canal would be supplied by either a 50 cfs pump (Alternatives 1, 2, and 6) or a 500 cfs pump (Alternatives 3, 4, and 5).

- Alternatives 2 through 6 lower wet season water levels in the L-31N canal, and throughout much of the eastern developed areas, to levels well below those predicted for the Base condition. Water budget computations indicate that this practice leads to continued over-drainage of the Rocky Glades and northern Taylor Slough wetlands. Low wet season water levels in the L-31N, C-111, and coastal canals also cause massive seepage losses to the east. Average annual seepage losses from the marshes west of the L-31N canal were in excess of 225,000 acre-feet, under the Base condition. For comparison, average annual inflows to the Shark Slough basin are approximately 550,000 acre-feet under the current operating schedule. This indicates that a large proportion of the water deliveries to the Park are lost, due to the maintenance of low water levels to the east.

- Our assessment showed that Alternatives 2 through 6 slightly lower groundwater levels in the western developed areas of the Rocky Glades and the Frog Pond, but groundwater levels will remain high under the base condition, and all of the proposed alternatives. Under all of these plans, the developed areas are subject to frequent root zone flooding under normal wet season conditions, and short periods of surface water inundations during extreme storm events. Flooding problems in these areas will continue to occur because of the low-lying nature of these lands, and their close proximity to the Everglades.

Our assessment of the alternatives was based solely on the predicted impacts of the proposed structural modifications. While this approach may be an acceptable method for designing flood control projects, it does not work for a multi-purpose project designed to also provide environmental benefits. Hydroperiods (the duration of surface water inundations) and hydropatterns (the spatial extent of surface water inundations) are the most important aspects of the Park's hydrology and, today, they are largely controlled by the operational levels in the adjacent canals. Changes in these parameters have profound effects on the associated plant and animal communities and need to be fully evaluated.

Thus, in addition to the proposed structural changes, operational adjustments need to be implemented to properly evaluate potential environmental benefits. For example, changes in structure capacities and canal design conditions should prompt changes in operational policies. Larger pump capacities must be balanced by increases in normal canal operational stages, or the increased capacities may provide drainage beyond the authorized levels of flood protection. Increased canal operational stages in turn allow more of the wet season runoff to be stored in the adjacent aquifer, which reduces dry season supplemental water demands. Higher wet season canal stages also reduce seepage losses from the wetlands and let the adjacent marsh water levels remain higher. These operational changes must be evaluated at the same time as the testing of structural alternatives, or the multiple purposes of the C&SF Project cannot be properly balanced.

Using our knowledge of the surface water and groundwater hydrology along the Park's eastern boundary, and the history of past water management problems in these areas, we have developed a conceptual plan which we believe will provide the authorized levels of flood protection to the eastern developed lands, while allowing for significant improvements in the hydrology of the adjacent natural areas. This new alternative would create a buffer zone between the eastern developed areas and the Park, which would provide an area to temporarily store excess runoff, before it is passed into the wetlands of the Park. This approach would:

1) improve the timing and duration of surface water inflows to both the Park and state lands,

2) reduce the documented over-drainage of the adjacent wetlands, and

3) allow the re-establishment of higher wetland stages throughout the natural areas of Northeast Shark Slough, Taylor Slough, and the lower C-111 basins.

All of these watersheds are hydrologically linked, and modifications proposed under separate GDM's, GRR's, FDM's, etc. do not allow for a comprehensive evaluation of the hydrological impacts, or ecological benefits, of proposed structural and operational modifications. Further evaluations, which will allow the testing of significant changes in both structures and current operational practices, are required before a preferred alternative can be reasonably selected.

2 The Flat, Wet, Lonely Wilderness

That is what Daniel N. Beard called Everglades National Park in his Special Report on the Everglades National Park Project in 1938 and he added

> *... and so it must remain forever.*

The reasons for establishing an Everglades National Park have not changed much since 1938, the Everglades are indeed a more subtle and dynamic environment than most areas with outstanding geographic features. Conservation of a fragile ecology, so dependent on the seasonal fluctuation of water levels were concerns in 1938 as much as they are today.

Fifty years later, 1988 brought more of the same, low water levels, coupled with a natural drought and artificial canal drawdowns. Water levels in the Rocky Glades, the headwaters of Taylor Slough, barely poked through to the surface. Unrelenting drainage of the swamp continues to take its toll, altering the landscape so much that today even slow-evolving biota, such as marsh vegetation communities, can be observed to disappear and be replaced by woody vegetation. Daniel B. Beard knew about the problem stating in his chapter on "The Effects of Human Use, Drainage:"

> *The most important problem to be settled before the Everglades Park is established is that of restoring water levels ...*

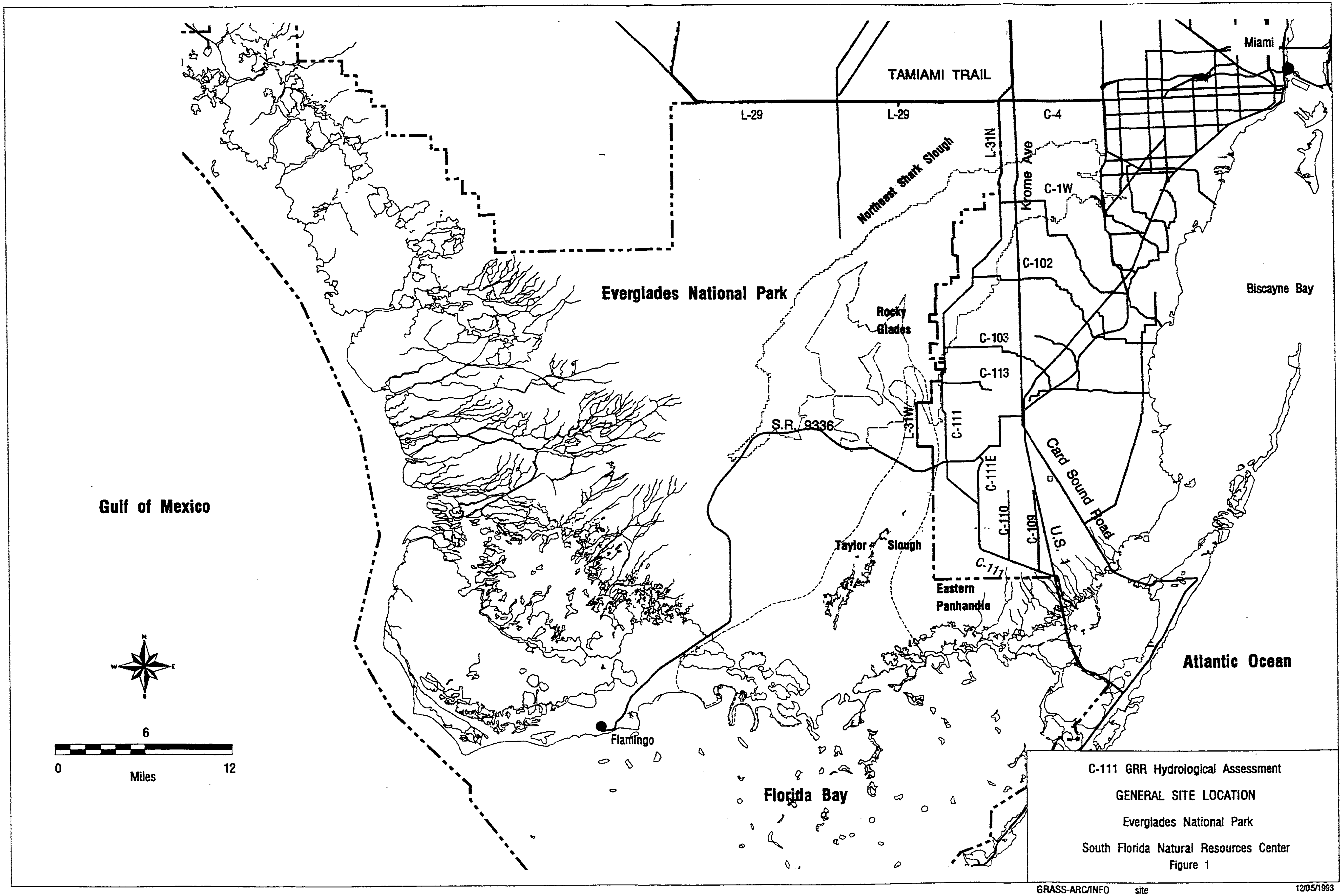
Serious efforts are needed to recreate the basic hydrology of a pre-drainage Park. Not until the long term decline of water levels has been reversed can restoration efforts begin to be addressed. Perhaps a synergistic approach coupled with wise administration will begin to show the results so that his goals may finally be realized:

> *In fifty years, the Everglades National Park is capable of becoming an outstanding place.*

3 Introduction

The purpose of this report is to provide a hydrological assessment of the proposed modifications to the canals and water contiol structures of the C-111 drainage basin. The C-111 basin covers an area of approximately 100 mi^2 and extends southward from Tamiami Trail to Florida Bay, and from the western side of the Atlantic Coastal Ridge well into Everglades National Park (ENP). The principal north-south levees and drainage canals are L-31N and C-111 (Fig. 1). These levees, canals and associated structures were constructed as part of the Eastern Protective Levee System (EPLS) of the Central and Southern Florida project (C&SF Project), authorized by the Flood Control Act of 1948 (PL 80-858). The Flood Control Act of 1954 (PL 83-780) authorized construction of the L-31W canal and levee. The Flood Control Acts of 1954 and 1962 (PL 86-645) authorized construction of the C-111 canal and levee system and improvements to several of the south Dade coastal canals (see [Lent *et al.*, 1993] for an overview). The primary purpose was to provide flood control for the developed lands east of the L-31N and C-111 levees. The development of this flood control project has led to severe over-drainage of wetlands in and adjacent to Everglades National Park. Concerns about the loss of natural habitats in the wetlands and degradation of Florida Bay sparked the process to develop solutions to reverse the decline of these natural areas.

The 1963 Corps GDM for South Dade County stated that the L-31N, C-102, and C-103 canals were to be constructed so that, during the design storm, approximately 28 square miles of land east of L-31N and west of the Seaboard Airline Railroad would be drained westward into Taylor Slough via L-31W canal [U.S. Army Corps of Engineers, 1963b]. The L-31W canal was specifically added as part of the 1963 GDM to replenish the freshwater supply to Taylor Slough. Unfotunately, the construction of the canal further divided the headwaters of Taylor Slough, placing a large portion of the watershed east of the L-31W canal, within the area now known as the Frog Pond. The initial GDM operational plan specified that S-175 and S-176 would remain closed under normal conditions. L-31N would be held as high as 6.5 ft. NGVD to promote the discharge of water into L-31W via S-174. Water would then spill overbank from the L-31W canal into Taylor Slough. Under flood conditions, up to 500 cfs would be discharged into L-31W via S-174 and out S-175, to maximize Taylor Slough inflows. The Everglades National Park-South Dade Conveyance System (SDCS) was authorized by Congress in 1968 (PL 90-483) to increase the conservation and conveyance of water supplies to ENP and the developed areas of South Dade. Improvements were made in the L-31N canal



C-111 GRR Hydrological Assessment

GENERAL SITE LOCATION

Everglades National Park

South Florida Natural Resources Center

Figure 1

to increase dry season water deliveries to Taylor Slough via canal L-31W and pump station S-332 (see [Lent *et al.*, 1993]).

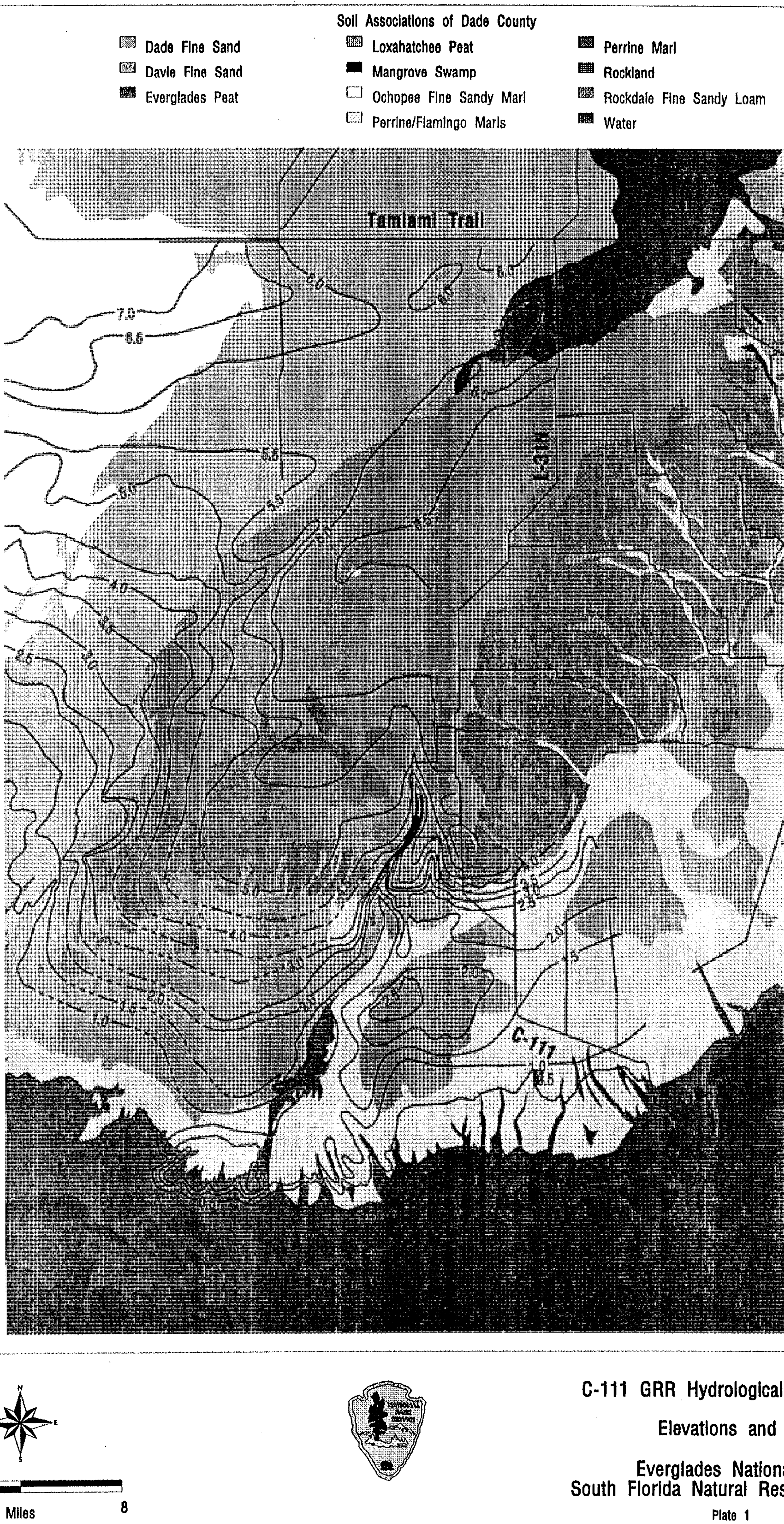
3.1 The Natural Features of the C-111 Basin

A generalized soils information superimposed with preliminary ground surface elevations in this portion of southern Dade County is shown in Fig. 2. The soil associations and related land elevations define the original landscape features within the C-111 basin. The soils information was taken from a University of Florida publication entitled Soils Associations of Dade County, Florida [Leighty *et al.*, 1954]. The ground surface elevations are from a GIS database developed by the Park, based on topographic surveys made for the SFWMD, COE, and ENP. This elevation contour map and existing soils data of the C-111 basin are used to define the landscape features important to the wetlands. A comparison of this recent data and the model's grid cell elevations has not been done. The contour map is being drawn to refine the elevations in use in the SFWMM and the natural system version. Further work is needed to refine the elevations to include the small-scale features of the landscape.

Much of the following site description is taken from an excellent summary on the physiographic features and original ecological conditions of the lower Everglades, Florida Bay, and the Florida Keys developed by the U.S. Fish and Wildlife Service [Shomer and Drew, 1982]. The soil descriptions indicate that all of the study area, except the higher elevated Atlantic Coastal Ridge (underlain by Rockdale fine sandy loam), was originally subject to seasonal flooding, due to the low elevations and/or poorly drained soils. Shark Slough shows up as the broad southwesterly trending arc of continuous wetlands underlain by Loxahatchee and Everglades Peats, which historically were inundated throughout most of the year. This is the continuation of the Everglades trough, which is a wide, slightly concave depression in the underlying limestone. Northwest of the Shark Slough wetlands the bedrock of the Everglades rises gradually into the Big Cypress Spur. This area is underlain by the Ochopee Marl. To the southeast of Shark Slough is an area referred to as the Rocky Glades (underlain by Rockland soils) which was historically inundated for a few months each year, at the peak of the wet season ([Shomer and Drew, 1982]). The name Rocky Glades was derived from the character of the limestone pinnacle rock exposed at the surface of much of this area. In its natural state, this area was characterized by rocky, open, muhly grass prairies, with thin eroded marl soils overlying a solution riddled limestone surface. The southern portion of this area slopes to the southeast, and forms the headwaters of the Taylor Slough watershed. This area historically provided surface water inflows principally from the low-lying portions which are underlain by the Perrine Marl.

This poorly drained, low-lying area extends for some distance eastward throughout much of the Frog Pond, and northward along the western flank of the Atlantic Coastal Ridge. From this point, the marl soils run southward down Taylor Slough, through a breach in the Atlantic Coastal Ridge. This isolated western-most extent of the Coastal Ridge forms Long Pine Key, which is the only high ground area in this portion of the Park. The soils and elevation information in this area clearly shows that much of the headwaters of the Taylor Slough watershed occurs to the east of the L-31W and C-111 canal and levee systems, well outside of the protected areas of the Park. The construction of these levees and canals has therefore isolated a large portion of the historical contributing area to Taylor Slough, which is a major reason for the long-standing conflicts over water management in this area. Most of the northern Taylor Slough basin west of L-31W has ground surface elevations in excess of 4.5 to 5.0 feet. In contrast, the very low elevations along the alignment of the L-31W canal and southward from the S-332 pump station, form a distinct dry season flowway, that historically maintained longer hydroperiods than the adjacent marshes. This area has continue to support a longer hydroperiod that the adjacent marshes following the implementation of dry season pumping at S-332. South of the main park road, the marl soils are deeper and are underlain by scattered areas of peat. Hydroperiods in this area increase due to additional surface water inflows from a second natural flowway located along the alignment of the lower L-31W canal. This area historically also received runoff from the marl areas along the eastern side of the Frog Pond. A portion of these flows have continued, to some extent, by wet season releases through S-175.

The lower C-111 or Eastern Panhandle basin is part of the Southeast Coastal Glades, which are underlain by a mixture of freshwater (Perrine) marls in the areas adjacent to the Coastal Ridge that transition into the Flamingo Marl near the coast. The Flamingo Marl forms in areas characterized by more salt-tolerant grasses and sedges. The soils in this area therefore reflect the variable nature of freshwater inflows and are a mixture of marine and freshwater marls. Under natural conditions, the lower C-111 basin would have received wet season runoff from the southern portion of the lower Atlantic Coastal Ridge, and provided the only outside source of freshwater to the northeastern portion of Florida Bay. Today the original pinelands in the southern Coastal Ridge area have been lost through the urban and agricultural expansion of Homestead and Florida City. Because of the development of these areas, much



C-111 GRR Hydrological Assessment

Elevations and Soils

Everglades National Park
South Florida Natural Resources Center

Plate 1

of the natural runoff is now routed eastward into Biscayne Bay. This accounts for a significant loss of natural sheetflow from the original upstream contributing area. This drainage has led to woody and exotic plant invasions into the northern marshes of the lower C-111 basin. In the mid 1960's the northern portion of the C-111 canal (adjacent to the Frog Pond) was constructed. This canal produced an artificial breach in the Coastal Ridge, that has allowed wet season runoff from northern Taylor Slough, and Northeast Shark Slough basins to be transferred into the lower C-111 basin. This has undoubtably increased wet season inflows, but the water enters at a point very low in the basin. The recent acquisition by the State of much of the northern marshes in this basin has led to increased pressure to re-introduce surface water flows as far north as possible, as a way of maximizing the benefits of natural sheetflow.

3.2 Water Management Problems in the C-111 Basin

In June, 1982, following record rainfall and widespread flooding caused by tropical storm Dennis, water levels in L-31N canal were lowered to provide flood protection to the developed areas of the East Everglades. In 1984 as part of a trade-off for increased water deliveries to Northeast Shark Slough (NESS), water levels in the canals along the eastern border of ENP were further lowered during both the dry and wet season. Development of lands formerly in low lying areas of the historical Taylor Slough watershed accelerated. Since that time the environmental degradation of the wetlands has accelerated and substantial areas in the headwaters of the Slough have lost surface water. Hydroperiods, the length of time that surface water is present during a year, were substantially reduced, to the point that these areas are losing their wetland character.

This reduction in canal water levels, below the authorized flood control elevations, has spurred an increase in farming and residential development in the East Everglades, Rocky Glades and the Frog Pond. Agricultural practices in these areas have changed from planting when water levels had naturally receded (at times this probably happened well into January) so that now seasonal crops are being planted at the height of the historical wet season. More recent demands for additional drainage to support year-round agriculture have further aggravated the lowering of marsh water levels in ENP. Farming probably took place in portions of these areas in the 1920's and definitely occurred in the 1940's in historical low-lying muck lands of Taylor Slough. With the advent of rock-plowing, a technique which breaks up the soft limestone, all of the low-lying farm lands were abandoned. As evidence, no farming activity can be found in these areas in the available aerial photos of the mid 1970's. With the ever-continuing drainage of the Everglades and the construction of L-31W, these low-lying areas again became attractive. Under the current drained conditions in Taylor Slough, it has even become possible to plant lime groves, an activity needing year-round low water levels.

Since the early 1980's, Everglades National Park has been pressing for improved water management practices in the Taylor Slough and C-111 basins, under the authority of the Congressionally mandated Experimental Water Delivery Program. We have frequently voiced our concern that the reductions in L-31N, L-31W, and C-111 canal operational stages over the past ten years were done without adequate environmental evaluations. The Park has completed numerous technical studies (see *e.g.,* [Johnson *et al.*, 1988], [Johnson and Fennema, 1989], [Loftus *et al.*, 1992], and [Lent *et al.*, 1993]) that have shown that these operational changes have caused serious wetland drainage impacts and associated ecological problems in the Rocky Glades, Taylor Slough, and the lower C-111 basin.

In November 1989, the Park sent the Corps a detailed summary of overall restoration goals for the Taylor Slough basin, related to the request for expansion of the scope of the 1988 Draft Canal 111 GDM. The Park emphasized that the starting point for all the restoration efforts should be a return to the original authorized canal operations criteria in the C-111 canal system. In 1990 the SFWMD implemented a series of structural and operational improvements as part of the C-111 Interim Project. The interim recommendations were designed as a short-term solution to two specific problems in the C-111 basin:

a) Increased flows into the lower C-111 basin resulting from the implementation of wet season stormwater pumping at S-331.

b) The lack of water management flexibility of the earthen plug (S-197) at the downstream end of the C-111 canal.

The District added a new water control structure (G-211) just south of the intersection of the L-31N and C-1W canals. This structure was installed to control seepage from Northeast Shark Slough into the L-31N canal upstream of S-331. In the lower C-111 basin the District modified the earthen plug at S-197 by adding 10 additional gated culverts. The original recommendations in the C-111 Interim Project also called for two additional operational changes in the central C-111 basin.

a) S-176 headwater stages were to be raised 0.5 feet, to reflect the reduced flood risk to the canal reach between S-331 and S-176 resulting from improved seepage control upstream of S-331.

b) The plan called for more effective use of the S-332 pump station. The District recommended that pumping be increased during the wet season to increase flows into Taylor Slough and away from the lower C-111 basin.

Neither of these changes were implemented at the start of the project because of concerns raised by South Dade agricultural interests.

In April 1993 the Army Corps of Engineers prepared a Draft Environmental Assessment for a two-year field test of improved water deliveries to the Taylor Slough basin. The plan called for implementation of the higher wet season water levels at S-176, as recommended by the SFWMD, and provisions to add supplemental pumps at the S-332 pump station to divert the majority of the L-31N runoff into the Taylor Slough watershed. This was done to reverse the current operational practices which depend on the use of S-176 to quickly route excess wet season rainfall into the lower C-111 basin. The District had also proposed backpumping water from the C-102 and C-103 canals westward to provide additional flows into Taylor Slough. This was proposed since gravity drainage from the western portions of these basins into Taylor Slough was part of the original design of the south Dade canal system, but has not been possible because of the low water levels maintained in the coastal canals. The backpumping plan was abandoned after a 1993 field test proved that pumping alone, without raising canal water levels, was an ineffective way of promoting increased flows into Taylor Slough.

The National Park Service agreed with the proposed two-year test, but stressed that the Park's major goal is to maintain optimum wet season water levels in the L-31N and L-31W canals as long as possible, and allow canal stages to recede naturally into the dry season. Strict adherence to the 5.0 and 4.5 foot temporary optimum criteria for S-176 and S-175 would be required, to avoid the potential of allowing the additional pumping capacity at S-332 to cause artificial canal drawdowns which over-drain the adjacent marshes. Common sense dictates that the only approach is to have all outflows from these canals balanced by inflows from their upstream water control structures. Lastly the Park stressed that re-establishing pre-project water levels and the natural seasonal response to rainfall in the upper portion of the Taylor Slough basin is the most reliable way of restoring natural inundations and flow patterns throughout the watershed, and improving freshwater inflows into Florida Bay.

Changes in water management in the C&SF Project have also had a substantial effect on the hydrology of the lower C-111 basin. After the L-31N canal stage reductions in 1982, and the initiation of S-331 flood control pumping in 1983 large flood water volumes drained from the upstream canal system and dumped through S-18C. These flows then passed through the C-111 gaps and S-197 ([Johnson *et al.*, 1993], [Johnson and Fennema, 1989] and [Lent *et al.*, 1993]). During the period of 1985–1988 flows through S-18C averaged in excess of 210,000 acre-feet, with nearly all the increase occuring between August and November. These excess wet season flows were greatly reduced after 1990, following the construction of the G-211 structure, which reduces seepage flows from NESS into the upper L-31N canal. The proximity of the lower gaps to tidewater meant that much of the water passed quickly through the marshes and was flushed into the estuaries of Northeast Florida Bay and Barnes Sound. The near-shore estuaries consequently suffered from rapid salinity fluctuations causing associated ecological problems ([Haunert, 1988] and [McIvor *et al.*, 1993]). Current management have shifted from providing the majority of this stormwater flow in the lower C-111, to distributing most of the flow into Taylor Slough.

To alleviate the stress on the Park's water resources, proposed structural modifications of the Project have been initiated under the Corps of Engineers General Re-evaluation Report process and seven alternatives have been proposed. These alternatives are summarized in the next section.

3.3 Summary of the Proposed Structural Alternatives

The proposed structural alternatives were summarized from a Corps of Engineers document (dated 11 August 1993) and details of the plans are shown in Figs. 3 and 4 and summarized below.

- Alternative 1. The primary purpose of this plan is to increase pumping at S-332 from 165 cfs to 1000 cfs to allow large storm water deliveries to be made to the main channel of Taylor Slough. Degrading the C-111 southern spoil piles is proposed to improve overbank flow southward into Florida Bay. A spreader canal (C-500E) is added which will provide minimal additional flood control benefits, but will add a little additional water to the impounded area north of the lower C-111 canal. The specific improvements are listed below:

  a) Construct a canal at Context road, supplied with a 50 cfs pump (S-332B) providing water to the headwaters of Taylor Slough.

b) Expand S-332 to 1000 cfs to provide additional water to the main channel of Taylor Slough.

c) Degrade the C-111 southern spoil piles, plug the C-109 and C-110 canals and build a new spreader canal east of the confluence of C-111 and C-111E, supplied with a 50 cfs pump (S-332C) from C-111.

- Alternative 2. The primary design feature of this plan is to add a new (1000 cfs) pump (S-332A) adjacent to S-174 which will discharge into a modified L-31W canal. The S-332 pump station would be abandoned. A new L-31W Extension Canal just east of the northern reach of the historical alignment of Taylor Slough, would maintain the current rated discharge capacity through to S-175. The new L-31W Extension Canal would allow the pumpage to be released as overbank flow to the west through the three western sections of the Frog Pond and then into Taylor Slough.

  a) same as Alternative 1a. Construct a canal at Context road, supplied with a 50 cfs pump (S-332B) providing water to the headwaters of Taylor Slough.

  b) Add a new 1000 cfs pump near S-174, remove most of L-31W and levee and replace it with a new canal approximately 1 mile to the east, with a capacity of 500 cfs and add a new 500 cfs gated structure (S-175A) north of S-175.

  c) same as Alternative 1c. Degrade the C-111 southern spoil piles, plug the C-109 and C-110 canals, and build a new spreader canal east of the confluence of C-111 and C-111E, supplied with a 50 cfs pump (S-332C) from C-111.

- Alternative 3. Excess flood waters would be pumped into a surge pool made up of the eastern sections of the Frog Pond and discharged into the western sections, which will act as a Stormwater Treatment Area (STA). The STA would discharge into Taylor Slough along the existing L-31W alignment through 10 culverts. This plan has the advantage that it allows for the detention and, if the culverts from the STA to the wetlands were regulated, for the slow release of excess storm water. The Spreader Canal, C-500E, would be supplied by a 500 cfs pump from C-111. This serves as the flood control outlet for lower C-111 basin, since C-111 south of S-332C would be backfilled. The overdrained triangle lands east of U.S. 1 would receive needed flow of 100 cfs.

a) A reservoir (surge pool) would be built in the eastern sections of the Frog Pond, supplied by a 1630 cfs pump (PS-332A) near S-174.

b) An STA would be constructedin the western sections of the Frog Pond, supplied through 10 culverts from the adjacent surge pool.

c) S-332 would be abandoned, and L-31W south of S-175 would be backfilled.

d) similar to Alternative 1c. Degrade the C-111 southern spoil piles, plug the C-109 and C-110 canals and build a new spreader canal east of the confluence of C-111 and C-111E, supplied with a 500 cfs pump (S-332B) from C-111. A culvert under US-1 will deliver 100 cfs to the marshes in the triangle lands east of U.S. 1.

e) The C-111 canal would be backfilled downstream of S-332B from S-18C to S-197. Abandon S-197 and S-18C.

- Alternative 4. This plan has a buffer zone between the developed, areas east of the L-31N and C-111 canals, and the natural areas of the Park. This buffer zone would extend from the southern terminus of the 8.5 mi^2 seepage levee to the intersection with L-31W. Flood control and water supply pumps would be spaced along this north-south levee with inflows supplied by L-31N. The advantage of this plan is that it allows more uniform discharge across the Rocky Glades and Taylor Slough headwaters. Unfortunately, this plan does not address the large seepage losses that occur through the levee into the developed lands west of the Eastern Protective Levee System (EPLS) formed by L-31N and C-111.

  a) Levee and canal system would be constructed which would provide water to the Rocky Glades and northern Taylor Slough through four 300 cfs pumps (S-332A, B, C, D).

  b) The East Everglades pump station (S-357) would be downsized to 300 cfs.

  c) Fill in part of L-31W, from the L-31N levee to S-332, but S-332 would be maintained and supplied with water from a new canal connected to the C-111 canal just north of S-175. The western three sections of the Frog Pond would serve as buffer areas.

  d) same as Alternative 3d. Degrade the C-111 southern spoil piles, plug the C-109 and C-110 canals and build a new spreader canal east of the confluence of C-111 and C-111E, supplied with a 500 cfs

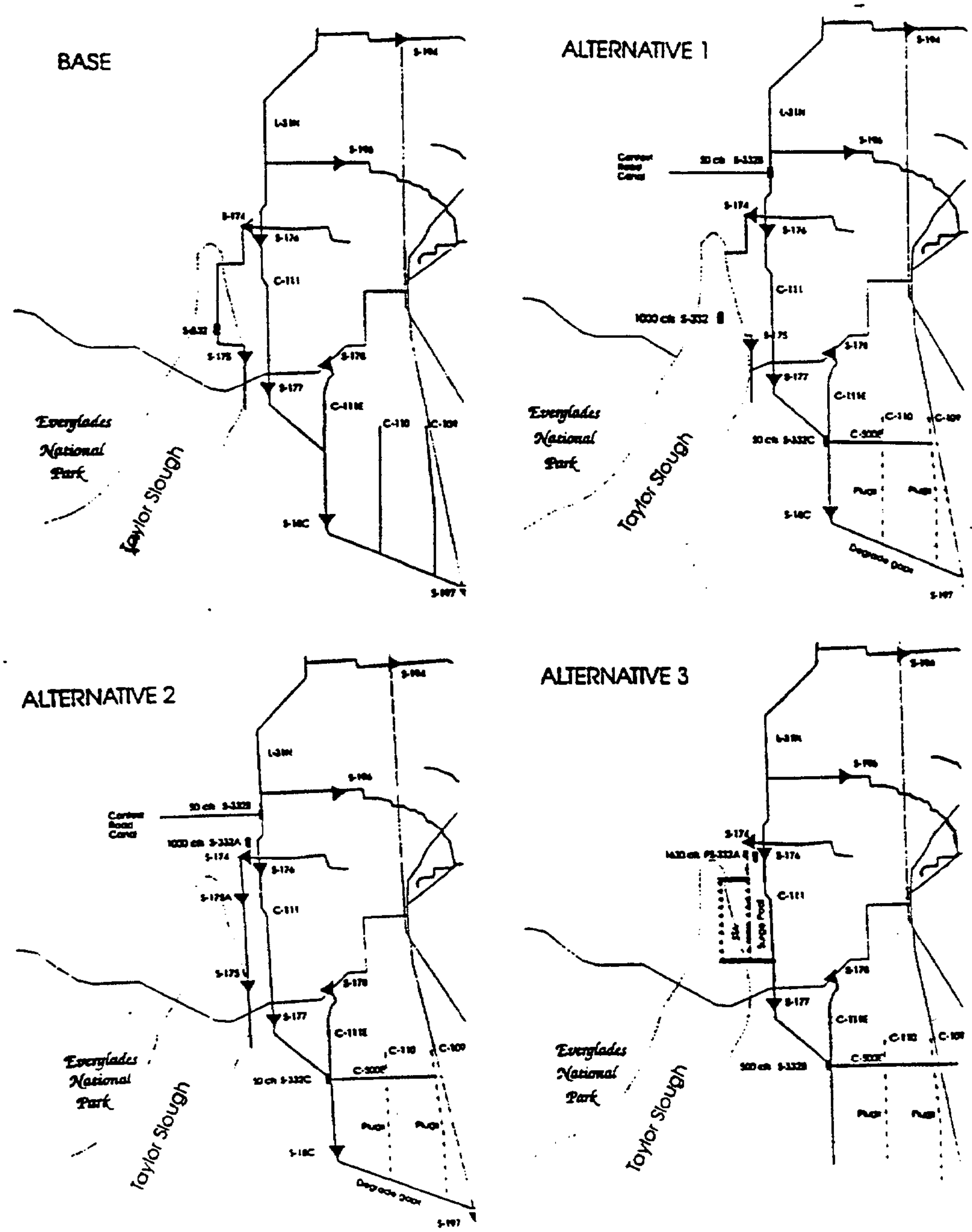


Figure 3: Sketches of Base, Alternatives 1, 2 and 3

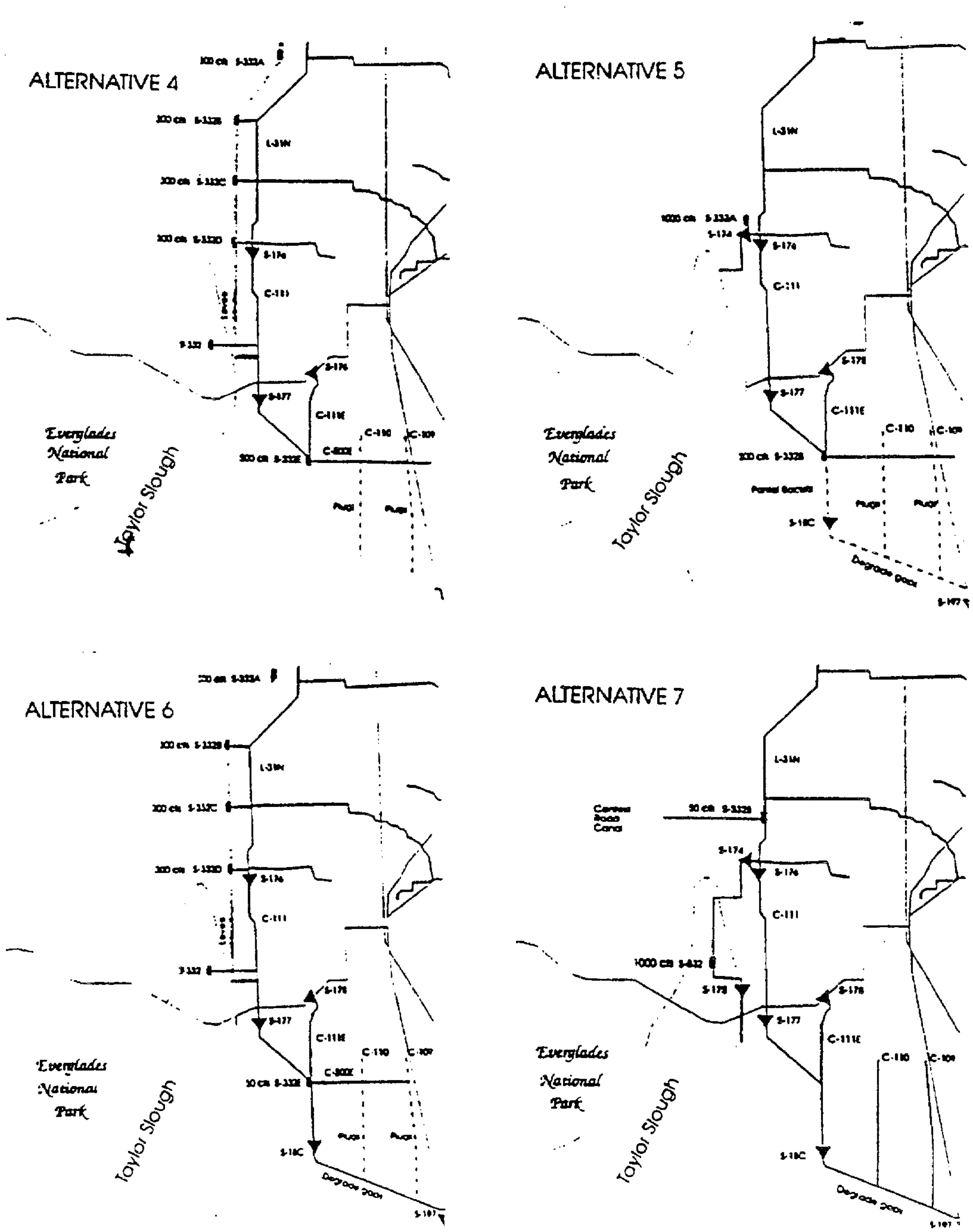


Figure 4: Sketches of Alternatives 4, 5, 6 and 7

pump (S-332B) from C-111. A culvert under US-1 will deliver 100 cfs to the marshes in the triangle lands east of U.S. 1.

e) same as Alternative 3e. The C-111 canal would be backfilled downstream of S-332B from S-18C to S-197. Abandon S-197 and S-18C.

- Alternative 5. This plan is similar in concept to alternatives 1 and 2. A 1000 cfs pump would be added near the S-174 structure and lower portion of the L-31W canal would be backfilled. The northern portion of L-31N would serve as a getaway canal for flood waters. The western sections of the Frog Pond would become part of a flow way. The lower part of C-111, south of S-18C, would be partially backfilled to retain the canal's use for flood control through the gaps and S-197. Both the north and south levees would be partially degraded. Additional flood control would be provided by the Spreader Canal, C-500E, supplied with a 500 cfs pump (S-332B).

  a) A new 1000 cfs pump would be added near S-174 and backfill part of L-31W.

  b) A flow way would be created through the eastern and western sections of the Frog Pond.

  c) C-111 would be backfilled to -6 ft. south of confluence with C-111E, and S-18C would be left operational.

  d) same as Alternative 3d. Degrade the C-111 southern spoil piles, plug the C-109 and C-110 canals and build a new spreader canal east of the confluence of C-111 and C-111E, supplied with a 500 cfs pump (S-332B) from C-111. A culvert under US-1 will deliver 100 cfs to the marshes in the triangle lands east of U.S. 1.

