HYDROLOGIC RESTORATION OF SOUTHERN GOLDEN GATE ESTATES CONCEPTUAL PLAN

FINAL REPORT
February 1996

Big Cypress Basin
South Florida Water Management District
Naples, Florida

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by
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Big Cypress Basin Board
South Florida Water Management District
Naples, Florida

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EXECUTIVE SUMMARY

The Southern Golden Gate Estates (SGGE) study area encompasses an approximately 94 square-mile area of sensitive environmental landscape in southwestern Collier County, south of Interstate 75 (I-75) between the Fakahatchee Strand and Belle Meade watersheds. It is an important surface storage and aquifer recharge area with a unique ecology of cypress, wet prairie, pine and hardwood hammock and swamp communities. It also includes three major flowways that contribute freshwater input to the Ten Thousand Island Estuary. Construction of road and drainage modifications in the 1960's and 1970's have overdrained the area resulting in reduction of aquifer storage, increased freshwater shock load discharges to the estuaries, invasion of upland vegetation and increased frequency of forest fires.

Concern over the gradual degradation of environmental quality and water supply potential of the region prompted the State of Florida to include the area as a component of the Save Our Everglades (SOE) program in 1985. Subsequently, the project was included in the State's Conservation and Recreation Lands (CARL) Acquisition program initiative for acquiring the entire project area under public ownership. In 1992 the Governor of Florida requested the South Florida Water Management District (SFWMD) to develop a conceptual hydrologic restoration plan for the SGGE to enhance the environmental value and water resources of the region. This study was initiated at this request to develop a detailed hydrologic restoration plan with the primary objectives of reducing overdrainage and restoring historic sheetflow patterns while maintaining the existing levels of flood protection for areas north of the project.

The Faka Union Canal Watershed that includes the SGGE and part of the Northern Golden

Gate Estates (NGGE), drains an approximately 189 square-mile area through a network of 70 miles of four primary canals namely, the Miller, Faka Union, Merritt and Prairie Canals. The water levels in these canals are controlled by 12 water control structures. The topography is characterized by low relief and poorly defined drainage patterns with ground elevations ranging from 24 feet NGVD in the headwaters to 2 feet NGVD near the outlet of the basin. Presently approximately 185,000 acre-feet of freshwater is discharged annually from the Faka Union Canal to the Faka Union Bay estuary as point source flow.

A continuous process hydrologic-hydraulic simulation model of the watershed was developed using the United States Environmental Protection Agency's (EPA) watershed modeling program Hydrologic Simulation Program-Fortran (HSPF) to quantify the rainfall-runoff patterns and soil storage components of the watershed. The model was calibrated at six locations in the basin. The watershed characteristics were simulated for a continuous 23-year period at a daily time step under existing and restoration plan development conditions.

Assessment of the simulated existing condition of the watershed indicates that the canals largely control the overall hydrology of the watershed discharging approximately 18 inches of runoff annually to the Faka Union Bay. The canals also intercept shallow groundwater outflow, and have continually lowered the water table. The generalized surficial groundwater flow directions vary seasonally. During the wet season when the groundwater levels are high, the flow patterns into the Faka Union Canal are in a south to southwesterly direction. As the dry season progresses, the groundwater movement shifts to an east-west direction, draining directly into one of the north-south canals. Construction of the canals has not only increased surface runoff, but has also increased the rate of groundwater outflow, causing seasonal groundwater outflow peaks that were not present before the canals were excavated.

Five alternative configurations of structural measures were developed and their performances at meeting the objectives of the project were evaluated by the simulation model. The alternative measures evaluated ranged from partial/incremental restoration to full scale approach with spreader channels, swale and road removal, placement of canal blocks, and flood control pumpage from areas north of I-75. Alternative 3C with structural components of 2.4 miles of spreader channels, 83 canal plugs in four canals, partial removal and leveling of 130 miles of road and tramways, and installation of three pump stations with a total capacity of 890 Horsepower and combined discharge capacity of 860 cfs, emergency backup generators and two portable pumps was found to be the optimum configuration of the recommended plan to achieve the desired objectives of the project. In addition to implementing the structural/nonstructural elements of Alternative 3C, other recommendations include: maintenance of a travel corridor through the project area connecting Everglades Boulevard and Jane's Scenic Drive along the Faka Union Canal for fire management by the Division of Forestry and for recreational public access; collection of additional streamflow data on the Miller, Faka Union and Merritt Canals at I-75; continuation and enhancement of the existing groundwater monitoring program in SGGE; determination of quantitative and qualitative success criteria for the project; maintenance of optimal stages in the flowways; implementation of the restoration with an interdisciplinary approach; use of a gradual and phased strategy for restoration implementation; and inclusion of the impacted areas outside of the project area into a CARL project boundary, either the Belle Meade or Save Our Everglades boundary. The estimated first cost of implementing the plan is $11,652,769 in 1995 dollars. A breakdown of the costs of the specific elements of the plan is shown below.

PLAN C COSTS

A.	Spreader Channels	$ 1,092,371
B.	Canal Plugs	3,594,454
C.	Road and Tram Removal	3,365,778
D.	Pump Stations	2,060,240
E.	Other Site Work	20,000
F.	Contingency	1,519,926
	Total	$11,652,769

Part of the funding for the initial cost of the project may be absorbed by the in-kind services of the Florida Division of Forestry (FDOF) who currently manages the public lands within SGGE. Using FDOF's staff and equipment for the road and tram removal would reduce the first cost by $3,365,778. Stockpiling the fill at the plug locations would eliminate hauling costs and reduce the cost further by $905,700. The funding required for the remainder of the project is $7,381,291.

The implementation of this plan would result in restoration of the hydrology of 113 square miles, including parts of Fakahatchee Strand, to near pre-development (pre-1960's) conditions. The increased water storage (surface and groundwater) would cause increased evaporation and recharge, which would result in an overall reduction of six inches of annual runoff basin wide. Freshwater point flow discharges of the Faka Union Canal will be reduced from an annual average of 260 cfs to 2 cfs and will be replaced by distributed runoff along a six-mile wide front through U.S. 41 bridges. Average annual groundwater levels will be one foot higher over existing conditions and will provide for additional groundwater storage amounting to 25 billion gallons. Hydroperiod criteria for the upland vegetation would not be exceeded.

A small area, approximately 1.1 square miles, of privately owned land in eastern Belle Meade, not currently within the Belle Meade CARL project boundary, intercepts a prominent and well-defined flowway that would be rehydrated with the implementation of this plan. From a water management perspective, the optimal solution will be to include this area within the Belle Meade or Save Our Everglades CARL project boundary so that the restoration of SGGE can be implemented.

After nearly two decades of efforts by numerous organizations and individuals to devise a hydrologic restoration plan for SGGE, land acquisition is underway to implement the restoration measures for protecting the future water supplies and environmental resources of the region. Acquisition of the entire project land under public ownership is the key element of the SGGE restoration plan. It is further recommended that the State of Florida's ongoing CARL acquisition efforts be accelerated, and the Big Cypress Basin Board continue its support for funding the Florida Department of Environmental Protection (FDEP) land acquisition personnel services so that implementation of the hydrologic restoration efforts can be commenced in the very near future.

1. INTRODUCTION

1-1. PROJECT BACKGROUND

The SGGE portion of the Save Our Everglades CARL project encompasses an area of approximately 94 square miles located in southwestern Collier County, south of I-75 (see Figure 1). It is an important area for future surface storage and aquifer recharge which serves as the headwaters of the central portion of the Ten Thousand Islands Estuary, part of the western Everglades. Construction of road and drainage modifications in the 1960's and 1970's have overdrained the area, allowing invasion of upland vegetation, wildfires, reduced aquifer storage, increased threat of salt water intrusion and frequent freshwater shock loads to the estuary.

The project area was identified in 1985 as a component of the Governor of Florida's Save Our Everglades program. Various studies have been conducted in the past to assess the feasibility of modifying the existing water control works to reduce and reverse the environmental and water resource impacts created by past overdrainage activities. The most recent of these is the U.S. Army Corps of Engineers (COE) Feasibility study, completed in May 1986, in which the COE performed a preliminary analysis of three conceptual plans. The COE study concluded that there is no basis for Federal involvement in modifications of the existing water control system and that the report provides conceptual information which could be used by State and local interests in determining long term solutions to local water management and related resource management problems in the basin.