- Alternative 6. This plan is a combination of the Taylor Slough modifications of Alternative 4 and the C-111 modifications of Alternative 1. The principal difference with Alternative 4 is that lower C-111 and S-197 would be retained, while the Spreader Canal (C-500E) is supplied by the smaller 50 cfs pump (S-332E).

  a) same as Alternative 4a. A new 1000 cfs pump would be added near S-174 and backfill part of L-31W.

  b) same as Alternative 4b. A flow way would be created through the eastern and western sections of the Frog Pond.

c) same as Alternative 4c. C-111 would be backfilled to -6 ft. south of confluence with C-111E, and S-18C would be left operational.

d) same as Alternative 1c. Degrade the C-111 southern spoil piles, plug the C-109 and C-110 canals and build a new spreader canal east of the confluence of C-111 and C-111E, supplied with a 50 cfs pump (S-332C) from C-111.

- Alternative 7. This plan was not modeled. The design purpose is to provide large additional flood control capacity at S-332. A small additional flood control benefit is attained by degrading the C-111 southern bank spoil piles.

  a) Pump station S-332 would be enlarged to 1000 cfs.

  b) The C-111 spoil piles would be degraded.

3.4 Evaluation Criteria

The hydrologic evaluation of the proposed alternatives is aided by a numerical hydrologic model, called the South Florida Water Management Model (SFWMM), which was used to provide output on flows, stages, water depths and hydroperiods for the affected areas. A one square mile grid cell version of the model (SFWMM–1x1, version 1.2), was used in the evaluation contained herein. In order to evaluate the alternatives a base condition was established, reflecting the authorized levels of canal stages and structure operations. The output of the model for the different alternatives were evaluated for eventual selection of a preferred alternative. The selection process uses principally the following criteria:

- Operational flexibility.

  a) Provide the necessary flexibility to return to the authorized canal and structure operations.

  b) Provide the added flexibility to allow continued experimentation and fine-tuning of ENP water deliveries.

- Restoration of pre-project conditions in ENP.

  a) Drastically reduce the documented wetland drainage effects of the L-31N, L-31W, and C-111 canals.

b) Restore more natural hydropatterns and hydroperiods throughout the Rocky Glades, Taylor Slough, and Eastern Panhandle marshes.

- Restore estuarine freshwater inflows.

  a) Provide the capacity to handle flood control flows, while eliminating the need to operate S-197.

  b) Discharge excess flood control runoff as far north as possible, to help restoration of natural volumes, distribution and timing of freshwater flows to Florida Bay.

- Protect/improve water quality at ENP inflows

  a) Maximize natural wetland sheetflow as a way of preserving water quality in the marshes.

  b) Provide a means of treating poor quality water and prolonging residence times outside of existing natural wetlands.

3.5 Flood Control in the Developed Areas

Although flood protection for the developed areas was the principal reason for the C&SF Project, subsequent concerns about water supply and environmental degradation have focused on the multiple purposes of the Project. Analyses done by the Corps of Engineers during the design process ([U.S. Army Corps of Engineers, 1963b], [U.S. Army Corps of Engineers, 1963a], [U.S. Army Corps of Engineers, 1965], [U.S. Army Corps of Engineers, 1966], and [U.S. Army Corps of Engineers, 1967]) and during subsequent proposed structural modifications provide information on the levels of flood protection for the developed areas covered by the Eastern Protective Levee System. A Draft GDM for Canal 111 was prepared in July 1988 ([U.S. Army Corps of Engineers, 1965]). This report contains a detailed analysis of the C-111 basin rainfall and sets maximum canal stages and ground water levels for several monitoring gauges at different flood frequencies.

To provide maximum flood protection for the agricultural areas in the C-111 basin, the GDM contains a frequency analysis of peak annual and winter growing season rainfall in the project area for durations of one through 20 days. A log-Pearson Type III distribution was utilized to compute rainfall frequencies. The GDM also states that the 27 largest 10–day rainfall totals recorded during the growing season were most likely or entirely within October. Further in the year, the chances of flooding are rapidly reduced, eliminating the need

Return Period (Years)	Flood Duration	Monitoring Points				
		G-855	G-596	S-196A	G-789	G-613
2	1–Day	6.98	6.81	6.22	6.08	4.17
10	1–Day	8.55	7.53	8.04	6.91	4.87
25	1–Day	9.13	7.79	8.71	7.22	5.13
50	1–Day	9.51	7.95	9.14	7.41	5.30
100	1–Day	9.85	8.11	9.53	7.59	5.45
2	2–Day	6.32	6.77	5.79	5.77	3.90
10	2–Day	7.24	7.50	7.54	6.60	4.36
25	2–Day	7.58	7.77	8.19	6.91	4.53
50	2–Day	7.80	7.94	8.60	7.10	4.64
100	2–Day	8.00	8.10	8.98	7.28	4.74
2	7–Day	5.84	6.45	5.38	5.24	3.27
10	7–Day	6.52	7.01	6.42	6.03	3.65
25	7–Day	6.77	7.21	6.80	6.33	3.80
50	7–Day	6.93	7.35	7.04	6.51	3.89
100	7–Day	7.07	7.46	7.27	6.68	3.97

Source: Corps of Engineers - GDM, Addendum 2, Canal 111

Table 1: Maximum Ground Water Levels for Selected Return Periods

for massive drainage since the growing season months of November through March are mild and have not received frequent intense rainfall. Thus, after October higher canal water levels generally do not raise the risk of flooding. The higher stages are crucial, however, to continued dry season water supply and environmental preservation.

The wet season storms are generally associated with tropical disturbances and if they occur late in the season, when ground water levels are already high, these storms will produce a lot of surface water. Maximum surface and ground water levels at various locations were estimated for the existing condition and listed for various return frequencies. Relevant parts of these tables corresponding with this report's monitoring points are reproduced as Table 1. SPF is the standard project flood which is defined as 125% of the 100-year storm. HW is the headwater or upstream side of the structure and TW refers to tailwater or downstream side of the structure.

Fast moving weather systems or local convective activity producing large

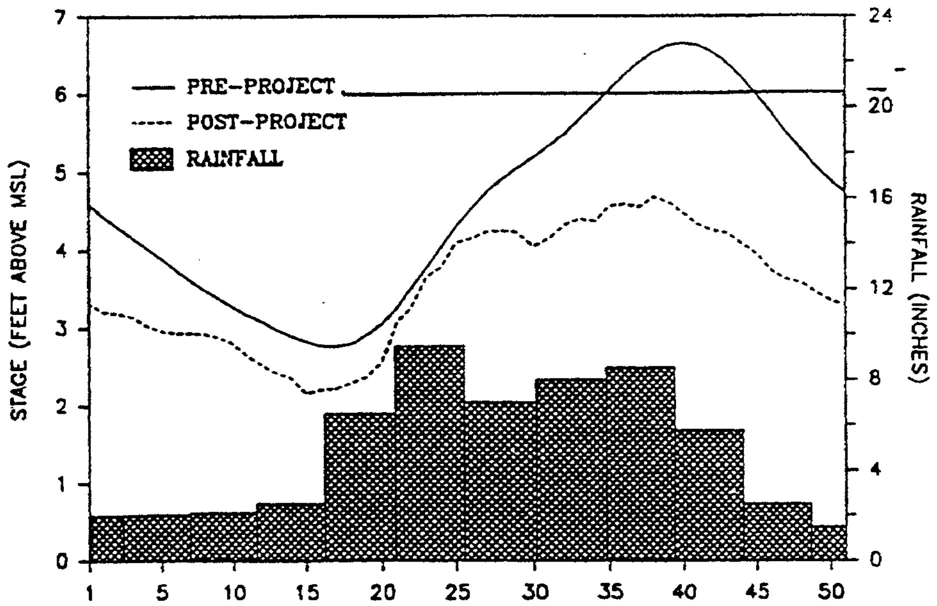


Figure 5: Pre- and Post-C&SF Project Stages at G-789

rainfall of relative short duration, *e.g.*, the 10-year, 1-Day rainfall, will bring stages to 6.91 ft. at G-789 (Table 1). Storms of this nature produce surface water ponding which rapidly infiltrates. Proper local drainage in the form of retention areas, perhaps in the form of ditches, rapidly draw this excess surface water and decreases the likelihood of crop damage from excessive ponding. Slow moving systems bringing storms of larger duration, *e.g.*, the 10-year, 7-Day storm has maximum stages at G-789 at 6.03 ft. These storms generally are of reduced intensity and rainfall rates rarely exceed infiltration and runoff rates over most of the area.

Even though the wet rainfall season is generally over by late October, the highest ground and surface water levels of the year generally do not occur until this time or in the first few weeks of the dry season. This is illustrated in Fig. 5 as a curve of typical pre-project ground water water levels at G-789, a stage recorder near S-176, and a bar graph of the typical annual rainfall distribution for the area. Note that the peak water levels occur in mid-October, well after the peak of the rainfall in September.

A comparison of maximum water levels with historical and SFWMM-1x1 data in the canal and at the monitoring points determines the existing and proposed flood protection at the given sites. An example of flood protection levels for the monitoring station G-789, located just east of L-31N, near S-176 is shown in Fig. 5. The authorized 10-year, 7-day storm water level for this station is shown on the graph, along with pre-project and post-project values. The pre-project values are based on the estimated average weekly stage at G-789 for the period from 1933 through 1947, using the methodology described in [Lent and Johnson, 1993b]. The post-project values represent the actual average weekly stages at G-789 based on the observed record for the period from 1965 through 1989, which coincides with the model simulation period. Average water levels at the peak of the wet season (week 40) are more than two feet lower under the post-project conditions. Average wet season water levels remain about two feet 1.5 ft. below the 1 in 10 year flood protection level. Under the pre-project conditions, average wet season water levels remained above 5.5 ft. from mid-august to early december. In contrast under post-project conditions average wet season water levels never exceeded 5.0 ft. and were more than 4.5 ft. for only 5 weeks. This is suprising, since G-789 is situated next to S-176 and the authorized optimum wet season water level is supposed to be 5.5 ft.

Current flood control operations of the C&SF Project during the peak rainfall months require reduced canal water levels which forces the removal of large quantities of water from the system. The historical peak water levels, which are a result of the natural slow release of rainfall generated storage of surface and ground water, which lagged well behind the end of the rainy season. This loss of water during the wet season causes the marsh to dry down more rapidly. This is further aggravated by the recent demands for agricultural drainage during this period. The acceleration of the canal wet season drawdowns has profound hydrological effects lasting well into the early spring. With the loss of substantial quantities of ground water, early spring rains must fill the subsurface first, greatly delaying the presence of surface water.

The loss of water storage near the surface and the accompanying deep drawdowns affect the aquatic communities in the marshes. The emptying of the near-surface solution cavities eliminates most of the aquatic productivity [Loftus *et al.*, 1992] and delays the build-up of adequate standing stocks of small fish and invertebrates. Thus, the effects of persistent wet season drawdowns, while lasting for a single year, can have ecological effects that carry over for several years.

4 Modeling

The 1x1 version of the South Florida Water Management Model (SFWMM-1x1, version 1.2) was used to aid in the evaluation of the proposed alternatives. This model simulates the hydrology south of Tamiami Trail and includes the majority of the freshwater wetlands of Everglades National Park (Fig. 6). The model incorporates all of the principal hydrologic processes and is primarily driven by rainfall and surface water inputs, obtained from the 2x2 version, along Tamiami Trail. These flows are input either into the canal system or directly into the wetlands. Surface water and ground water flows are modeled along with canal discharges, evapotranspiration and infiltration. A rough calibration and verification was carried out by the SFWMD, Lower District Planning Department, as part of the GRR process.

The model area is divided into 47 rows and 73 columns for a total of 3431 grid cells, each one mile by one mile. The actual model domain consists of 1557 cells, for a total of 1557 mi^2 (see Fig. 6). The northern boundary follows along Tamiami Trail, a convenient boundary, since known canal and structure operations may be input directly. All of the C&SF Project features that lie within the model domain are simulated, as well as ground and surface water flows.

Rainfall drives the hydrology in South Florida and thus the model. A standard simulation run is made by using the historical 25-year rainfall record, from 1965 to 1989. The SFWMM-1x1 uses 13 rainfall basins for input(Fig. 7). Annual, wet and dry season totals for the period of record used in the model are given in Table 2. A typical seasonal variation of the annual rainfall is shown in Fig. 8 for rainfall basin 7. To aid the selection of the dry and wet season seasonal subseries of the rainfall basins were used. The dry season months, November through April, receive about 20% of the total precipitation. The remaining months, May through October, constitute the wet season months. To present the information produced by the model for average, wet and dry conditions an evaluation of the 25-year rainfall record was conducted. This analysis defined the seasons and years which could best be used to represent the spectrum of hydrologic conditions in the basin. The years chosen for this analysis are

— Average: Water year November 1976 through October 1977.

— Wet: Water year November 1968 through October 1969.

— Dry: Water year November 1973 through October 1974.

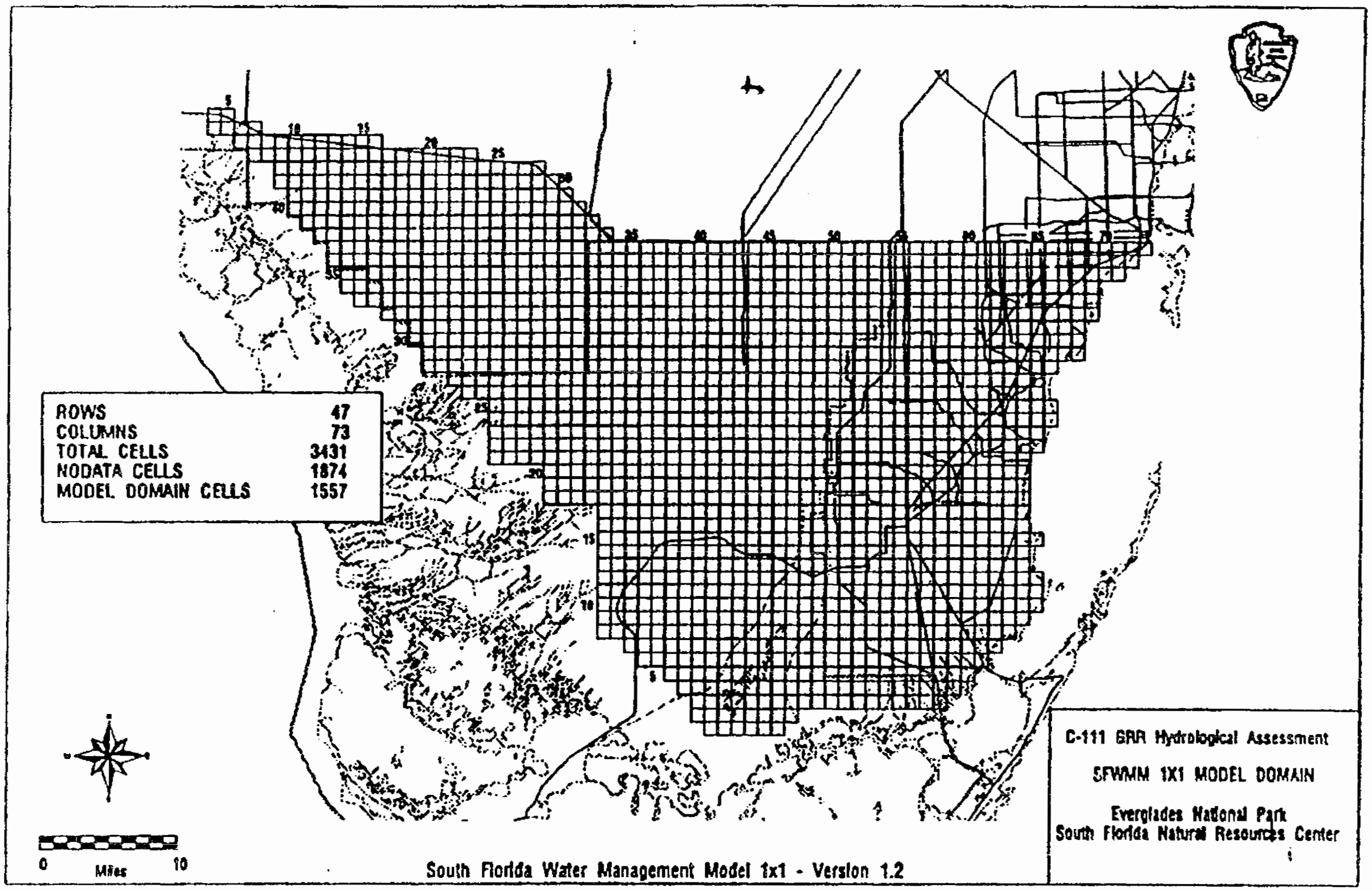


Figure 6: Modeling Domain.

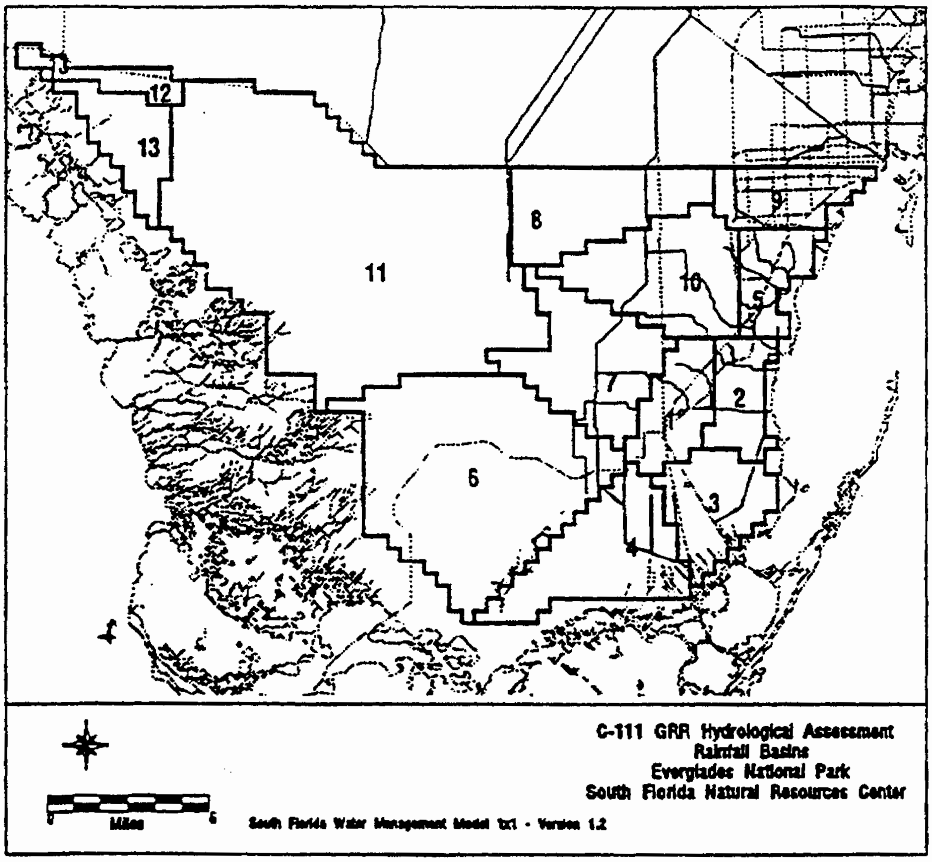


Figure 7: SFWMM-1x1 Rainfall Basins.

End-of-month values, monthly averages as well as daily information produced by the model for these specific years and 25-year averages of the output values, were used to present the results of the model runs. Water years are used in many instances to present the data from the beginnning of the specific dry season through the end of the specific wet season.

Other hydrologic processes simulated in the model are more specific. An important consequence of the canal system in South Florida is the large levee seepage from the marsh. For example, the levee adjacent to L-31N is simulated in two segments from S-335, at Tamiami Trail and L-31N intersection, southward to S-176, located at the north end of the Frog Pond. Under Base conditions seepage volumes through the levee from the wetlands west of L-31N average over 225,000 acre-feet per year. The large structures, the S-12's, supplying flows to Shark Slough deliver on the average 550,000 acre-feet per year

Rainfall Total in Inches							
Basin	Annual	Wet Season	Dry Season	Basin	Annual	Wet Season	Dry Season
1	56.0	44.0	12.0	8	48.0	38.0	10.0
2	44.0	33.0	11.0	9	57.0	43.0	14.0
3	41.0	31.0	10.0	10	56.0	43.0	13.0
4	44.0	34.0	10.0	11	46.0	36.0	10.0
5	51.0	38.0	13.0	12	58.0	47.0	11.0
6	55.0	44.0	11.0	13	50.0	41.0	9.2
7	57.0	45.0	12.0	Ave.	51.0	40.0	11.0

Table 2: Rainfall Means for SFWMM–1x1 Basins.

under the current operational schedules.

All of the processes are based on physical parameters provided through input. Infiltration of the surface to the ground water regime and the very important process of evapotranspiration are also modeled as part of the hydrologic system. Many of the parameters are assigned values obtained through field experiments and some of these are adjusted during the calibration process. Ground water is simulated as a two-dimensional single aquifer. A single layer is used, because all of the important water resources issues occur in the surficial aquifer. Wellfields in the developed areas are included in this portion of the model. A total of 199.9 MGD (223,888 AFY) is withdrawn from the Biscayne aquifer, including withdrawals made by two wellfields in west Dade, pumping a total of 40 MGD. Overland flow in the wetlands is also modeled as a two-dimensional process. Canals discharge into the adjacent grid cells, where the overland flow routine computes the exchange with the downstream cells.

Output from the model can be specified in many different forms. For the analysis contained herein, end-of-month values of water levels were used for illustrating the spatial surface water patterns. Daily water levels data was used to compute average monthly values for use in the analysis at the monitoring point locations. These daily values were also used to compute the hydroperiods. Total monthly flow data was used for all the canal and structure flows, and also for the analysis of the flowline data.

In order to evaluate the model's output of each of the alternatives for restoration benefit, it is desirable to compare the results against pre-drainage hydrology. No compatable 1x1 natural system version of the 1x1 SFWMM exists as it does for the 2x2 version. The incompatability of the grid size

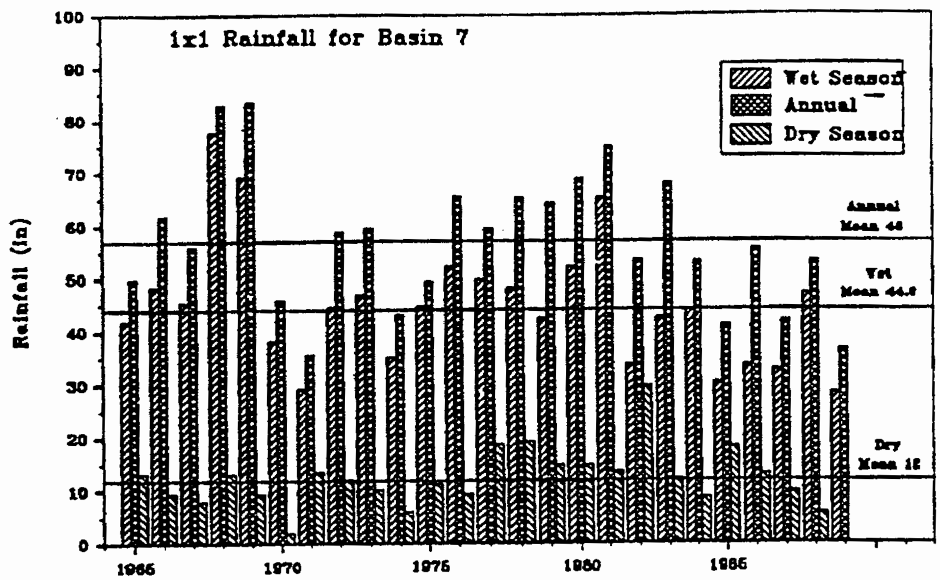


Figure 8: Total and Seasonal Variation for Rainfall Basin Number 7.

between the 2x2 version of the Natural System Model and the different rainfall basins, boundaries and model domain, did not warrant the effort to make comparisons between the two models.

5 Flow and Stage Comparisons in the L-31N, L-31W and C-111 Canals

A key feature of the GRR structural improvements is the provision to return to authorized canal and control structure operations. This is a critical element of the GRR since current water management operations of the relevant structures (Fig. 9) in the L-31N, L-31W, and C-111 canals cause over-drainage of the adjacent marshes, and allow large volumes of wet season runoff to be routed from one drainage basin into another. With the implementation of the Modified Water Deliveries improvements in the East Everglades wet season pumping at S-331 will be terminated. The southern L-31N basin (the reach between S-331 and S-176) traverses the Rocky Glades, which are the headwaters of the Taylor Slough basin. Appendix B, a separate volume to this report, provides the complete set of average monthly canal water levels for all of the alternatives.

5.1 L-31N Flow and Stage Comparisons

Fig. 10 shows the computed discharges through S-174 and S-176 under the base condition, for the 1980 through 1989 period. Note that all of the wet season outflows from the L-31N canal are passed through S-174. In contrast, flows through S-176 are limited to dry season deliveries, except during the high rainfall period in August and September of 1981. This indicates that simply returning to the authorized canal stages and operations would allow the majority of the wet season runoff to be redirected back into the Taylor Slough basin, rather than being dumped into the lower C-111 basin. This same pattern of redirecting L-31N outflows into the Taylor Slough basin via S-174 is maintained in all of the proposed structural alternatives.

A problem with inter-basin transfers of water continues to occur under the Base condition and one of the alternatives. Fig. 11 shows the estimated discharges through S-194 and S-196 under the Base condition and Alternatives 1 and 4, for the period 1980 through 1989. This graph indicates that significant volumes of wet season runoff are released eastward through the C-102 and C-103 canals under the Base condition and Alternative 1. This is contrary to the original design of the south Dade canal system, which was to pass excess water from the western portion of the Atlantic Coastal Ridge, westward into Taylor Slough [U.S. Army Corps of Engineers, 1963b]. This problem is substantially reduced (during all years except 1981) under Alternatives 2 through 6, which

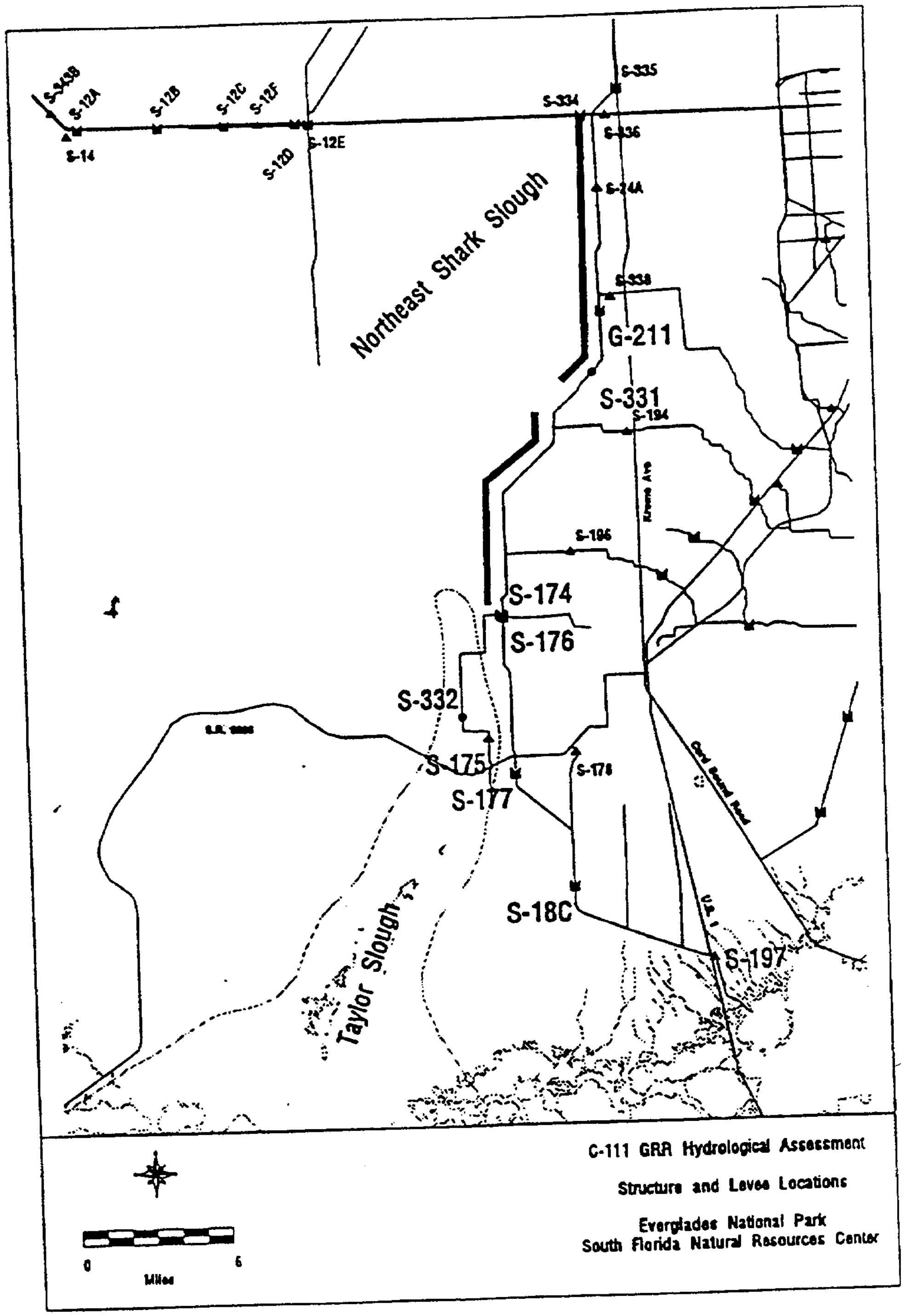


Figure 9: Selected structures in the L-31N, L-31W and C-111 Canals.

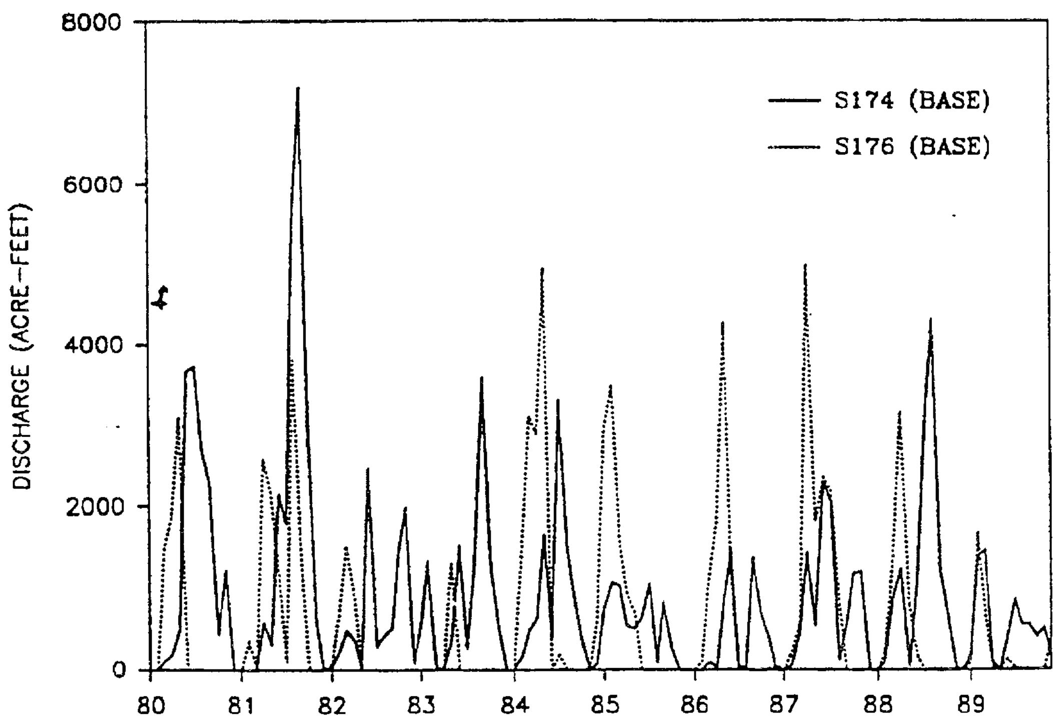


Figure 10: Discharges through S-174 and S-176.

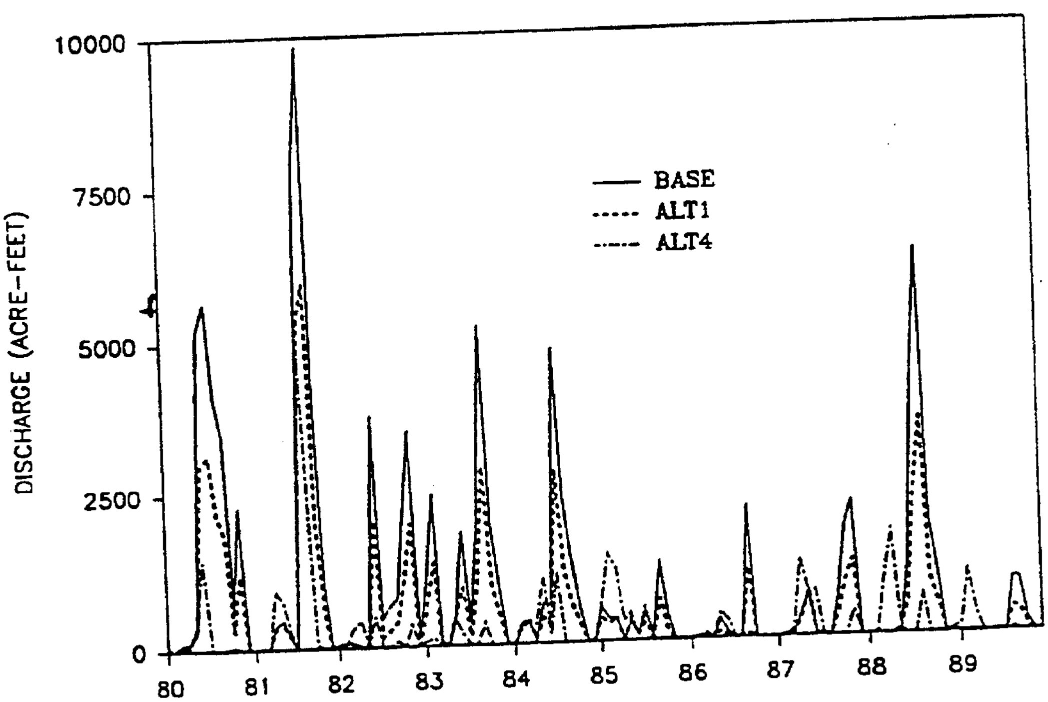


Figure 11: Discharges through S-194 and S-196.

redirect these flows westward into Taylor Slough. These alternatives reduce the eastern diversion of flows from the Taylor Slough headwaters, but they do not address the loss of surface water flows from the original contributing areas east of the L-31N canal.

Fig. 12 shows the estimated average monthly stage in the L-31N canal upstream of S-176, under the Base condition and Alternatives 4 and 5. The monthly averages were calculated based on canal water level data for the entire 25 year simulation period. We plotted only two of the alternatives, but all of the proposed structural plans substantially lower wet season canal water levels well below the Base condition, particularly during the period from August through October. Fig. 13 compares the estimated discharges out of the L-31N canal system and into Taylor Slough using a single large pump (such as in Alternatives 2, 3 and 5) versus a multiple pumping approach (such as in Alternatives 4 and 6). The multiple pump approach maintained S-176 headwater stages slightly higher, reducing the L-31N average wet season outflows by approximately 20,000 acre-feet per year. This means that more of the wet season runoff was retained in the adjacent marshes, rather then being drained into the L-31N canal and then pumped back into Taylor Slough. Multiple outflow pumps have the added advantage of allowing fine-tuning of the L-31N canal stages throughout the canal reach, and distributing marsh inflows over a broader front.

5.2 L-31W Flow and Stage Comparisons

Fig. 14 shows the estimated discharges into the L-31W canal under the Base condition and Alternatives 1 and 5. Alternatives 1 and 5 both include the addition of a new 1000 cfs pump station to convey flows westward into Taylor Slough, but the pumps are located at the site of the existing S-332 pump and adjacent to S-174, respectively. Note that the Base condition diverts, on average approximately 21,000 acre-feet of wet season runoff from the L-31N canal westward into the L-31W canal. Alternative 1 generally diverts only slightly more wet season runoff from the L-31N basin than the Base condition (approximately 25,000 acre-feet). In contrast, Alternative 5 diverts on average, more than 2.5 times the volume of the base condition (approximately 54,000 acre-feet). Unfortunately this is accomplished by substantially lowering L-31N canal water levels throughout the wet season. Since S-331 remains closed throughout the wet season, the majority of this excess runoff is the result of seepage losses from the drainage of the Rocky Glades wetlands into the L-31N canal.

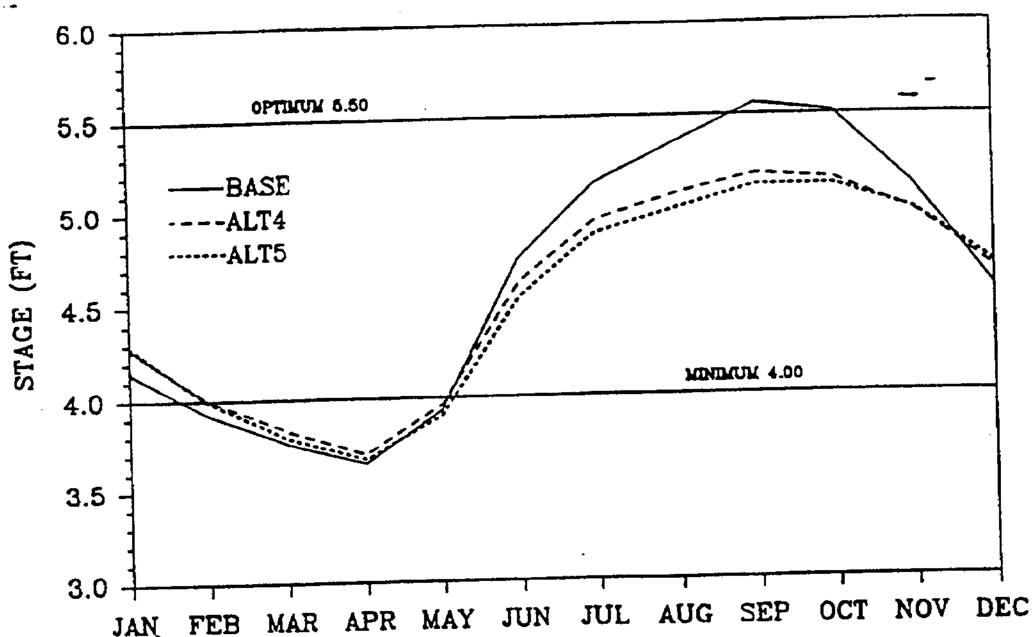


Figure 12: Average Monthly Canal Water Levels at S-176

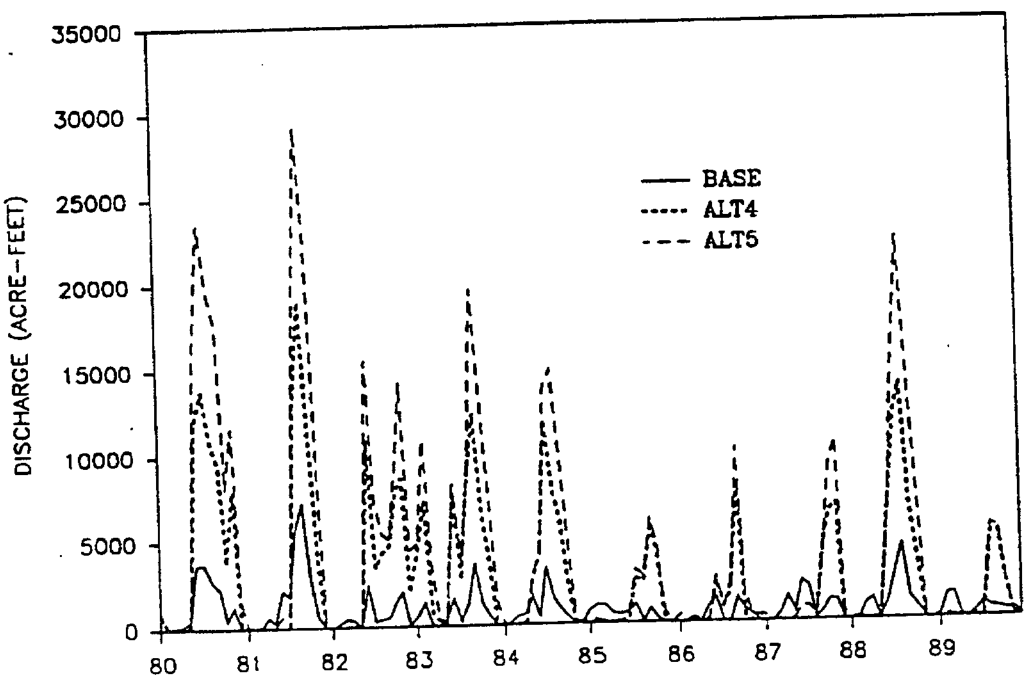


Figure 13: Discharges out off L-31N

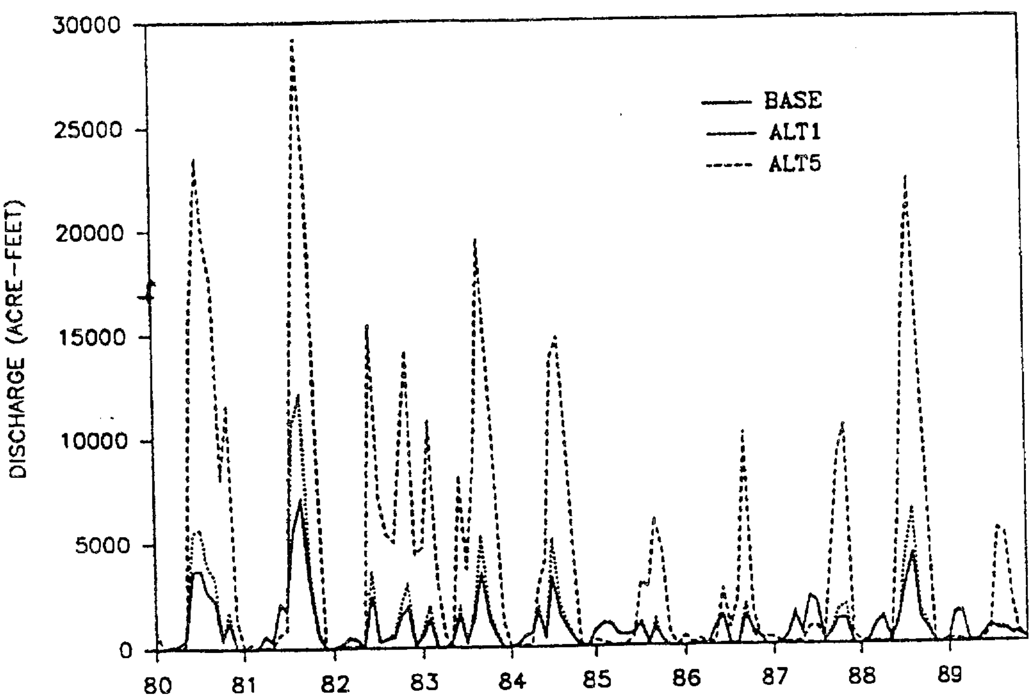


Figure 14: Discharges into L-31W via S-174.

5.3 C-111 Flow/Stage Comparisons

As stated earlier, S-176 is essentially not used to pass wet season runoff southward into the C-111 basin under the Base condition, or any of the alternatives. Small dry season inflows are provided to the C-111 basin for water supply. Fig. 15 shows the estimated discharges through S-177 under the base condition and three of the alternatives for the period from 1980 through 1989. The modeling results are highly variable, but they indicate that during most years, discharges are made through S-177 into the lower C-111 basin, with large flows occuring during high wet season rainfall periods such as 1981 and 1989. Under the Base condition and Alternatives 1, 2, and 6 average wet season outflows through S-177 averaged between 5,300 and 8,500 acre-feet. In contrast, average wet season flows through S-177 average between 11,000 and 18,400 acre-feet under Alternatives 3, 4, and 5. This increase is a result of the addition of a 500 cfs pump at the C500E spreader canal. Average monthly canal water levels for the C-111 canal upstream of S-177 are provided in Fig. 16. Alternatives 4 and 6 tend to lower average wet season water levels because most of the excess L-31N runoff is pumped into the marshes north of the Frog Pond. In contrast, Alternatives 2, 3, and 5 pass the excess L-31N runoff into Taylor Slough through a degraded L-31W canal or via the Frog Pond. This causes water levels to increase in the eastern portion of the Frog Pond, which contibutes groundwater seepage back into the C-111 canal, and maintains higher S-177 water levels.

Fig. 17 shows the estimated discharges through S-18C into the lower C-111 basin and the discharges through the new S-332B/C pump station at the C500E spreader canal for Alternatives 1 and 5. Under Alternative 1 the S-332C pump is limited to 50 cfs, so the discharges remain small, and all excess runoff is passed through the existing S-18C structure. Under Alternative 5 the S-332B pump is increased to 500 cfs, so the discharges are large, and additional outflows are provided by S-18C, which releases flows into the partially backfilled C-111 canal. Annual wet season outflows from the C-111 canal downstream of S-177 averaged between 14,400 and 18,300 acre-feet under the Base condition and Alternatives 1, 4, and 6. Average wet season outflows increased to between 20,000 and 25,000 under Alternatives 2, 3, and 5. This indicates that excess runoff from the C-111 basin can be effectively removed through the addition of the C-500E spreader canal and a large capacity pump. The use of a 50 cfs capacity pump will do little to remove excess wet season runoff, which means that the lower C-111 canal would have to be left intact.

A serious problem has been observed under the Base condition and all of the

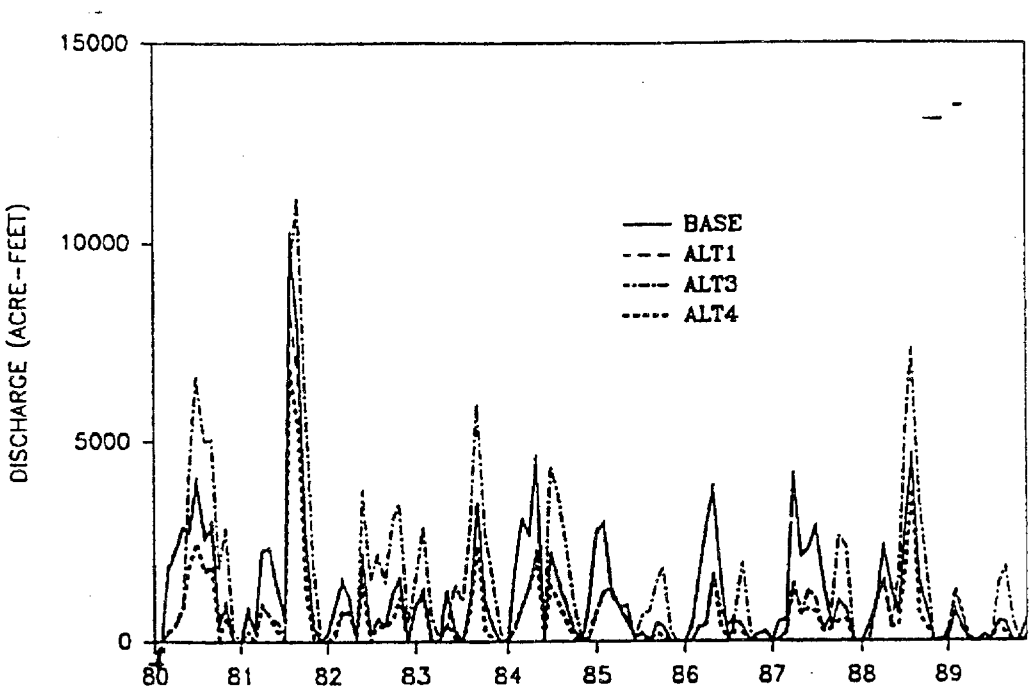


Figure 15: Discharges through S-177 into the Lower C-111 Basin

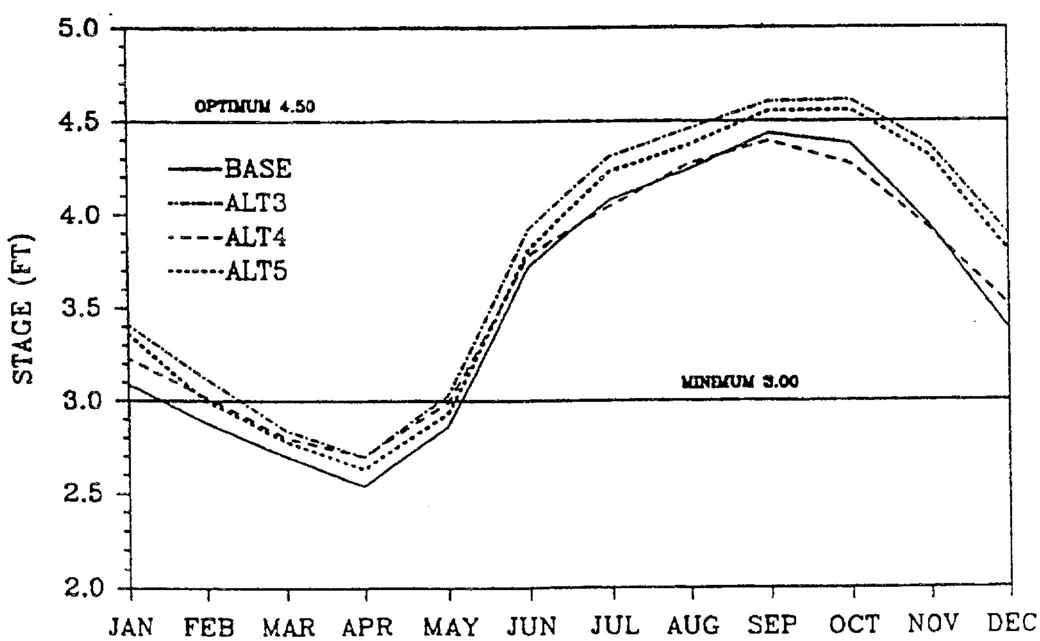


Figure 16: S-177 Headwater Stages

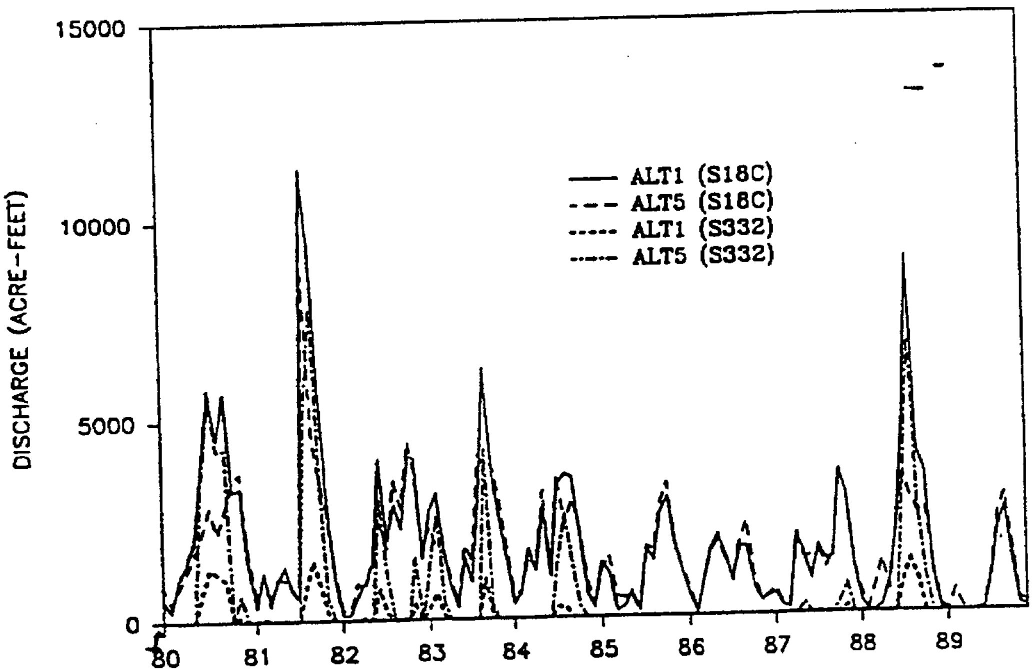


Figure 17: S-18C flows and S-332B/C

alternatives that leave the lower C-111 canal intact. Fig. 18 shows the annual total flows through S-197 under the Base condition and Alternatives 2 and 6 for the 25 year simulation. In these model runs large freshwater releases (some in excess of 30,000 acre-feet) are made through S-197 into Manatee Bay during the years with high wet season rainfall. These high flow periods are most conspicuous throughout the wet seasons of 1966, 1968, and 1969 and during August through November in 1981 and 1988. Rapid influxes of freshwater are known to have detrimental impacts on the downstream estuarine biota, and the need to discontinue S-197 releases has been a major driving force prompting the development of the C-111 GRR.

Fig. 19 shows the average monthly canal stage for the reach of the C-111 canal between S-177 and S-18C under the Base condition and Alternatives 3, 4, and 5. Alternatives 3 and 4 tend to raise wet season canal water levels, while Alternatives 1, 2, 5, and 6 show only minor differences from the Base condition. This suggests that alternatives that discharge excess L-31N runoff into Taylor Slough at locations as far south as S-175 have a high likelyhood of loosing much of this water as groundwater return flow to the C-111 canal downstream of S-177. The Park has suspected that this happens under current

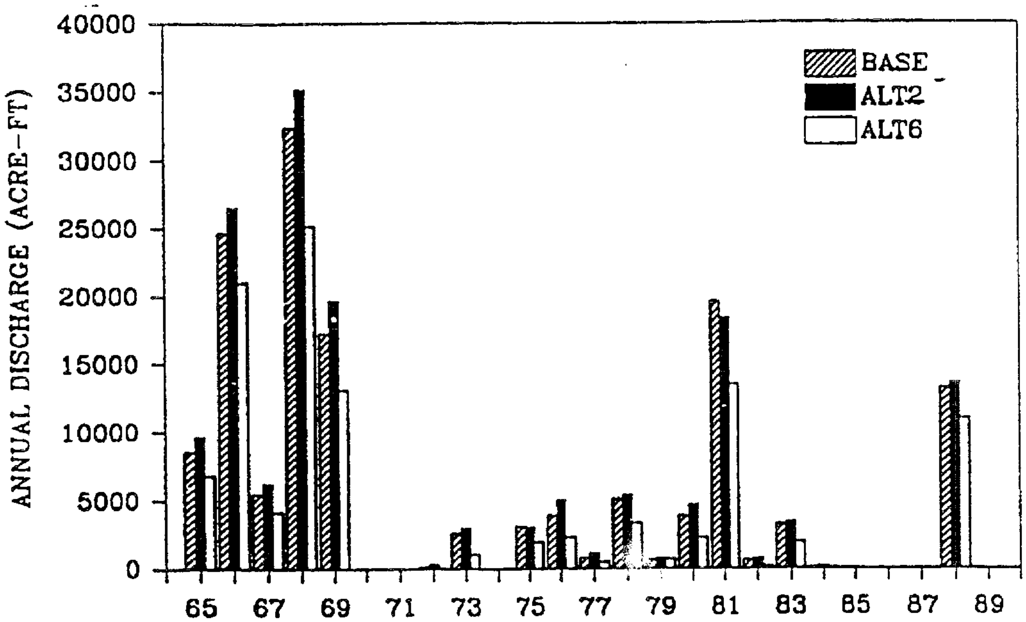


Figure 18: Annual Total Flows through S-197

operating conditions since canal stages downstream of S-177 are maintained several feet lower then the more natural marsh elevations in Taylor Slough downstream of S-175.

Fig. 20 shows the average monthly canal water levels in the C-500E spreader canal under the Base condition and Alternatives 1, 4, and 5. Alternatives 3, 4, and 5 include the new 500 cfs pump station, and have a significant impact on raising wet season canal water levels. In contrast, Alternatives 1, 2, and 6 add only a 50 cfs pump station which maintains wet season stages close to those under the Base condition. One disturbing problem is the extremely low water levels predicted at this location in the dry season. This indicates that the wet season stormwater inflows drain out of the system quickly, and supplemental dry season inflows are ineffective at maintaining wetland stages.

6 Water Budget Computations

A series of wet and dry season water budgets were calculated for the reaches of the L-31N and C-111 canals between S-331 and S-18C under the Base condition and the six proposed alternatives. In each case, all of the structure inflows and outflows for the specific canal reaches were calculated for the 1977 wet season,

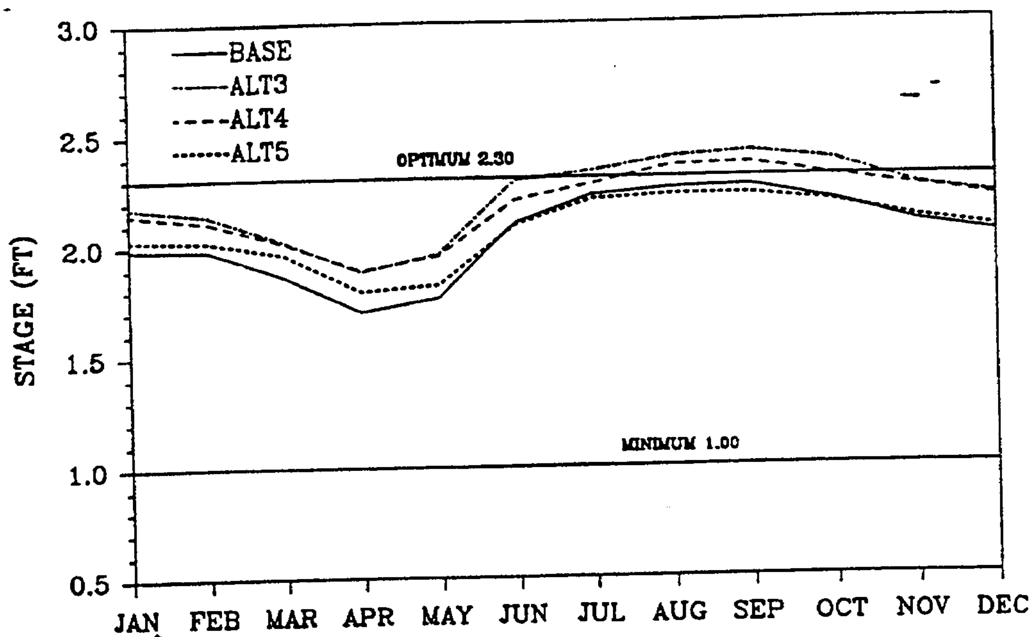


Figure 19: Average Monthly Canal Stage in Central C-111, between S-177 and S-18C

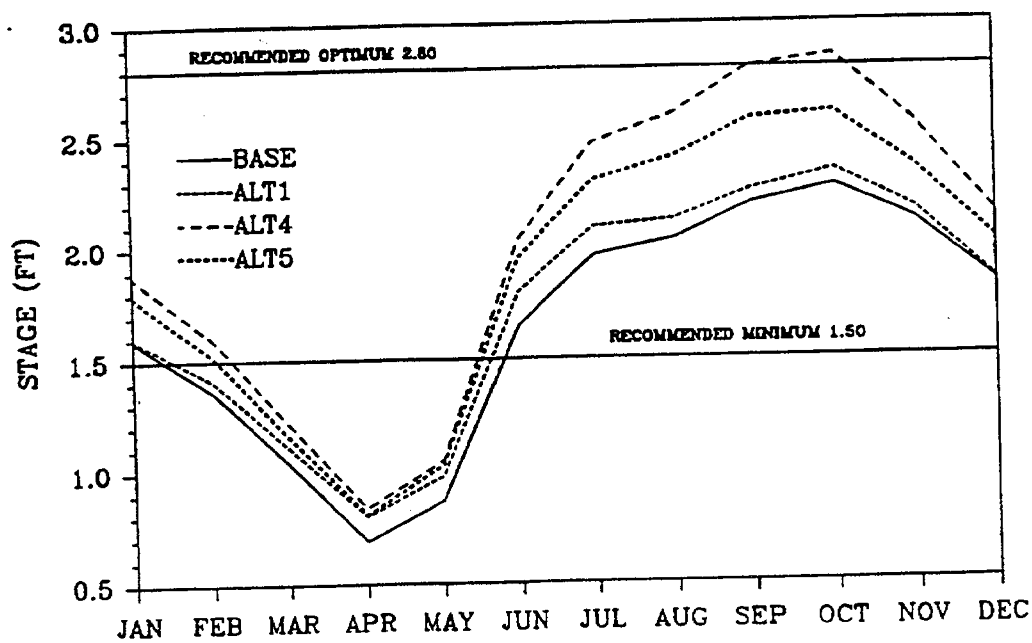


Figure 20: Average Monthly Canal Levels in C-500E

which represents an average rainfall period for the 25 year simulation. Inflows and outflows were included for the L-31W canal under the Base condition and Alternative 1, but the remaining alternatives significantly modified the canal system, making water budget estimates inappropriate.

6.1 Wet Season Water Budgets in the L-31N and C-111 basins

Figs. 21 and 22 show the wet season water budgets under the Base condition and the six proposed alternatives for the canal systems during the period from June through October, 1977. The numbers adjacent to each structure represent the total wet season discharges in acre-feet for each of the water control structures. For the entire 25-year simulation there were no wet season inflows into the L-31N canal via the S-331 pump station. Under the Base condition, L-31W outflows for the 1977 wet season were approximately 23,300 acre-feet. Of this total, 40 percent of the outflows were discharged into the L-31W canal via S-174, and the remaining 60 percent was discharged eastward via S-194 and S-196. As stated earlier, these eastward diversions are inconsistent with the original design of the south Dade canal system, and represent a significant loss of flows from the Taylor Slough basin. Note that Alternative 1 has similar eastern diversions, but the remaining alternatives virtually eliminate these eastward losses. Alternatives 2 through 6 significantly increase the wet season outflows from the L-31N canal system. Alternative 6 increases these outflows to more than 67,000 acre-feet. The increased outflows are the result of reductions in L-31N canal water levels, to stages well below the levels required to provide the authorized level of flood protection to the basin. The tables in Appendix B list the wet season inflows and outflows for the 25 year simulation period. During high rainfall years such as 1968 and 1969, Alternatives 2 through 6 drain tremendous volumes of runoff from the L-31N canal system. Alternative 5, in particular, drains more that 110,000 acre-feet from the L-31N canal system during each of the 1968 and 1969 wet seasons. This is more that 50,000 acre-feet in excess of the Base condition. Again the source of most of this water is the over-drainage of the marshes of the Rocky Glades.

The wet season water budget diagrams also show that in the upper C-111 canal (between S-176 and S-177) Alternatives 3, 4, and 5, have much higher wet season outflows during the 1977 average year. This is the result of a 500 cfs pump at the C500E spreader canal. Alternative 3 produces a three-fold increase in wet season outflows, largely in response to the seepage losses from the Frog Pond impoundment. This again suggests that structural plans that

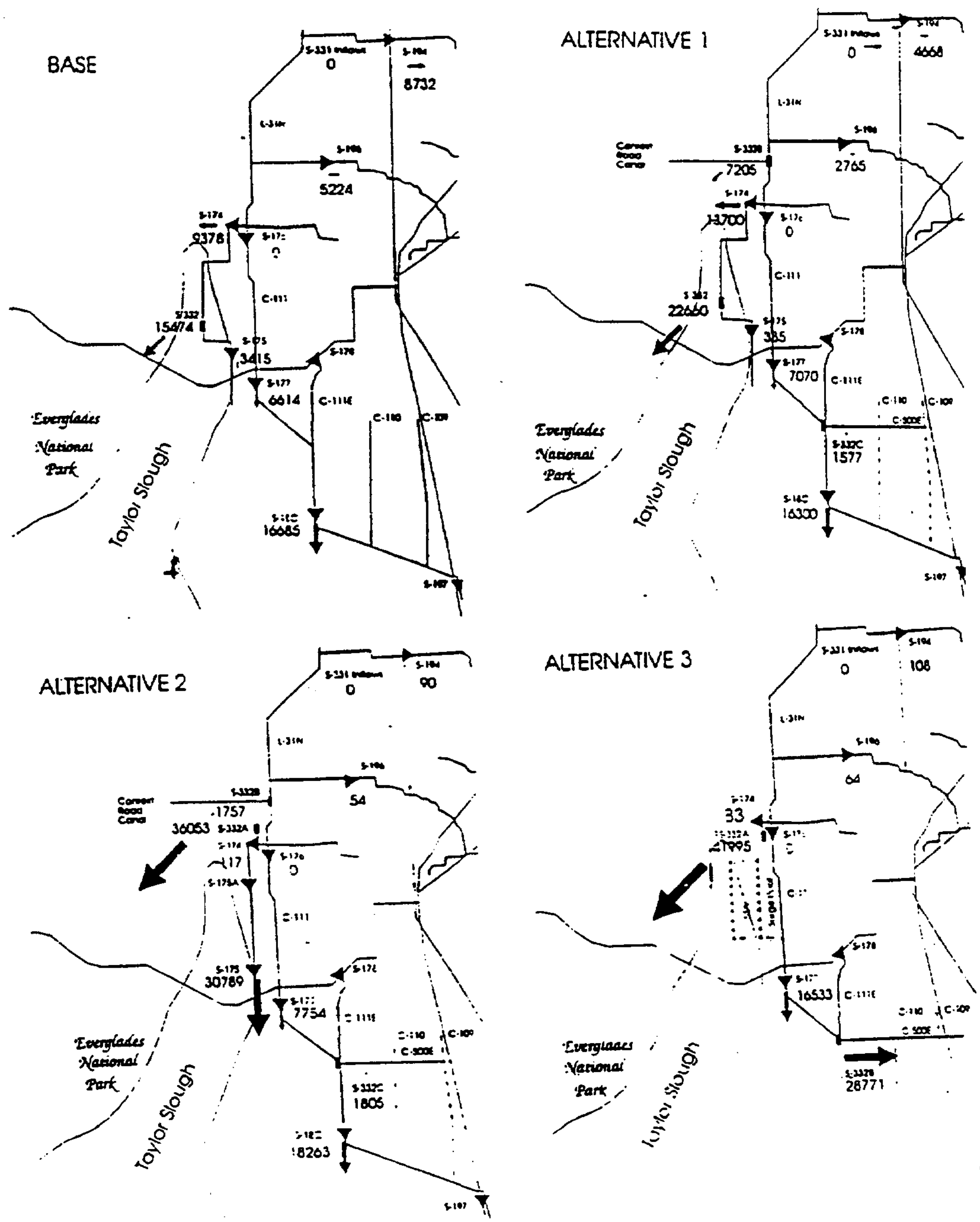


Figure 21: Wet Season Water Budgets for Base condition and Alternatives 1, 2 and 3

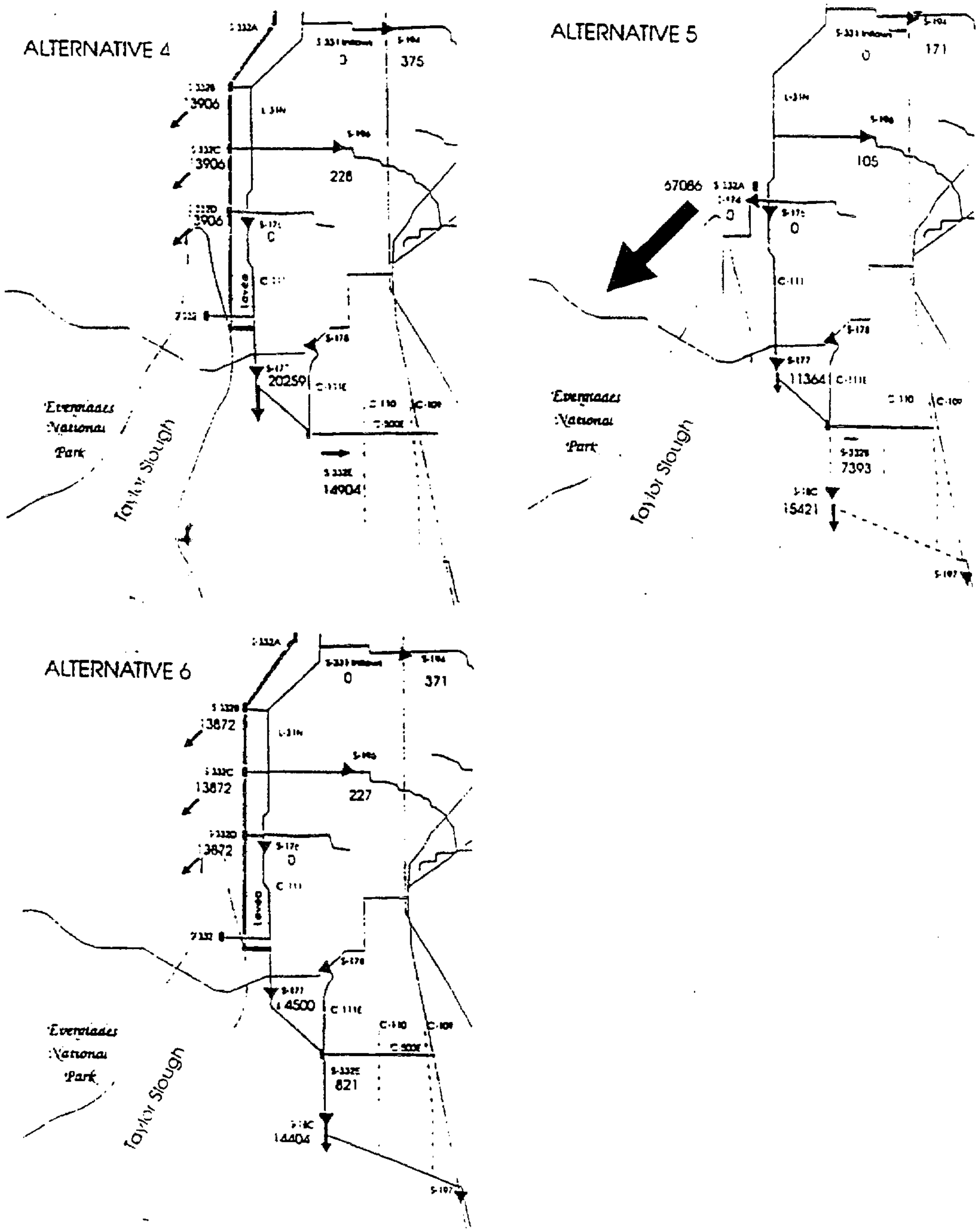


Figure 22: Wet Season Water Budgets for Alternatives 4, 5, 6.

remove the lower C-111 canal and replace the needed outflows with a large pump station and spreader canal provide an effective way of protecting the developed lands adjacent to the upper C-111 canal. The water budget for the middle reach of the C-111 canal (between S-177 and S-18C/S-332) also indicates that the proposed pump station and spreader canal can effectively drain this portion of the C-111 basin, as well as gravity releases through S-18C, without the risk of damaging freshwater outflows into Manatee Bay.

6.2 Dry Season Water Budgets in the L-31N and C-111 basins

Figs. 23 and 24 show the dry season water budgets under the Base condition and the six proposed alternatives for the canal systems during the period from November 1976 through May 1977. The numbers adjacent to each structure represent the total dry season discharges in acre-feet for each of the water control structures. Supplemental dry season pumping at S-331 provided just under 17,000 acre-feet to the L-31N basin under the Base condition. All of the alternatives had similar inflow volumes. For the 25 year simulation, dry season supplemental inflows averaged approximately 14,400 acre-feet, and peaked at just under 32,000 acre-feet in the dry season of 1971. These figures are incredibly low given the expected dry season supplemental water demands estimated by the Corps in their 1973 GDM for the South Dade Conveyance System (U.S. Army Corps of Engineers 1973). This report states that "pumping demands at S-331 are estimated at 264,800 acre-feet annually." The dry season supplemental pumping at S331 simulated in the model is approximately 5% of the Corps expected volumes. Clearly, the modeling has not captured the authorized operational practices of the SDCS.

These dry season inflows into the L-31W and C-111 canals are inadequate to meet the Congressionally mandated Minimum Delivery Schedule. Note that the required 38,000 acre-feet pumping at S-332 into the Taylor Slough basin essentially never occurs, and that inflows into the S-174 canal to support these required pumpages are never made. During the 1977 average year, outflows from the L-31W canal were more than double the inflows. For the 25 year simulation, the L-31W canal system under the Base condition produces a net loss of water from the Taylor Slough headwaters of approximately 11,000 acre-feet. This shows that the L-31W canal continues to be used to provide drainage for the Frog Pond, in violation of its design purpose. A review of the average dry season canal water levels in the L-31N and C-111 canals (Figs 12 through 19) show that the Base condition and all of the alternatives allow the

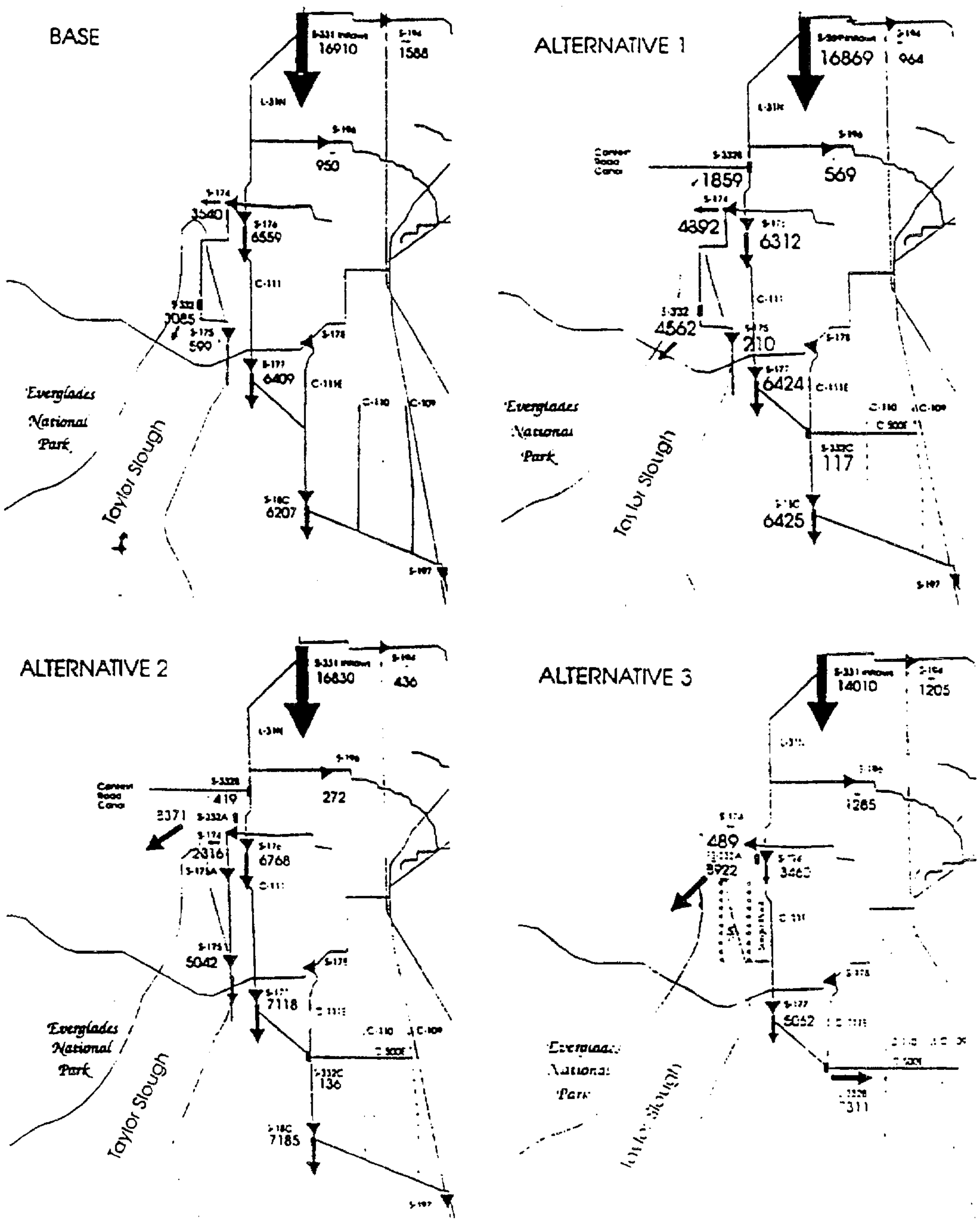


Figure 23: Dry Season Water Budgets for Base condition and Alternatives 1, 2 and 3

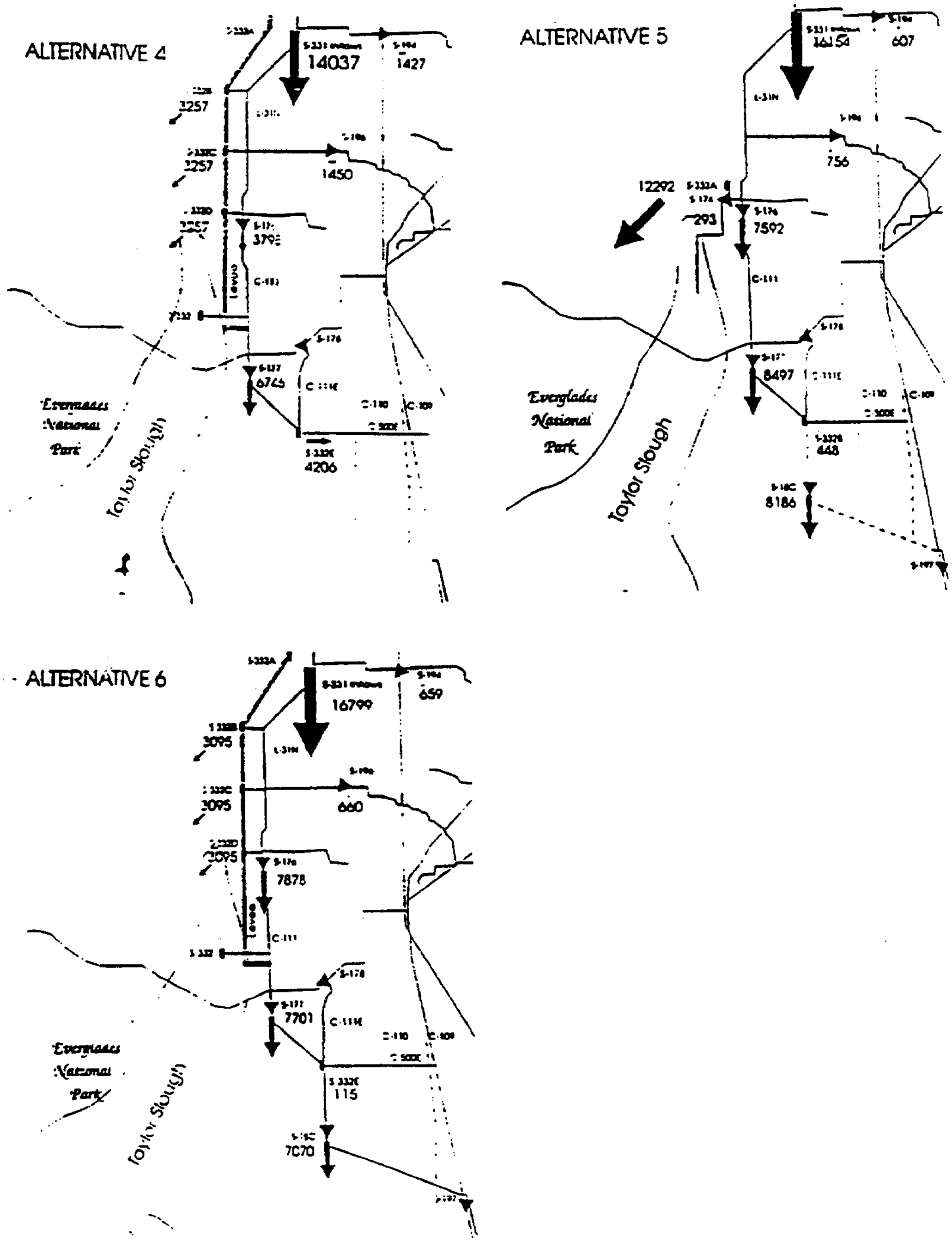


Figure 24: Dry Season Water Budgets for Alternatives 4, 5, 6.

canal stages to fall well below the dry season minimum stages established for the South Dade Conveyance System. This again is a reflection of the lack of dry season supplemental inflows from the upstream Water Conservation Areas.

7 Marsh Flowline Comparisons

A series of six flowlines were defined in each of the model runs to examine the potential impacts of the proposed alternatives on surface water and groundwater flows through the marshes of the Rocky Glades, Taylor Slough, and the Lower C-111 basin.

Fig. 25 shows the location of each of these flowlines, all but two of the lines are oriented east to west, to estimate the predominant north to south flow. The differences in total annual surface water and groundwater flows along each flowline for the Base condition and the six proposed alternatives were computed and are tabulated in the separate volume containing the appendix. Due to the lack of surface water during a large part of the year the groundwater flows made up slightly over 50% of the total annual flows in the over-drained marshes of the Rocky Glades, but the percentage decreased in the downstream direction, accounting for 10% or less at the marsh flowlines within southern portions of Taylor Slough and the Eastern Panhandle basins. Under average historical conditions in the C-111 basin, in places where there was persistent surface water, the ground water contribution to the water budget has been estimated to be about 10% of surface water flow. The contribution varies depending on the local transmissivity of the aquifer and the amount of surface water present through the year. For the Base condition and all of the alternatives, approximately 75% to 85% of the total annual surface water and groundwater flows occurred during the wet season, in response to local rainfall and flood control operations.