Subsequent to the COE study a "Committee on the Restoration of Golden Gate Estates" (CRGGE) was established in 1987 by the Kissimmee River-Lake Okeechobee-Everglades Coordinating Council to keep the restoration of SGGE on the agenda of the State's important environmental projects. The committee recommended accelerated acquisition of the lands of SGGE

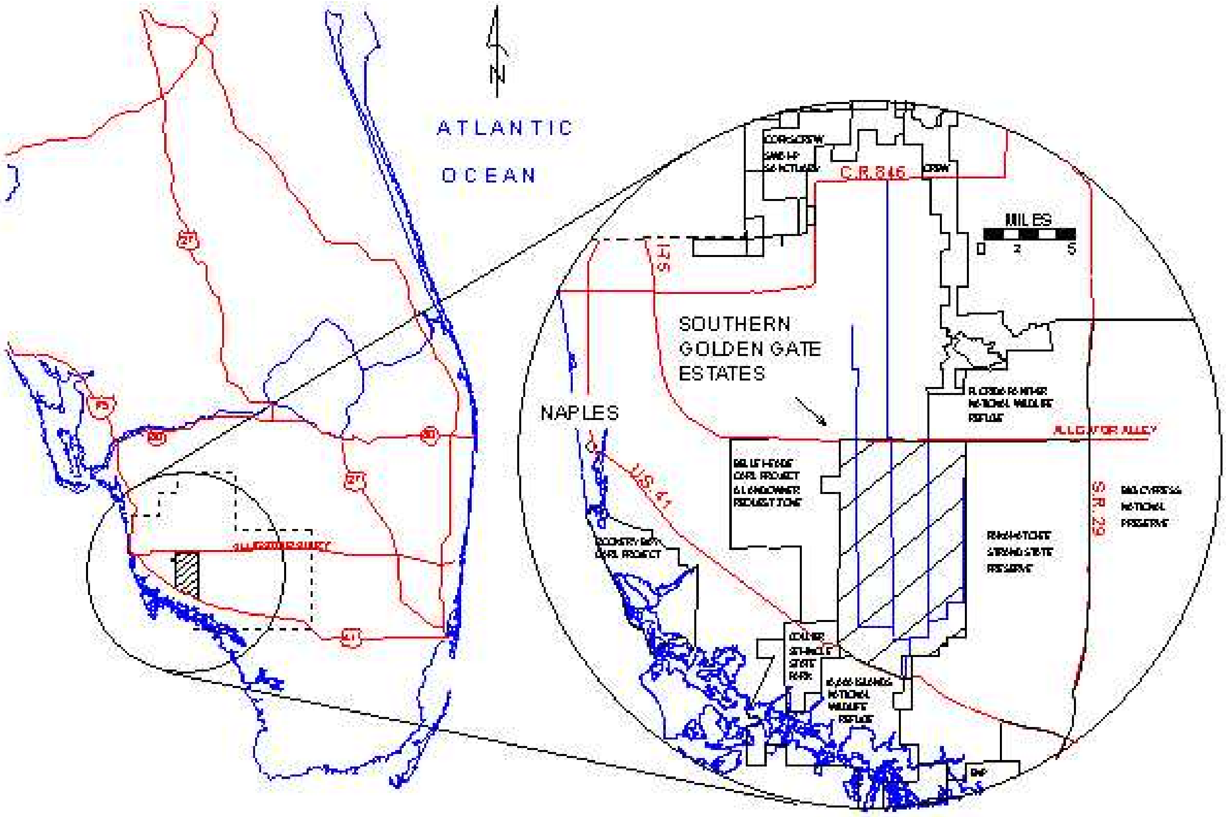


Figure 1. The Study Area

in the State's CARL acquisition program. Under the auspices of the CARL program initiative, the Florida Department of Environmental Protection (formerly Florida Department of Natural Resources) is purchasing land in the project area for conservation and restoration. As of September 30, 1995, 16,697 acres of land in 6,737 parcels have been acquired by the State. The CRGGE also recommended further evaluation of the COE plan to develop an implementable physical restoration program. In 1992 Governor Chiles requested that the District develop a conceptual hydrologic restoration plan.

This project will provide a working plan to accomplish these objectives for the entire SGGE area. In particular, restoration alternative plans will be based on a continuous process, long term simulation of the hydrologic-hydraulic features of the watershed that had not been represented in earlier studies.

1-2. HISTORICAL DEVELOPMENT OF GOLDEN GATE ESTATES

The Faka Union Canal system was excavated by the Gulf American Corporation (GAC) as part of a real estate development project called Golden Gate Estates (GGE). The extensive canal and roadway system was designed to allow year-round occupation of land that was once seasonally flooded for several months each year (COE study, 1986). Construction of the southern canal system was begun in 1968 and completed by mid 1971. Since that time, the ecological balance that existed for hundreds of years has been severely altered and in some places the existing landscape does not resemble the historic conditions at all. Construction of the canals has led to both increased volumes and rates of runoff from the watershed which has had lasting effects on the area's water supply, vegetation, wildlife, and coastal estuaries.

The canals intercept large volumes of surface and subsurface flow and quickly divert them to the Faka Union Bay and the Ten Thousand Island Estuary of the Gulf of Mexico resulting in less surface water available for storage. Since groundwater recharge is achieved primarily through infiltration from surface detention storage, reduced groundwater recharge threatens both groundwater supply for the region and the natural barrier to salt water intrusion. Continued overdrainage has caused an eventual lowering of the groundwater table. This has caused vegetation to change from wetland dominant to transitional and upland systems with invasive exotic species. The extreme dry conditions caused by overdrainage have resulted in more frequent and more intense wildfires with a greater destructive impact on vegetation.

The increased runoff rate has had severe effects on the receiving estuaries. Historically, the estuaries would receive broad, slow moving sheets of water that were capable of carrying essential nutrients but not high sediment loads. This has been replaced with point loads of freshwater at the Faka Union Canal outlet that push salinity levels down and result in freshwater discharge shocks throughout the Ten Thousand Island Estuary. The increased runoff rate drains the area quickly and does not allow the hydroperiods necessary to sustain wetland vegetation. A study by Carter et al., 1973, indicated that approximately a one-foot drop in the water table reduces cypress productivity by 40 percent.

1-3. PRIOR STUDIES AND REPORTS

A number of studies have been conducted over the past 20 years regarding the Golden Gate Estates Development and canal network. These studies have been reviewed and were referred to periodically as the project progressed for hydrological, biological and ecological information of the study area. All of these studies assumed some limited development in SGGE. The studies and their summaries are described below.

One of the first studies conducted was "A Hydrologic Study of the GAC Canal Network" (1974) by Black, Crow and Eidsness, Inc. for the Board of Collier County Commissioners. This study pointed out hydraulic deficiencies with the GAC canal network including how it has altered surface flow patterns and yet is unable to convey even a 10-year flood. The study recommended improvements in the system with ways to lessen the environmental impacts of the canals but did not address wetland restoration issues to predevelopment conditions. The study did provide valuable information regarding the hydrology of the GGE and hydraulics of the canals.

Because most of GGE is owned privately, any significant change in its land use or hydrology would affect privately owned land. To address this legal issue the Golden Gate Estates Study Committee (GGESC), appointed by the Board of County Commissioners in 1975, hired Mr. Frank E. Maloney, Dean Emeritus and Professor of Law of the University of Florida to examine the legal issues associated with altering the water management system in GGE. In his "Report On Water Resources Problems of Western Collier County," (1975) Mr. Maloney concluded that

> **"There is sufficient legal authority available either at the County, Water Management District, State or Federal levels to make it possible to stabilize water run-off in the Golden Gate Estates area and to control, reduce or hopefully eliminate the substantial waste of fresh water resources of Collier County, while at the same time reducing or eliminating the effects of salt water intrusion which have resulted from the unnecessary lowering of ground water elevations. Such stabilization would also result in reducing the siltation effects of the pulse discharges of large quantities of water from the GAC Canals."**

Based on Mr. Maloney's legal opinion, the GGESC proceeded with developing a restoration plan for SGGE. The GGESC released the "Golden Gate Estates Redevelopment Study" (1977) which is essentially made up of Dean Maloney's first report and one other. The second report called "An Ecological and Hydrological Assessment of the Golden Gate Estates Drainage Basin, with Recommendations for Future Land Use and Water Management Strategies," was written by Tropical BioIndustries, and contains geographical, hydrological and biological information regarding the study area, some of which had been supplemented by more recent information. This study recommended a land use strategy for creating flowways that resemble the historic flow pattern and creating conservation areas (mostly in the southern portion of GGE) where urban development would not be allowed. This plan was further evaluated by the COE.

It was soon realized by the GGESC that a proper permanent solution may take many years to implement because it would affect thousands of parcels of privately owned land and the major changes to the roads and canals would be very costly. An interim plan was developed by consulting engineers CH2M Hill called "Proposed Interim Modifications, Golden Gate Estates Canal System" (1978) for the Board of County Commissioners. This plan called for raising the crest elevations of several weirs by flashboards that would allow maintenance of canal water elevations at any desired level between existing elevations and ground level. It also recommended installing four earthen plugs to separate the Golden Gate Canal drainage basin from the Faka Union Canal drainage basin and thereby reduce runoff into the Naples Bay. The plugs would also reduce runoff into Faka Union Bay by diverting runoff to neighboring Fakahatchee Strand. All of the weir modifications outlined in the plan except the earthen plugs have been implemented. The potential legal issues of this plan were addressed in a report called "Legal Ramifications of Implementation of the Interim Action Program in Golden Gate Estates, Collier County, Florida" (1979) by Dean Frank Maloney.

"Canal Discharge Impacts of Faka Union Bay" by John Wang and Joan Browder evaluated the effects of the canal discharge on the Faka Union Bay's salinity using data analysis and numerical modeling. They concluded that the three inputs to the Bay (groundwater seepage, canal discharge and rainfall) have a high interrelation and depending on the location in the Bay, all three may be significant factors for determining salinities. They also concluded that groundwater levels may better represent actual discharge rates than the recorded canal discharges.

In the report "Impacts of Surface Drainage on Groundwater Hydraulics" (Flora C. Wang, Allen R. Overman, 1981), the authors quantified the difference of surface and subsurface runoff before and after the construction of the canals. They concluded the canals have increased surface runoff by approximately 50 percent and caused a drawdown of the water table of approximately two feet at a distance of one mile from the canal.

In a report called "Impacts of Drainage Canals on Surface and Subsurface Hydrology of Adjacent Areas in South Florida" (1977), Flora C. Wang used a water balance model to show monthly balances of precipitation, evapotranspiration, soil moisture and runoff. The report quantified the effects of the canal systems on the shallow aquifer and summarized this in a table showing estimated water table drawdown and its corresponding distance away from the canal.

A report by Environmental Science and Engineering, Inc. called "Golden Gate Estates Groundwater and Septic Tank Investigation" (1979) summarized the results from soil and water quality samples withdrawn from 130 sites in Golden Gate Estates. This report contains a map of the major lithologic unit profiles in the study area.

"A Report on Acceptance and Flooding Golden Gate Estates" (1977) by Stanley W. Hole and Associates identified several roads and canals to be accepted by Collier County and various canals were inspected and a general assessment of the flood conditions within the Estates were provided. This report provided some short term (1-2 months) data observations.

Engineering consultants Connell, Metcalf & Eddy published a report called "A Hydraulic

Study of the South Golden Gate Estates Canal Network, Collier County, FL" (1978). This hydrologic and hydraulic study used the Soil Conservation Service (SCS) method of determining runoff for the lower portion of the Estates and an event-based model (10-year, 5-day storm event). This report provides some information regarding soil type in the study area, however, more detailed soil information is currently available.

The most recent report, done by the COE called "Golden Gate Estates Feasibility Report" (1986), evaluated three alternatives for modifying the canal network. This report was used as a primary reference in the present study and the third restoration alternative presented in the report, which originated from the GGESC, was used as a primary reference for developing alternative restoration scenarios. The COE Feasibility Report used an event-based model to predict flood hydrographs and the extent of floodplains. The report from the COE was preceded by a Reconnaissance Report in 1980.

Another study used as data source includes "The Big Cypress National Preserve" (Michael J. Duever et al., 1986) which provides valuable information about the regional wetland ecosystems and, in particular, hydroperiod regimes of wetlands.

1-4. INTERAGENCY COORDINATION

This study has been conducted primarily by the Big Cypress Basin of the South Florida Water Management District. Active participation by numerous public agencies, private groups and non-profit environmental organizations provided valuable assistance throughout the development of this restoration plan. The project was instituted under the directive of the Governor’s office as a part of the Save Our Everglades Program initiative. The Florida Department of Community Affairs

(DCA) in cooperation with the U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) provided partial funding for the project through a grant under the auspices of the Florida Coastal Zone Management Program.

The FDEP conducted a parallel study for development of a watershed management plan for the Rookery Bay National Estuarine Research Reserve and the Ten Thousand Islands Aquatic Preserve. Efforts of that study were continuously coordinated with this project, particularly in identification of historic flowways and for development of structural alternatives. The Collier County Stormwater Management Department which operated the canals and water control structures in the SGGE area before those were adopted by the Big Cypress Basin, contributed significantly by providing data on water levels and operation logs of the water control structures for the earlier periods. Considerable efforts were also coordinated with the State Park Service personnel of the Fakahatchee Strand State Preserve. The preserve is the closest neighbor of the SGGE project area, and hydrologic restoration of SGGE would prove beneficial to the overall management of the flora and fauna of the preserve.

The Florida Division of Forestry (FDOF) provided sufficient input in identifying the restoration measures specific to the management of recreational forestry in the SGGE area. Considerable support in all phases of the project development were also received from various departments of the SFWMD.

2. PROBLEM IDENTIFICATION

2-1. PLANNING ISSUES

The rapid growth of southwest Florida and Collier County in particular, during the past two decades with increased population and accompanying urban development has stimulated significant concerns regarding the water and environmental resources of the region. A myriad of issues relating to water supply, flood protection, water quality and natural ecosystems have emerged from poorly planned urban developments in sensitive environmental settings like SGGE. The documented evidences that several hundred miles of bulldozed limerock roads and dredged canals have adversely impacted five major hardwood strands, two primary freshwater aquifers, three major hydrologic flowways and numerous habitats speak of the problems brought forth by the development of SGGE. A summary of the issues pertinent to water supply, natural ecosystems, flood control, and water quality specific to this project is presented below.

2-1.1 Water Supply

The major freshwater aquifers underlying the SGGE region are the Water Table, Lower Tamiami and Sandstone Aquifers. The Water Table and Lower Tamiami Aquifers are the primary sources of water supply and occur within the Surficial Aquifer system. The Sandstone Aquifer, a part of the intermediate aquifer system is separated from the surficial system by low permeability sediments, and is only present on the northern part of the watershed. The primary sources of recharge to the surficial aquifer system is rainfall. Downward movement of water through the leaky confining beds underlying the water table recharges the Lower Tamiami Aquifer. Since most of the SGGE canals are located in areas where the limestone of the shallow aquifer is within ten feet of the land surface, there is a direct hydraulic connection between the canal system and the upper portions of the Surficial Aquifer. Thus, rapid rate of runoff provided by the canals is a prime cause of depletion of groundwater storage. The overdrainage by canals have caused general drawdown of approximately two feet, at a distance of one mile from the canals in the Faka Union Canal watershed (Wang and Overman, 1981).

The City of Naples Eastern Golden Gate Wellfield is located along the Faka Union Canal between weirs Faka Union No. 4 and Faka Union No. 5. With a maximum daily allocation of 21.0 million gallons per day, this wellfield provides the lion's share of the potable water for the City and its unincorporated service area. Recharge from the canal does influence the yield of the wellfield. Protection of the long term sustained yield of this wellfield is one of the primary water supply related issues for the restoration of SGGE.

2-1.2 Flood Control

Continued maintenance, and possibly enhancement of the existing level of service for flood control provided by the Golden Gate and Faka Union Canal system is of prime concern to the residents of GGE. In spite of a very aggressive canal maintenance program undertaken by the Big Cypress Basin, the rapid urban growth and subsequent encroachment into the low-lying natural storage areas have resulted in occasional flooding in historic lowlands in some locations in NGGE. The desired stormwater management level of service identified for the Estates area by Collier County is protection against a 10-year recurrence interval flood, while for the urban corridor (areas west of a line one mile east of CR 951) is for a 25-year flood.