7.1 Flows through the Rocky Glades

Two flowlines were included in this area. The northern-most flowline (RCKGL) cuts across the central Rocky Glades, just south of the East Everglades. This flowline showed that no changes would be expected in the surface water and groundwater flows in this area. Under Alternatives 4 and 6, a 300 cfs pump station (S332A) is added at the southwest corner of the proposed East Everglades seepage control system. This caused ponding immediately downstream of the pump, which produced a slight reversal in surface water

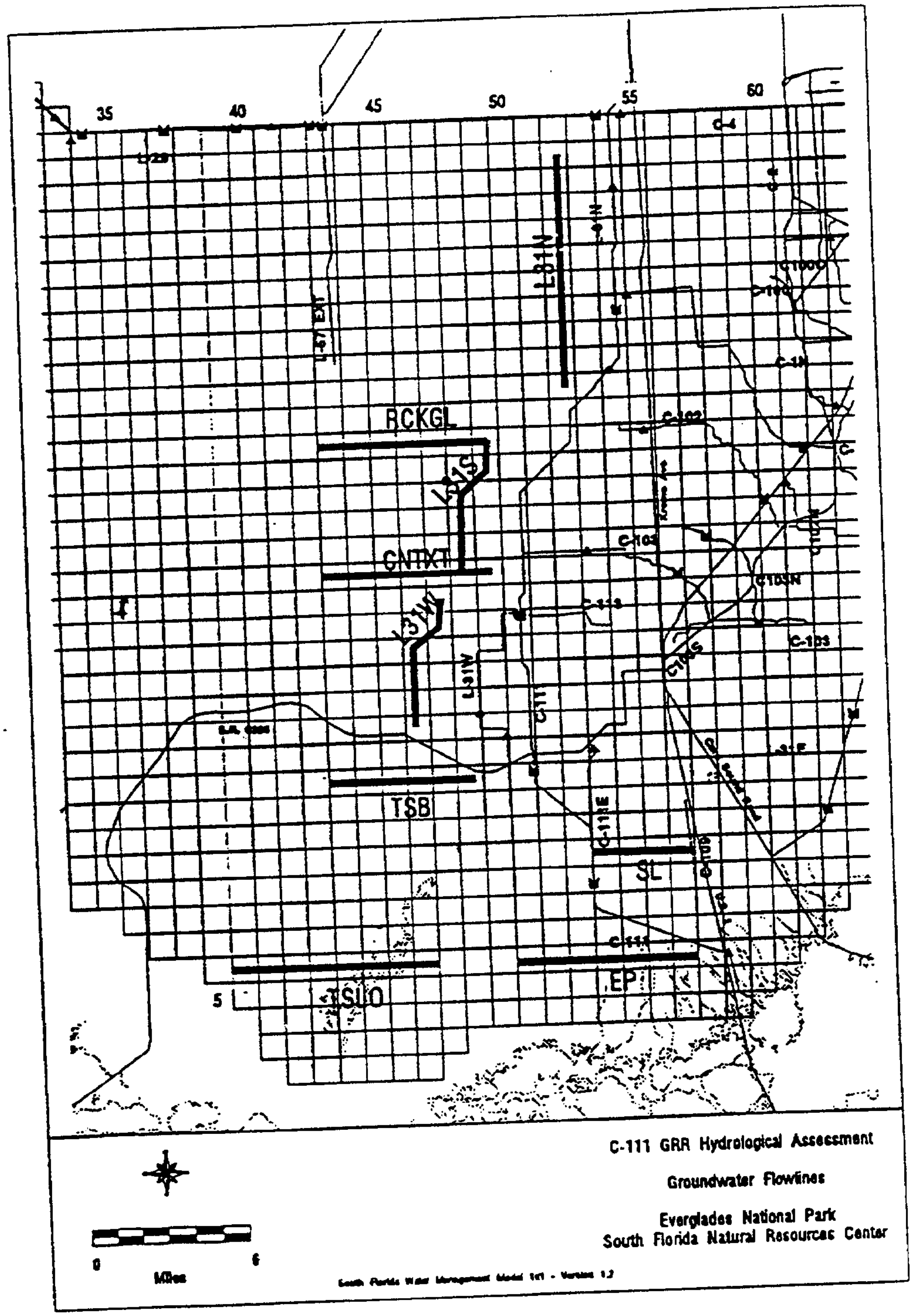


Figure 25: Flow line locations.

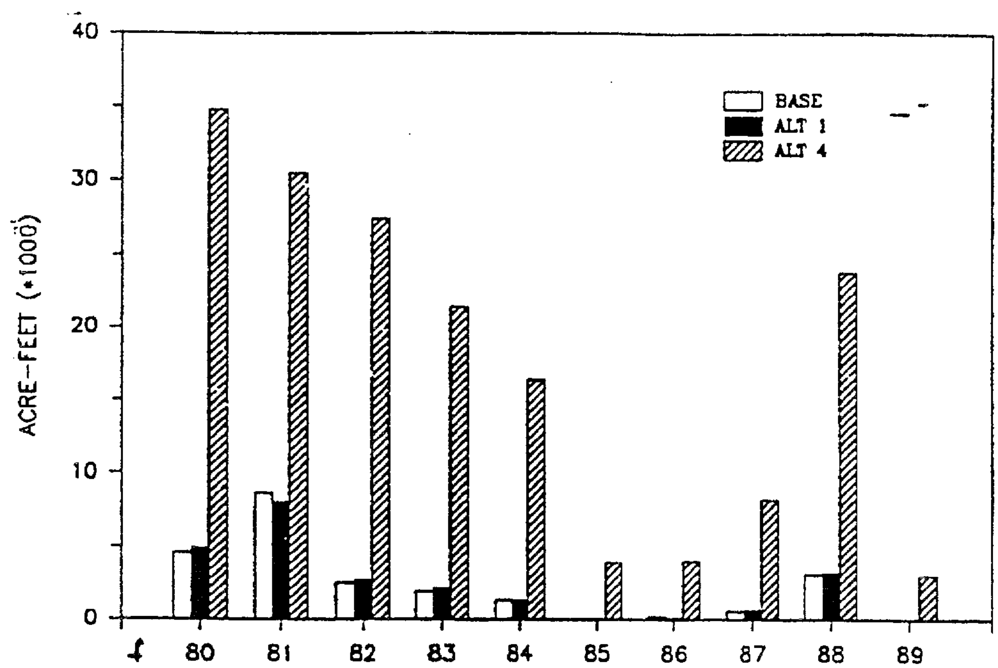


Figure 26: Surface Water Flows across the Context Road Flowline.

and groundwater flow directions. Flows in the southern portion of the Rocky Glades were examined at a flowline oriented along Context Road (CNTXT). Under the Base condition and Alternatives 1, 2, 3, and 5 groundwater flow is slightly greater than surface water flow, and all of the alternatives produced a slight reduction in flows. Fig. 26 shows the annual surface water flows for the Base and two of the alternatives for the period from 1980 through 1989. Under Alternatives 4 and 6, surface water flows were increased by an average of 19,000 acre-feet per year, and by more than 30,000 acre-feet during high rainfall years. These changes are a response to the direct marsh inflows from the S-332B and S-332C pump stations.

7.2 Flows through Taylor Slough

Two flowlines were included in this area. The first is located just south of the Taylor Slough Bridge flow-section (TSB) to allow later comparisons with the historical published flows. At this flowline groundwater flows accounted for approximately 30% of the total annual flows, and showed only minor changes in response to the proposed structural changes. Fig. 27 shows the annual surface

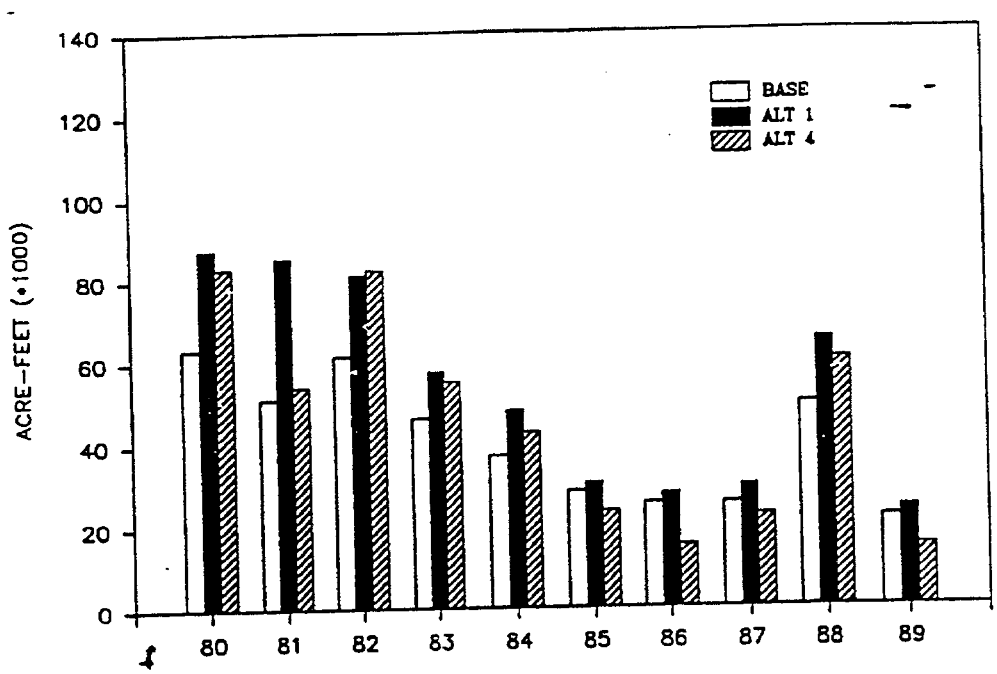


Figure 27: Annual Taylor Slough Bridge Surface Flows.

water flows for the Taylor Slough Bridge flowline under the Base condition and two of the alternatives, for the period from 1980 through 1989. Average annual surface water flows were approximately 44,000 acre-feet for the 25-year period under the base condition and increased slightly under all of the alternatives. Alternative 1 had the greatest impact, increasing average annual surface water flows by approximately 15,000 acre-feet. This is a response to the enlargement of the existing S-332 pump station proposed under this alternative. Fig. 28 shows the annual surface water flows at the southern Taylor Slough flowline for the Base and two of the alternatives, for the period from 1980 through 1989. Average annual surface water flows were approximately 69,000 acre-feet under the Base condition for the 25-year period, and all of the alternatives, except 3 and 5, produced a slight increase of up to 10%. Groundwater flow at this point contributed approximately 10% of the total annual flow, and none of the alternatives had a significant impact on flow volumes.

7.3 Flows through the Eastern Panhandle

Two flowlines were included in this area. The northern-most flowline is located in the State lands just south of the proposed C-500E spreader canal. The Base

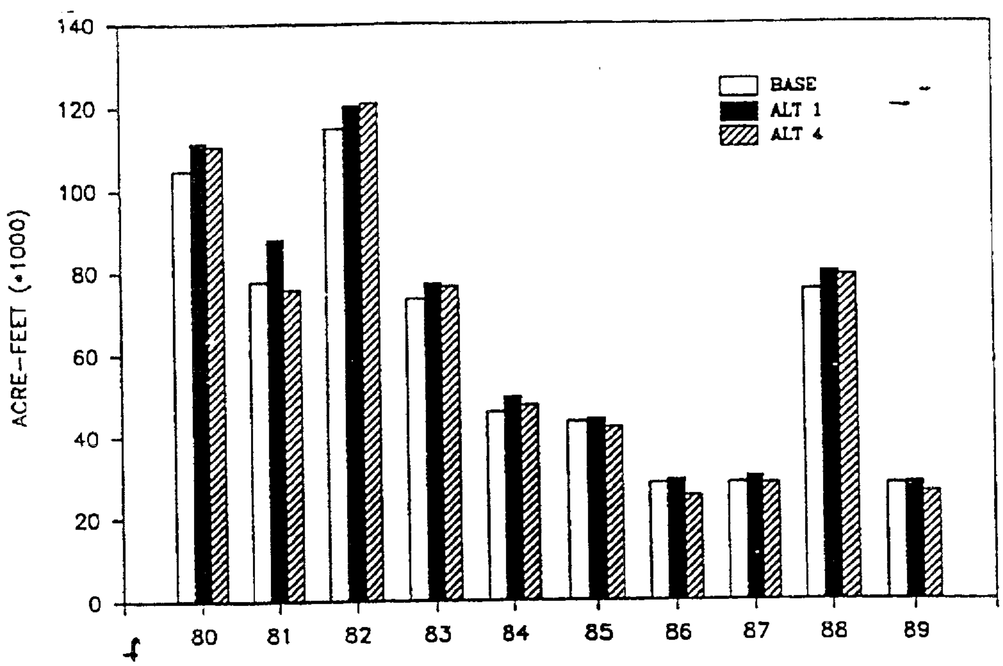


Figure 28: Annual Southern Taylor Slough Surface Flows.

condition suggests that surface water and groundwater flows in this area are insignificant. In contrast, surface water flows were increased significantly under all the alternatives, particularly Alternatives 3, 4 and 5, which proposed the installation of a 500 cfs pump station at the intersection of C-111E and the new C-500E canal. Fig. 29 shows the annual surface water flows for the flowline in the lower portion of the Eastern Panhandle basin under the Base condition and two of the alternatives, for the period from 1980 through 1989. At this flowline average annual surface water flows were approximately 74,000 acre-feet for the 25-year period under the Base condition, and increased by slightly more than 10% under Alternatives 3 and 5. Again, groundwater flow contributed approximately 10% of the total annual flow, and none of the alternatives had a significant impact on flow volumes.

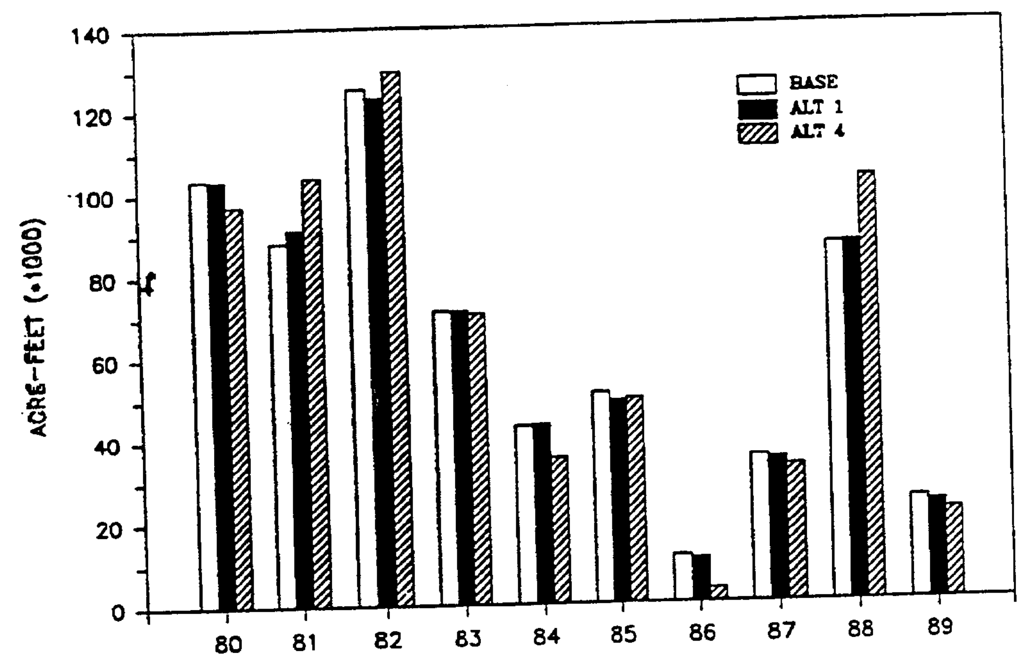


Figure 29: Annual Eastern Panhandle Surface Flows.

8 Stages and Hydroperiods at Selected Monitoring Points

Twenty-one grid cells were selected to examine the temporal water depth and hydroperiod characteristics of the Base condition and the six structural alternatives. These grid cells correspond to actual monitoring point locations (Fig. 30) which have actual water level recorders, so the model results could also be compared with actual data. This comparison will determine the level of calibration for the wetland stages. This analysis was not done for this report. Discrepancies often will occur since the modeled water level data represents a computed value assigned throughout the selected 1 mile by 1 mile grid cell, not the water level at a specific gage. The gage names will be used instead of the grid cell locations throughout this section of the report as a way of simplifying the nomenclature. For each grid cell, descriptive statistics were tabulated from the modeled daily water level data to define the wet and dry season attributes, and frequency analyses were tabulated to describe the flooding and drying characteristics. In addition, a series of water level hydrographs and stage exceedence curves were developed for a representative set of grid cells.

The preliminary modeling results prepared by the Corps of Engineers showed that the structural modifications could be expected to have their greatest effect on water levels in the marshes of the Rocky Glades, Taylor Slough, and lower C-111 basins, since these are the areas that would receive the excess stormwater runoff. Therefore, the water depth and hydroperiod analyses were designed to examine the potential hydrologic impacts of the proposed structural modifications for a set of five sub-regions dividing these and the developed areas.

a) Four grid cells were chosen to characterize the hydrologic conditions in the developed areas east of the L-31N and C-111 canals. These grid cells included one gage (G-855) east of Krome Avenue in the upper L-31N basin, two gages (S-196A and G-789) in the lower L-31N basin, and one gage (G-613) adjacent to the C-111E canal (Fig. 30).

b) Four grid cells were similarly chosen to characterize the hydrologic conditions in the 8.5 square mile residential area (G-596), and in the agricultural areas of the Rocky Glades (G-3437 and RUTZKE) and the Frog Pond (FROGP).

c) Three gages (G-3115, R-3110, and TSB) were selected to estimate the hydrologic impacts expected in the Rocky Glades and upper Taylor Slough.

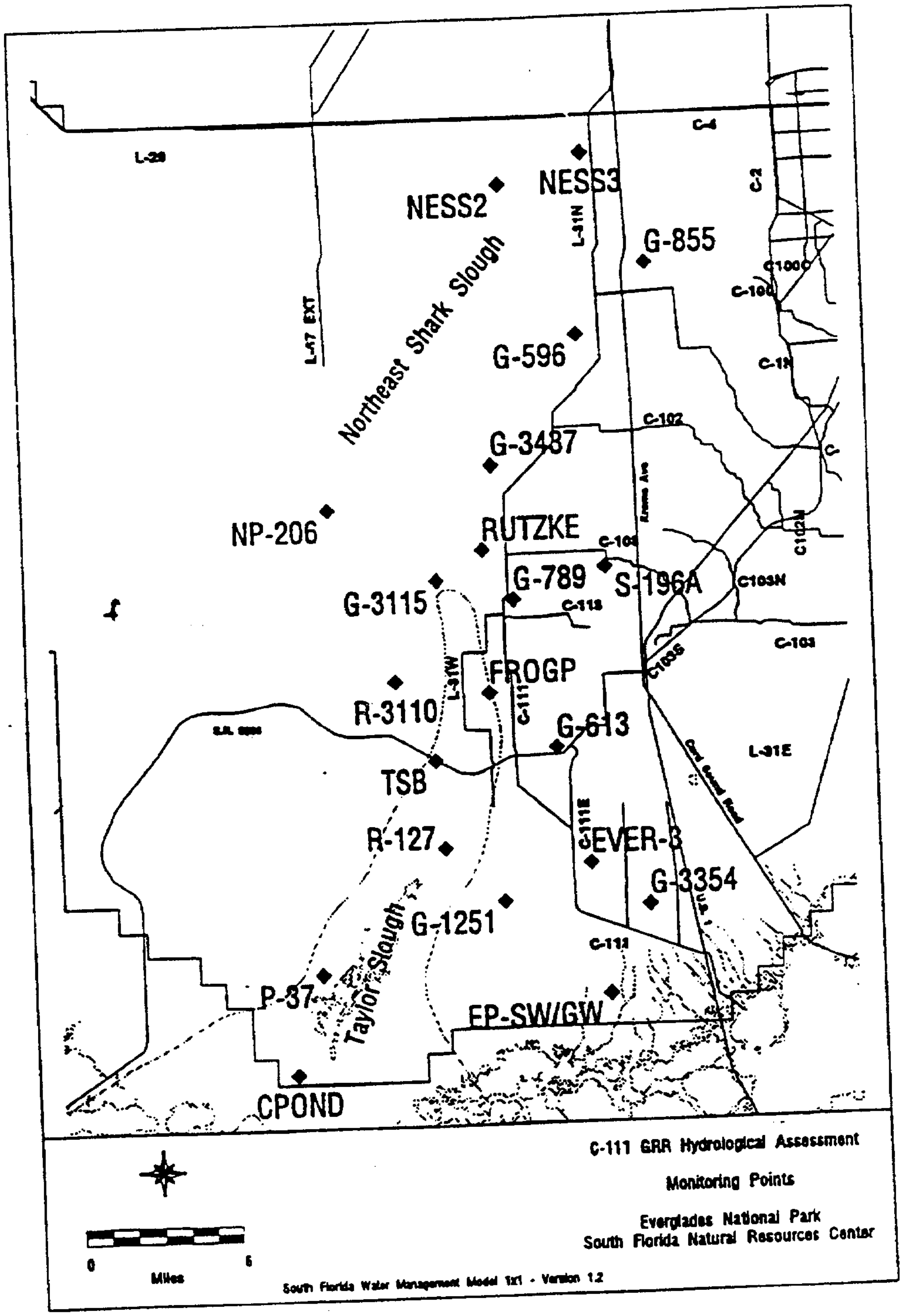


Figure 30: Selected Monitoring Point Locations

d) Three gages (R-127, P-37, and CPOND) were similarly selected to describe the estimated hydrologic changes expected in the lower Taylor Slough basin.

e) Four gages (EVER-3, G-3354, EP-SW/GW, and G-1251) were selected to characterize the expected changes in the wetlands adjacent to the lower C-111 canal.

The results of this analysis are described in the next five subsections. Hydrographs, stage exceedence curves, tables of descriptive statistics, and flooding/drying frequency tables for all of the selected grid cells in these sub-regions are included in the separate volume containing Appendix B.

8.1 Water Depth/Hydroperiod Impacts in the Eastern Developed Areas.

Fig. 31 shows the expected water level conditions at gage G-789 in the lower L-31N basin under the base and alternative plans. The hydrologic conditions at this site are typical of the conditions in the eastern developed areas. Note that water depths essentially always remained more than 1.5 feet below the ground surface at all four of the representative grid cells, throughout all of the model runs. Alternatives 2 through 6 tend to slightly lower the average monthly wet season water levels at G-855, S-196A, and G-789 during most years. This suggests that the increased outflow capacity provided by pumping directly out of the L-31N canal can provide a slight increase in the level of flood protection in these areas. At G-613 in the C-111E basin, wet season water levels tended to rise slightly (particularly under Alternatives 3 and 5).

8.2 Water Depth/Hydroperiod Impacts in the Western Developed Areas.

Fig. 32 shows the expected water level conditions at the RUTZKE gage in the Rocky Glades agricultural area, under the base and alternative plans. The hydrologic conditions at this site are typical of the conditions in the western urban and agricultural areas. Hydrographs, stage exceedence curves, tables of descriptive statistics, and flooding/drying frequency tables for all of the selected grid cells in this sub-region are included in the separate appendix. Note that water levels are highly variable in all of these areas, and that surface flooding would be expected to occur during periods of high wet season rainfall.

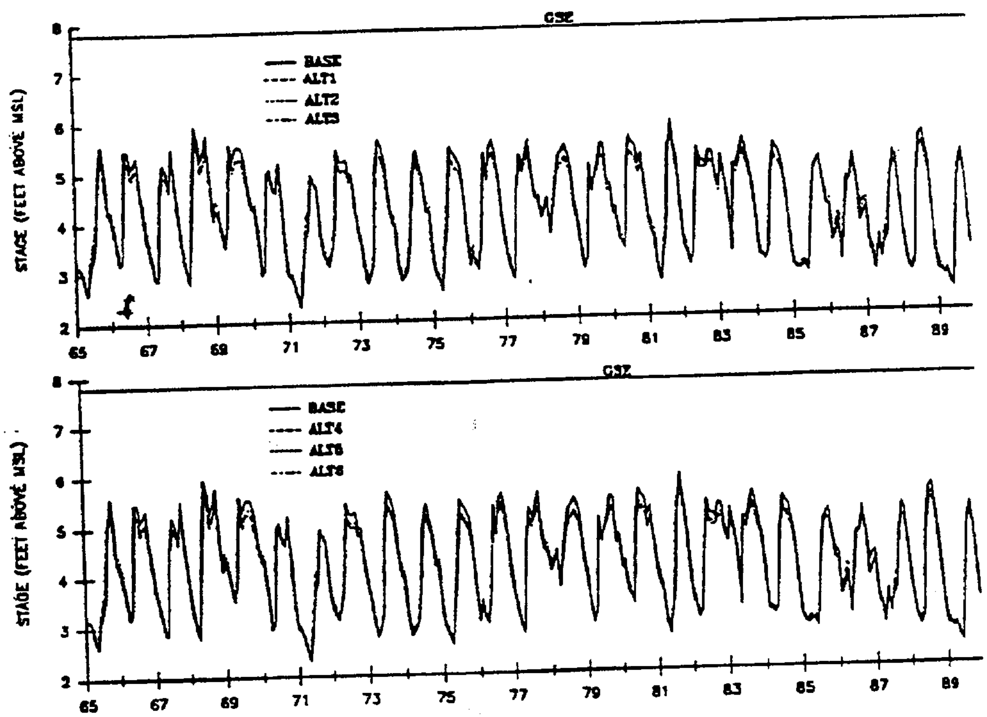


Figure 31: Stages at G-789

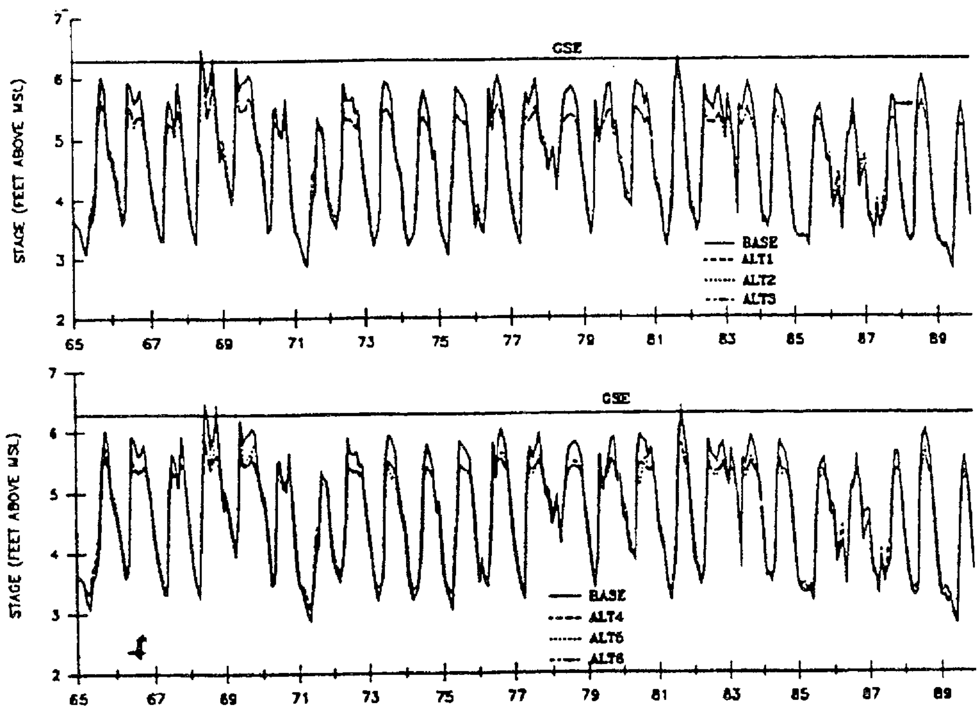


Figure 32: Stages at RUTZKE

Alternatives 2 through 6 all slightly lowered wet season water levels compared to the base condition, presumably in response to the increased outflow capacity in the L- 31N canal. At the Frog Pond gage, Alternatives 4 and 6 tend to lower wet season water levels, while Alternatives 2, 3, and 5 significantly raised wet season water levels, and Alternative 1 showed essentially no major changes. In general, the agricultural areas of the Rocky Glades and the Frog Pond had water levels rising into the root zone (less than 1.50 feet below the ground surface) approximately 50 percent of the time under all of the model runs. At gage G-596 in the East Everglades, flooding within the root zone occurred approximately 40 percent of the time, even with the added protection of the proposed seepage control system associated with the Modified Water Deliveries GDM. This shows that all of the developed areas west of the Eastern Protective Levee System are at a high risk of flooding due to their proximity to the Everglades.

8.3 Water Depth/Hydroperiod Impacts in Upper Taylor Slough and the Rocky Glades.

Fig. 33 shows the expected water level conditions at the R-3110 gage in the upper Taylor Slough basin, under the base and alternative plans. The hydrologic conditions at this site are typical of the conditions in the Rocky Glades headwaters and the upper portion of the Taylor Slough watershed. The model results indicate that all of the marshes in this sub-region experience surface water flooding for 3 to 9 months each year under the base condition and the proposed alternatives. The results vary quite a bit in this area in response to the differences in the location of structure inflows, but all of the alternatives produced an increase in wet season water levels. In the Rocky Glades wetlands, Alternatives 4 and 6 have the most significant impact on wet season water levels, and hydroperiods showed a slight increase of approximately 10 percent (1 month). Alternatives 1, 3, and 5 have the greatest impact on wet season water levels in the marshes adjacent to the L-31W canal. At gage R3110, hydroperiods increased by up to 15 percent (under Alternatives 3 and 5). Wet season water levels also showed a small increase at the TSB gage, but hydroperiods were unaffected, or decreased slightly.

8.4 Water Depth/Hydroperiod Impacts in Lower Taylor Slough.

Fig. 34 shows the expected water level conditions at the P-37 gage in the lower Taylor Slough basin, under the base and alternative plans. The hydrologic conditions at this site are typical of the conditions in the watershed south of the L-31W canal system. The model results indicate that all of the marshes in this sub- region experience surface water flooding for 6 to 10 months each year under the base condition and the proposed alternatives. Wet season water levels at the P-37 and the CPOND gages showed almost no change under any of the alternatives. The R-127 gage showed a slight reduction in wet season water levels under Alternatives 3 and 5, presumably in response to the reduced conveyance caused by the removal of the lower portion of the L-31W canal. At all 3 grid cells the hydroperiods were essentially unaffected by any of the proposed structural changes.

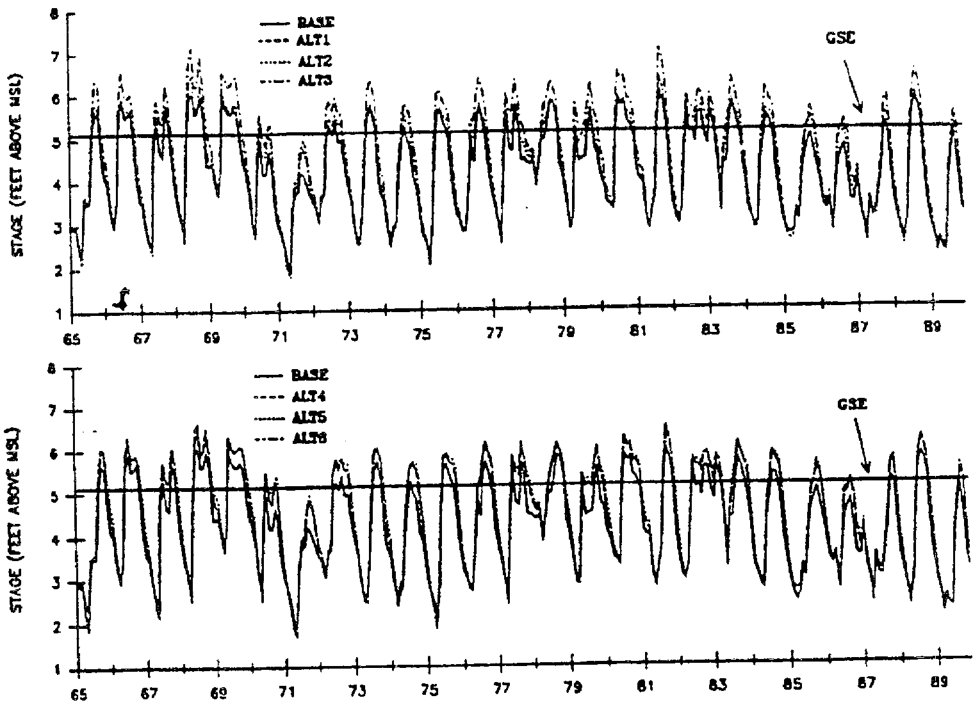


Figure 33: Stages at R-3110

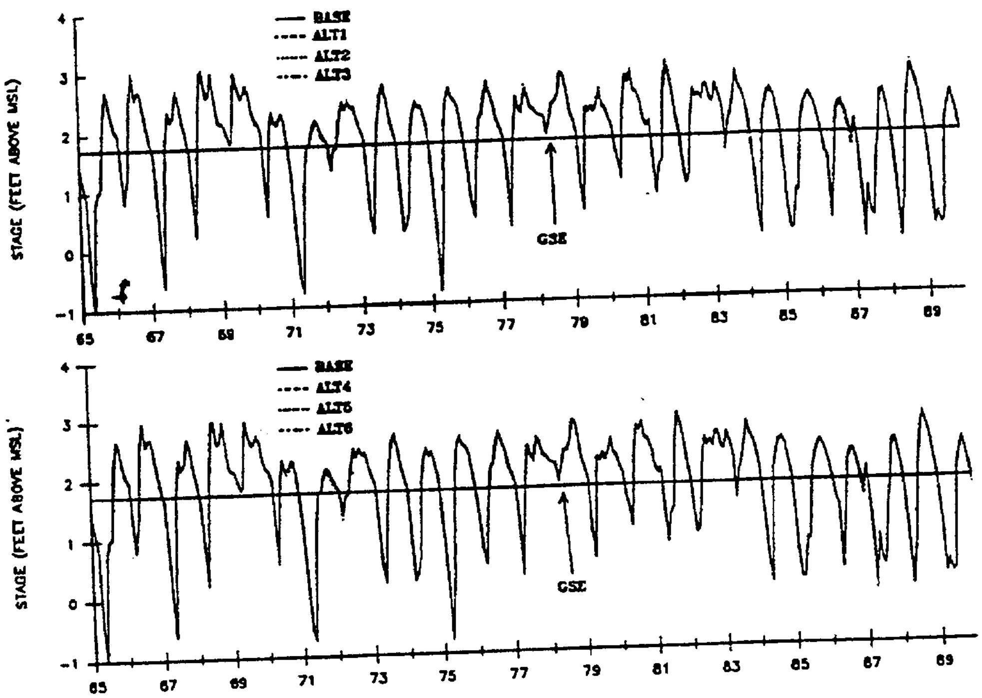


Figure 34: Stages at P-37

8.5 Water Depth/Hydroperiod Impacts in the Lower C-111 Basin.

Fig. 35 shows the expected water level conditions at the G-3354 gage in the lower C-111 basin, under the base and alternative plans. The hydrologic conditions at this site are typical of the conditions in the impounded area just north of the C-111 canal system. At the G-3354 gage, Alternatives 1, 2, and 6 slightly lower wet season water levels, while Alternatives 3, 4, and 5 significantly lower wet season water levels. This is presumably as a result of the removal of the northern levee, which is used as fill to completely or partially backfill the lower C-111 canal. At gages EP-SW/GW and G-1251 water levels and hydroperiods show no significant impacts during the wet season under any of the proposed alternatives. During the dry season, water levels tend to be lower under all the alternatives that backfill the C-111 canal. Examination of all of the gages in this area shows that the marshes north of the C-111 canal have substantially higher wet season water levels, and maintain much longer hydroperiods then the wetlands south and west of the C-111 canal. This is a result of the levee system along the northern and eastern side of the lower C-111 canal. This levee system holds back wet season runoff which would otherwise provide sheetflow to the downstream marshes and Florida Bay.

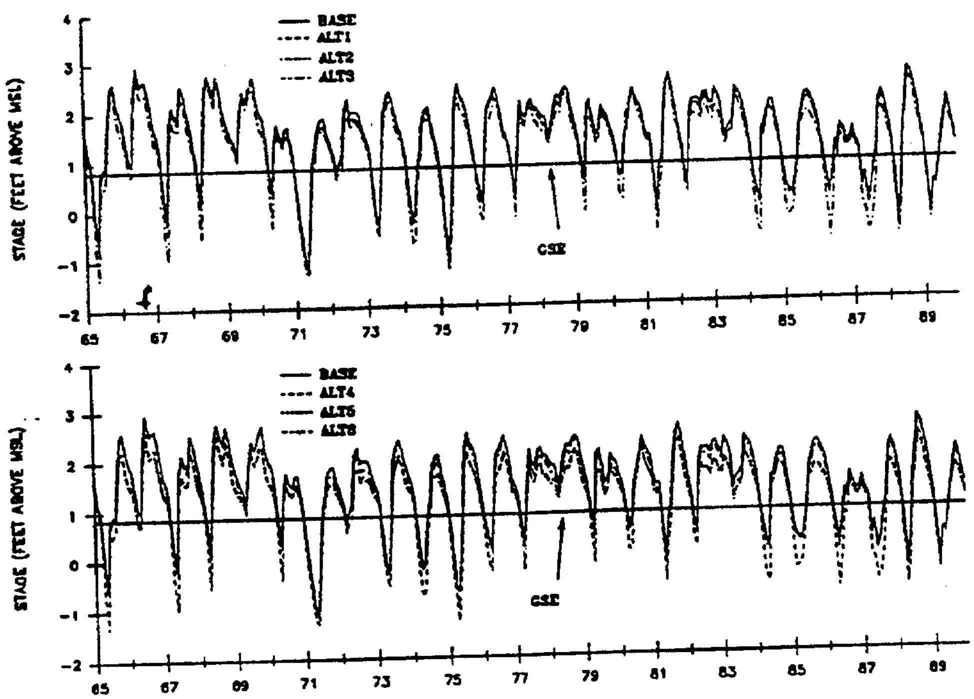


Figure 35: Stages at G-3354

9 Spatial Surface Water Depth Comparisons

One of the many outputs of the model are end-of-month surface water depths for each grid cell. These values were post-processed and brought into GRASS, a public domain GIS package. GRASS has excellent spatial analysis features, which were used to compute the differences in water depths between the base condition and the alternatives. ARC/INFO© and GRASS overlays were used to make water depth and hydroperiod maps, which were helpful in making spatial comparisons. Surface water depths for each cell were placed into specified categories and both a tabulation and map were produced. The spatial analyses consisted principally of surface subtractions between base and each alternative. These subtractions compute the difference in water depth between the two model outputs and are carried out on each corresponding grid cell. All of the runs were computed so that the base condition was subtracted from each of the alternatives. Thus, a negative number indicates reduced surface water depths (increased drainage) in that cell, while a positive value indicates increased surface water depths under the alternative.

The first set of data obtained from the model runs and post-processed are the total number of cells, or area in mi^2, which are inundated with depths greater than 0.01 ft. These depths consist of all the classes from category 2 and up (see Table 3). The water depth values at the end of each particular month were averaged over the entire 25-year period and the total number of inundated cells or mi^2 (each cell is one mile square) are tabulated and presented in Appendix B. Using this approach alone makes it difficult to determine the differences between the base and alternative plans. The average monthly values and the average annual values indicate that little or no increase in surface water occurs under any of the alternatives.

9.1 Average Changes in Surface Water Depth for the 25-Year Period

To illustrate the spatial patterns of increases and decreases of surface water depths, surface subtractions were computed and tabulated in different categories. These categories are presented in Table 4, the "difference" indicates the difference in water depth between base and alternative. Only categories with small ranges in values were needed, since large changes in surface water depths did not occur anywhere in any of the model runs, indicating the lack of significant water depth decreases or increases in the wetlands.

The results of these surface substractions are shown in Table 5. The top

Category	Depth Range	Category	Depth Range
1	no surface water	6	1.0 < depth ≤ 1.5 ft.
2	0.01 < depth ≤ 0.25 ft.	7	1.5 < depth ≤ 2.0 ft.
3	0.25 < depth ≤ 0.50 ft.	8	2.0 < depth ≤ 2.5 ft.
4	0.50 < depth ≤ 0.75 ft.	9	depth > 2.5 ft.
5	0.75 < depth ≤ 1.00 ft.		

Table 3: Surface Water Depth Classifications

Subtraction Category	Difference in Water Depth	Depth Category	Difference in Water Depth
1	difference < -0.10 ft.	5	0.10 > difference ≥ 0.20 ft.
2	-0.10 ≤ difference < 0	6	0.20 > difference ≥ 0.30 ft.
3	no difference	7	difference > 0.30 ft.
4	0.10 > difference ≥ 0.10		

Table 4: Classifications for the Changes in Surface Water Depth Analysis

section of the table contains the increases in area which have additional surface water inundation under each proposed alternative. Conversely, the bottom section tabulates the areas which have less surface water under the proposed alternative than they had under the base condition. The latter section of the table contains the area during each month which have lower water depth under the alternative than under base conditions. A large section of this increased drainage is located in the Eastern Panhandle area, where under several of the alternatives, the deep water pools north of C-111 will be eliminated.