This plan addresses the concerns that hydrologic restoration of SGGE involving modification of the existing canals and water control structures may imperil flood control of the rapidly urbanizing NGGE area. This SGGE restoration plan incorporates appropriate means of maintaining, and where practical, enhancing the flood control functions of the NGGE.

2-1.3 Natural Ecosystems Management

A unique combination of ecosystem dominates the landscape of SGGE with a vast extent of wet prairies, pine and cabbage palm flatwoods, hardwood hammocks and tidal marshes. The sloughs, strands and wet prairies carry the freshwater surface flow to the Ten Thousand Island Estuaries, one of the largest mangrove systems in Florida. As explained elsewhere in this report, the large scale development of SGGE has played an effective role in overdraining the pristine forested and emergent wetlands, and degraded the productivity of the wetland system due to shortened hydroperiods. In addition, invasion of exotic plants like melaleuca and Brazilian pepper is beginning to pose problems to the native ecosystem and habitat. Since the hydrology of an area is the basis for structuring the type of plant and animal community that will exist, changes to the hydrology can cause a reorganization of the plant and animal community structure. For SGGE, the protection and management of the sensitive environmental resources is to be achieved by public acquisition and restoration of the affected lands as outlined in numerous plans proposed over a two-decade period. Statutory changes to the Areas of Critical State Concern Program in 1993 proposed designating certain areas of Collier County as the Big Cypress Areas of Critical State Concern, and recommended: "The acquisition of Save Our Everglades CARL projects needs to be completed. The SFWMD's Big Cypress Basin Board should continue to provide funding to FDEP for staff dedicated to the acquisition of the Southern Golden Gate Estates portion of the Save Our Everglades project. The Land Selection Advisory Council should elevate the priority rankings of these projects to demonstrate the importance of these projects to the protection of the natural resources within the Big Cypress Area of Critical State Concern. The Board of Trustees should support the FDEP in using eminent domain to acquire these two CARL projects if voluntary negotiations are not successful." (District Water Management Plan; South Florida Water Management District, 1995)

2-1.4 Water Quality

Good quality of water is essential to all forms of life. In so far as the physical and chemical conditions of surface waters in the Class III freshwater bodies (recreation, fish and wildlife propagation) of the SGGE area are concerned, they generally meet the acceptable state standards. The quality of groundwater is also within the FDEP's drinking water standard for potable supply. However, at issues are the quality and routing of the receiving waters of the Faka Union Bay and the Ten Thousand Islands, where enormous volumes of freshwater outflow from the Faka Union Canal System create abnormal salinity levels throughout the year.

The discharge from the Faka Union Canal varies seasonally with a large amplitude. This results in large fluctuations in the salinity levels and current patterns with enormous shocks to the aquatic biota of the Faka Union Bay, and often, too little freshwater input to the surrounding saline areas. The rapid decline in the salinity to near freshwater conditions have caused prolonged salinity stresses and has eliminated or displaced a high proportion of the benthic, midwater and fish plankton communities from the Bay. Such suppressed plankton development have resulted in very low relative abundance of midwater fish and also considerable drop in shellfish harvest levels. Seagrass meadows are no longer a prevalent habitat type in the Bay. Instead, bare sandy mud and algal areas predominate. The impact on commercial and recreational fisheries have been very significant.

2-2. PROJECT GOALS AND OBJECTIVES

The present study is instituted to develop a detailed hydrologic restoration plan of SGGE that would achieve the following objectives:

a. Wetland hydroperiod restoration (pre-Golden Gate Estates development)

b. Surface water sheetflow restoration

c. Replacement of concentrated shock load discharges to estuaries with distributed sheetflow

d. Improved water supply storage and aquifer recharge

e. Enhanced surface water deliveries to the adjacent Fakahatchee Strand State Preserve

f. Reduction of overdrainage of Fakahatchee Strand

g. Reduction of overdrainage of the adjacent Florida Panther National Wildlife Refuge

h. Maintenance of existing flood protection for areas north of I-75

2-3. SUMMARY OF EXISTING CONDITIONS

2-3.1 Meteorology

Typical of humid subtropical regions, the SGGE area undergoes about a 7-month dry season and a 5-month wet season. The average annual temperature is about 75 degrees, with record extremes ranging from 105 degrees in summer to 25 degrees in winter. Annual rainfall averages for nearby Naples average 53 inches and within Collier County annual rainfall has varied from a low of 30 inches to a high of 105 inches. During the wet season (May through October), nearly 80 percent of the annual rainfall occurs. Much of the rainfall is returned to the atmosphere by evaporation from soil and free water surfaces, and transpiration through plants. Under natural conditions the combined process of evapotranspiration accounts for an approximate loss of 45 inches of water per year. Thus only about eight inches of average annual precipitation is available for surface runoff and groundwater recharge.

2-3.2 Surface Water Hydrology

The Faka Union Canal watershed, including SGGE and part of NGGE, historically encompassed an area of approximately 234 square miles (Black, Crow, and Eidsness, Inc. study, 1974). However, the extent of the historic drainage area has been reduced due to construction of roads, canals and urban and agricultural development. The existing Faka Union Canal watershed is approximately 189 square miles containing approximately 70 miles of canals with 12 weir structures, and the majority of the watershed includes a grid-like system of roads spaced every quarter mile. The topography of the basin is characterized by low relief and poorly defined drainage patterns. Elevations range from 24 feet NGVD in the extreme north end with a gradual slope in the central and southern part to elevations of 2 feet NGVD near the outlet of the basin some 28 miles to the south. Over the basin, the water flows in a general southwest direction.

Historically, the general water movement can be characterized by slow, overland sheetflow a few inches to a few feet deep and several miles wide. Much of the drainage is concentrated in slightly lower sloughs and strands. Figure 2 shows the location of the existing Faka Union Canal watershed and the approximate location of the surface drainage divide prior to the construction of the Golden Gate Estates canal system. Since the construction of the canals, the surface flow patterns have been changed and the roads and canals largely control the subbasin boundaries.

Prior to development, the Faka Union Canal watershed was characterized by flat, swamp lands containing cypress trees, islands of pine forests, and wet and dry prairie. Much of the area was regularly inundated by several feet of water during the wet season (COE study, 1986). During the wet season, overland runoff would be stored in depressional areas and the peak flows would be attenuated and a longer hydroperiod would be maintained well into the dry season.

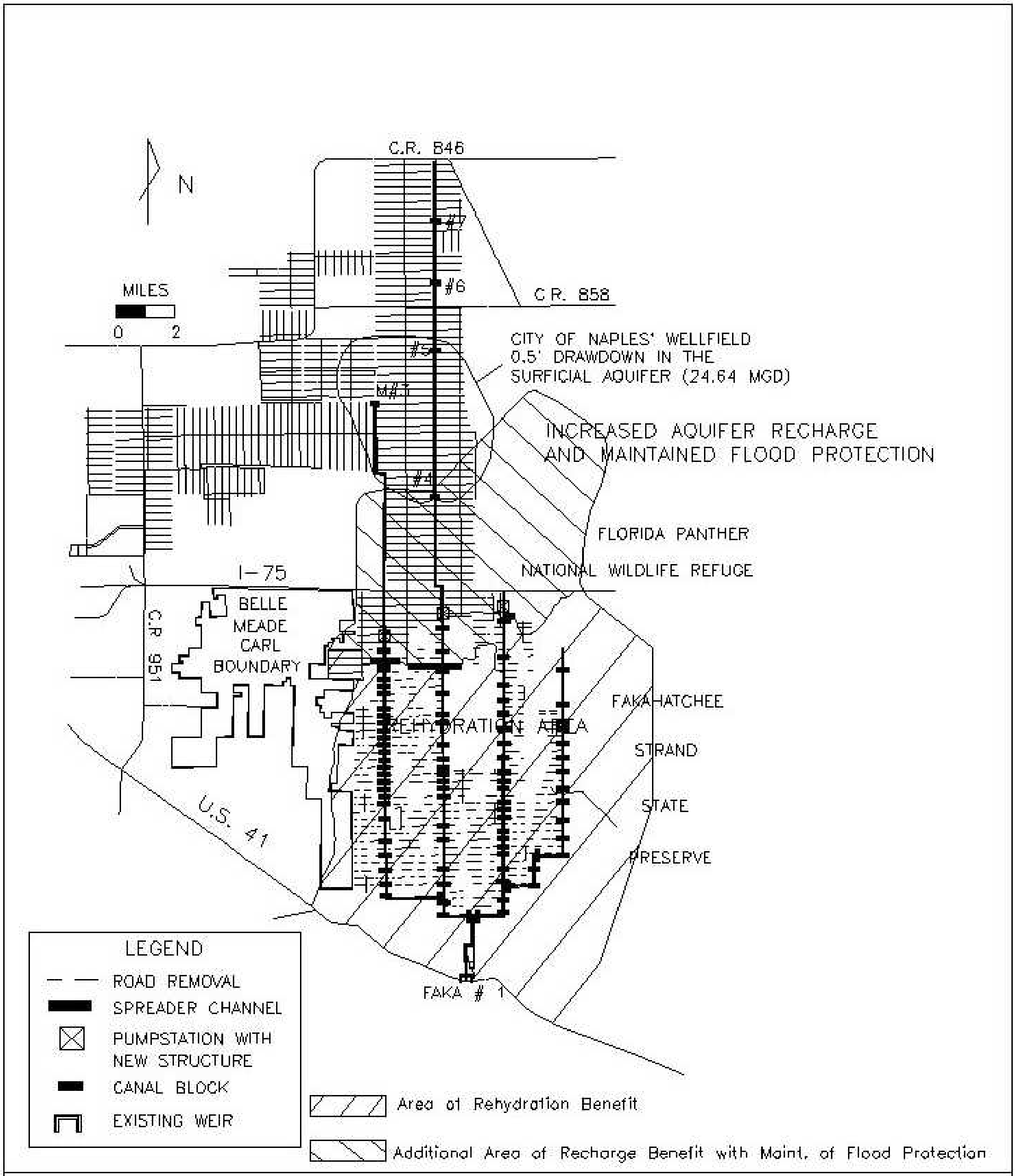


FIGURE 2 Area of Rehydration in Recommended Plan

The storage within these wetlands is a part of the hydrology of the watershed. Subsurface flow, groundwater recharge and evapotranspiration are major components in the hydrologic cycle. As the wet season ends and throughout the dry season, water stored in depressions is slowly depleted as it recharges the shallow Water Table Aquifer and is used by vegetation in the evapotranspiration process. This reduces the amount of surface runoff. It has been estimated that, of the 50+ inches of rain received in western Collier County, historical natural runoff is on the order of 0 to 10 inches annually (Runoff in Florida, 1966). The Black, Crow, and Eidsness study estimated that, after construction of the canals, annual runoff for the Faka Union watershed has increased to about 17 inches.

2-3.3 Groundwater

The groundwater in western Collier County is composed of three major aquifer systems, namely the Surficial Aquifer system, the Intermediate Aquifer system and the Floridan Aquifer system. The Surficial Aquifer system, which is the most important in terms of public water supply, contains the Water Table Aquifer and the Lower Tamiami Aquifer. The Intermediate Aquifer system, whose primary aquifers are the Sandstone and the Mid-Hawthorn, is not extensively used. The Floridan Aquifer system, consisting of the Lower Hawthorn and Suwannee formations, is yet to be explored for adequate hydrogeologic evaluation. In Collier County, the Water Table Aquifer is generally flat and follows the topography of the land, however local water table flow patterns are influenced by water levels within the drainage canals (COE study, 1986).

Since the Water Table Aquifer is open to the land surface, it responds very quickly to changes in monthly rainfall, and direct infiltration from rainfall is the main source of recharge. Other sources of recharge are inflow from surface water bodies, such as canals, subsurface flow from adjacent areas and upward seepage from semi-confined aquifers. Generally, recharge from the lakes and canals is minimal; however, this recharge does occur after rainfall events when the canal levels immediately upstream from the weirs are higher than adjacent groundwater levels (COE study, 1986).

2-3.4 Soils

Most of the soils in SGGE are characterized as moderately well to poorly drained and are often subject to prolonged flooding. Vegetation is shaped by soil type, topography, water or hydroperiod, fire and geology. Because of the strong correlation between soil type and vegetation, observation of soil types in SGGE provides information about predevelopment natural flowways and land cover. Duever et al. (The Big Cypress National Preserve, 1986) classified four major soil groups (rock, sand, marl and organics) in the Big Cypress National Preserve. These major soil groups are also found in the SGGE area.

Major lithologic units in Golden Gate Estates were also identified in a report called "Golden Gate Estates Groundwater and Septic Tank Investigation" (1979), and also in subsequent groundwater investigations performed by the South Florida Water Management District. Observations from 130 well sites showed major soils of sand, clay, marl, weathered rock, shell beds, soft sandy limestone and dense, hard limestone. Generally, it was shown that the SGGE area consists of a top layer 0-15 feet thick of sand, clay, marl and weathered rock over a layer of moderate to low permeable soft, sandy limestone and marl 20-50 feet thick over a moderately permeable limestone layer.

Detailed soils map available from recent USDA-SCS soil surveys identifies the entire range of hydric and non-hydric soils and are used in the present study.

2-3.5 Land Use

A large portion of the Faka Union Canal watershed is part of GGE and is zoned for single-family residential land use. Some previously farmed areas in the northern part of the watershed are now zoned residential and commercial. The residential zoning is low density with minimum lot size of 2-1/4 acres. The remaining area is used for agriculture, predominately truck farming, except in areas of persistent flooding. The most populated areas are north of State Route 84 or Alligator Alley (I-75) especially near Golden Gate Boulevard. Telephone and electric services are not available in most areas south of Alligator Alley and the area remains generally undeveloped. A small urban area exists at the extreme southern end of the area called Port of the Islands.

Land use maps were obtained from both the SFWMD and Collier County. Land cover complex designations north of Alligator Alley were generally accurate; however, south of Alligator Alley they did not adequately reflect the current uses of the land. Using a combination of soil maps, satellite land photos and field surveys, land uses were determined for this portion of the watershed.

2-3.6 Wetlands

A large portion of SGGE historically was dominated by wetland vegetation species such as cypress. Vegetation maps are available in the reports by Tropical BioIndustries and in the COE Feasibility report. These maps are very useful but may not represent current conditions due to the succession of plant communities created by overdrainage.

Table 1 (COE, 1986) shows the dominant plant communities in the SGGE area as determined in 1973. The majority of the land cover in SGGE is identified as wetlands. The loss of sufficient hydroperiods necessary to sustain wetland vegetation has caused a severe alteration of the historical plant species composition from that of wetland to upland or invasive exotics. As wetlands are drained, the organic soils that support wetland vegetation growth can be destroyed by fire, oxidation, shrinkage and compaction. In addition, the processes responsible for the formation of these soils

TABLE 1

PLANT COMMUNITIES IN THE SOUTHERN GOLDEN GATE ESTATES AREA AS DETERMINED IN 1973 (COE STUDY)

Community	Acres	Percent of Total
Cypress Forest	42,020	45
Uplands	14,180	15
Mixed Swamp Forest	13,060	14
Cypress-Pine Forest	9,841	11
Dry Prairie	7,333	8
Wet Prairie	2,455	3
Dwarf Cypress Forest	873	1
Pine Prairie	851	1
Pine Forest	822	1
Canals	658	1
Melaleuca and/or Brazilian Pepper*	387	<1
Estuarine**	210	<1

* This had the National Wetlands Inventory classification of palustrine, scrub/shrub, broad-leaved evergreen (PSS3). Typical species are Melaleuca, wax myrtle, sandweed (Hypericum). These evergreen shrub swamps may result from burning cypress swamps. This specific identification was not reported by Tabb and has not been ground-truthed.

** North of U.S. Highway 41 only.

cannot take place during a shortened hydroperiod (The Restoration of Golden Gate Estates, 1992). The long inundation characteristic of cypress forests protects it from fire but once drained, the forests are burned more frequently. This can cause slower growth rates and hinder regeneration. Cypress forests cannot survive or develop in areas with frequent fires (The Restoration of Golden Gate Estates, 1992). Slash pines are more resistant to fire and even require fire to prevent natural succession to a hardwood hammock. Saw palmettos are extremely fire resistant. The more frequent and intense fires in SGGE have resulted in a large part of the previously dominant cypress forest to be invaded by pine and palmettos, and later by exotic species like Brazilian peppers.