In order to realize some benefit to the Park, the surface water depth increases for the preferred alternative should be significant. Category 7 contains the areas which show increases of greater than 0.03 ft. of surface water depth. This category of very modest increase in water depth is tabulated in Table 6. No benefits during the dry season are derived from any of the alternatives, this is indicated as the zero in the months from January through April. Small increases, less than 10 mi^2, are realized in Alternatives 3 through 6 during the wet season months. The increase in Alternative 3 during the wet season is due to the additional area inundated in the Frog Pond (the Surge Pool and STA) and the increase in deliveries to the Eastern Panhandle. This additional inundation in the lower C-111 basin is principally due to the large seepage losses from the Surge Pool being picked up in the canal and passed into C-500E by

Water depth increases with the alternative Categories > 3. Positive Differences.						
Month	A1–Bse	A2–Bse	A3–Bse	A4–Bse	A5–Bse	A6–Bse
January	165	141	257	453	188	455
February	115	109	190	404	171	399
March	69	58	121	281	106	275
April	53	52	100	209	79	186
May	98	125	134	251	123	225
June	192	254	232	389	228	359
July	249	318	339	509	310	472
August	271	310	365	586	330	535
September	321	340	398	650	382	586
October	323	327	404	684	384	630
November	269	279	367	632	304	587
December	191	186	275	521	212	495
Average	193	208	265	464	234	433

Water depth decreases with the alternative Categories < 3. Negative Differences						
Number of Cells or Area in mi^2						
Month	A1–Bse	A2–Bse	A3–Bse	A4–Bse	A5–Bse	A6–Bse
January	26	33	24	50	88	28
February	29	36	33	50	90	33
March	18	23	27	30	60	19
April	25	26	62	64	66	35
May	37	36	107	94	98	65
June	54	55	146	131	142	139
July	39	46	122	102	127	118
August	42	57	128	58	136	81
September	56	88	137	69	143	87
October	38	78	128	61	137	69
November	23	47	47	31	117	34
December	24	31	24	34	95	27
Average	34	46	82	65	108	61

Table 5: Average Number of Cells which Show a Change in Surface Water Inundation.

Category 7. Differences greater than 0.03 ft.						
Number of Cells or Area in mi²						
Month	A1–Bse	A2–Bse	A3–Bse	A4–Bse	A5–Bse	A6–Bse
January	0	0	0	0	0	0
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	1	0	1	0
June	1	0	14	8	8	7
July	0	0	20	9	12	9
August	0	3	25	16	14	15
September	2	6	29	26	18	22
October	0	2	26	16	20	16
November	0	0	5	2	6	2
December	0	0	1	0	0	0
Average	0	1	10	6	7	6

Table 6: Average Number of Grid Cells which Show a Change in Surface Water Depth greater than 0.03 feet.

the 500 cfs pump. Increases in wet season water levels in Alternative 5 occur west of S-174, due to the addition of the large pump. Spacing of pumps west of the Eastern Protective Levee System at five location produces water level increases which are located adjacent to the discharges, starting just south of the 8.5 m^2 area.

9.2 Average Changes in Surface Water Depth for Selected Water Years

The end-of-month surface water depths for the selected water years of 1976–1977, 1973–1974 and 1968–1969 were also post-processed and tabulated. The total area which is inundated with surface water depths greater than 0.01 ft. at the end of every month during the selected year and the annual averages are tabulated in the tables in Appendix B. The information was used to make comparisons between the Base and alternative conditions. By subtracting the water depths between the alternative and base, similar to the procedure described earlier, the difference in water depths were obtained. A positive difference (diff > 0) indicates a gain in water depth with the alternative. The results were again classed in the specific categories (see Table 4)

Category	A1–Bse	A2–Bse	A3–Bse	A4–Bse	A5–Bse	A6–Bse
Average Water Year 1976-1977						
diff ≤ -0.1	0	0	2	7	8	1
$-0.1 <$ diff < 0	30	57	49	35	71	41
No change	1297	1263	1203	938	1203	965
$0 <$ diff ≤ 0.1	225	220	259	524	239	503
$0.1 <$ diff ≤ 0.2	5	16	23	36	18	32
$0.2 <$diff ≤ 0.3	0	1	11	13	12	12
diff> 0.3	0	0	10	4	6	3
Dry Water Year 1973-1974						
diff ≤ -0.1	0	1	2	6	9	0
$-0.1 <$ diff< 0	32	45	106	39	108	41
No change	1347	1319	1255	1084	1252	1099
$0 <$diff ≤ 0.1	178	189	172	409	167	400
$0.1 <$ diff ≤ 0.2	0	3	14	17	16	16
$0.2 <$diff≤ 0.3	0	0	5	2	2	1
diff > 0.3	0	0	3	0	3	0
Wet Water Year 1968-1969						
diff ≤ -0.1	4	4	8	12	13	6
$-0.1 <$ diff < 0	40	62	64	67	89	78
No change	1129	1059	921	762	951	805
$0 <$diff ≤ 0.1	373	405	469	615	447	580
$0.1 <$ diff ≤ 0.2	4	22	59	70	38	61
$0.2 <$ diff≤ 0.3	3	2	13	27	11	24
diff> 0.3	4	3	23	4	8	3

Table 7: Surface Water Depth Differences for Selected Water Years

and are summarized in Table 7 for the water years defined earlier.

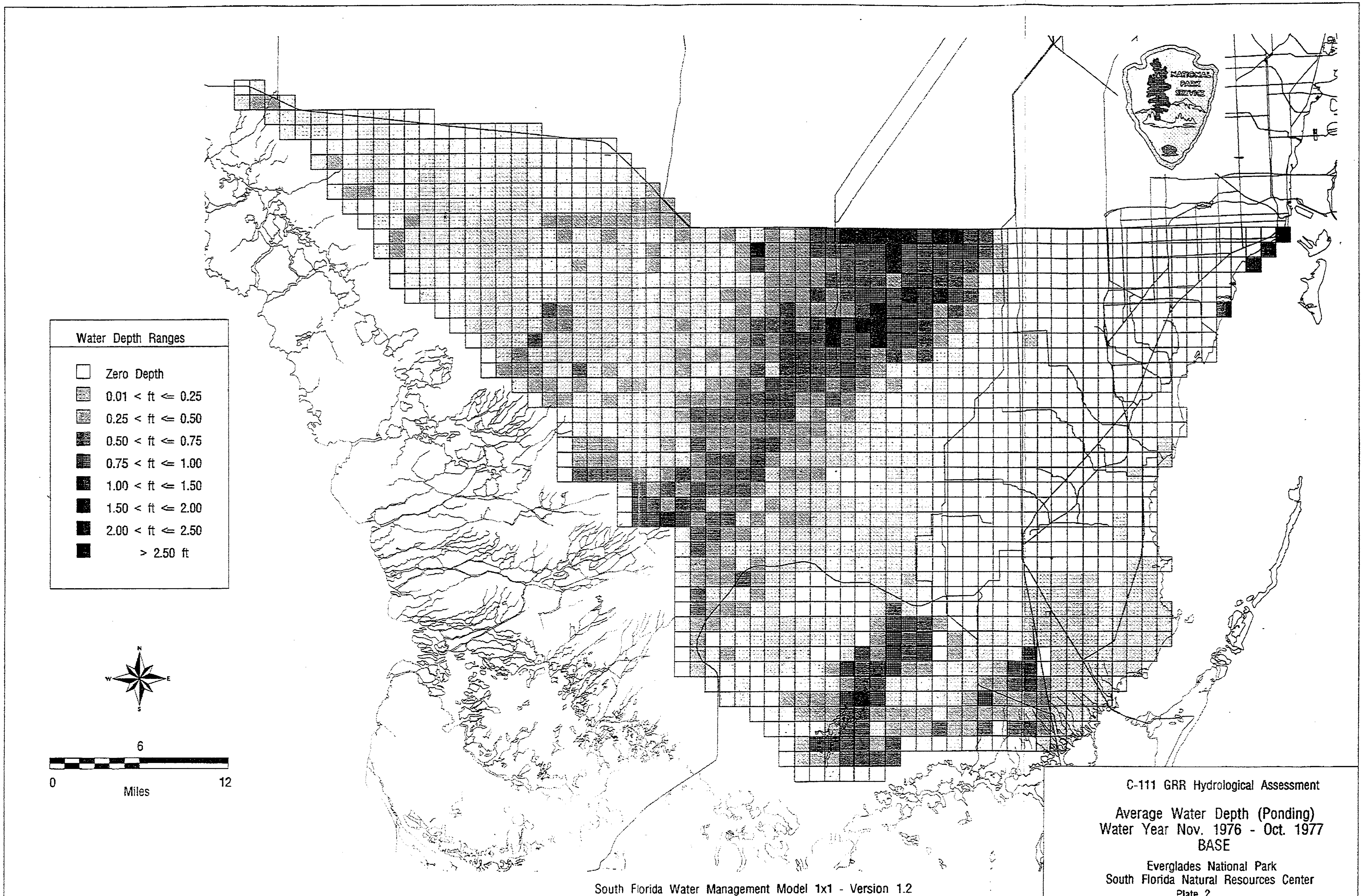
In addition to the tabulation the spatial distribution of the increases and decreases in water depths can be visualized by inspecting the surface subtraction maps between the base and each of the alternatives. The same categories were used as presented in Table 7. The water year 1976–1977 was selected for its "average" condition. The end-of-month water depth values were used to compute an annual average. Color plate 2 (Fig. 36) presents the average water depth for the water year 1976–1977 for the base condition. Color plates 3 thru 8 (Figs. 37, 38, 39, 40, 41, and 42) show the spatial water depth differences between each alternative and base as tabulated in Table 7.

Using the table and the plates, the spatial distributions (hydropatterns) of the water depths in base and the changes that occur in the alternatives can be described. The Base condition (Fig. 36, Plate 2) shows the pattern of surface water for different depth categories. The Shark Slough, Taylor Slough and the flow section in the Eastern Panhandle can be readily distinguished. The ponding in the State lands north of the cutouts in lower C-111 can also be discerned. During these average conditions no surface water greater than two feet occurs, however during the wet season some deep water pools are present. The Rocky Glades and northern Taylor Slough have very little standing water which lasts throughout the year, the average conditions are less than 0.25 ft. This area extends as far south as the S-332 pump and persistent standing water does not occur until south of the Park road.

Similar conditions prevail in Alternatives 1, 2, 3 and 5. Most of the surface water is located near the discharge point in Taylor Slough. The Rocky Glades area receives negligible benefit from these alternatives. Alternatives 4 and 6 show a wider distribution of surface water extending well into the Rocky Glades. Most of the increases in surface water are small (less than 0.2 ft.) but at least the area of persistent inundation has almost doubled (Table 7), as compared to the other alternatives. If seepage can be controlled and canal levels are brought back to proper operational levels, the concepts contained in these alternatives may provide some hydrological benefit to the wetlands.

The additional drainage illustrated by the yellow colorations in the figure and tabulated as negative categories in Table 7 occur in the Rocky Glades in Alternatives 2, 3 and 5. This is a result of the continued practice of draining NESS and passing the excess water via the canals to the large pumps next to Taylor Slough. All of the alternatives show a decrease in surface water in the Eastern Panhandle. Most of this decrease is due to the reduction of discharge through S-176 to the south, and the removal or degradation of lower C-111 in Alternatives 3, 4 and 5, without compensating with higher operational canal levels in C-500E and C-111.

Operational changes are needed in all of the alternatives. Proper canal stages may show some benefit in the wetlands of the C-111 basin, but changes were not tested as part of this report.



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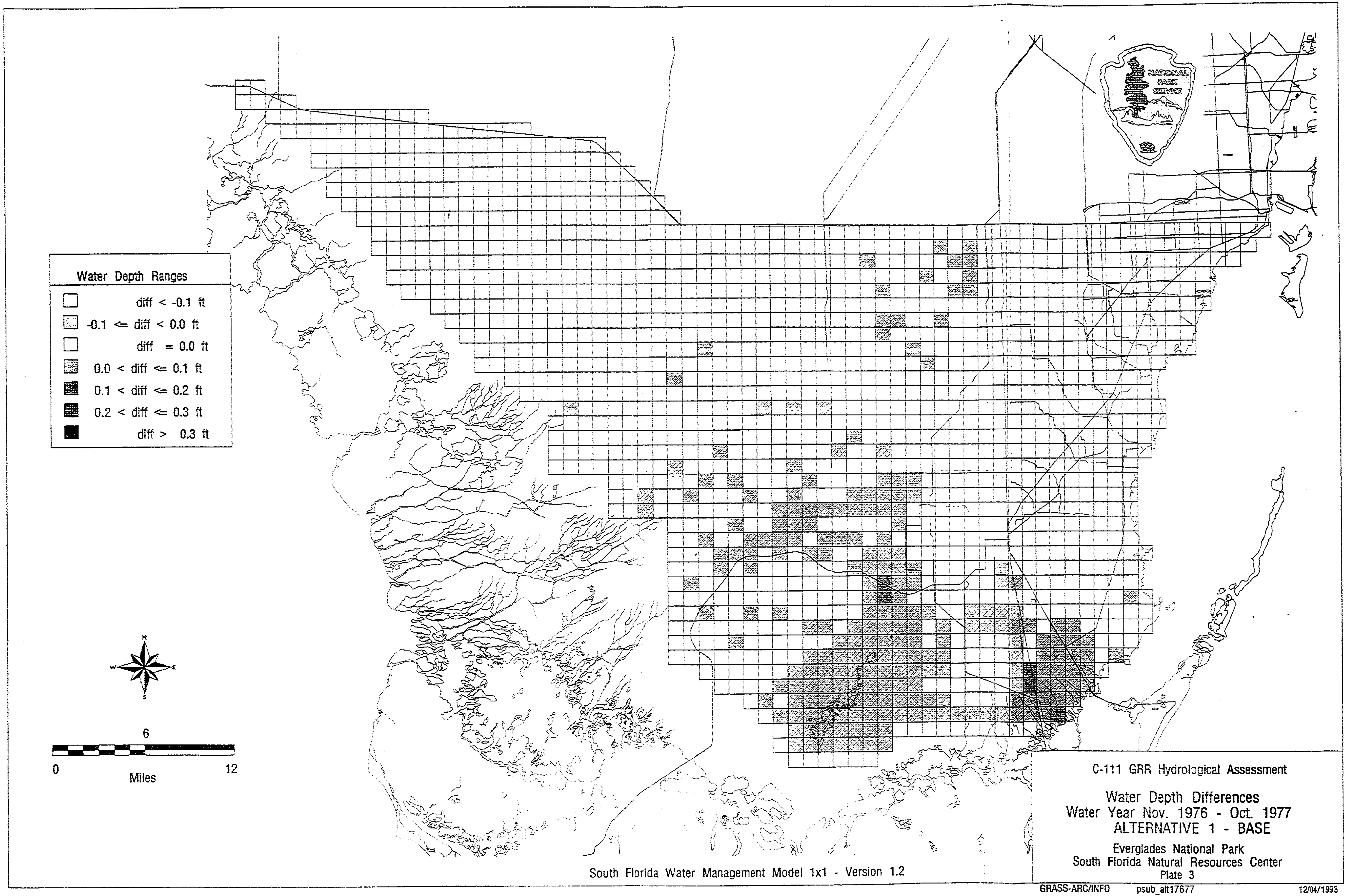

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-0.1 <= diff < 0.0 ft
diff = 0.0 ft
0.0 < diff <= 0.1 ft
0.1 < diff <= 0.2 ft
0.2 < diff <= 0.3 ft
diff > 0.3 ft
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Miles
12
NATIONAL PARK SERVICE
South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Water Depth Differences
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 1 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 3
GRASS-ARC/INFO
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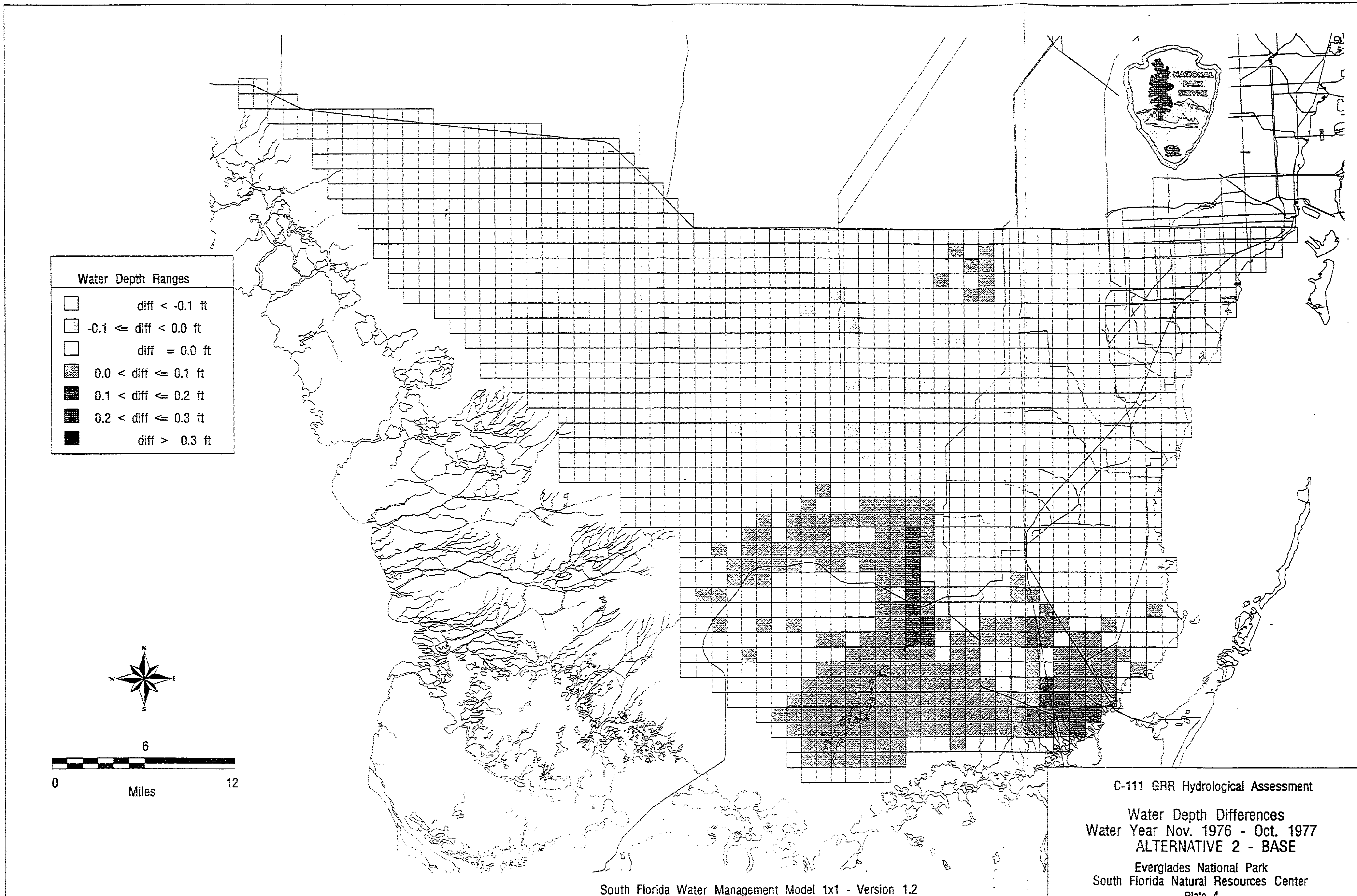

C-111 GRR Hydrological Assessment

Water Depth Differences
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 2 - BASE

Everglades National Park
South Florida Natural Resources Center
Plate 4

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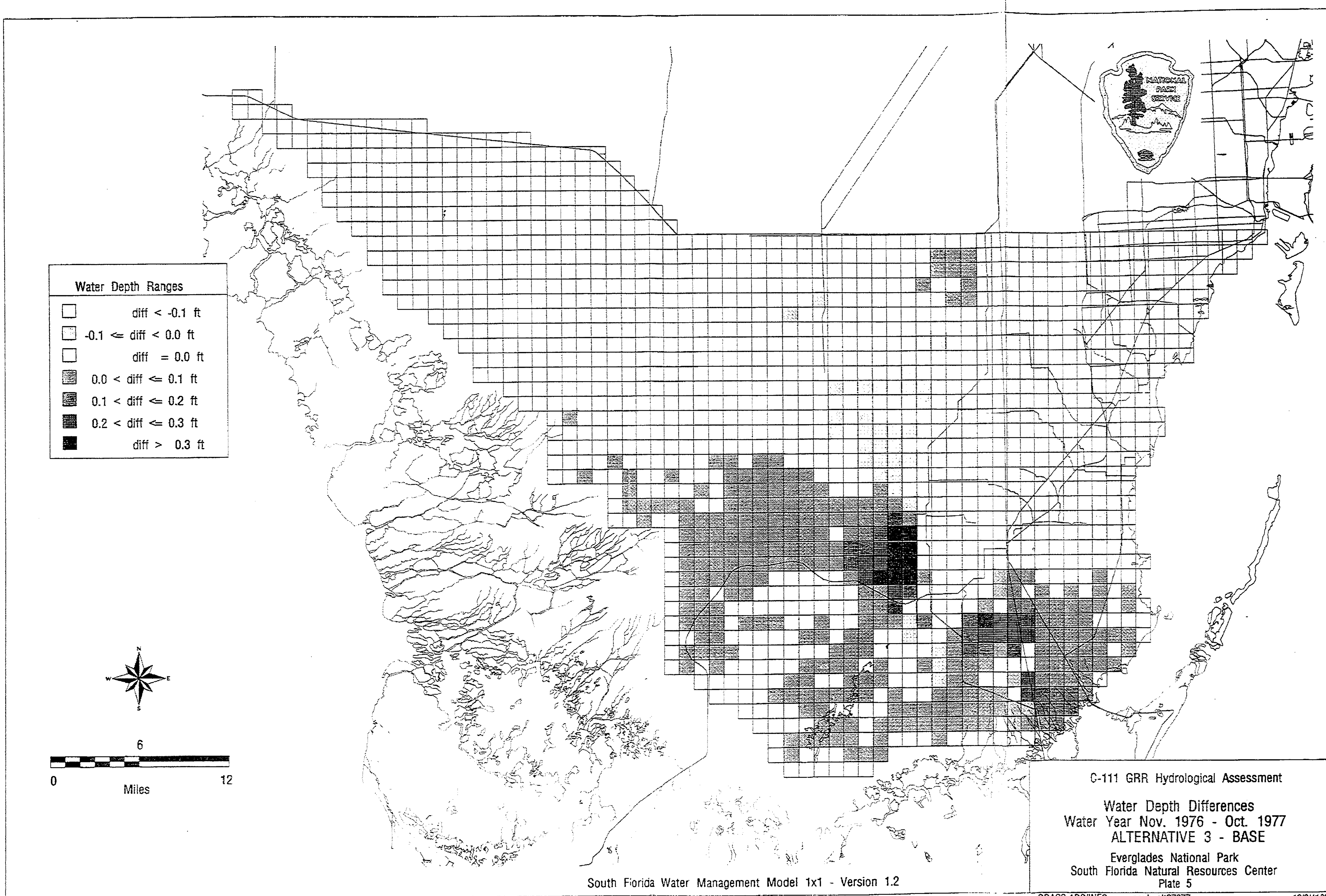
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0.2 < diff <= 0.3 ft
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South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Water Depth Differences
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 3 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 5
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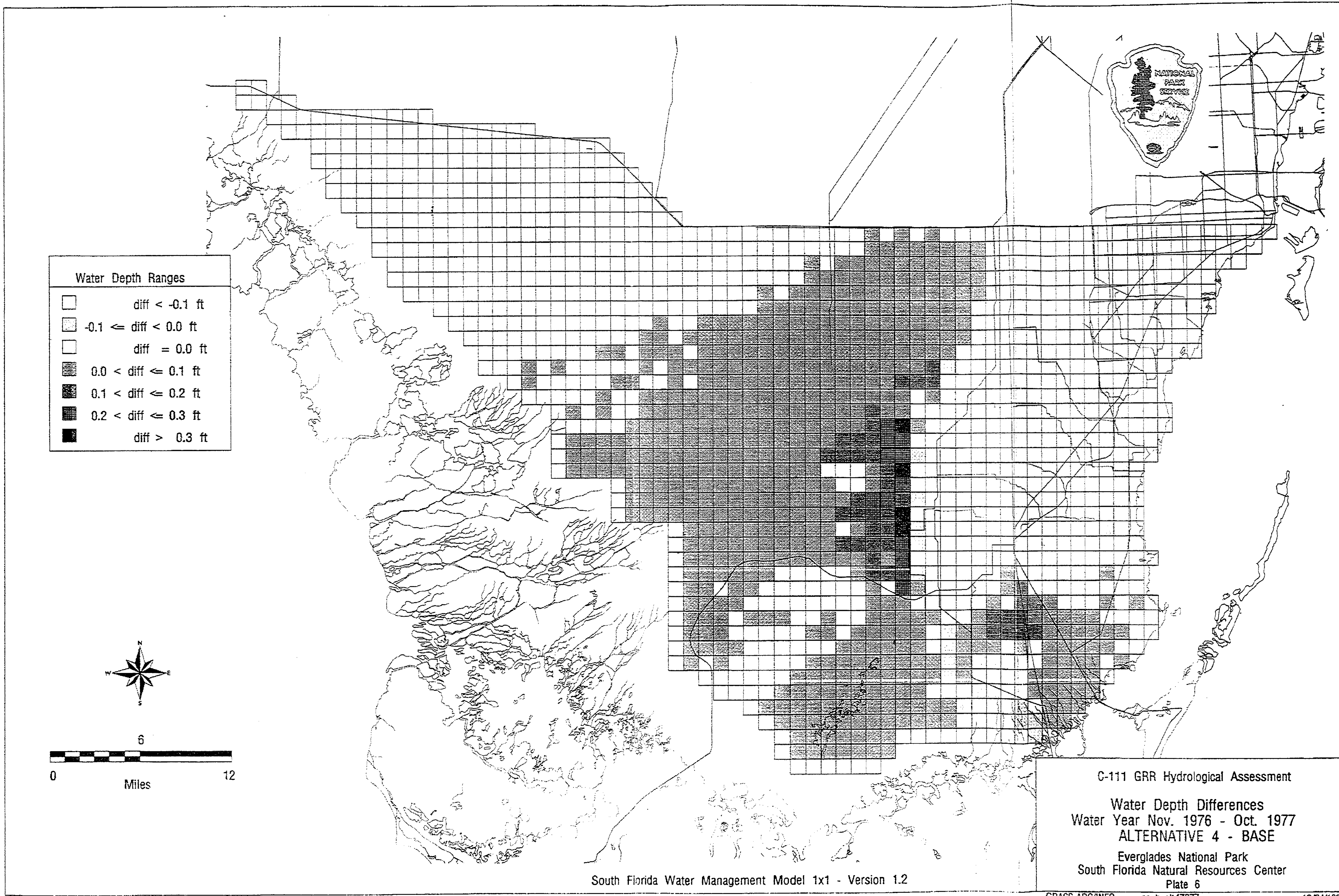

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NATIONAL PARK SERVICE
South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Water Depth Differences
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 4 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 6
GRASS-ARC/INFO
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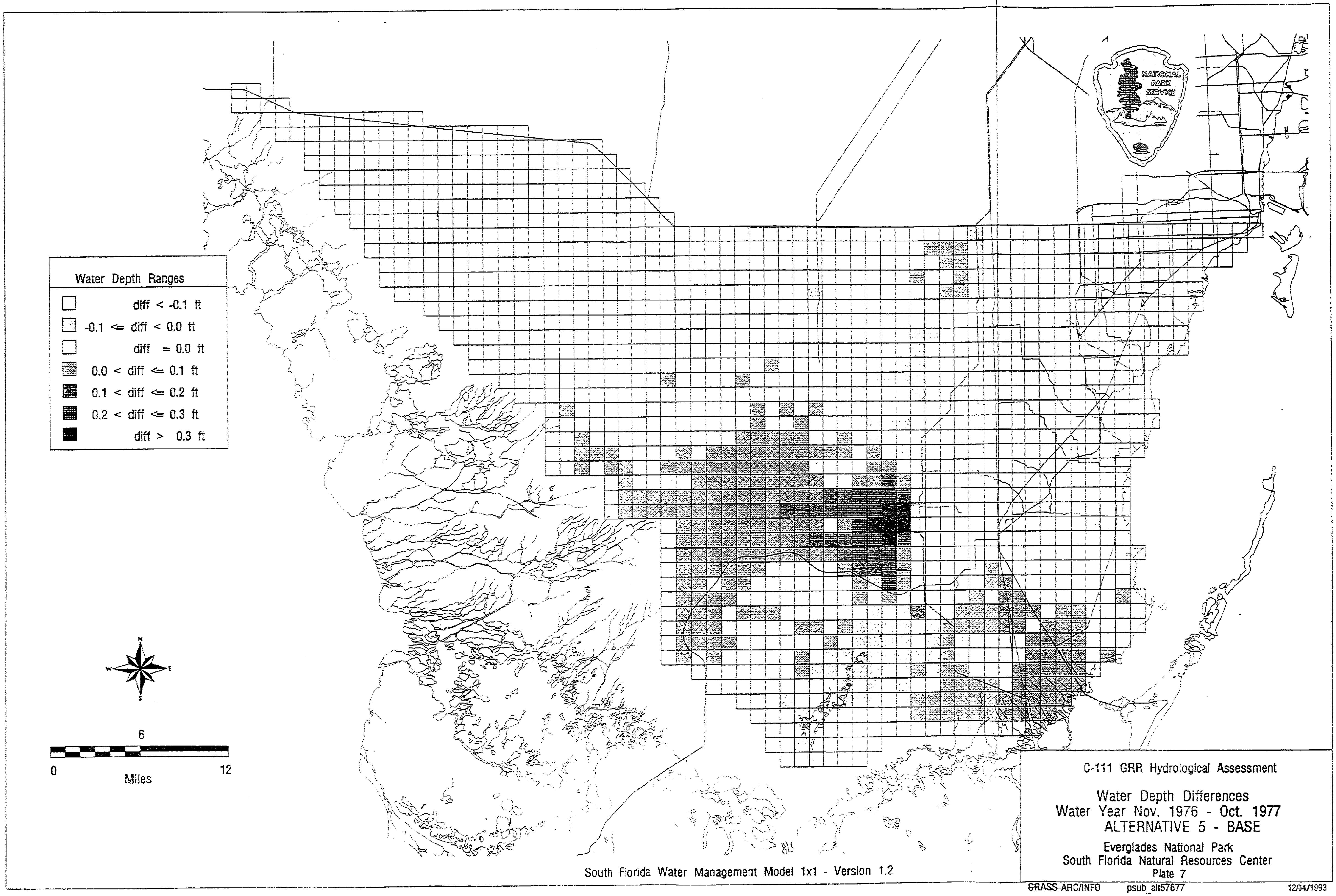
12/04/1993



NATIONAL PARK SERVICE
Water Depth Ranges
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Miles
South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Water Depth Differences
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 5 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 7
GRASS-ARC/INFO
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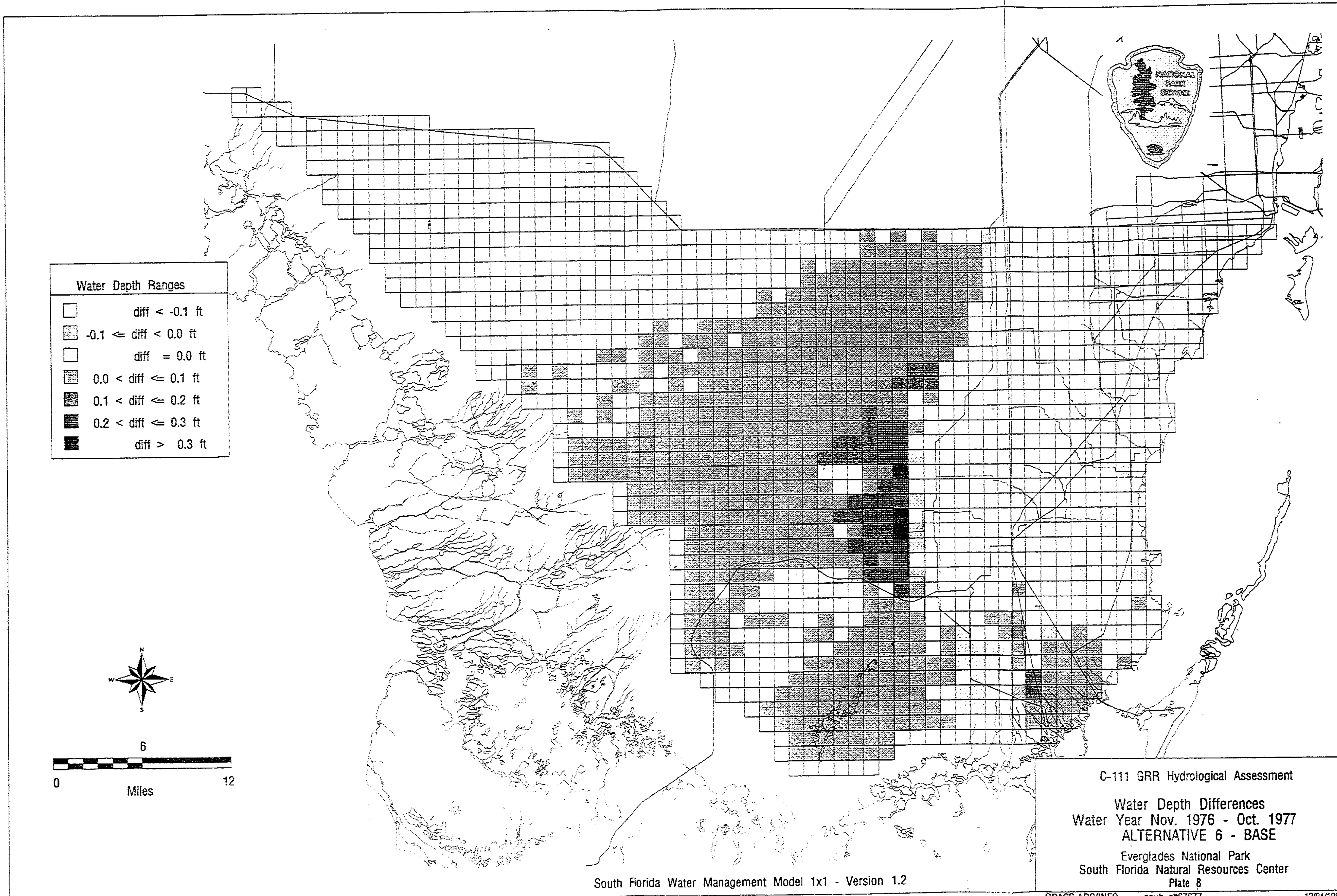
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Miles
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South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Water Depth Differences
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 6 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 8
GRASS-ARC/INFO
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Time Ranges	
transitional	< 3 months
short	3 – 5 months
intermediate	6 – 10 months
long	11 – 12 months

Table 8: Hydroperiod Classifications

10 Spatial Hydroperiod Comparisons

The length of time that a grid cell has surface water during a particular water year is the hydroperiod of that cell. Daily surface water depths (ponding) for each grid cell were obtained for each of the alternatives and the Base condition. Annual (water year) hydroperiods for each grid cell were computed from this information by adding the number of days when surface water depth exceeded 0.01 ft. To reduce the amount of information the hydroperiods were subdivided into four time categories (Table 8). The transitional category, for example, is the class of cells which is not considered a fully functional wetland in the Everglades, but is viewed as being overdrained and no longer capable of maintaining native wetland vegetation. Many of these areas have experienced severe fire damage, suffer from exotic woody plant invasion and have low periphyton production. The hydroperiod information for the Base condition and each of the alternatives for a typical average, dry and wet year is presented in Table 9. This table lists the total model area in mi^2 which remains inundated for a particular time period.

For example, under the Base condition, during a typical average year 176 mi^2 of the model domain was inundated for less than 3 months per water year, while the area covered under Alternative 6 saw a reduction of 23 mi^2 in the transitional category.

10.1 Changes in Hydroperiods for Selected Water Years.

Surface subtractions on the hydroperiods were carried out in GRASS between the base run and each alternative. The results are summarized in Table 10 for the water years under consideration. This table describes the difference between the hydroperiods (Δp) for three depth ranges. The positive categories list the additional area in mi^2 which has that range of additional hydroperiod, while the two negative categories are the areas with reduced inundation.

Condition	none 0	transitional < 3 mnths	short 3-5 mnths	intermediate 6-10 mnths	long 11-12 mnths
	Average Year 1976-1977		Depth > 0.01		
Base	339	176	284	515	243
Alternative 1	341	165	284	520	247
Alternative 2	345	156	279	531	246
Alternative 3	338	159	260	554	246
Alternative 4	345	156	245	567	244
Alternative 5	339	160	257	554	247
Alternative 6	348	153	247	559	250
	Dry Year 1973-1974		Depth > 0.01		
Base	387	137	257	738	28
Alternative 1	396	133	253	747	28
Alternative 2	395	123	269	743	27
Alternative 3	392	117	267	755	26
Alternative 4	396	109	264	760	28
Alternative 5	397	113	267	753	27
Alternative 6	401	108	260	759	29
	Wet Year 1968-1969		Depth > 0.01		
Base	287	128	81	411	650
Alternative 1	287	124	76	414	656
Alternative 2	290	123	71	417	656
Alternative 3	287	120	65	424	661
Alternative 4	288	125	70	420	654
Alternative 5	288	121	69	432	647
Alternative 6	290	122	74	409	662

Table 9: Total Model Area (mi^2) Inundated for each Hydroperiod Category.

Category	A1-Bse	A2-Bse	A3-Bse	A4-Bse	A5-Bse	A6-Bse
	Average Year 1976-77		Depth > 0.01			
$\Delta p \leq -30$	0	4	3	8	3	4
$-30 < \Delta p < 0$	70	128	111	94	121	88
$\Delta p = 0$	1098	1096	990	800	966	821
$0 < \Delta p \leq 15$	353	259	326	524	375	523
$15 < \Delta p \leq 30$	27	36	52	55	31	55
$30 < \Delta p \leq 45$	6	14	26	22	18	19
$45 < \Delta p \leq 60$	0	5	17	14	10	11
$\Delta p > 60$	3	15	32	40	33	36
	Dry Year 1973-74		Depth > 0.01			
$\Delta p \leq -30$	0	1	9	15	4	
$-30 < \Delta p < 0$	51	130	134	87	178	77
$\Delta p = 0$	1180	1172	1061	862	1069	905
$0 < \Delta p \leq 15$	315	211	269	498	236	498
$15 < \Delta p \leq 30$	6	19	37	44	30	36
$30 < \Delta p \leq 45$	3	11	11	12	11	9
$45 < \Delta p \leq 60$	0	2	11	15	7	11
$\Delta p > 60$	2	11	25	24	22	21
	Wet Year 1968-1969		Depth > 0.01			
$\Delta p \leq -30$	0	4	6	15	7	9
$-30 < \Delta p < 0$	86	130	111	106	153	101
$\Delta p = 0$	1124	1099	1059	1021	1055	1045
$0 < \Delta p \leq 15$	328	291	244	301	246	314
$15 < \Delta p \leq 30$	16	22	68	73	46	60
$30 < \Delta p \leq 45$	1	6	35	20	19	15
$45 < \Delta p \leq 60$	2	1	16	13	20	8
$\Delta p > 60$	0	4	18	8	11	5

Table 10: Difference between Hydroperiods

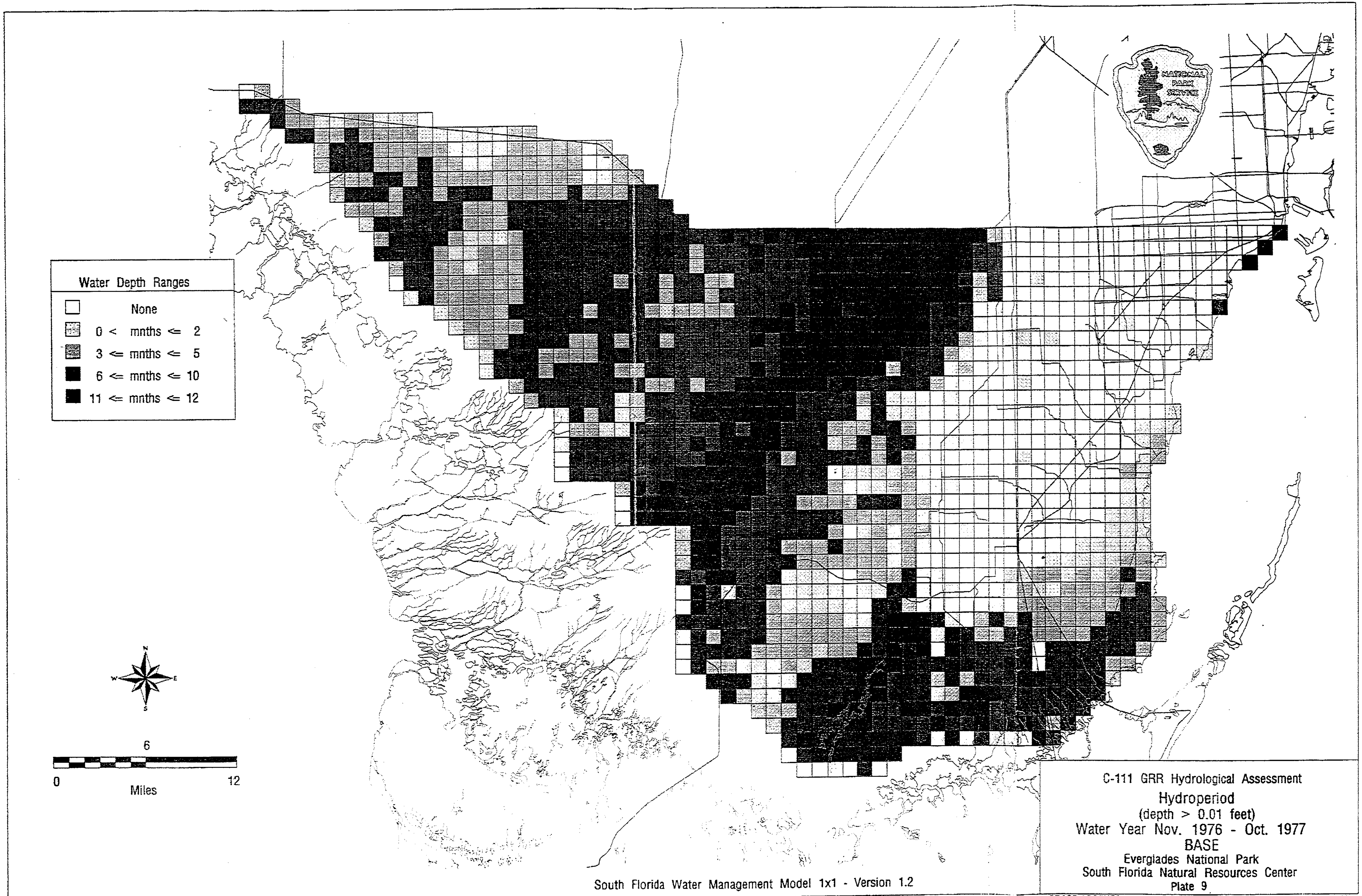
The average water year of 1976–1977 was used to illustrate the spatial distribution of the different hydroperiod categories. The base condition tabulated in Table 9 is shown in Color plate 9 (Fig. 43) using the same categories described earlier. Color plates 10 thru 15 (Figs. 44, 45, 46, 47, 48, and 49) show the spatial hydroperiod differences tabulated in Table 10.