The shortened hydroperiod of wet prairies "has resulted in an inhibited growth of periphytic algae, which sustain the small forage fish. Additionally, there is no standing water for these fish," (The Restoration of Golden Gate Estates, 1992). Larger animals, particularly wading birds, cannot survive without this food source.

An extensive roadway system in SGGE has resulted in a loss of canopy that has affected understory vegetation, air flows and temperature. Many species, including some endangered orchids and bromeliads, require exact temperature and/or humidity conditions.

2-3.7 Canals and Structures

The Faka Union Canal system is made up of four major canals (Miller, Faka Union, Merritt and Prairie) and extends north from the estuaries of the Ten Thousand Islands nearly to County Road 846, a distance of some 28 miles. The canals are trapezoidal in shape and have an average excavated depth of approximately 10 feet from top of bank to bottom of channel with surface widths ranging from 45 to over 200 feet. Cross-section information of the canals is limited because only design drawings and some limited surveys are available. As-built drawings were not available. Faka Union Canal discharge records measured at the gaging station located upstream from the outfall weir are available starting in 1969. The average discharges for the period of record are 115 cfs during the dry season (November through May) and 460 cfs during the wet season (June through October), with an extreme discharge of 3,200 cfs occurring right after the canals were built.

Most of the canals have been infested with weeds a majority of the time except when they were first constructed in the early 1970's and recently (1990-present) when an aggressive weed control program was undertaken by the Big Cypress Basin. The weed growth was very dense and severely limited the hydraulic performance of the canals.

The purpose of the Golden Gate Estates canal system was to (1) provide rapid drainage of surface water, (2) lower the water table to reduce flooding and (3) provide fill for development. They were made to intercept large volumes of surface flow and quickly divert them to the Gulf of Mexico. The construction of the weirs were intended to prevent overdrainage during the dry season.

The effects of the canals on the area's hydrology has been significant and far reaching. The runoff that once slowly drained as overland sheetflow is now channelized in the canals and is released as a point discharge at the south end of the Faka Union Canal. This channelization results in both increased runoff volumes and runoff rates. Less runoff is available for groundwater recharge. Due to the shallowness of the Water Table Aquifer, the canals have affected the groundwater levels. "Most of the canals in the system are located in areas where the limestone of the shallow aquifer is within 10 feet of the land surface. Since many of the canals are 10 feet or more in depth there is a direct hydraulic connection between the canals system and the upper portions of the shallow aquifer.

Undoubtedly, construction of the GAC canal network has resulted in some drainage of the shallow aquifer, which has caused a general lowering of the groundwater table during the dry season." (Black, Crow and Eidsness, Inc. study, 1974). One study (Wang, 1978) concluded the water table was lowered one and a half to two feet after the construction of the canals. A field investigation (Swayze and McPherson, 1977) showed a drop in the water table of approximately two feet at a distance of 6,000 feet from the canal.

3. PROBLEM ANALYSIS

3-1. STUDY DESIGN FOR PROJECT

3-1.1 Hydrologic and Hydraulic Modeling Criteria

Prior to the selection of a hydrologic-hydraulic simulation modeling tool for use in the development of the restoration plan for SGGE, a set of criteria was developed to judge the applicability of an available simulation program. It was decided that the ideal modeling program should have the following capabilities or features.

1. Be able to continuously simulate the hydrologic-hydraulic behavior of the canal-aquifer system for a considerably long period.
2. Be able to accurately incorporate the hydrologic-hydraulic effects of land use changes, particularly the time history impact of the development of roads and canals on the overall hydrology of the area.
3. Be able to project water table-surface water flow relationships under different restoration alternative plans.

Although a number of available hydrologic-hydraulic models are known to have the capability of meeting some of the above selection criteria, a search was made for an integrated and comprehensive model that would specifically simulate water table-surface water flow relationship in a continuous process. Based upon these requirements a specific, well documented hydrologic-hydraulic model contained within a program package called the Hydrologic Simulation Program - FORTRAN (HSPF) Version 10 was selected. HSPF is a comprehensive program package for simulation of watershed hydrology and water quality developed for the U.S. Environmental

Protection Agency by Hydrocomp, Inc.

HSPF is the latest product resulting from more than 20 years of process research and model development, testing, refinement and application. The initial stages of this research effort involved the development of the Stanford Watershed Model (Crawford & Linsley, 1966) and the Hydrocomp Simulation Program (HSP) (Hydrocomp, 1969). These two models provided the basic theory and framework for the continuous simulation of hydrologic and hydraulic processes in HSPF. During the second phase of development (1970's), water quality processes were superimposed on the relevant transport components. The present Hydrologic-Hydraulic Water Quality Simulation package of HSPF is, therefore, an extension and improvement of three previously developed models: (1) the Agricultural Runoff Management (ARM) Model, (2) the Non-point Source runoff (NPS) Model, and (3) the Hydrologic Simulation Program (HSP, including HSP Quality).

Simply put, this simulation model uses such meteorological information as the time history of rainfall, temperature, wind movement, solar radiation, evaporation; such characteristics of the land surface as land use patterns, slopes, soil types and agricultural practices to simulate the hydrologic processes that occur in a watershed. The result of this simulation is a time history of the quantity and quality of the runoff. The model then takes these results along with the information about the stream channels in the watershed and simulates the hydraulic processes that occur in the stream system. This part of the simulation produces a time history of water quantity and quality at any point in the stream system. HSPF includes a data management system to process the large amounts of input data for the simulations and equally large amounts of simulated output. Program sub-routines are also provided to statistically analyze the data for ease of presentation and interpretation. HSPF can be applied to a wide range of water resource problems. The key attribute that makes it applicable to such a wide variety of water resource problems is its ability to simulate the continuous behavior of time-varying physical processes and provide statistical summaries of the results.

More specifically, HSPF was found to meet the following objectives of the study:

- HSPF has the ability to model all aspects of the hydrologic cycle including direct runoff, interflow, soil moisture, shallow groundwater storage and outflow. The understanding of the complete water cycle in the study area is important to a successful restoration plan.
- HSPF has the ability to continuously model over a long time record (20 years or more). This allows a wide range of meteorologic and hydrologic conditions (drought and flood) to be studied.
- Most importantly, the continuous simulation allows the designer to observe the time-history of the hydrologic-hydraulic behavior both during storm events and the rain-free intervals in between. This is very important in wetland restoration.
- HSPF has the ability to model channel and reservoir routing. This is done using hydrologic routing techniques.

3-1.2 Modeling Algorithms

The basic concept of the HSPF modeling is based on the lumped parameter approach where the watershed is divided into “land segments,” each with relatively uniform meteorologic, soil and land use characteristics. Similarly the channel system is segmented into "reaches" with each reach demonstrating uniform hydraulic properties. The entire watershed is then represented by specifying the reach network, i.e. the connectivity of the individual reaches, and the area of each land segment that drains to each reach. Each land segment is then modeled to generate runoff to the stream channel. The algorithm of the hydrologic and hydraulic submodels contained in HSPF is discussed below. These separate discussions emphasize the function of each submodel within the overall modeling scheme, the types of algorithms that are contained within each submodel, data needs, and the kind of outputs that each submodel provides.

3-1.2a Hydrologic Submodel

The principal function of the Hydrologic submodel is to determine the volume and temporal distribution of flow from the land to the canal system. This submodel currently contains two application modules - PERLND (pervious land module) and IMPLND (impervious land module). As used here, the concept of runoff from the land is broadly interpreted to include direct or surface runoff, interflow and groundwater flow to streams. The amount and rate of runoff from the land to the watershed stream system is largely a function of two factors. The first is the meteorological events which determines the quantity of water available on or beneath the land surface, and the second is the nature and use of the land.

The basic physical unit on which the hydrologic submodel operates is called the "Hydrologic Land Segment." It is defined as a surface drainage unit that exhibits unique combinations of meteorological parameters, such as precipitation and temperature, and land characteristics, such as degree of perviousness, soil type and slope. A strict interpretation of this definition would lead to the conclusion that there is virtually an infinite number of hydrologic land segments within even a small watershed because of the large number of meteorological parameters and land characteristics and because such parameters exhibit a continuous spatial variation throughout the watershed.