The hydroperiod color plate illustrating the Base condition (Fig. 43, Plate 9) shows the long hydroperiods in the central portion of the sloughs. The long hydroperiod in the original main flowway of Shark Slough, now referred to as Northeast Shark Slough, is well illustrated. The lack of significant periods of inundation along the eastern edge of Shark Slough and into the headwaters of Taylor Slough was caused by the drainage operations of the C&SF Project. Much of the historical peripheral marsh between the Coastal Ridge and the main Sloughs has disappeared. Current attempts to re-inundate NESS, the Rocky Glades and Taylor Slough are an attempt to regain a portion of these marshes. With all of the alternatives, moderate increases in hydroperiods are observed near the main discharge points (the new pumps). Although increases near these points occur, all the alternatives decrease the length of the hydroperiods in the historical eastern Rocky Glades and lower C-111 area.

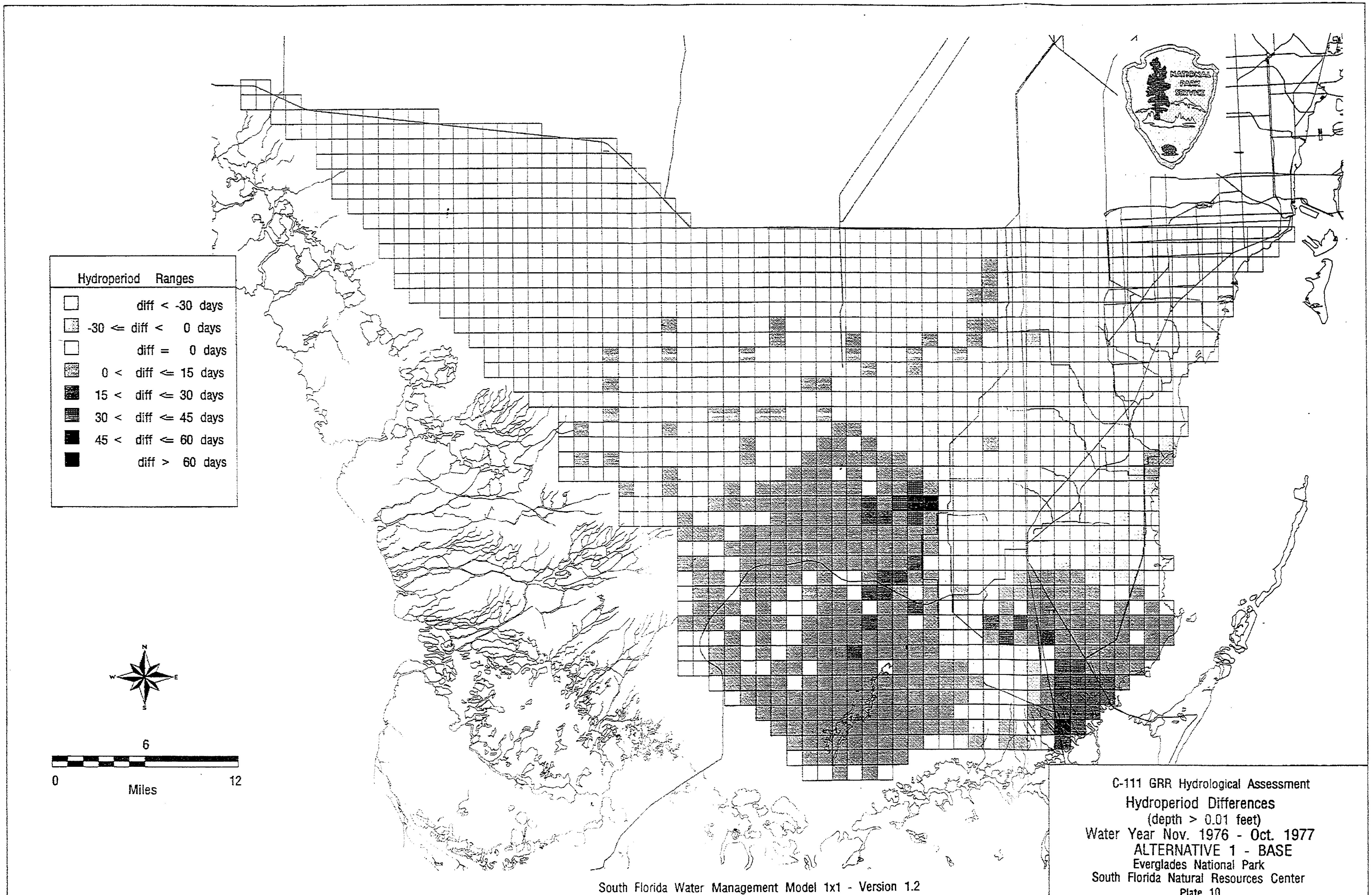
In excess of 15% of the area show a reduction in surface water if any of the alternatives is implemented. During the 1976–1977 water year Alternative 2 increased the drainage of the Rocky Glades and central Taylor Slough to such an extent that 40% of the increase in hydroperiod gained in the headwaters of Taylor Slough, by the large pump, is lost (see Table 10). Moderate gains are made with Alternatives 4 and 6, the area which had a longer hydroperiod, up to 2 weeks, increased by 67%. The spatial differences between each of the alternatives and Base indicate that the hydroperiods in the Eastern Panhandle, especially in the impounded marshes east of S-18C are substantially shortened. Under current water management practices, these areas have long hydroperiods. Lowering of the canal levels and the partial or total removal of the levees with Alternatives 3, 4 and 5 show reductions in hydroperiods of up to one month.

Inspection of the color plates clearly shows the operational practices of the C&SF Project. With large pumps located at single points, as all but two of the alternatives do, increases the ability to provide additional flood protection, but also causes vast areas in the wetlands to experience additional drainage. The small gains made in hydroperiods at selected points in the marshes are offset by the losses in the historical eastern Rocky Glades and lower C-111 area. Even with the spacing of pumps and the short increase in retention of flood waters in Alternative 3, no significant spatial gains in hydroperiods are made.

The need to incorporate new operational criteria to maintain stages, thereby increasing hydroperiods, and the lack of attempts to control the seepage losses into L-31N, L-31W and C-111 are two of the most important items why the alternatives fail to provide even moderate gains in the spatial distribution of hydroperiods.



GRASS-ARC/INFO base_hyd7677d.0 12/06/1993



C-111 GRR Hydrological Assessment

Hydroperiod Differences

(depth > 0.01 feet)

Water Year Nov. 1976 - Oct. 1977

ALTERNATIVE 1 - BASE

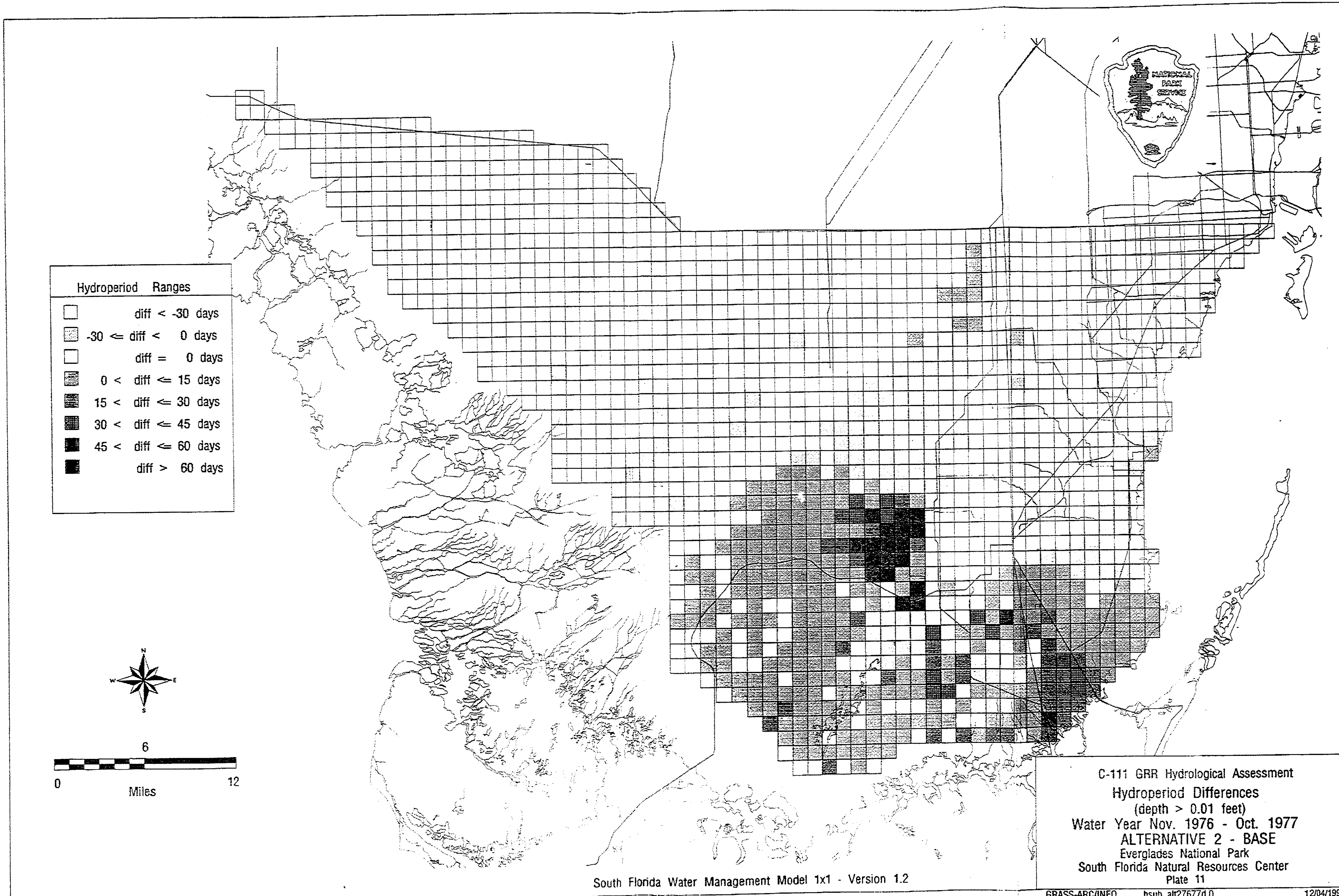
Everglades National Park

South Florida Natural Resources Center

Plate 10

South Florida Water Management Model 1x1 - Version 1.2

GRASS-ARC/INFO hsub_alt17677d.0 12/06/1993



Hydroperiod Ranges
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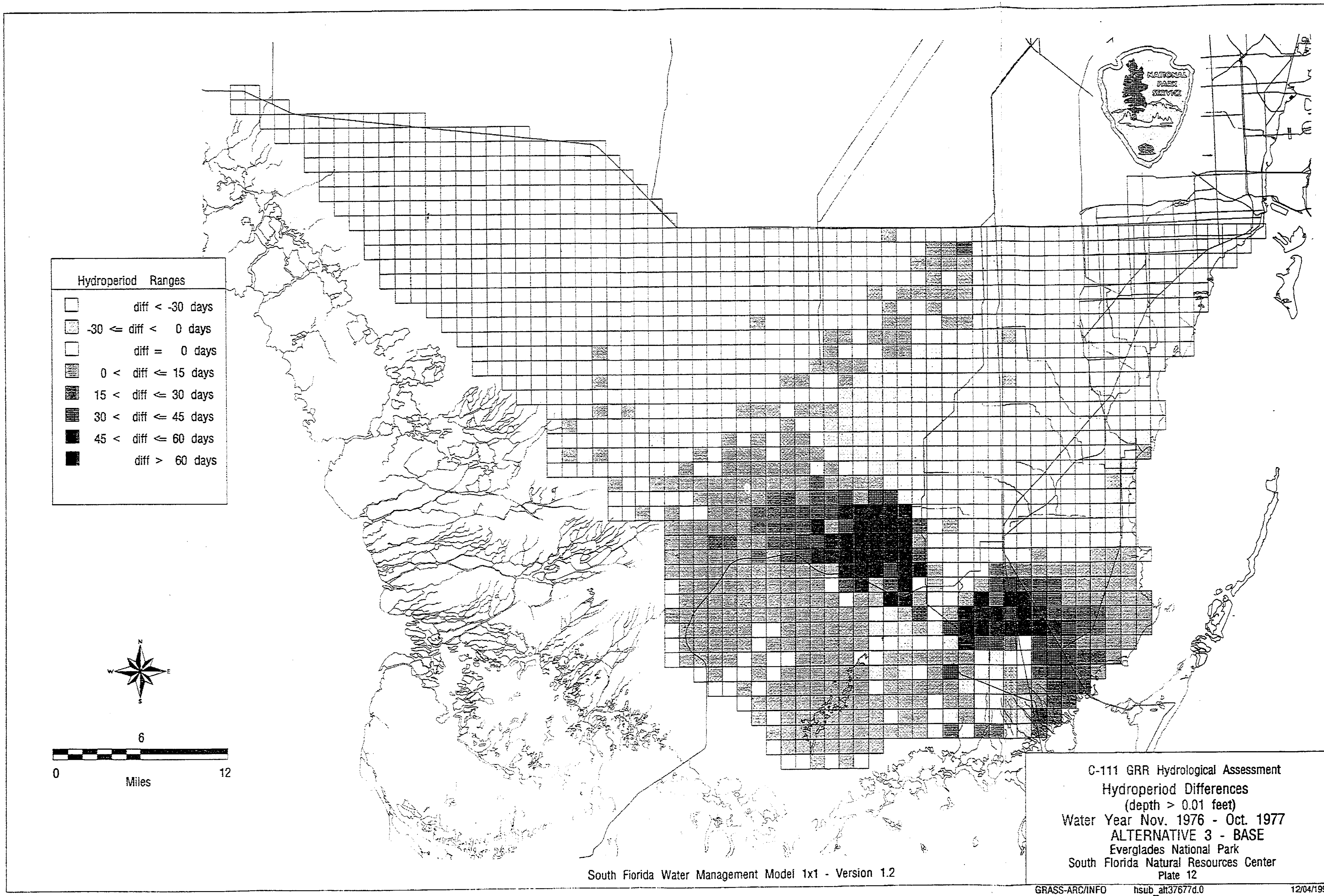
-30 <= diff < 0 days
diff = 0 days
0 < diff <= 15 days
15 < diff <= 30 days
30 < diff <= 45 days
45 < diff <= 60 days
diff > 60 days
N
S
W
E
6
0
Miles
12
NATIONAL PARK SERVICE
South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Hydroperiod Differences
(depth > 0.01 feet)
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 2 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 11
GRASS-ARC/INFO
hsub_alt27677d.0
12/04/1993



NATIONAL PARK SERVICE
Hydroperiod Ranges
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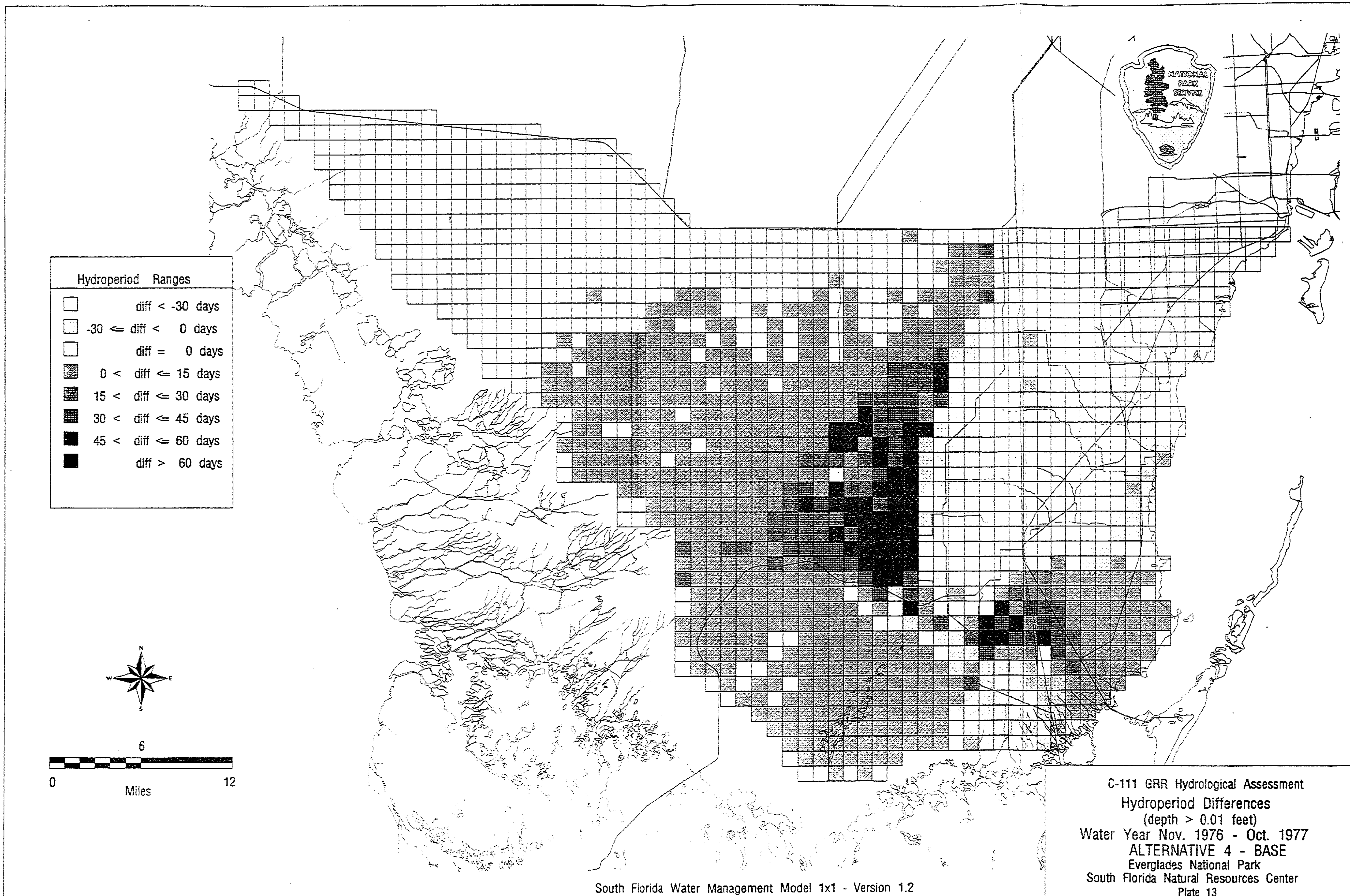
diff = 0 days
0 < diff <= 15 days
15 < diff <= 30 days
30 < diff <= 45 days
45 < diff <= 60 days
diff > 60 days
N
W
E
S
6
0
Miles
12
C-111 GRR Hydrological Assessment
Hydroperiod Differences
(depth > 0.01 feet)
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 3 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 12
South Florida Water Management Model 1x1 - Version 1.2
GRASS-ARC/INFO
hsub_alt37677d.0
12/04/1993


NATIONAL PARK SERVICE
Hydroperiod Ranges
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0 < diff <= 15 days
15 < diff <= 30 days
30 < diff <= 45 days
45 < diff <= 60 days
diff > 60 days
N
W
E
S
6
0
Miles
12
South Florida Water Management Model 1x1 - Version 1.2
C-111 GRR Hydrological Assessment
Hydroperiod Differences
(depth > 0.01 feet)
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 4 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 13
GRASS-ARC/INFO
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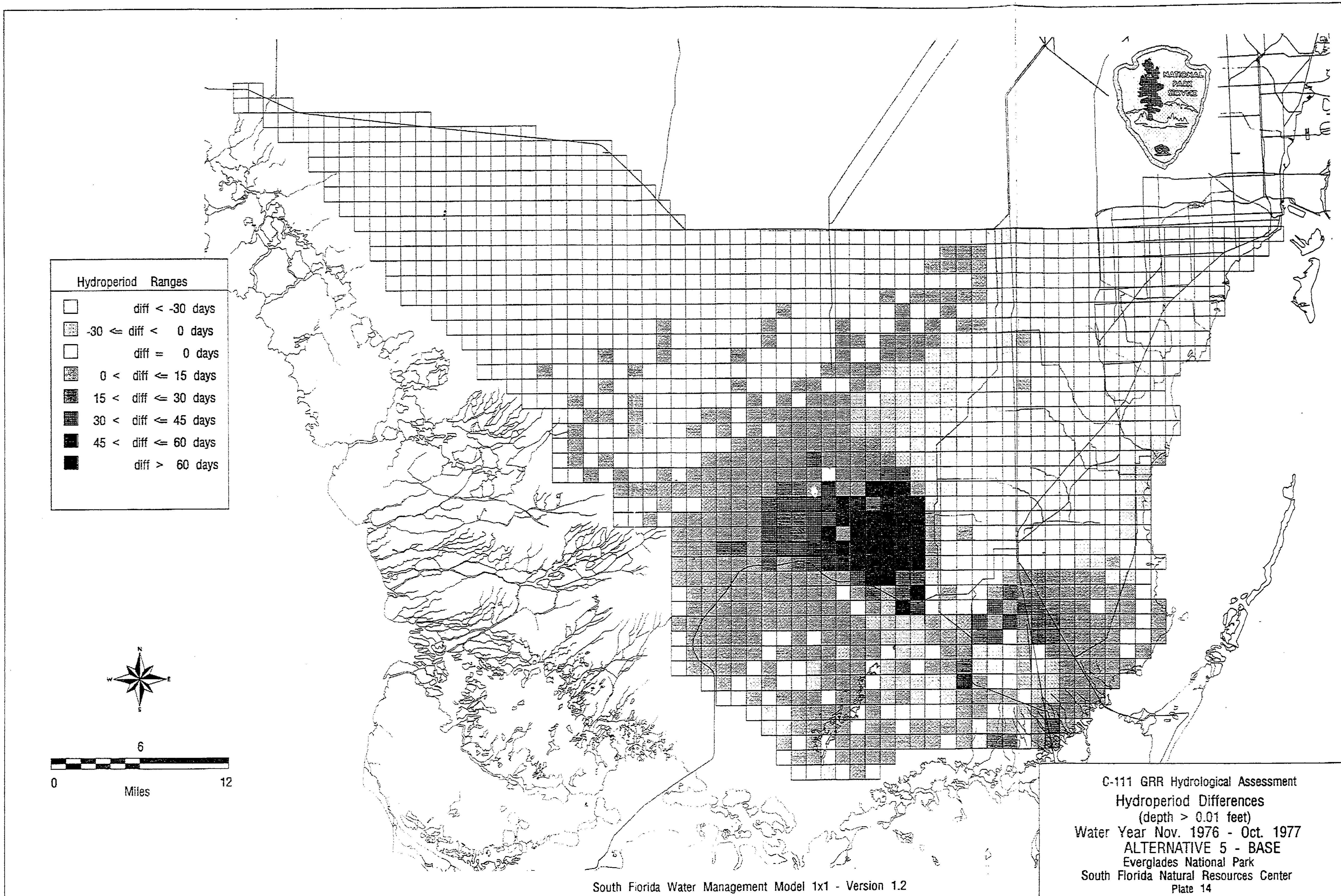
12/04/1993



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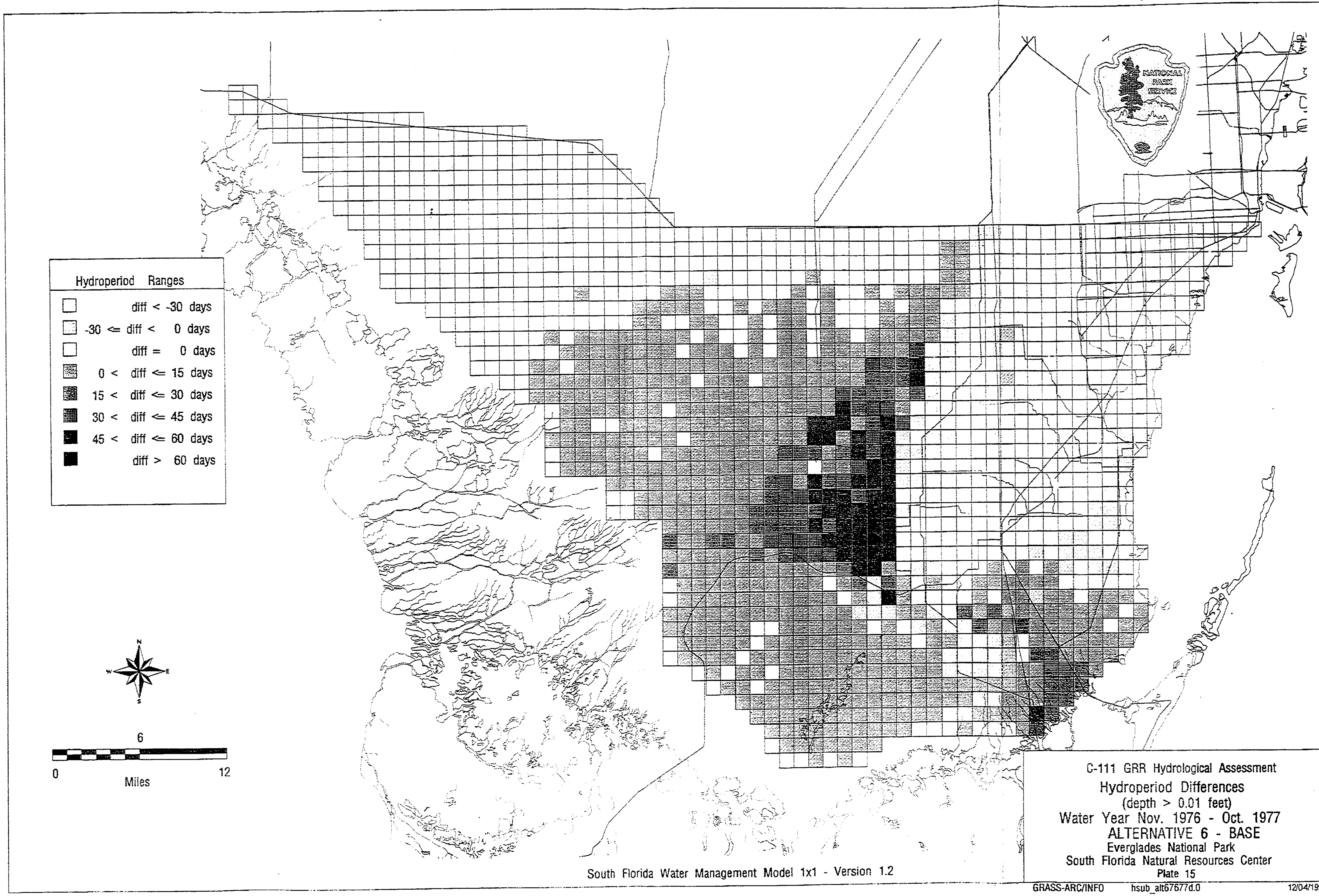
NATIONAL PARK SERVICE
Hydroperiod Ranges
diff < -30 days
-30 <= diff < 0 days
diff = 0 days
0 < diff <= 15 days
15 < diff <= 30 days
30 < diff <= 45 days
45 < diff <= 60 days
diff > 60 days
N
W
E
S
6
0
12
Miles
C-111 GRR Hydrological Assessment
Hydroperiod Differences
(depth > 0.01 feet)
Water Year Nov. 1976 - Oct. 1977
ALTERNATIVE 6 - BASE
Everglades National Park
South Florida Natural Resources Center
Plate 15
South Florida Water Management Model 1x1 - Version 1.2
GRASS-ARC/INFO
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12/04/1993

11 Conclusions

The following sections summarize the analysis of the previous sections.

11.1 Summary of Canal Stage and Flow Comparisons

Under the Base condition and Alternative 1 the majority of the outflows from the L-31N basin pass eastward through the C-102 and C-103 canals. This is contrary to the original design operations of the south Dade canal system, and represents a significant loss of water from the regional system. This problem is substantially reduced under Alternatives 2 through 6, which redirect these flows westward into Taylor Slough, via S-174 or the new S-332A-D pumps. All of these alternatives greatly increase flows into Taylor Slough. Alternatives 1, 2, and 5 discharge into the main channel of Taylor Slough, using large pumps located at a single location. In contrast, Alternative 3 discharges into the Frog Pond, and has culverts which spread flows out along the L-31W canal. Alternatives 4 and 6 use five moderate size pumps to spread water out over the wetlands of the Rocky Glades and northern Taylor Slough. Unfortunately all of these flow increases are created by substantially lowering L-31N wet season canal water levels well below the Base condition, particularly during the months of August through October. This leads to over-drainage of the wetlands in the Rocky Glades and northern Taylor Slough.

Wet season inflows into the lower C-111 basin are greatly reduced under all of the plans, since S-176 is essentially not used to pass runoff southward into the C-111 basin except during the dry season. This has the benefit of redirecting flows westward into Taylor Slough, but will result in drier conditions in the Eastern Panhandle basin. Moderate discharges are made through S-177 into the lower C-111 basin during most years, with larger flows occuring during periods of high wet season rainfall (such as in 1981 and 1989). Under Alternatives 3, 4, and 5 flows through S-177 significantly increase, as a result of the addition of a 500 cfs pump at the C-500E spreader canal. Alternatives 4 and 6 tend to lower average S-177 wet season water levels because most of the excess L-31N runoff is pumped into the marshes north of the Frog Pond. In contrast, alternatives 2, 3, and 5 pass the excess L-31N runoff into Taylor Slough through a degraded L-31W canal or via the Frog Pond. This causes water levels to increase in the eastern portion of the Frog Pond, which contibutes groundwater seepage to the C-111 canal, and maintains higher water levels upstream of S-177. Alternatives 3 and 4 tend to raise wet season canal water levels downstream of S-177, while Alternatives 1, 2, and 5 show only minor differences from the base condition. This suggests that alternatives that discharge excess L-31N runoff into Taylor Slough at locations as far south as S-175 have the likelyhood of loosing this water due to groundwater return flow to the C-111 canal downstream of S-177.

Under Alternatives 1, 2, and 6 the S-332C pump (which discharges into the C-500E spreader canal) is limited to 50 cfs, so the discharges remain small, and all excess runoff is passed through the existing S-18C structure. Under Alternatives 3, 4, and 5 the S-332B/E pump is increased to 500 cfs, so the discharges are large, and have a significant impact on the downstream marshes. Average wet season outflows from the lower C-111 canal increase significantly under Alternatives 2, 3, and 5. This suggests that excess runoff from the C-111 basin can be effectively removed through the addition of the C-500E spreader canal and a large capacity pump. Large freshwater releases (some in excess of 30,000 acre-feet) are made through S-197 into Manatee Bay during the years with high wet season rainfall under Alternatives 1, 2, and 6 that leave the lower C-111 canal intact. Rapid influxes of freshwater are known to have detrimental impacts on the downstream estuarine biota, and the discontinuation of S-197 releases has been a major driving force prompting the development of the C-111 GRR.

Our wet season water budget analyses indicate that during high rainfall years such as 1968 and 1969, Alternatives 2 through 6 drain tremendous volumes of runoff from the L-31N canal system. Alternative 5, in particular, drains more that 110,000 acre-feet from the L-31N canal system during each of the 1968 and 1969 wet seasons. This is more that 50,000 acre-feet in excess of the Base condition. Again the source of most of this water is the over-drainage of the marshes of the Rocky Glades.

Supplemental dry season pumping at S-331 averaged approximately 14,400 acre-feet, and peaked at just under 32,000 acre-feet for the 25-year simulation. These figures are approximately 5% of the volumes estimated by the Corps in their 1973 GDM for the South Dade Conveyance System [U.S. Army Corps of Engineers, 1973]. Dry season inflows into the L-31W and C-111 canals are inadequate to meet the Congressionally mandated Minimum Delivery Schedules. Average dry season canal water levels in the L-31N and C-111 canals show that under the Base condition and all of the alternatives, canal stages fall well below the established dry season minimum stages. Clearly, the C-111 GRR modeling has not captured the authorized operational practices of the SDCS.

11.2 Summary of Marsh Flowline Comparisons

In general, groundwater flows through the wetlands made up slightly over 50% of the total annual flows at the Rocky Glades flowline, but the percentage decreased downstream, accounting for 10% or less at the flowlines within southern portions of Taylor Slough and the Eastern Panhandle basins. For the Base condition and all of the alternatives, approximately 75% to 85% of the total annual surface water and groundwater flows occurred during the wet season. The seasonal flow reductions occured rapidly so that by December, there was very little flow passing through the wetlands and into the downstream estuaries. Under Alternatives 4 and 6, surface water flows at the Context Road flowline were significantly increased, particularly during high rainfall years. These changes are a response to the direct marsh inflows from the proposed S-332B and S-332C pump stations.

Average annual surface water flows at the Taylor Slough Bridge flowline were approximately 44,000 acre-feet under the base condition, and increased slightly under all of the alternatives. Flows under Alternative 1 showed the greatest impact in response to the proposed enlargement of the existing S-332 pump station. Average annual surface water flows along the lower Taylor Slough flowline were approximately 69,000 acre-feet under the Base condition, and all of the alternatives, except 3 and 5, produced a slight increase of up to 10%.

Under the Base condition and Alternatives 1, 2, and 6 surface water and groundwater flows through the upper Eastern Panhandle flowline are generally insignificant. In contrast, surface water flows are increased significantly under Alternatives 3, 4 and 5, which include the installation of a proposed 500 cfs pump at the intersection of C-111E and the new C-500E canal. At the southern flowline average annual surface water flows were approximately 74,000 acre-feet under the base condition, and increased by slightly more than 10% under Alternatives 3 and 5. Again, groundwater flow contributed approximately 10% of the total annual flow.

11.3 Summary Stages and Hydroperiods at Selected Monitoring Points

Within the developed areas east of the L-31N and C-111 canals, water levels remained more than 1.5 feet below the ground surface throughout all of the model runs. Alternatives 2 through 6 tend to slightly lower wet season water levels at G-855, S-196A, and G-789 during most years. This suggests that the increased outflow capacity provided by large pumps can provide a slight improvement in the level of flood protection in these areas. At G-613 in the C-111E basin, wet season water levels tended to rise slightly (particularly under Alternatives 3 and 5), in response to the maintenance of higher water levels in the Frog Pond.

Water levels in the developed areas west of these canals are more variable, but all of the structural plans examined show high groundwater levels during the wet season, and short periods of surface water flooding are predicted in the agricultural areas of the Rocky Glades and the Frog Pond during periods of high wet season rainfall. In the Rocky Glades developed areas Alternatives 2 through 6 slightly lower wet season water levels compared to the base condition, in response to the increased outflow capacity in the L-31N canal. In the Frog Pond. Alternatives 4 and 6 tend to lower wet season water levels, while Alternatives 2, 3, and 5 significantly raise wet season water levels. All of the developed areas west of the Eastern Protective Levee System have a significant risk of flooding due to the low-lying nature of these lands, and their close proximity to the Everglades.

The marshes in the upper Taylor Slough basin experience surface water flooding for 3 to 9 months each year under the base condition and the proposed alternatives. The water depth and hydroperiod changes vary quite a bit in this area in response to differences in the location of structure inflows. All of the alternatives produced increases in wet season water levels, but provided only modest hydroperiod improvements. In the lower Taylor Slough basin water levels and hydroperiods showed almost no change under any of the alternatives.

In the impounded wetlands north of the lower C-111 canal, alternatives 1, 2, and 6 slightly lower wet season water levels while alternatives 3, 4, and 5 significantly lower wet season water levels. This is presumably a result of the removal of the northern levee, which is used as fill to completely or partially backfill the lower C-111 canal. In the marshes south and west of the lower C-111 canal water levels and hydroperiods show no significant changes during the wet season under any of the proposed alternatives. During the dry season, water levels tend to be lower under all of the alternatives that backfill the C-111 canal. The modeling results confirm that the marshes north of the C-111 canal have substantially higher wet season water levels, and maintain much longer hydroperiods then the wetlands south and west of the C-111 canal. This is a result of the levee system along the northern and eastern side of the lower C-111 canal, which holds back wet season runoff. Under natural conditions this area would have provided sheetflow to the downstream marshes and Florida Bay.

12 Recommendations

To provide environmental benefits to the wetlands of Everglades National Park any proposed structural and operational changes must show a reversal of the on-going drainage. None of the alternatives offered to the Park for evaluation showed any significant increase in hydroperiods and hydropatterns. Restoration goals of returning the wetlands to pre-project conditions at a minimum (*i.e.*, increasing stages in the natural areas and allowing the proper seasonal fluctation of these stages) remain elusive under the alternatives. Seasonal fluctuations of surface and ground water levels at the 21 monitoring gauges, computed for the entire 25 year model period, barely show any increase at all. Spatial water depth differences between base and the alternatives, show slight depth increases in the areas adjacent to the pump discharges, but low canal stages cause large seepage losses back into the canal. The significant environmental benefits of the project are not related to restoration of the wetlands, only a fraction of the wetlands receive increases of more than 0.3 ft. With Alternative 3 the annual average end-of-month surface water depths increases are greater than 0.03 ft. over an area of only 10 mi^2. Projected necessary increases in stages in the wetlands west of the confluence of C-111 and L-31W range from 0.5 ft. in the dry season to more than 2.0 ft. in the wet season [Lent and Johnson, 1993a]. Flow comparisons for the model using the base and alternatives indicate relatively modest increases in surface and ground water flows across flowlines located across selected locations in the Park.

Restoration of the Everglades cannot begin without looking at modest increases in water level to approach pre-project or pre-drainage conditions. Unless alternatives which mimic a more natural Everglades are designed and tested, any proposed project has a good chance of failing to provide hydrological benefit to the majority of the natural areas under consideration. To promote sheetflow, discharge to the wetlands requires the use of many entry points to maintain the high stages in areas adjacent to the levees and farther into the sloughs. Large pumps at specific convenient discharge points serve to expedite the release of flood control waters and provide the ability to expand their use for continued drainage operations during the end of the wet season. The use of smaller pumps of the total capacity necessary for flood control and spaced at many locations, such as the pumps in Alternative 4, with the surge pool and storm water treatment area, such as those in Alternative 3, buffering the natural system from the developed areas, would continue to provide the necessary flood protection. These concepts also make it possible to implement the higher wetland stages and to allow the proper seasonal fluctuation of these stages to meet restoration goals. The use of detention/retention areas would also reduce large flood control releases to Manatee Bay, and retain the water for slow release to the wetlands. These areas provide a small increase in local storage capacity and will maintain higher wetland stages into the early part of the dry season. Detention areas discharge water into the wetlands through pumps, culverts or spillways, while retention areas discharge waters into the wetlands through groundwater and levee seepage, thus releasing the flood waters slowly over a longer time period. Impoundment areas constructed adjacent to the wetlands and serving as a buffer zone between the developed and the natural areas can function as these detention/retention basins.

The high conductivity of the surficial limestone aquifer in the C-111 basin makes it difficult for developed areas requiring low ground water levels to coexist immediately adjacent to natural areas which require high surface and ground water levels. A buffer zone can serve as a transitional land area where water levels step down gradually from the west to the east. Parts of this buffer zone can serve as detention and retention lands for flood control purposes, and also serve as filtration lands for the runoff from developed lands. Authorized levels of flood protection would exist as originally proposed, designed and built for the lands east of the Eastern Protective Levee System, while areas within the buffer zone, but outside the mostly wet detention/retention areas, would experience frequent surface water inundation, especially during the wet season.

Design of a project for environmental purposes needs to include the operational flexibility to allow iterative refinement of the operational procedures. Benefits in the natural areas cannot be determined in the same fashion as benefits for a flood control project, where the process consists of the sizing of a pump and the selection of a convenient discharge point. Hydrological assessments for environmental benefit done in a swamp must look at the temporal and spatial patterns of surface water. To implement this process the operation of the system as well as the structural modifications must be included. It is unfortunate that the limited GRR timeframe allowed only the testing of proposed alternative plans under the established base operational criteria. With the addition of larger canals and larger pump capacities, the entire C&SF Project should be operated differently for both flood control and water supply purposes. These changes should be addressed during the evaluation process, not established after the preferred alternative is selected. Operational criteria must be locked in as part of the entire process, otherwise the preferred alternative may not work for most of its intended purpose (viz. the L-31W canal).

Following the guidelines established for the evaluation of the alternatives and the realization that restoration efforts for ENP must use a holistic approach, the Park's staff is providing a conceptual approach of an alternative which addresses the issues of stage restoration in the headwaters of Taylor Slough and NESS, principally by the reintroduction of surface water at multiple entry points, the establishment of detention and retention areas, and a buffer zone. Since none of the alternatives address wetland restoration sufficiently, the Park's staff is including a conceptual plan, Alternative 8, which incorporates the findings of the analysis contained in this report.

12.1 Concepts of Alternative 8

Using several of the alternatives offered for consideration, particularly the features offered in Alternatives 3 and 4, the Park's staff have revisited the structural proposals to more fully include benefits for the Park's water resources. To assess this plan and, if desired, the previously offered alternatives, operational guidelines have to be established during the continued evaluation process. An iterative process is needed in order to fully document and evaluate the system's response to both the structural and operational modifications.

Alternative 8 has as its main goal restoration of the stages in the natural areas of the C-111 basin. To this end a buffer zone is added to provide the GRR's desired flood control improvements, while maintaining higher water levels in the adjacent wetlands of the Rocky Glades and northern Taylor Slough. Present and future concerns about water quality and the need for detention/retention areas, to hold excess storm water, require the construction of impounded areas which can serve this function. Not all of the lands within the buffer zone can be used or are required for use as detention/retention zones. However, landuses that are incompatable adjacent to a wet Everglades probably will not function well in the buffer zone. Also, a substantial connection with Water Conservation Area 3B is included in this plan. This connection is proposed in the form of large flow ways or control structures to meet ENP goals to restore Northeast Shark Slough (NESS) to a functioning wetland. Flow into NESS will undoubtedly affect the stages in the headwaters of Taylor Slough and has to be included in the evaluation process, since the needs for additional flow capacity to NESS has not been adequately addressed in the Corps Modified Water Deliveries GDM.

The conceptual details of this alternative are divided into a structural component and an operational component, the details are as follows (see Fig. 50):

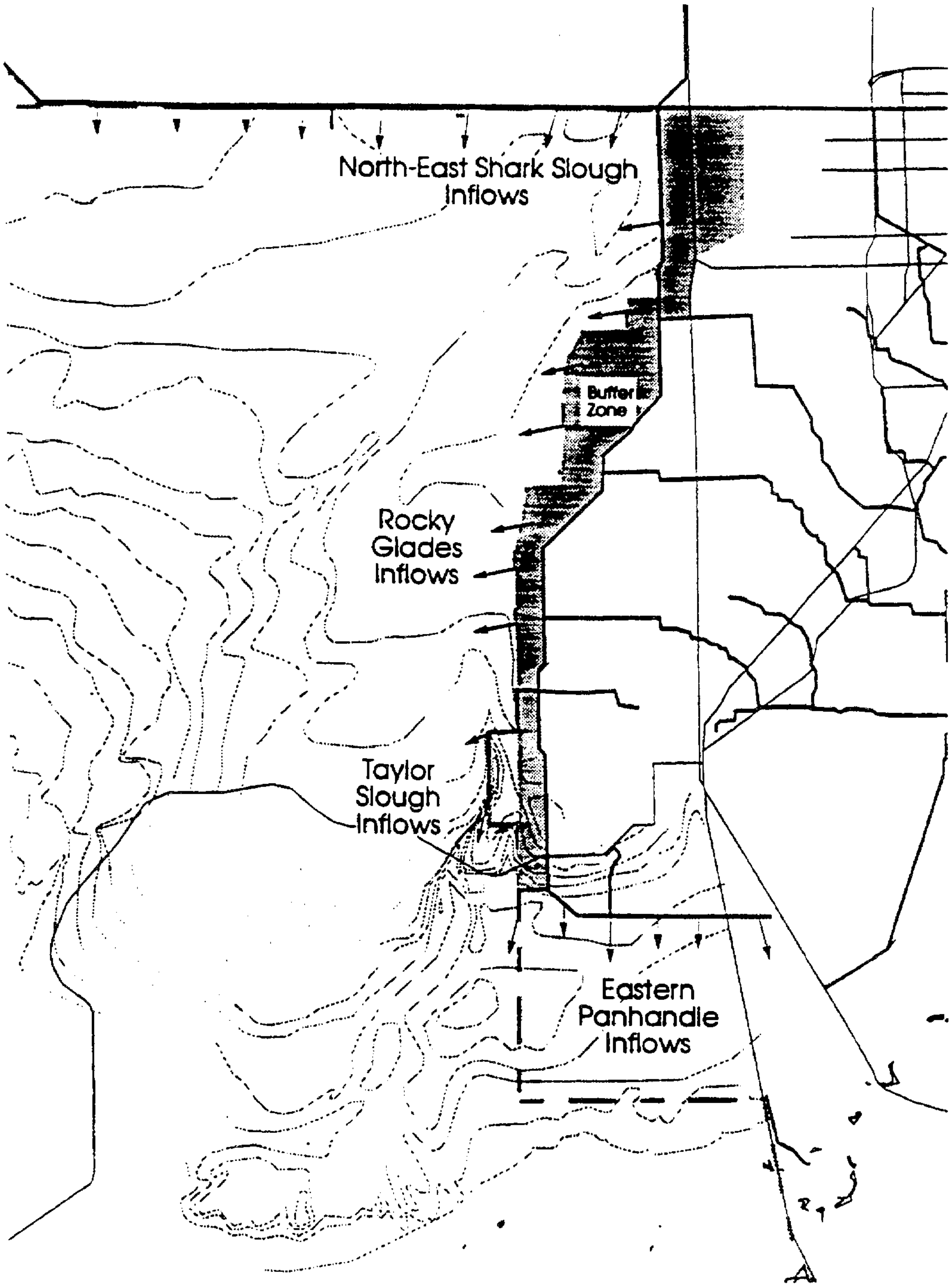

Figure 50: Proposed Alternative 8

- Structural Component
  - Eliminate or degrade L-67A and C in the water conservation areas, to allow sheetflow to occur for delivery to NESS.
  - Construct several large flow ways or water control structures across Tamiami Trail to provide water supply for Northeast Shark Slough.
  - Eliminate L-67E and remove structural components.
  - Constuct a levee from the north end of the 8.5 sq mi. area to a point south of S-175 and create a buffer area between L-31N/C-111 and the levee.
  - Compartmentalize some or all off the developed and natural lands within this buffer zone to serve as retention/detention areas.
  - Provide the necessary pumps to maintain the authorized levels of flood control to lands east of the EPLS and let this excess water discharge into detention or retention areas west of the levees.
  - Discharge water supply to the wetlands through multiple points from the detention areas.
  - Pass all storm water runoff into detention/retention basins within the buffer zone prior to discharging into the natural wetlands.
  - Eliminate L-31W, C-109, C-110 and C-111 south of the confluence with C-111E and remove structural components.
  - Construct a new canal, the Spreader Canal from C-111E east across US-1 (C-500E).
- Operational Component
  - Maintain pre-project stages in the wetlands including the areas along the entire Eastern Protective Levee System.
  - Restore authorized canal levels in L-31N and C-111.
  - Retain L-31N basin runoff for discharge to the west instead of through the Coastal Ridge canals (C-102 and C-103).
  - Implement rainfall based formulas for discharges into NESS, the Rocky Glades, Taylor Slough and the Eastern Panhandle based on wetland water level targets.
  - Allow flow deliveries to occur from the north (via S-331) into L-31N when needed to maintain canal/marsh water levels.

The design of pumps for flood control will be accomplished by the Corps and SFWMD. For the natural areas west of the buffer strip the emphasis is on stages, the SFWMD and COE should perform the work to compute flows necessary to accomplish the stage targets. Target stages recently computed for the headwaters of Taylor Slough (see [Lent and Johnson, 1993a]) are reproduced here as guidelines (Fig. 52). The stages from the long term record at G-789 are intended to be applied to the marsh gauge on Context Road (G-3115). The detailed development of wet and dry season operations, implementation of rainfall formulas will be done jointly by the ENP, COE and SFWMD.

A typical detention/retention area is shown in Fig. 51. This is a conceptual plan and complete details of this plan need to be worked out to include all the uses of the C&SF Project. Alignments of detention/retention basins, pumping capacities, locations of spillways and culverts should be refined during the evaluation process. The principle is to allow flood waters (Fig. 53) to be pumped into the detention areas and be discharged from this area through culverts and spillways and overbank flow. Water supply (Fig. 54) would be met through pumps and overbank flow. All flood control and water supply waters would enter the wetlands through the detention/retention areas.

An evaluation of this alternative through the use of a natural version and the management version of the SFWMM model is required to refine the conceptual approach and to test structural components and operational procedures and their effects on the Park.

Prioritization of the areas of immediate concern, those which provide the greatest immediate benefit cannot be ascertained in the extremely short time allowed for the re-evaluation phase of the process. As water supply conflicts such as the development of a West Dade wellfield illustrate, the process of resolving regional water supply issues may best be coordinated with all the on-going planning, evaluation and design processes. Such a process will aid considerably in the management of South Florida's precious resource. The piecemeal processing of regional water supply and flood control issues will only lead to future failures.

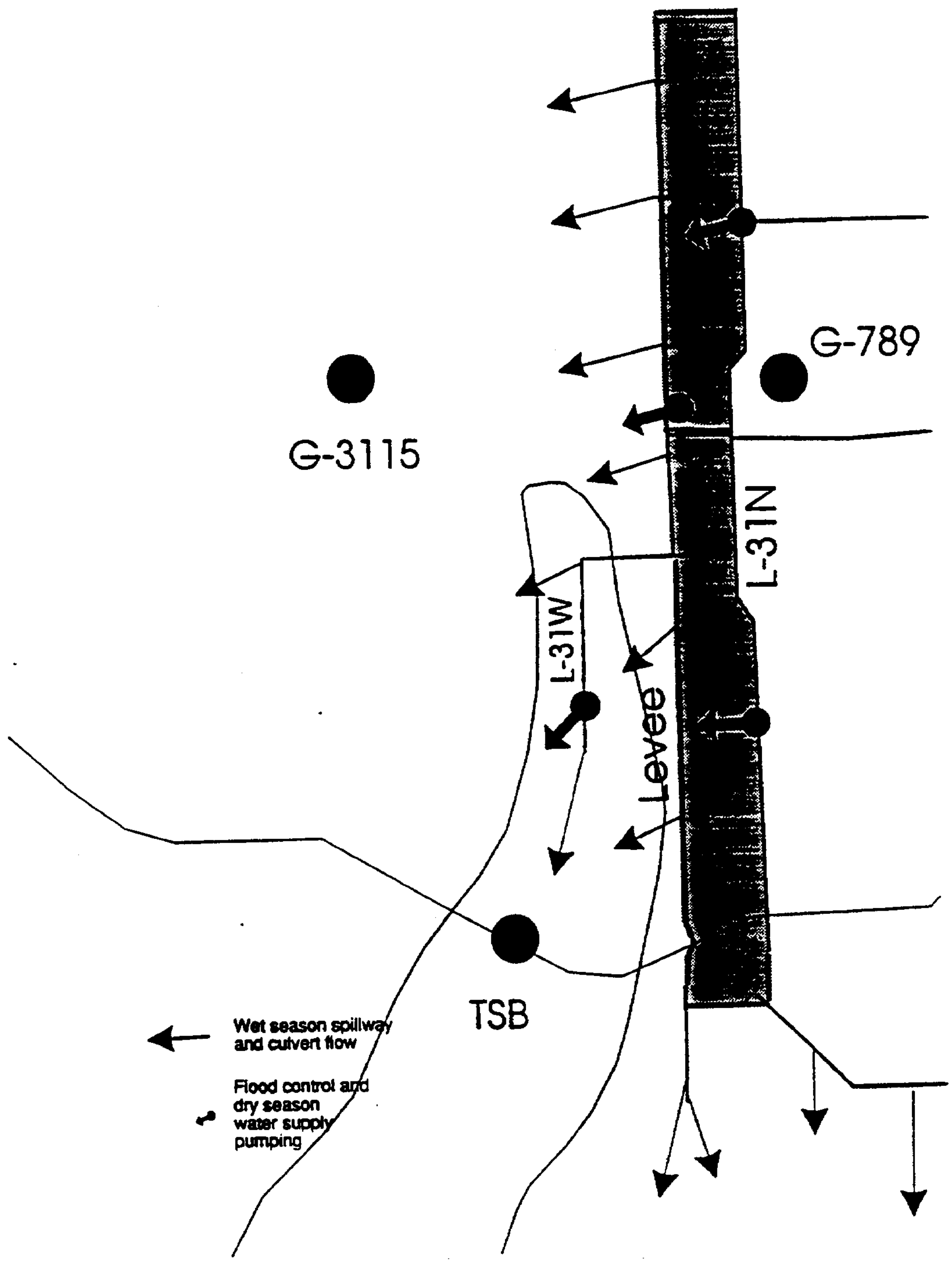

Figure 51: Detention/Retention Area in the Frog Pond

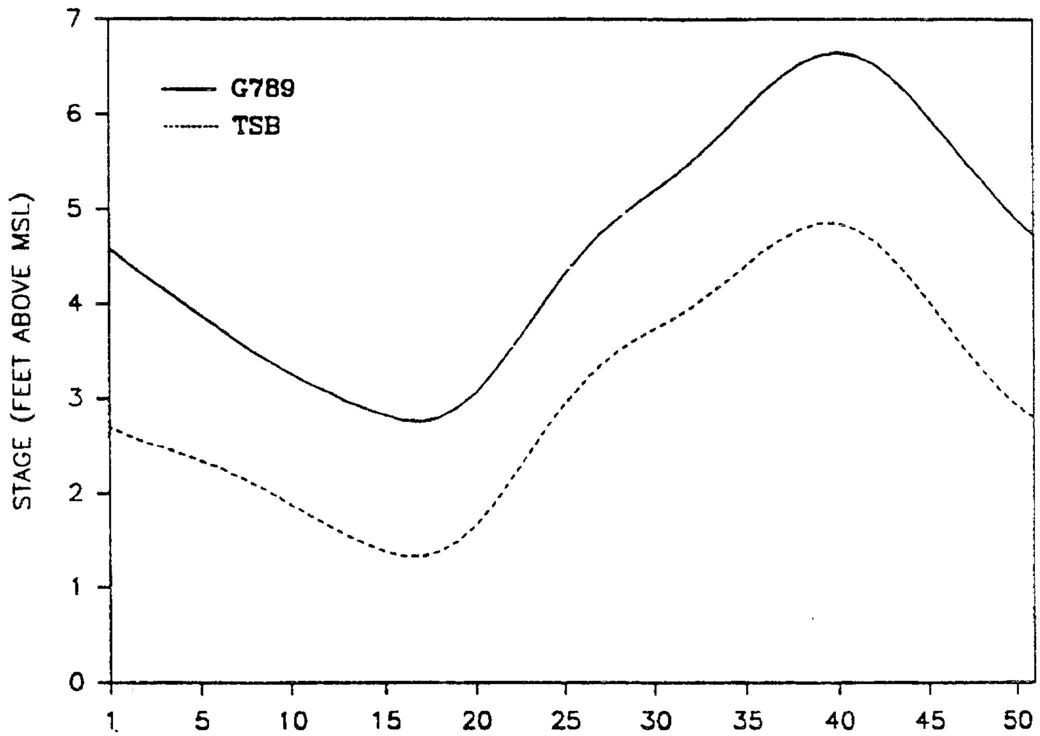

Figure 52: Target Stages in Taylor Slough

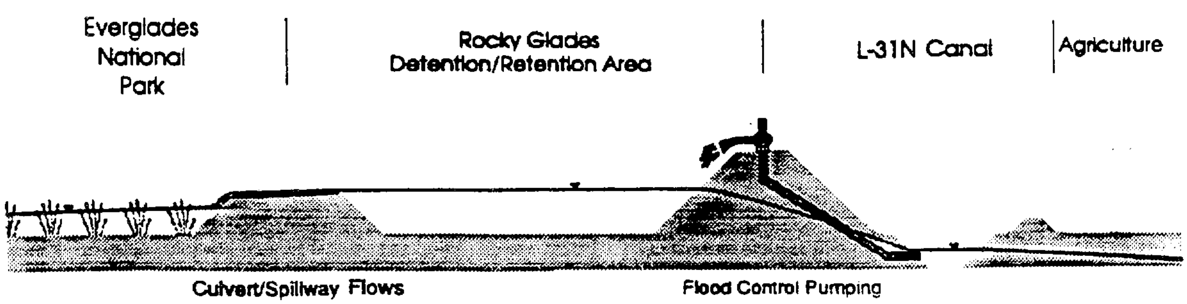

Figure 53: Cross Section across a Typical Canal and Levee System

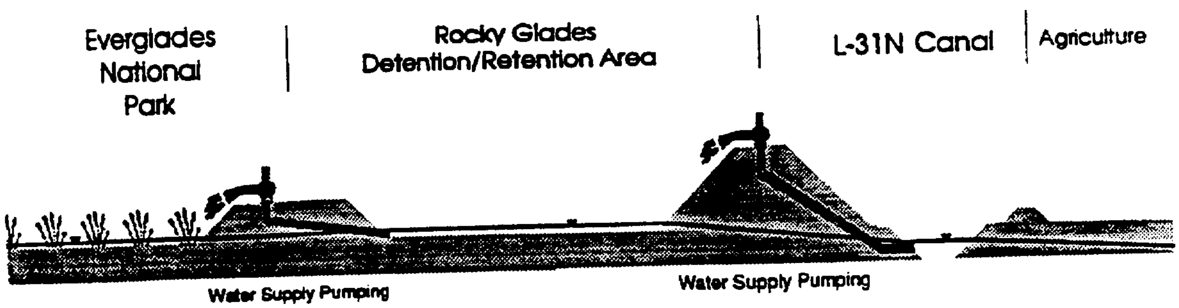

Figure 54: Cross Section across a Typical Canal and Levee System

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Technical Report SFNRC 93–4

Appendix A

National Park Service
Everglades National Park
South Florida Natural Resources Center

February, 1994

A Introduction

This appendix is intended to provide a more detailed hydrological assessment of the principal subbasins within the C-111 drainage basin and to illustrate the need to include necessary structural modifications to the C&SF project for environmental benefit. Justification of the need to include detention/retention areas and a wider spatial distribution of pumps and culverts is addressed. The analysis contained herein also addresses questions raised during the U.S. Army Corps of Engineers' Project Review Conference and evaluates the modifications of Alternative 6 as proposed by the Corps. The results of this analysis intend to show the regional effects that the changes in water deliveries brought about by each of the proposed alternatives will have on the natural areas within each subbasin.

The spatial data used in this appendix are also based on the South Florida Water Management District's model (SFWMM–1x1, see section 4). The SFWMM–1x1 is a regional model with a 1 mile by 1 mile grid resolution. Some of the detail proposed in the alternatives and specifically the changes proposed to Alternative 6 are of smaller spatial resolution than the model is capable of capturing. Details of the levee locations, the proposed detention/retention basins, and exact pump locations cannot be evaluated until modeling efforts using finer grid resolutions are completed. The Park anticipates that these studies will be done during the next phase of the proposed project. Also, during this next phase the necessary operational changes and water supply issues must be discussed and evaluated. The following analysis was completed using the output from Alternatives 1 through 6 and are only intended to show a regional comparison, *i.e.*, changes occuring in subbasins as a whole, between each alternative and the base condition.

A.1 Subbasin Areas

The boundaries of the subbasins used in the analysis of the SFWMM–1x1 output were selected based on soils, elevation, and hydroperiod information and are shown in Fig. 1. Seven subbasins were used to illustrate the changes:

1) Northeast Shark Slough (NESS) (111 mi^2). The boundary of this subbasin was defined by Tamiami Trail in the north and by the Loxahatchee and Everglades Peats along the northwest and southeast boundaries. The downstream boundary was defined by the 5.0 foot contour line. South of this contour the central portion of the slough looses its definition and expands into a more regional and southwesterly direction.

2) Shark Slough (SS) (78 mi^2). This subbasin continues the flow from Northeast Shark Slough and is bounded near its lower end by East Slough to the northwest and by the higher lands of the Rocky Glades to the east. The lower boundary of Shark Slough coincides with the area where a more dendritic pattern of small streams occurs and eventually flows into well-defined channels, (*e.g.* the Shark River).

3) Rocky Glades (RG) (134 mi^2). Southeast of the Northeast Shark Slough subbasin and east of northern Shark Slough are the higher elevated Rocky Glades underlain with Rockland soils. This subbasin is bounded to the east by the L-31N canal. The southern boundary is defined by the Rockdale sandy soils which underlie the Long Pine Key area.

4) Upper Taylor Slough (UTS) (23 mi^2). The Taylor Slough watershed was divided into two units by the Park Road (State Road 9336). The upper Taylor Slough subbasin was defined by the extent of the Perrine marl soils, which form the upstream extent of the well-defined historical drainage of Taylor Slough.

5) Lower Taylor Slough (LTS) (84 mi^2). This subbasin is receiving flow from upper Taylor Slough and some drainage from Long Pine Key, which flows to the southwest into the ponds and lakes of the upper estuary of Florida Bay. The southern-most portion of Taylor Slough falls outside the model domain, the subbasin's eastern boundary was defined by a rise in elevation which is underlain by Rockland and Perrine marls that separate Taylor Slough from the Eastern Panhandle.

6) Lower Eastern Panhandle (LEP) (36 mi^2). East of lower Taylor Slough the low elevation freshwater and marine marls are divided by the lower reach of the C-111 canal. The lower Eastern Panhandle subbasin is bounded to the east and north by the C-111 canal and flows southerly into the upper estuaries of Florida Bay.

7) Upper Eastern Panhandle (UEP) (50 mi^2). The drainage north and east of lower C-111 is bounded by the Rockdale sandy soils of the Coastal Ridge to the north and Card Sound Road to the east. Since several of the alternatives include flow across US–1, the triangle area to the east was included in this subbasin.

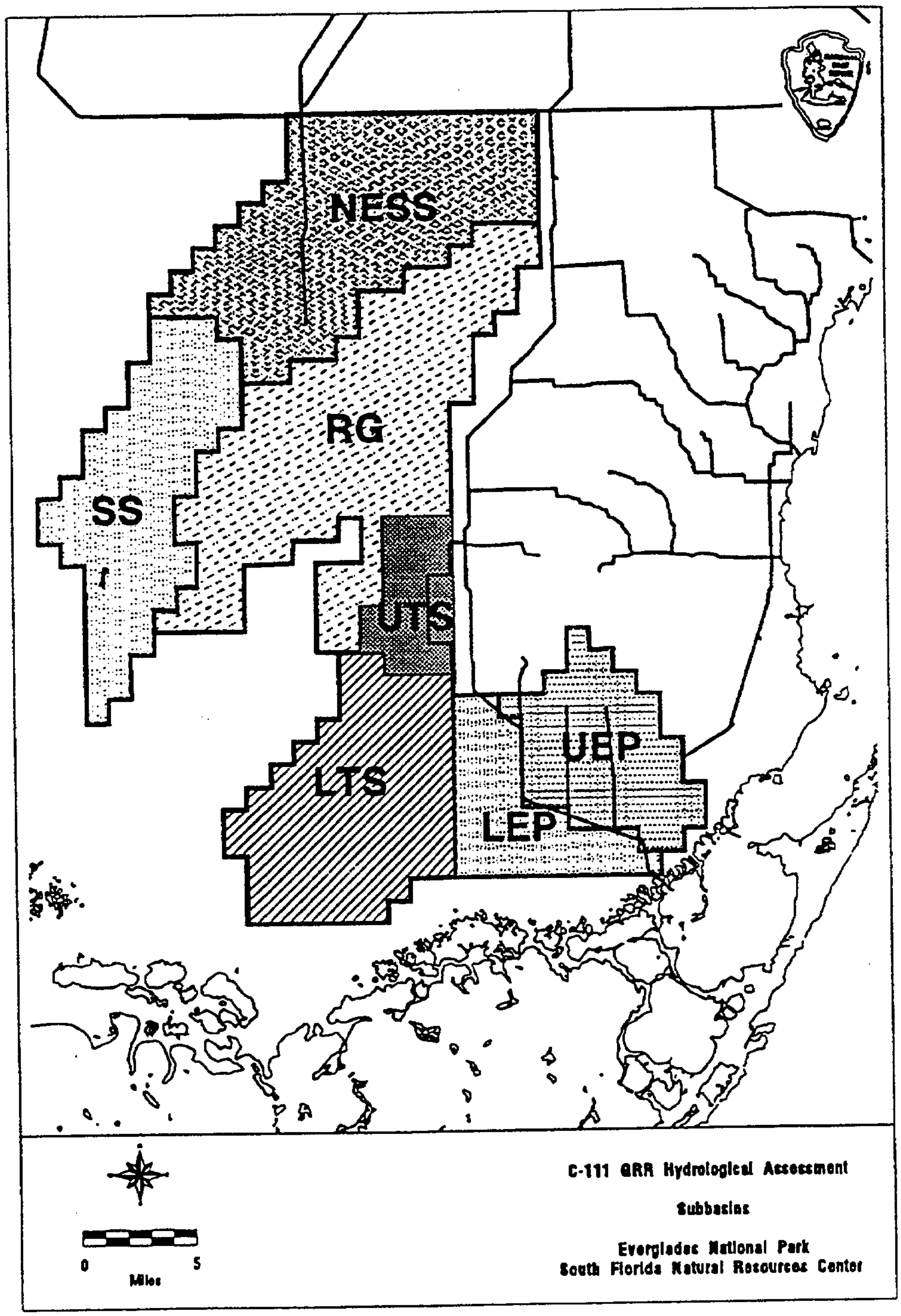

Figure 1: Definition of the Seven Subbasins and their Boundaries.

A.2 Subbasin analysis

The subbasins were used to investigate the impacts of the proposed alternatives on the surface water hydroperiods and water depths of these areas. The daily surface water depths (ponding) for each of the grid cells in the subbasins were tabulated from the same output data files used in section 10 of the main report.

The surface subtractions between each of the alternatives and the base condition for the subbasins is tabulated in Table 1. The average year, 1976–1977, was used herein, but tables containing the data for the typical wet and dry year are published in Appendix B. The following analysis is based on the hydroperiod data contained in Table 10 of the main report. Visual inspection of Plates 9 through 15 also aids in illustrating the hydroperiod changes. Table 1 is subdivided into the seven subbasins, each contains three rows of data. The row labeled "less" are the number of grid cells (or square miles) which have reduced inundation from the base condition, the row labeled "none" contains the number of cells where no change in hydroperiod was observed ($\Delta p = 0$ in Table 10) and the row labeled "more" are the number of cells which have more inundation, thus longer hydroperiods. The following tabulation did not distinguish how long or how deep the changes in water depth were. Generally the increases were quite small (see the color plates for the spatial and temporal categories).

The changes in hydroperiods for the average year, 1976–1977, indicate some of the benefits associated with the wider spacing of pumps as in Alternatives 4, 6 and 6A, which provide multiple discharge points to the wetlands. Both Alternatives 4 and 6 (6A) have four pumps spaced evenly from south of the 8.5 mi^2 area to the north end of the Frog Pond. The increases in hydroperiod in the Rocky Glades show up in 121 and 120 grid cells, respectively, with only 9 cells having reduced hydroperiods. Although Alternative 5 shows an increase in 91 cells, this occurs in the lower portion of the Rocky Glades, while the upper portion shows negative impacts in 34 cells with reduced hydroperiods (see Plate 14). Changes due to detention/retention areas do not show up well in the output, due to the problem of spatial scale. The difference in pump size and location of the alternatives using the large pumps also does not indicate any significant change in hydroperiods in Taylor Slough, whether the water is delivered in the Rocky Glades or discharged as a large volume in Taylor Slough near S-332 or S-174 is not distinguishable in lower Taylor Slough. As might be expected, moving pump capacity farther north affect the upper Taylor Slough subbasin slightly.

Hydroperiods in the Upper Eastern Panhandle subbasin increase due to the addition of the east-west spreader canal. Increases occur in the northern portion of this subbasin, reduced hydroperiods are noted in the southern part. This is probably due to a change in water allocation from lower C-111 to Taylor Slough and from the lower panhandle to the northern portion within the subbasin. The lower Eastern Panhandle subbasin shows a similar pattern, increases in Hydroperiods are generally to the west of C-111 (see Plates 9 through 15), while decreases are noted in the area of the C-111 cutouts. Alternative 4, which takes out lower C-111, actually shows 23 cells with less hydroperiod and only an increase of 12 cells. This pattern is expected. Base conditions allow ponding to occur in the impounded areas north of lower C-111, if the canal is removed and operational changes are not implemented to bring the diverted (to Taylor Slough) water back into C-111, any analysis will show no environmental benefit. This is the reason why recommendations in the main body of the report strongly suggested to discuss and test operational policies.

In addition to the hydroperiod analysis of the subbasins, changes in water depths for April and October for the average year of 1976–1977 (Table 2) is used to illustrate the seasonal changes occuring in the subbasins. Tables containing the data for the typical wet and dry year are published in Appendix B. Due to the time constraints, only Alternatives 1, 4 and 6 were used to compare against the Base condition. The table is similar to the hydroperiod table (Table 1), the tabulation is of average monthly (obtained from daily data) water depth changes between each alternative and base. During 1977, April is the driest month and October is the wettest month, this pattern is similar to the dry and wet years shown in the appendix.

During April, most of the C-111 basin is dry under base and any alternative, it is not clear at this time why the data shows that there are higher surface water levels in Northeast Shark Slough and Shark Slough. During the wet month, October, both Alternative 4 and 6 show water depth increases in the Rocky Glades, Northeast Shark Slough and Shark Slough. Water depth increases in these areas with Alternative 1 are much smaller, illustrating again the benefits of using multiple entry points. Water introduced north of and in the headwaters of Taylor Slough regardless of location or number of entry points allow both the upper and lower Taylor Slough subbasins to be much wetter during this month.

A.3 Comparison of Alternative 6A and Alternative 8

Alternatives 1 through 6 are discussed and illustrated in section 3 and the conceptual approach of Alternative 8 is located in section 12. A description and evaluation of Alternative 6A is presented in this section. It is again unfortunate that the short timeframe allowed for the follow-up work (one week) does not allow for a more detailed comparison of Alternatives 6A and 8. As the main body of this report concludes, the hydrological benefits in the wetlands, particularly in the lower C-111 basin, must be evaluated with operational changes in mind. Most of the alternatives redirect water that would be delivered into the lower C-111 basin, the Eastern Panhandle, under the base condition and discharge it into the wetlands of the Rocky Glades and Taylor Slough. The hydrological restoration of the wetlands in the Eastern Panhandle are as important as the areas to the north. The rapid releases of fresh water through the lower cutouts into the upper estuary of Florida Bay and through S-197 into Barnes Sound have to be eliminated and the discharges diverted into detention/retention areas. This will aid in the overall process of returning the system to more natural hydroperiods and hydropatterns.

- **Alternative 6A.** This plan is a modification of Alternative 6 and addresses the large seepage losses along the L-31N canal, and the need for detention/retention areas. The components of this plan are shown in Fig. 2 and the specific improvements are discussed below:

  a) A levee would be built approximately 0.5 mile west of L-31N, beginning opposite C-102, but not tied into the levee around the 8.5 mi^2 area. This levee would run southward into the Frog Pond area. The area in between the canal and this levee would serve as a buffer zone to reduce the leakance back to the canal, due to the proposed higher stages in the wetlands to the west.

  b) A second levee would be built approximately 0.5 mile west of the first levee. The area in between the two levees would be a detention/retention area serving as a surge pool for stormwater runoff. This area may also provide water quality benefits by filtering canal water.

  c) Four pump stations, S-332A, S-332B, S-332C and S-332D, with four 75 cfs pumps each, would provide water from L-31N to the detention/retention areas via lined canals across the buffer zone.

d) Eight 36" culverts with stop logs and one 300 ft. emergency spillway would discharge water from the detention/retention area into the wetlands of the Rocky Glades and prevent backflow.

e) The eastern portion of the Frog Pond would be enclosed with levees and S-332D would supply water to the detention/retention area to the north.

f) A new, lined canal would supply water to the existing S-332 pump station (165 cfs) and to the existing structure S-175 (500 cfs). The L-31W canal south of S-175 would remain in place, but the northern section above S-332 would be backfilled.

g) A new spreader canal, C-111N, east of the confluence of C-111 and C-111E supplied by a 50 cfs pump (S-332E) would deliver water to the impounded area north of the lower C-111 canal through overbank flow.

h) The C-109 and C-110 canals would be plugged at regular intervals to induce sheet flow from west to east.

i) The lower C-111 canal would remain in place, but the southern spoil piles would be degraded to allow improved overbank flow southward into Florida Bay.

The concepts of Alternative 8 and its components, discussed in section 12, and shown in more detail in Fig. 3, were endorsed by the Department of the Interior and used as guidelines in evaluating the most recent structural modifications, as defined by Alternative 6A, for this project. In concept, the modifications proposed to supply water to the southern portion of the Rocky Glades and the headwaters of Taylor Slough are similar. Our original transmittal of Alternative 8 did not contain the details of levee and pump placement. Alternative 6A provides more detail on the location to control the seepage problem, but it is clear that additional refinements will be needed during the design phase when detailed analysis is possible, but the use of three levees to stairstep the proposed higher water levels between the canal and the wetlands will retain more water in the wetlands.

The northern Rocky Glades have an improved seepage control system with the addition of the levee, the L-31W tieback, but the proposed levee does not tie in to the 8.5 mi^2 area levee as is proposed in Alternative 8. Problems may occur when the desired increases in water depths in Northeast Shark Slough raise water levels in the northern Rocky Glades. It is conceivable that water levels west of the 8.5 mi^2 area will be high enough that flow will occur

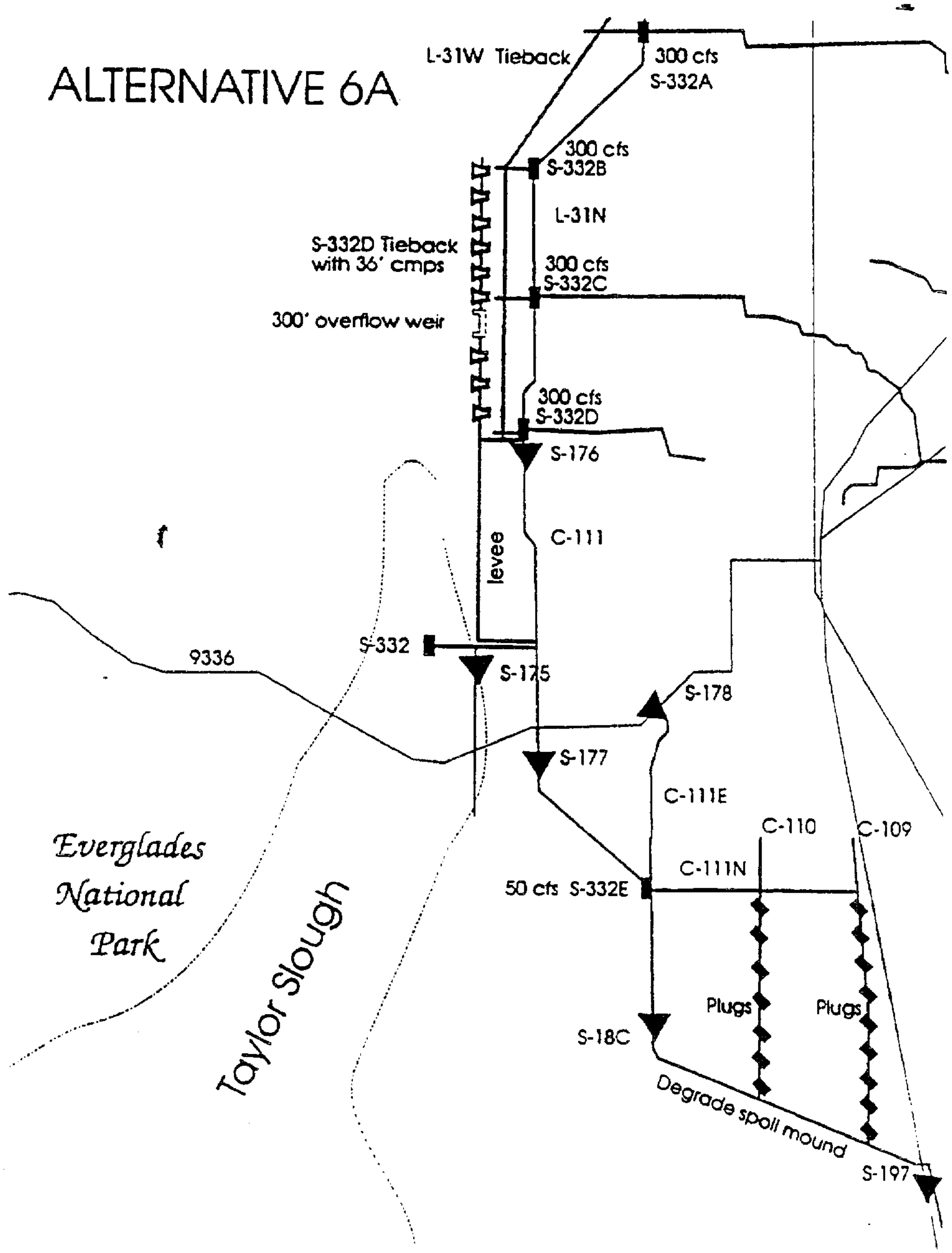

Figure 2: Alternative 6a

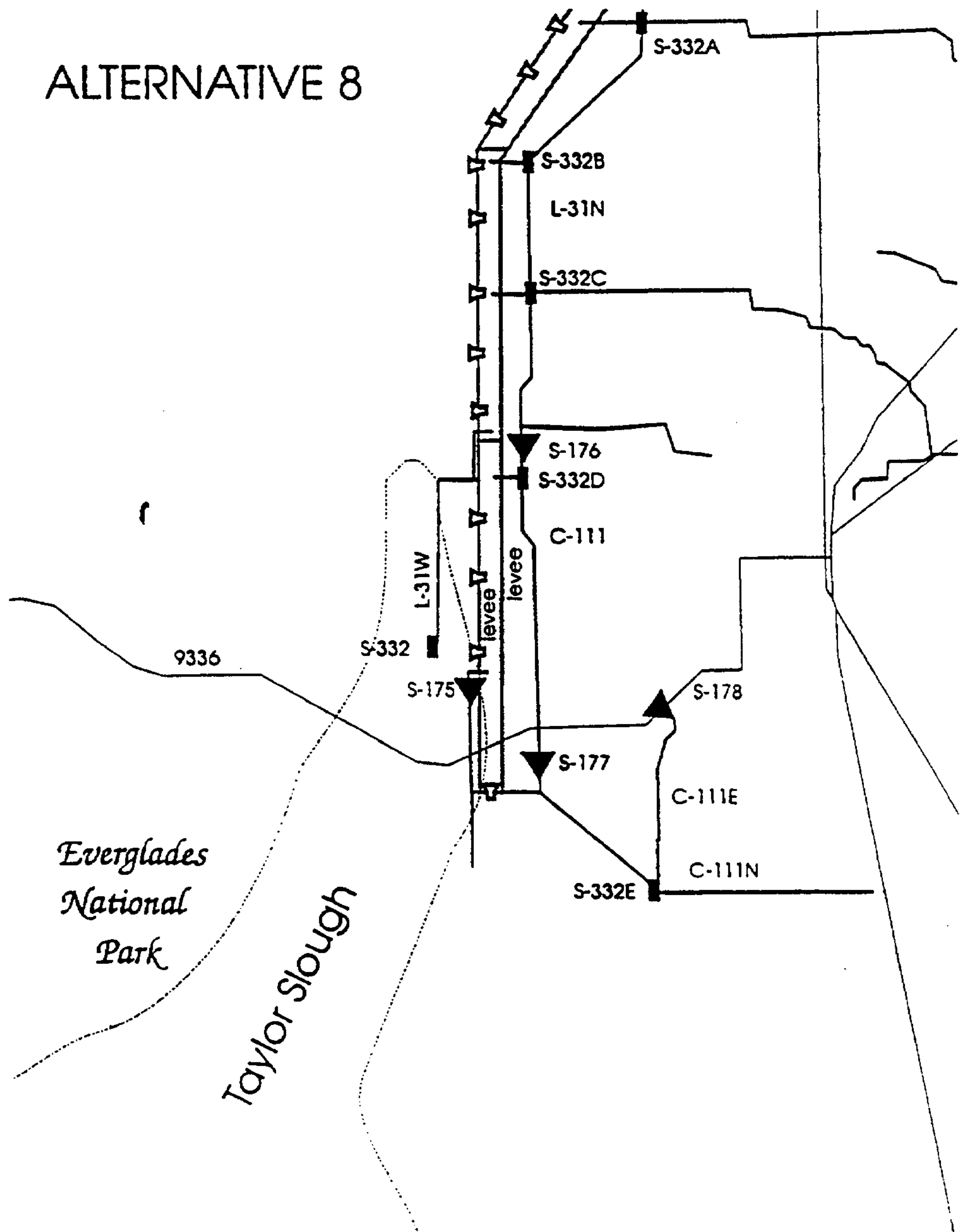

Figure 3: Alternative 8

from west of the levee into the protected area. In this area the C-111 project abuts the Modified Water Deliveries project, and a resolution of the boundary between the two projects is needed. S-332A may be better placed at the soutern terminus of the 8.5 mi^2 area instead of next to L-31N if a continuous levee is built as proposed in Alternative 8, details such as these need to be worked out during the design phase of the project.