The practical and operational definition of a hydrologic land segment used within this model is a surface drainage unit consisting of a subbasin or a combination of subbasins, within the geographic area which can be considered represented by a particular meteorologic station and which is relatively uniform with respect to three land characteristics: soil type, slope, and land use or cover.

Module PERLND simulates a pervious land segment with the above mentioned homogenous hydrologic and climatic characteristics. Water movement is modeled along three flow paths: overland flow, interflow and groundwater flow. Each of these three paths experiences differences in time delay and differences in interactions between water and its various dissolved constituents. A variety of storage zones are used to represent the storage processes that occur on the land surface and in the soil horizons.

The hydrologic submodel operating on a time interval of one hour or less continually and sequentially maintains a water balance between the various hydrologic processes by incorporating a running account of the quantity of water that enters, leaves and remains within each phase of the hydrologic cycle during each successive time interval. The water balance accounting operation is performed by the PWATER (pervious land - water budget simulation) section of the PERLND module. The fluxes and storages simulated in this module with special reference to the groundwater component are described below.

The time series SUPY (water supply) representing the moisture supplied to the land segment primarily includes rain. SUPY is then available for interception. Interception storage is the water retained by any storage above the overland flow plane. For pervious areas the interception storage is mostly on vegetation. Any overflow from interception storage is added to the surface external lateral inflow to produce the total inflow into the surface detention storage. Inflow to the surface detention storage is added to the existing storage to make up the water available for infiltration and runoff. Moisture which directly infiltrates, moves into the lower zone and groundwater storage. Other water may go to the upper zone storage, may be routed as runoff from surface detention or interflow storage, or may stay in the overland flow plane from which it runs off or infiltrates at a later time.

The processes of infiltration and overland flow interact and occur simultaneously depending on the degree of perviousness and saturation of the land surface. The water in surface detention will later infiltrate reoccurring as interflow or it can be contained in the upper zone storage. Water infiltrating through the surface and percolating from the upper zone storage to the lower zone storage may flow to active groundwater storage, or may be lost by deep percolation to inactive groundwater storage. Active groundwater eventually reappears as base flow, but the deep percolation is considered lost from the simulated system.

Lateral external inflows to interflow and active groundwater storage are also possible for simulation. Evapotranspiration is simulated in all phases of the storages associated with the process, i.e. from interception storage, upper and lower zone storages, active groundwater storage, and directly from base flow.

3-1.2b Hydraulic Submodel

The primary function of the hydraulic submodel is to accept as input the runoff from the land surface and the discharge of groundwater as produced by the hydrologic submodel, aggregate it, and route it through the stream system, thereby producing a continuous time series output of discharge values at predetermined locations along the streams of the basin. Module RCHRES (reach-reservoir) of this submodel simulates the processes that occur in a single reach of an open channel or a completely mixed lake or reservoir. Flow through the element of the reach is assumed to be unidirectional. All inflows to the element are summed and enter the element without distinction as to location of the entry. The outflow from the element may be distributed across several targets by the user to properly represent normal outflows, diversions, etc. Evaporation, precipitation, solar radiation and other heat exchange fluxes take place on the surface area of the water and are computed along the reach.

The hydraulic behavior in the channel system or of a reservoir controlled by water control structures is modeled on a continuous basis using the hydrologic reservoir routing technique. Use of this routing procedure requires that a stage-discharge-cumulative storage table (FTABLE) be prepared for each canal reach or reservoir with the values selected so as to encompass the entire range of possible reservoir water surface elevations. A given stage-storage relationship can have up to five different discharges for a given reach or reservoir thus facilitating the simulation of a variety of potential outlet works and operating procedures. As simulated by the routing algorithm, a volume of flow enters the reach during a given time increment with the flow entering from the reach immediately upstream or coming directly from the land contiguous to the reach. The incremental volume of flow is added to that already in the reach at the beginning of the time interval, and the FTABLE is then used to estimate the discharge rate within the reach during the time increment and, thereby, the volume of flow that would discharge from the reach during the time increment. The volume of water in the reach at the end of the time increment is then calculated as the initial volume plus the inflow volume minus the outflow volume. The above computational process is then repeated for the next time increment and, as in the case for the first time increment, the average flow rate from the reach is obtained. The channel routing computations proceed in a similar manner for subsequent time increments in the reach in question and for all other reaches, thus effectively simulating the passage of flood waves through the channel system.

3-1.2c Groundwater Flow Submodel

The groundwater flow that contributes to streamflow is calculated in HSPF as part of the hydrologic submodel described above. The groundwater flow patterns in HSPF are simulated using a storage/outflow relationship that is controlled mainly by several calibrated parameters. HSPF limits the groundwater flow simulation to only that portion of the groundwater that contributes to streamflow. All other groundwater flow is lumped together as "inactive" groundwater that is lost from the system through deep percolation. Since this study is concerned with the upper portions of the Water Table Aquifer and its interaction with the canal system, this approach was acceptable. However, additional groundwater flow analysis was conducted using the U. S. Geological Survey's modular three dimensional finite difference groundwater flow (MODFLOW) program for the purpose of determining seepage from the proposed spreader channels to the I-75 ditch. An analysis of the entire groundwater system was needed to determine seepage flow. Both a two dimensional and three dimensional groundwater flow simulation system were constructed.

3-1.3 Basic Fluxes of Simulation of the SGGE Model

With respect to the application of HSPF to investigate the effects of canals and land development in the SGGE area, the basic fluxes of hydrologic simulation with and without the effects of restoration plans on overall sheetflow pattern and hydroperiod regime are to be simulated by the PWATER section of the PERLND module of the program. Water movement in the PERLND module will be modeled along three flow paths: overland flow, interflow and shallow groundwater flow. The impervious land module (IMPLND) was not utilized for the simulation.

The water balance for each land segment will be simulated through the processes of inflows, outflows and storages taking place in the following six surface and subsurface storage zones.

1. Interception storage (CEPS)
2. Surface storage (SURS)
3. Interflow storage (IFWS)
4. Upper zone storage (UZS)
5. Lower zone storage (LZS)
6. Active groundwater storage (AGWS)

Hydraulic simulation for routing runoff from land surface and discharge from groundwater through the canals are to be performed by the HYDR (hydraulic behavior simulation) section of the RCHRES module. This module will simulate the hydraulic processes in the canals to produce discharge rates and hydrographs.

3-2. MODEL DEVELOPMENT

The tasks necessary in the HSPF model application were database development, segmentation of the watershed and canals, calibration and verification, and finally, model simulation of the alternatives. Although HSPF has the capability to simulate water quality, this option was not used at this time.

3-2.1 Database Development

3-2.1a Time Series Database

The HSPF program uses a time series database called the Time Series Storage (TSS) file. Although HSPF, through its utility programs, has the ability to store, retrieve and manage the time series data it uses, a stand alone program called ANNIE developed by U. S. Geological Survey (USGS) was utilized in this project for this purpose. ANNIE has an extensive Watershed Data Management (WDM) program package, and provides an easier to understand, more interactive and efficient system of time series data management. HSPF also can utilize meteorological data such as temperature, wind speed, solar radiation and dew point temperature for the calculation of snow melt, dissolved oxygen levels and other water quality parameters. The SGGE model involved application of two modules (PERLND and RCHRES) and meteorological data input of only precipitation and pan evaporation were used. In addition to the meteorological data present in the WDM file, streamflow and stage data available at various calibration points were added to the WDM file for easier manipulation during the calibration and verification processes.

3-2.1b Meteorological Data

The meteorological data required by the PERLND module are continuous precipitation and evaporation data, preferably in daily or hourly values. Daily meteorological values in the study area were collected by the National Weather Service and the SFWMD in cooperation with several public and private organizations.

A. Rainfall

The Thiessen polygon method for estimating areal extent rainfall distribution was used in this study. Figure 3 shows the division of the study area into Thiessen polygons. Two queries were made in the SFWMD Hydrometeorological Database (DBHYDRO) for rainfall. The first was for rainfall in Collier County and the second was broadened to include all rainfall stations in Townships 45-53 South and Ranges 25-30 East. After observation, six major rainfall stations were chosen to be the centers of the Thiessen polygonal subareas. These stations and their years of available data are shown below. Stations Marco Tower, Royal Hammock and Six-L Farms were grouped together as one station because of their close proximity to one another.