Proposed modifications in the Frog Pond differ between Alternative 6A and Alternative 8 in the manner that water is discharged into the adjacent wetlands, and the use of the western Frog Pond as a detention/retention basin. Alternative 6A proposes to pump water to the north detention/retention area and keeps the eastern Frog Pond as a totally enclosed area. Water to the existing S-332 pump and to the S-175 control structure will be delivered through a canal leading from C-111, and the lower end of L-31W would remain. Alternative 8 uses the existing L-31W canal to supply S-332 from the northern detention/retention basin. This would allow overbank flow from the north-south aligned portion of L-31W to occur during the wet season. The lower part of L-31W past S-332 would be filled in down to the S-175 structure. Alternative 8 uses the Frog Pond as a detention/retention area and allows outflows to occur westward. It also uses existing structure S-175 to pass flows from the detention/retention area south through the remaining reach of the L-31W canal for discharge in the wetlands.

The proposed modifications in the Eastern Panhandle are minimal and remain identical to Alternative 6. This region differs the most from Alternative 8. The purpose of the east-west spreader canal without modifications to lower C-111 is not clear. The impounded areas it is intended to supply by the 50 cfs pump are already full of water most of the year and these areas can probably serve as an example, what hydrological restoration of the lower wetlands should look like. The purpose of the spreader canal in Alternative 8 is to replace the lower part of C-111 canal and allow the distribution of water as sheetflow to the marshes farther north. This would meet the original C-111 GRR project goal of eliminating direct freshwater releases to the estuaries via S-197.

A.4 Changes in Flood Protection

All of the alternatives were modeled only as structural improvements and no operational changes were made to the existing system. The optimum wet season water levels are maintained at the structures and outflow capacity is as specified under the authorized project authority. The authority for the General Reevaluation study for the C-111 canal system is tied to the completion

Design Discharge (cfs)									
	332	S175	S18C	332A	332B	332C	332D	332E	Total
Base	165	500	2100						2765
Alt 6A	165	500	2100	300	300	300	300	50	4015

Table 3: Structure Capacities for Base and Alternative 6A Conditions

of features originally authorized by the 1968 Flood Control Act. This act authorized the construction of the ENP-South Dade Conveyance System, which added new water control structures to the existing canal system for the purpose of conservation and conveyance of water supplies to Everglades National Park, and for expanding agricultural and urban needs. Keep in mind that the 1968 act authorized the SDCS solely for the purpose of increased water supply and improved conveyance, and did not provide the specific authority to increase the level of flood protection within the C-111 canal system.

Table 3 lists the structure discharges for the Base and Alternative 6A condition. Note that this indicates that Alternative 6A provides a 69% increase in total outflow capacity for the C-111 basin. Alternative 8 is a conceptual plan and focuses on elements for environmental benefit, which are stage targets in the wetlands. The sizing of the pumps to maintain authorized levels of flood control must be accomplished by the COE and SFWMD, with this goal in mind. The structures listed in this table are the surface water discharge points into the wetlands and into Barnes Sound via S-197, which is capable of handling all of the S-18C discharges. The tabulation is exclusive of discharges occuring through the coastal canals to the east. To our knowledge these capacities do not change as part of any proposed project.

Alternative 8 eliminates the lower C-111 canal and proposes to transfer the flood control capacity of S-18C to the pumps delivering water into the detention/retention basins and the spreader canal, C-111N. Additonal gravity drainage could be used through emergency spillways at locations along the canal where secondary drainages to Taylor Slough and the Eastern Panhandle exist.

A.5 Conclusions

As requested, a comparison of Alternative 8 and Alternative 6A was made, based on the division of the wetlands into subbasins. The salient points regarding the need to have a buffer zone to control seepage and the need to built detention/retention areas to capture stormwater runoff have been discussed.

The subbasin analysis clearly shows the benefits of spacing the pumps along L31N and C-111 instead of concentrating the capacity at a single point. The model, because of its regional scale, fails to capture the details of the detention/retention areas and the placement of seepage control levees. These must be addressed when finer resolution models are available and other detailed calculations can be made.

As was shown in the body of the report and in the subbasin analysis the benefits associated with the re-introduction of surface water in the Rocky Glades comes at the expense of Base conditions in the Eastern Panhandle. Operational and water supply issues must be addressed in the next phase of the process, to prevent the detoriation of existing conditions in the lower C-111 basin.

ANNEX G

C-111 MARL MODEL BACKGROUND

C-111

PROCEDURE FOR RANKING ALTERNATIVES BASED ON HYDROLOGY AND REPORTED PERIPHYTON-PRODUCING CONDITIONS

C-111 alternatives were ranked by calculating "hydrohabitat units" (HU) for each, based on water depths and frequency of flooding in the "zone of optimum development of marl" (Tabb and Kenny, 1969 - enclosure 1). The maximum, minimum, and average historic water levels reported by Tropical Bioindustries, Inc. (1990) are standards to which we compared projected alternative water levels under three water level exceedance frequencies: 10 percent (wet period), 50 percent (average period), and 90 percent (dry period). The procedure is as follows:

1. Construct a model (marl model) to rate the projected alternative water levels against the reported historic conditions. The model produces 3 values between 0 and 1.0: a value comparing each of the 3 exceedance frequencies to historic water levels under wet, average, and dry conditions.

2. Calculate a hydrohabitat index (HhI)--the cube-root of the product of the 3 model values--for the upper (west) basin and the lower (east) basin under each alternative.

3. Calculate the hydrohabitat units for each alternative. HhUs are the product of the HhI and the square miles with increased hydroperiod--a value for each basin under each alternative. The alternative plans would permit higher water levels in areas larger than the marl zone, and the total area of increased flooding is used in calculating respective alternatives' hydrological units.

<u>NOTES:</u>

CONSIDERATIONS FROM TBI (1990).

Marl soils were formed and maintained under an average hydroperiod of about 7 months.

Water levels may have reached lows of 20-30 inches below ground level. Water recession of from 24 inches to 30 inches below ground level might cause rapid and complete loss of water from marl soils and death of plants.

The average water depth was 8.5 inches over marl soil and ranged from 3.2 inches to 20.9 inches.

Seasonal water depths of 6.5 feet in Shark River Slough (SRS) and the east Everglades in Everglades National Park caused SRS and Taylor Slough waters to meet and flow to Florida Bay.

The model would provide for a hydrohabitat index (HI) value of 1.0 for water depths and conditions as follows:

Depths no less than 0 inches (i.e., ground level) would be exceeded 90% of the time, and

Depths no less than 8.5 inches would be exceeded 50 % of the time, and

Depths up to 21 inches may be reached 10% of the time.

Water levels below -30 inches would result in a HU value of zero.

References cited:

Tabb, D.C. and N. Kenny, 1969. Contour mapping of the coastal plain of Everglades National Park by the periphyton method. Inst. of Mar. Sci., Univ. of Miami, Coral Gables, Florida, in Tropical Bioindustries, 1990.

HhI x square miles affected = hydrohabitat units (HhU) for an alternative increment. A western and an eastern increment are separable.

CALCULATING HYDROHABITAT INDEXES

Where D = water depth in inches and H = hydrohabitat index:

For wet period:

If D > 0 and <= 21, H = 1.0.
If D > 21 and <= 24, H = 7.3 - 0.3D.
If D > 24, H = 0.1.

For average period:

If D >= 8.5, H = 1.0.
If D > 0 and < 8.5, H = 0.1 + 0.106D.
If D <= 0, H = 0.1.

For dry period:

If D >= 0, H = 1.0.
If D < 0, H = 1 + 0.033D.

FIGURE EIS-G-1
Marl Prairie Model - Hydrohabitat Index vs. Water Depth

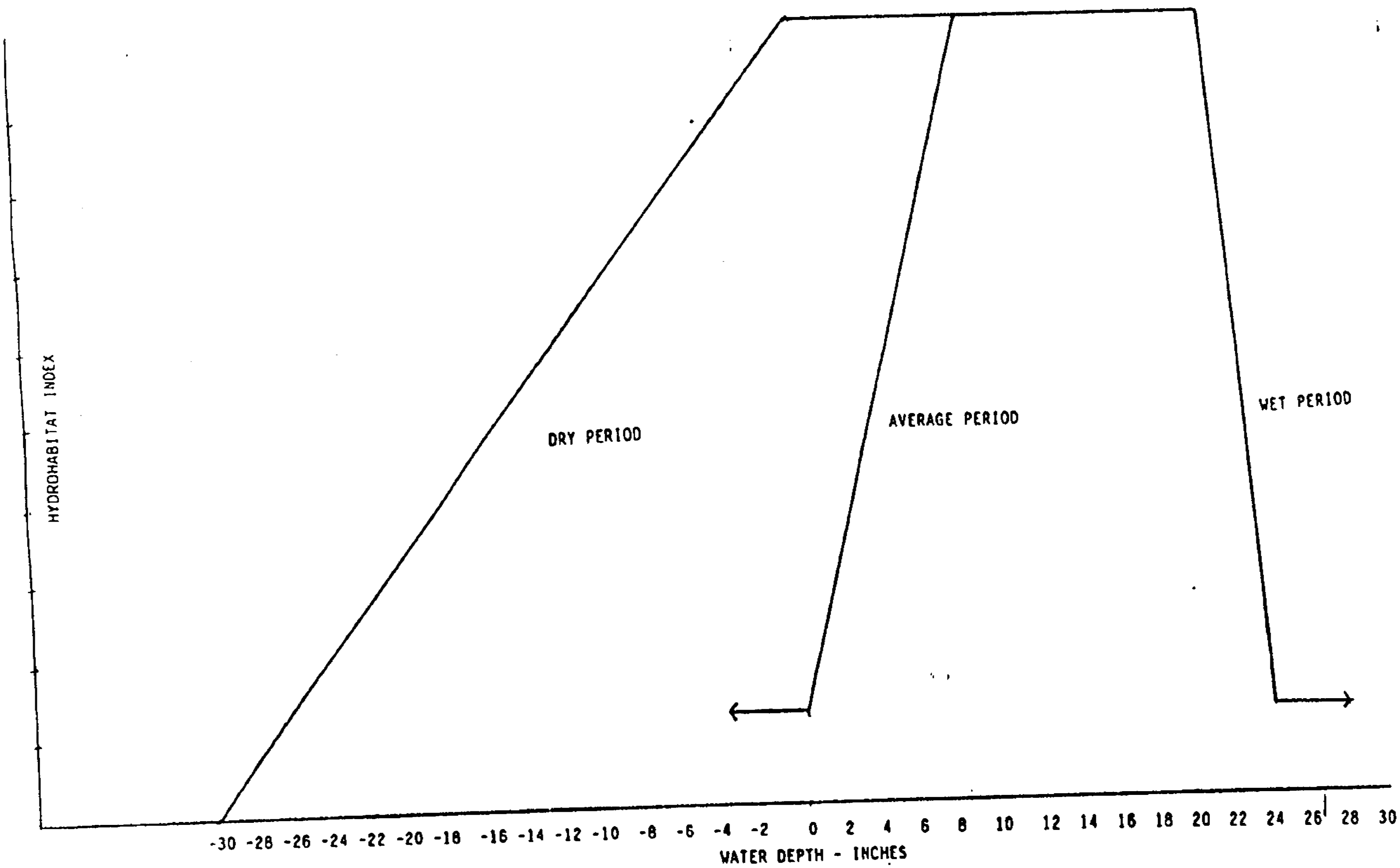

Figure EIS-G-1 Marl Prairie Model - Hydrohabitat Index vs. Water Depth

C-111 Marl Model Data.

10% EXCEEDANCE

ALT 1	NODE	GRND ELEV	ALT 1	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
	244.00	1.13	2.11	0.98		11.76
	243.00	1.52	2.45	0.93		11.16
E	253.00	0.20	1.42	1.22	14.64	
E	255.00	0.05	1.36	1.31	15.72	
	547.00	1.32	2.24	0.92		11.04
	550.00	1.05	1.79	0.74		8.88
E	558.00	0.90	1.91	1.01	12.12	
	751.00	1.85	2.61	0.76		9.12
E	755.00	0.83	2.29	1.46	17.52	
	847.00	1.44	3.13	1.69		20.28
E	853.00	1.63	2.39	0.76	9.12	
E	858.00	1.10	2.00	0.90	10.80	
	1050.00	3.45	3.23	-0.22		-2.64
	1147.00	1.95	3.72	1.77		21.24
	1153.00	2.19	2.58	0.39		4.68
	1347.00	3.95	4.83	0.88		10.56
	641.00	1.88	2.73	0.85		10.20

50% EXCEEDANCE

NODE	ELEV	ALT 1	WATER IN FEET	DEPTH-INCHES WEST	DEPTH-INCHES EAST
244.00	1.13	1.73	0.60		7.20
243.00	1.52	1.88	0.36		4.32
253.00	0.20	0.92	0.72	8.64	
255.00	0.05	0.86	0.81	9.72	
547.00	1.32	1.73	0.41		4.92
550.00	1.05	1.25	0.20		2.40
558.00	0.90	1.17	0.27	3.24	
751.00	1.85	1.88	0.03		0.36
755.00	0.83	1.47	0.64	7.68	
847.00	1.44	2.44	1.00		12.00
853.00	1.63	1.68	0.05	0.60	
858.00	1.10	1.35	0.25	3.00	
1050.00	3.45	2.44	-1.01		-12.12
1147.00	1.95	2.72	0.77		9.24
1153.00	2.19	2.07	-0.12		-1.44
1347.00	3.95	4.19	0.24		2.88
641.00	1.88	2.21	0.33		3.96

90 % EXCEEDANCE

NODE	ELEV	ALT 1	WATER IN FEET	DEPTH-INCHES WEST	DEPTH-INCHES EAST
244.00	1.13	0.28	-0.85		-10.20
243.00	1.52	0.38	-1.14		-13.68
253.00	0.20	-0.55	-0.75	-9.00	
255.00	0.05	-0.51	-0.56	-6.72	
547.00	1.32	0.26	-1.06		-12.72
550.00	1.05	-0.17	-1.22		-14.64
558.00	0.90	-0.14	-1.04	-12.48	
751.00	1.85	0.40	-1.45		-17.40
755.00	0.83	0.08	-0.75	-9.00	
847.00	1.44	0.89	-0.55		-6.60
853.00	1.63	0.58	-1.05	-12.60	
858.00	1.10	-0.08	-1.18	-14.16	
1050.00	3.45	1.42	-2.03		-24.36
1147.00	1.95	1.75	-0.20		-2.40
1153.00	2.19	1.02	-1.17		-14.04
1347.00	3.95	2.44	-1.51		-18.12
641.00	1.88	0.61	-1.27		-15.24

WEST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 21.24 INCHES 10HI 0.93
FOR 50% EXCEEDANCE, MIN DEPT -12.12 INCHES 50HI 0.10 WHI= 0.27
FOR 90% EXCEEDANCE, MIN DEPT -24.36 INCHES 90HI 0.20
SQ. MI 895.00 WHU= 242 ALT 1 HU= 294
AVG DEPTHS 13.32 10.57 INCHES AVG DEP 5.48 3.07 INCHES

EAST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 17.52 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT 0.60 INCHES 50HI= 0.16 EHI= 0.44
FOR 90% EXCEEDANCE, MIN DEPT -14.16 INCHES 90HI= 0.53
SQ MI= 118.00 EHU= 52
AVG DEP -10.66 -13.58 INCHES

C-111 Marl Model Data.

10% EXCEEDANCE

ALT 2	NODE	GRND ELEV	ALT 2	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
	244.00	1.13	2.13	1.00		12.00
	243.00	1.52	2.47	0.95		11.40
E	253.00	0.20	1.44	1.24	14.88	
E	255.00	0.05	1.37	1.32	15.84	
	547.00	1.32	2.30	0.98		11.76
	550.00	1.05	1.84	0.79		9.48
E	558.00	0.90	1.92	1.02	12.24	
	751.00	1.85	2.68	0.83		9.96
E	755.00	0.83	2.29	1.46	17.52	
	847.00	1.44	3.25	1.81		21.72
E	853.00	1.63	2.39	0.76	9.12	
E	858.00	1.10	2.01	0.91	10.92	
	1050.00	3.45	3.47	0.02		0.24
	1147.00	1.95	3.93	1.98		23.76
	1153.00	2.19	2.59	0.40		4.80
	1347.00	3.95	4.48	0.53		6.36
	641.00	1.88	2.75	0.87		10.44

50% EXCEEDANCE

NODE	ELEV	ALT 2	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	1.76	0.63		7.56
243.00	1.52	1.87	0.35		4.20
253.00	0.20	0.95	0.75	9.00	
255.00	0.05	0.88	0.83	9.96	
547.00	1.32	1.72	0.40		4.80
550.00	1.05	1.25	0.20		2.40
558.00	0.90	1.18	0.28	3.36	
751.00	1.85	1.88	0.03		0.36
755.00	0.83	1.48	0.65	7.80	
847.00	1.44	2.39	0.95		11.40
853.00	1.63	1.69	0.06	0.72	
858.00	1.10	1.35	0.25	3.00	
1050.00	3.45	2.42	-1.03		-12.36
1147.00	1.95	2.67	0.72		8.64
1153.00	2.19	2.09	-0.10		-1.20
1347.00	3.95	3.63	-0.32		-3.84
641.00	1.88	2.20	0.32		3.84

90 % EXCEEDANCE

NODE	ELEV	ALT 2	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	0.25	-0.88		-10.56
243.00	1.52	0.37	-1.15		-13.80
253.00	0.20	-0.52	-0.72	-8.64	
255.00	0.05	-0.44	-0.49	-5.88	
547.00	1.32	0.23	-1.09		-13.08
550.00	1.05	-0.19	-1.24		-14.88
558.00	0.90	-0.10	-1.00	-12.00	
751.00	1.85	0.44	-1.41		-16.92
755.00	0.83	0.13	-0.70	-8.40	
847.00	1.44	0.84	-0.60		-7.20
853.00	1.63	0.62	-1.01	-12.12	
858.00	1.10	-0.06	-1.16	-13.92	
1050.00	3.45	1.41	-2.04		-24.48
1147.00	1.95	1.64	-0.31		-3.72
1153.00	2.19	1.06	-1.13		-13.56
1347.00	3.95	2.17	-1.78		-21.36
641.00	1.88	0.61	-1.27		-15.24

WEST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 23.76 INCHES 10HI= 0.17
FOR 50% EXCEEDANCE, MIN DEPT -12.36 INCHES 50HI= 0.10 WHI= 0.15
FOR 90% EXCEEDANCE, MIN DEPT -24.48 INCHES 90HI= 0.19
SQ MI = 829.00 WHU= 124
AVG DEPTHS 13.42 11.08 INCHES

ALT 2 HU= 184
AVG DEP 5.64 2.35 INCHES

EAST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 17.52 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT 0.72 INCHES 50HI= 0.18 EHI= 0.46
FOR 90% EXCEEDANCE, MIN DEPT -13.92 INCHES 90HI= 0.54
SQ MI= 130.00 EHU= 60
AVG DEP -10.16 -14.07 INCHES

C-111 Marl Model Data.

10% EXCEEDANCE

ALT 3	NODE	GRND ELEV	ALT 3	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
	244.00	1.13	2.09	0.96		11.52
	443.00	1.52	2.43	0.91		10.92
E	453.00	0.20	1.49	1.29	15.48	
E	455.00	0.05	1.37	1.32	15.84	
	547.00	1.32	2.20	0.88		10.56
	550.00	1.05	1.85	0.80		9.60
E	558.00	0.90	1.92	1.02	12.24	
	751.00	1.85	2.47	0.62		7.44
E	755.00	0.83	2.12	1.29	15.48	
	847.00	1.44	3.06	1.62		19.44
E	853.00	1.63	2.38	0.75	9.00	
E	858.00	1.10	2.01	0.91	10.92	
	1050.00	3.45	3.45	0.00		0.00
	1147.00	1.95	3.63	1.68		20.16
	1153.00	2.19	2.99	0.80		9.60
	1347.00	3.95	4.69	0.74		8.88
	641.00	1.88	2.71	0.83		9.96

50% EXCEEDANCE

NODE	ELEV	ALT 3	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	1.73	0.60		7.20
443.00	1.52	1.86	0.34		4.08
453.00	0.20	0.93	0.73	8.76	
455.00	0.05	0.83	0.78	9.36	
547.00	1.32	1.70	0.38		4.56
550.00	1.05	1.22	0.17		2.04
558.00	0.90	1.12	0.22	2.64	
751.00	1.85	1.84	-0.01		-0.12
755.00	0.83	1.45	0.62	7.44	
847.00	1.44	2.37	0.93		11.16
853.00	1.63	1.69	0.06	0.72	
858.00	1.10	1.38	0.28	3.36	
1050.00	3.45	2.43	-1.02		-12.24
1147.00	1.95	2.64	0.69		8.28
1153.00	2.19	2.27	0.08		0.96
1347.00	3.95	3.92	-0.03		-0.36
641.00	1.88	2.20	0.32		3.84

90 % EXCEEDANCE

NODE	ELEV	ALT 3	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	0.25	-0.88		-10.56
443.00	1.52	0.36	-1.16		-13.92
453.00	0.20	-0.67	-0.87	-10.44	
455.00	0.05	-0.74	-0.79	-9.48	
547.00	1.32	0.23	-1.09		-13.08
550.00	1.05	-0.24	-1.29		-15.48
558.00	0.90	-0.42	-1.32	-15.84	
751.00	1.85	0.19	-1.66		-19.92
755.00	0.83	-0.22	-1.05	-12.60	
847.00	1.44	0.79	-0.65		-7.80
853.00	1.63	0.22	-1.41	-16.92	
858.00	1.10	-0.15	-1.25	-15.00	
1050.00	3.45	1.30	-2.15		-25.80
1147.00	1.95	1.65	-0.30		-3.60
1153.00	2.19	1.06	-1.13		-13.56
1347.00	3.95	2.25	-1.70		-20.40
641.00	1.88	0.61	-1.27		-15.24

WEST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 20.16 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT -12.24 INCHES 50HI= 0.10 WHI= 0.25
FOR 90% EXCEEDANCE, MIN DEPT -25.80 INCHES 90HI= 0.15
SQ MI = 917.00 WHU= 229
AVG DEPTHS 13.16 10.73 INCHES

ALT 3 HU= 284
AVG DEP 5.38 2.67 INCHES

EAST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 15.84 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT 0.72 INCHES 50HI= 0.18 EHI= 0.43
FOR 90% EXCEEDANCE, MIN DEPT -16.92 INCHES 90HI= 0.44
SQ MI= 127.00 EHU= 55
AVG DEP-13.38 -14.49 INCHES

C-111 Marl Model Data.

10% EXCEEDANCE

ALT 4	NODE	GRND ELEV	ALT 4	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
	244.00	1.13	2.11	0.98		11.76
	443.00	1.52	2.45	0.93		11.16
E	453.00	0.20	1.45	1.25	15.00	
E	455.00	0.05	1.34	1.29	15.48	
	547.00	1.32	2.23	0.91		10.92
	550.00	1.05	1.82	0.77		9.24
E	558.00	0.90	1.84	0.94	11.28	
	751.00	1.85	2.48	0.63		7.56
E	755.00	0.83	1.95	1.12	13.44	
	847.00	1.44	3.13	1.69		20.28
E	853.00	1.63	2.20	0.57	6.84	
E	858.00	1.10	1.95	0.85	10.20	
	1050.00	3.45	3.21	-0.24		-2.88
	1147.00	1.95	3.73	1.78		21.36
	1153.00	2.19	2.74	0.55		6.60
	1347.00	3.95	4.54	0.59		7.08
	641.00	1.88	2.73	0.85		10.20

WEST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 21.36 INCHES 10HI= 0.89
FOR 50% EXCEEDANCE, MIN DEPT -12.24 INCHES 50HI= 0.10 WHI= 0.26
FOR 90% EXCEEDANCE, MIN DEPT -24.60 INCHES 90HI= 0.19
SQ MI = 1034.00 WHU= 269 ALT 4 HU= 314
AVG DEPTHS 12.04 10.30 INCHES

50% EXCEEDANCE

NODE	ELEV	ALT 4	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	1.73	0.60		7.20
443.00	1.52	1.87	0.35		4.20
453.00	0.20	0.91	0.71	8.52	
455.00	0.05	0.75	0.70	8.40	
547.00	1.32	1.71	0.39		4.68
550.00	1.05	1.24	0.19		2.28
558.00	0.90	1.04	0.14	1.68	
751.00	1.85	1.83	-0.02		-0.24
755.00	0.83	1.37	0.54	6.48	
847.00	1.44	2.40	0.96		11.52
853.00	1.63	1.66	0.03	0.36	
858.00	1.10	1.34	0.24	2.88	
1050.00	3.45	2.43	-1.02		-12.24
1147.00	1.95	2.69	0.74		8.88
1153.00	2.19	2.23	0.04		0.48
1347.00	3.95	3.82	-0.13		-1.56
641.00	1.88	2.20	0.32		3.84

AVG DEP 4.72 2.64 INCHES

90 % EXCEEDANCE

NODE	ELEV	ALT 4	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	0.26	-0.87		-10.44
443.00	1.52	0.39	-1.13		-13.56
453.00	0.20	-0.72	-0.92	-11.04	
455.00	0.05	-0.84	-0.89	-10.68	
547.00	1.32	0.26	-1.06		-12.72
550.00	1.05	-0.23	-1.28		-15.36
558.00	0.90	-0.46	-1.36	-16.32	
751.00	1.85	0.19	-1.66		-19.92
755.00	0.83	-0.30	-1.13	-13.56	
847.00	1.44	0.83	-0.61		-7.32
853.00	1.63	0.18	-1.45	-17.40	
858.00	1.10	-0.22	-1.32	-15.84	
1050.00	3.45	1.40	-2.05		-24.60
1147.00	1.95	1.67	-0.28		-3.36
1153.00	2.19	1.06	-1.13		-13.56
1347.00	3.95	2.11	-1.84		-22.08
641.00	1.88	0.63	-1.25		-15.00

EAST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 15.48 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT 0.36 INCHES 50HI= 0.14 EHI= 0.39
FOR 90% EXCEEDANCE, MIN DEPT -17.40 INCHES 90HI= 0.43
SQ MI= 116.00 EHU= 45
AVG DEP-14.14 -14.36 INCHES

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10% EXCEEDANCE

ALT 5	NODE	GRND ELEV	ALT 5	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
	244.00	1.13	2.09	0.96		11.52
	243.00	1.52	2.42	0.90		10.80
E	253.00	0.20	1.45	1.25	15.00	
E	255.00	0.05	1.39	1.34	16.08	
	547.00	1.32	2.18	0.86		10.32
	550.00	1.05	1.78	0.73		8.76
E	558.00	0.90	1.81	0.91	10.92	
	751.00	1.85	2.49	0.64		7.68
E	755.00	0.83	1.95	1.12	13.44	
	847.00	1.44	3.07	1.63		19.56
E	853.00	1.63	2.11	0.48	5.76	
E	858.00	1.10	1.92	0.82	9.84	
	1050.00	3.45	3.45	0.00		0.00
	1147.00	1.95	3.65	1.70		20.40
	1153.00	2.19	2.63	0.44		5.28
	1347.00	3.95	4.46	0.51		6.12
	641.00	1.88	2.69	0.81		9.72

50% EXCEEDANCE

NODE	ELEV	ALT 5	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	1.71	0.58		6.96
243.00	1.52	1.84	0.32		3.84
253.00	0.20	0.92	0.72	8.64	
255.00	0.05	0.89	0.84	10.08	
547.00	1.32	1.69	0.37		4.44
550.00	1.05	1.23	0.18		2.16
558.00	0.90	1.07	0.17	2.04	
751.00	1.85	1.79	-0.06		-0.72
755.00	0.83	1.33	0.50	6.00	
847.00	1.44	2.36	0.92		11.04
853.00	1.63	1.65	0.02	0.24	
858.00	1.10	1.31	0.21	2.52	
1050.00	3.45	2.38	-1.07		-12.84
1147.00	1.95	2.61	0.66		7.92
1153.00	2.19	2.10	-0.09		-1.08
1347.00	3.95	3.81	-0.14		-1.68
641.00	1.88	2.19	0.31		3.72

90 % EXCEEDANCE

NODE	ELEV	ALT 5	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	0.24	-0.89		-10.68
243.00	1.52	0.36	-1.16		-13.92
253.00	0.20	-0.54	-0.74	-8.88	
255.00	0.05	-0.45	-0.50	-6.00	
547.00	1.32	0.21	-1.11		-13.32
550.00	1.05	-0.20	-1.25		-15.00
558.00	0.90	-0.18	-1.08	-12.96	
751.00	1.85	0.47	-1.38		-16.56
755.00	0.83	0.12	-0.71	-8.52	
847.00	1.44	0.80	-0.64		-7.68
853.00	1.63	0.70	-0.93	-11.16	
858.00	1.10	-0.12	-1.22	-14.64	
1050.00	3.45	1.35	-2.10		-25.20
1147.00	1.95	1.58	-0.37		-4.44
1153.00	2.19	1.06	-1.13		-13.56
1347.00	3.95	2.11	-1.84		-22.08
641.00	1.88	0.60	-1.28		-15.36

WEST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 20.40 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT -12.84 INCHES 50HI= 0.10 WHI= 0.26
FOR 90% EXCEEDANCE, MIN DEPT -25.20 INCHES 90HI= 0.17
SQ MI = 938.00 WHU= 244
AVG DEPTHS 11.84 10.01 INCHES

ALT 5 HU= 294
AVG DEP 4.92 2.16 INCHES

EAST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 16.08 INCHES 10HI= 1.00
FOR 50% EXCEEDANCE, MIN DEPT 0.24 INCHES 50HI= 0.13 EHI= 0.41
FOR 90% EXCEEDANCE, MIN DEPT -14.64 INCHES 90HI= 0.52
SQ MI= 123.00 EHU= 50
AVG DEP-10.36 -14.35 INCHES

C-111 Marl Model Data.

10% EXCEEDANCE

ALT6/6A	NODE	GRND ELEV	ALT6/6A	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
	244.00	1.13	2.10	0.97		11.64
	443.00	1.52	2.45	0.93		11.16
E	453.00	0.20	1.41	1.21	14.52	
E	455.00	0.05	1.35	1.30	15.60	
	547.00	1.32	2.22	0.90		10.80
	550.00	1.05	1.78	0.73		8.76
E	558.00	0.90	1.90	1.00	12.00	
	751.00	1.85	2.61	0.76		9.12
E	755.00	0.83	2.27	1.44	17.28	
	847.00	1.44	3.13	1.69		20.28
E	853.00	1.63	2.37	0.74	8.88	
E	858.00	1.10	2.00	0.90	10.80	
	1050.00	3.45	3.22	-0.23		-2.76
	1142.00	1.95	3.72	1.77		21.24
	1153.00	2.19	2.57	0.38		4.56
	1347.00	3.95	4.55	0.60		7.20
	641.00	1.88	2.73	0.85		10.20

50% EXCEEDANCE

NODE	ELEV	ALT6/6A	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	1.73	0.60		7.20
443.00	1.52	1.87	0.35		4.20
453.00	0.20	0.90	0.70	8.40	
455.00	0.05	0.85	0.80	9.60	
547.00	1.32	1.71	0.39		4.68
550.00	1.05	1.24	0.19		2.28
558.00	0.90	1.15	0.25	3.00	
751.00	1.85	1.86	0.01		0.12
755.00	0.83	1.46	0.63	7.56	
847.00	1.44	2.40	0.96		11.52
853.00	1.63	1.67	0.04	0.48	
858.00	1.10	1.34	0.24	2.88	
1050.00	3.45	2.42	-1.03		-12.36
1142.00	1.95	2.68	0.73		8.76
1153.00	2.19	2.07	-0.12		-1.44
1347.00	3.95	3.77	-0.18		-2.16
641.00	1.88	2.20	0.32		3.84

90 % EXCEEDANCE

NODE	ELEV	ALT6/6A	WATER IN FEET	DEPTH-INCHES EAST	DEPTH-INCHES WEST
244.00	1.13	0.27	-0.86		-10.32
443.00	1.52	0.39	-1.13		-13.56
453.00	0.20	-0.50	-0.70	-8.40	
455.00	0.05	-0.41	-0.46	-5.52	
547.00	1.32	0.27	-1.05		-12.60
550.00	1.05	-0.17	-1.22		-14.64
558.00	0.90	-0.05	-0.95	-11.40	
751.00	1.85	0.52	-1.33		-15.96
755.00	0.83	0.17	-0.66	-7.92	
847.00	1.44	0.85	-0.59		-7.08
853.00	1.63	0.69	-0.94	-11.28	
858.00	1.10	-0.09	-1.19	-14.28	
1050.00	3.45	1.44	-2.01		-24.12
1142.00	1.95	1.66	-0.29		-3.48
1153.00	2.19	1.07	-1.12		-13.44
1347.00	3.95	2.11	-1.84		-22.08
641.00	1.88	0.62	-1.26		-15.12

WEST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 21.24 INCHES 10HI= 0.93
FOR 50% EXCEEDANCE, MIN DEPT -12.36 INCHES 50HI= 0.10 WHI= 0.27
FOR 90% EXCEEDANCE, MIN DEPT -24.12 INCHES 90HI= 0.20
SQ MI= 1027.00 WHU= 277 AVG DEPTHS 13.18 10.20 INCHES

ALT6/6A HU= 332 AVG DEP 5.32 2.42 INCHES

EAST BASIN

FOR 10% EXCEEDANCE, MAX DEPT 17.28 INCHES 10HI= 1.00 EHI= 0.43
FOR 50% EXCEEDANCE, MIN DEPT 0.48 INCHES 50HI= 0.33
FOR 90% EXCEEDANCE MIN DEPT -14.28 INCHES 90HI= 0.53
SQ MI= 128.00 EHU= 55

AVG DEP -9.80 -13.85 INCHES

ANNEX H

CONCEPT OF ENVIRONMENTAL MONITORING CENTRAL AND SOUTHERN FLORIDA PROJECT

C-111

CONCEPT OF ENVIRONMENTAL MONITORING CENTRAL AND SOUTHERN FLORIDA PROJECT

C-111

The foundation for project monitoring was laid in 1992 as part of environmental planning. A cooperative effort between the ENP, the USFWS, and the USACE produced a plan of studies for projecting the impacts of C-111 alternative plans. The plan of studies called for comparison of the projected impacts of considered alternatives in relation to historical (natural) and existing (base) hydrological conditions. Impacts on the principal vegetative communities are assessed using a "natural systems" hydrological model that is validated with soils and historical water stage information. Species and natural community responses to historical, base, and alternative hydrological conditions are assessed with input from acknowledged experts.

Study protocols will be refined during the detailed design phase to produce a detailed ecological monitoring plan. The plan will be an interagency product, involving Department of the Interior agencies, the National Oceanic and Atmospheric Administration (NOAA), the State of Florida, the U.S. Army Corps of Engineers, and the South Florida Water Management District. Opinions of experts on various ecosystem components (species, plant and animal ecology) will be sought. The monitoring plan will be implemented, beginning in the detailed design phase and continued through construction. It is expected that the monitoring program will be continued after construction and during project operations under the leadership of ENP and/or SFWMD. A conceptual outline of the management plan appears below.

A CONCEPTUAL MONITORING PLAN OUTLINE C-111--TAYLOR SLOUGH PROJECT

<u>Assumption:</u> The C-111--Taylor Slough area will be a managed system, with water supplied in quantities, frequencies, and durations to be agreed upon by the appropriate agencies in compliance with existing laws and directives and in consideration of all affected parties.

<u>Project Goal:</u> The project goals are: (a) restoration of the historical hydropatterns of the Taylor Slough, C-111 basin, eastern Florida Bay and Barnes Sound estuaries, functioning in response to the adjacent, upstream, long-hydroperiod, Shark Slough system; and (b) selection of a modified system based on a water supply regime necessitated by consideration of requirements of the greater, Central and Southern Florida Project for Flood Control and Other Purposes. The C&SF Project is under restudy, and the results and recommendations from that study are expected to affect the C-111--Taylor Slough system.

Study Objectives: Detect ecological and hydrological responses to actual project operations including establishment of pre-operations baselines. Enable measurement of attainment of Project Goal. Permit formulation of remedial measures as necessary.

Study Team: Representatives of the Department of the Interior agencies, the National Oceanic and Atmospheric Administration (NOAA), the State of Florida, the U.S. Army Corps of Engineers, the South Florida Water Management District and other interested agencies.

Period of Study: Upon approval of this GRR-EIS and until the end of the construction period, or 8 years.

Cost: Estimated cost for monitoring is $8,000,000.

Data Storage and Retrieval: Data will be stored and retrieved with an HEC-DSS or similar data retrieval system and displayed by means of a Geographic Information System.

Study Elements:

STUDY AREA - Taylor Slough and headwaters to (include) Shark Slough
Coastal sloughs, mangroves
Barnes Sound, Manatee Bay
Florida Bay nearshore (define) between Highway 1 and Central Florida Bay
Affected area west of C-111 and L-31N

WATER
Supply - Annual hydroperiods, depths, timing, interannual hydropatterns
Quality - nutrients, salinity, pesticides

SYSTEM LINKAGE
Shark River Slough, Florida Bay, Water Conservation Areas

SPECIES/COMMUNITIES
Plant communities; indigenous dominant, native and exotic invaders, periphyton. Sampling regimen will reveal trends in species dominance and productivity in response to project operation hydrology.

Invertebrates; crustaceans (macro-, micro-), insects (forage, pollinators, weed control), other (annelids). Sampling will be designed to reveal responses to project operation hydrology of organisms that function as fish-food, pollinators, and plant control .

Fishes. Species and productivity responses to hydrology.

Amphibians/Reptiles. Species that are significant biomass producers used as food by wading birds will be sampled to reveal biomass response to hydrology. American alligator function and significance as habitat modifier will be assessed in relation to hydrology.

Wading Bird Species or Guilds. Sampling will indicate reproductive success in relation to project-induced hydrology. Some species may be grouped in guilds.

Endangered or threatened (include prey). Impact of project-induced hydrology on listed species will be assessed. (Wood Stork, Snail Kite, Cape Sable Sparrow, American Crocodile, etc.) American crocodile reproductive success in relation to hydrology.

Procedures: Monitoring station establishment will accommodate standard methods of sampling and statistical analysis. Insofar as the aforestated criterion will permit, stations for each study element will be located in proximity to stations for other elements, with separations to ensure no disturbance from other element sampling. Sampling station locations will be recorded in a Geographical Information System (GIS), as will sampling data from each study element. Sampling will represent each identified sub-area in the study area. Data will be transformed into information that can be entered in the GIS, permitting retrieval and comparison of study element information, e.g., biological responses to hydrology; predator response to food patchiness or concentration; comparison among food chain echelons. Wildlife and Plant community monitoring protocols will be developed by interagency teams.

ANNEX I

C-111

C-111 DRAFT REPORT RECIPIENTS

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C-111
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