Rainfall Station	Period of Record
Corkscrew Swamp Sanctuary	1959-1993
Silver Strand Grove	1983 - 1993
Miles City Tower	1969 - 1993
Copeland Tower	1969 - 1993
Collier County Landfill	1981 - 1993
Marco Tower	1969 - 1982
Royal Hammock State Park	1983 - 1986
Six-L Farms	1986 - 1988

Missing records were generated with a program called RFAVGM, developed by SFWMD's Department of Research, which uses nearby rainfall stations to estimate one average daily rainfall record. Table 2 summarizes the missing data generation of the six major Thiessen polygons.

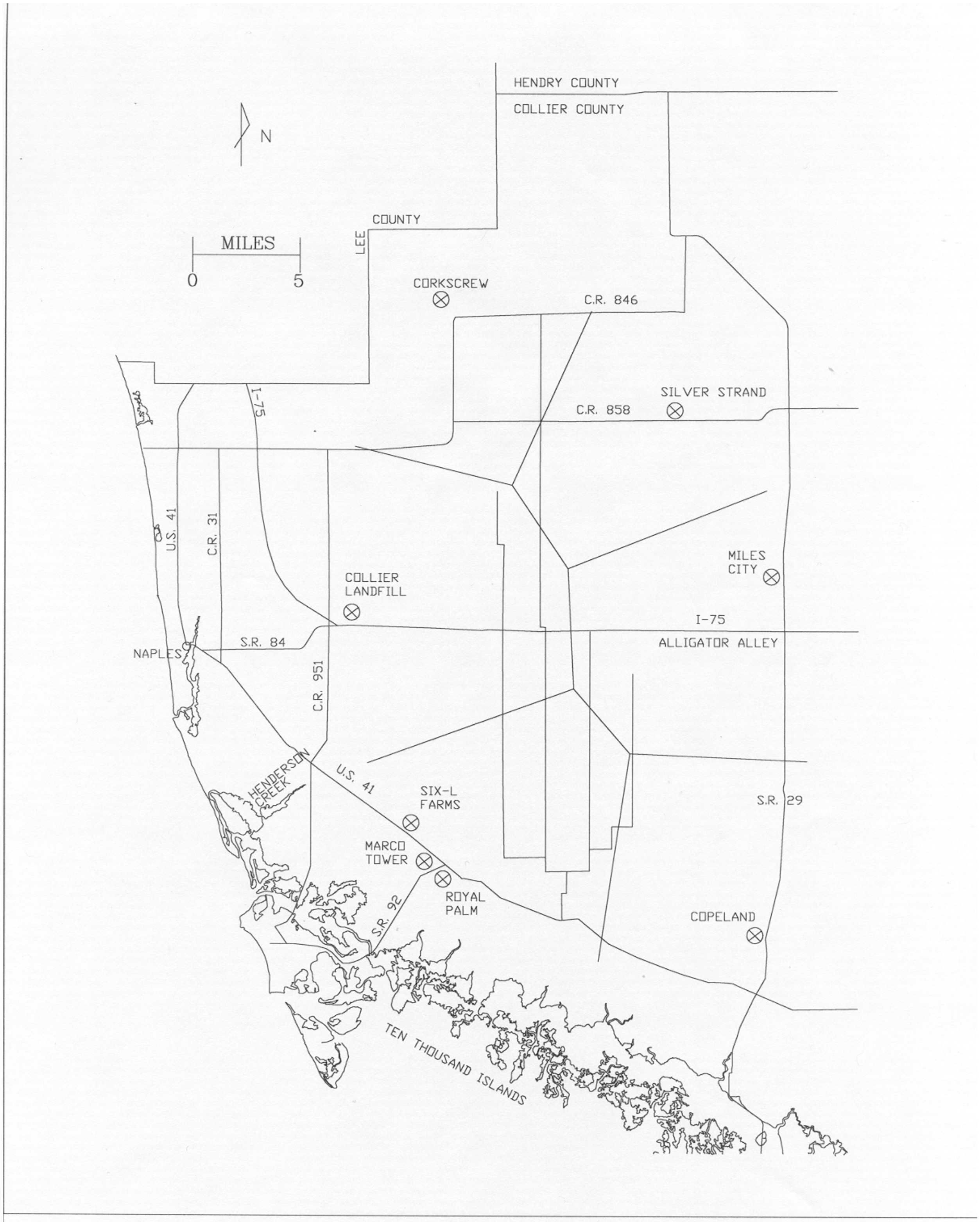


FIGURE 3. Thiessen Polygons for Rainfall Distribution

B. Evaporation

Since no one station close to the project area was found to have continuous records of pan evaporation data for the simulation period 1970 to 1992, the overall evaporation database used for the project was a combination of five stations, with missing records generated from weighted average values. Evaporation stations in Lee, Collier, Hendry, Broward and Dade counties were queried in the SFWMD's DBHYDRO database. The following stations were found to have reasonably continuous data for the period of record of 1970 to 1992: Corkscrew Swamp Sanctuary, Caribbean Gardens in Naples, Lehigh Acres, Clewiston, Tamiami Trail at 40-mile bend, Homestead and Hialeah. Hialeah and Homestead were not used because these stations are located on the east coast of Florida and were not considered representative of the project location. The following table shows the stations and the time periods used.

TABLE 2

RAINFALL DATA GENERATION FOR MISSING RECORDS IN THE POLYGONS

Polygon No.	Polygon Name Missing	Complete Years Missing	% of Total Records Data	Stations Used for Generation and the Years of Available
1	Corkscrew Swamp Sanctuary	None	1.7	Corkscrew Tower (1969-1990) Immokalee #3NNW (1941-1992)
2	Silver Strand	1/70-6/83	60.0	Corkscrew Headquarters (1959-1993) Miles City Tower (1969-1993) Immokalee #3NNW (1941-1992)

				Hendry Correctional Institute (1978-1983)
3	Miles City	None	4.0	Fakahatchee Strand (1984-1990) Hendry Correctional Institute (1978-1983) Immokalee #3NNW (1941-1992) Corkscrew Headquarters (1959-1993) Copeland Tower (1969-1993)
4	Copeland	None	2.7	Miles City Tower (1969-1993) Fakahatchee Strand (1984-1990) Everglades City (1924-1992)
5	Collier-Seminole State Park	1/89 - 12/92	38.6	Marco Fire Station (1981-1993) Copeland Tower (1969-1993) Everglades City (1924-1992) Naples Court House (1981-1993)
6	Collier Landfill	1/70 - 12/80	51.9	Naples Tower (1969-1993) Naples (1942-1992) Marco Tower (1969-1982)

Evaporation Station	Periods Used
Tamiami Trail, 40-Mile Bend	1/70-6/74, 9/77-3/78
Corkscrew Swamp Sanctuary	7/74-8/77
Caribbean Gardens, Naples	4/78-12/78, 1/81-10/83
Lehigh Acres	1/79-12/80
Clewiston	11/83-12/92

Any missing data was filled in using averages calculated from the days of the respective months before and after the missing data.

Generally, the Tamiami Trail station has poor records after 1975. The first period of record (1/70-6/74) contained 14 percent estimated values and less than one percent missing values. The second period (9/77-3/78) contained three percent estimated and 22 percent missing values. The Corkscrew Swamp Sanctuary data was very good, containing less than one percent missing records and less than one percent estimated records. Caribbean Gardens data contained four percent estimated and two percent missing data. Also years 1979 and 1980 were missing. Lehigh Acres data which was used for years 1979 and 1980 contained three percent missing data and 42 percent estimated data. The estimated data is based on observed values in the field summed over a period of days and averaged over those days. For the Clewiston record, the preferred DBKEY from DBHYDRO were used for years 1983-1990 which contained no missing data. Years 1991 and 1992 came from the regular set of data and contained less than one percent missing data.

3-2.1c Calibration Data

The HSPF model for SGGE was calibrated using data from three streamflow stations and three stage stations located at various points through out the watershed. Figure 4 shows the

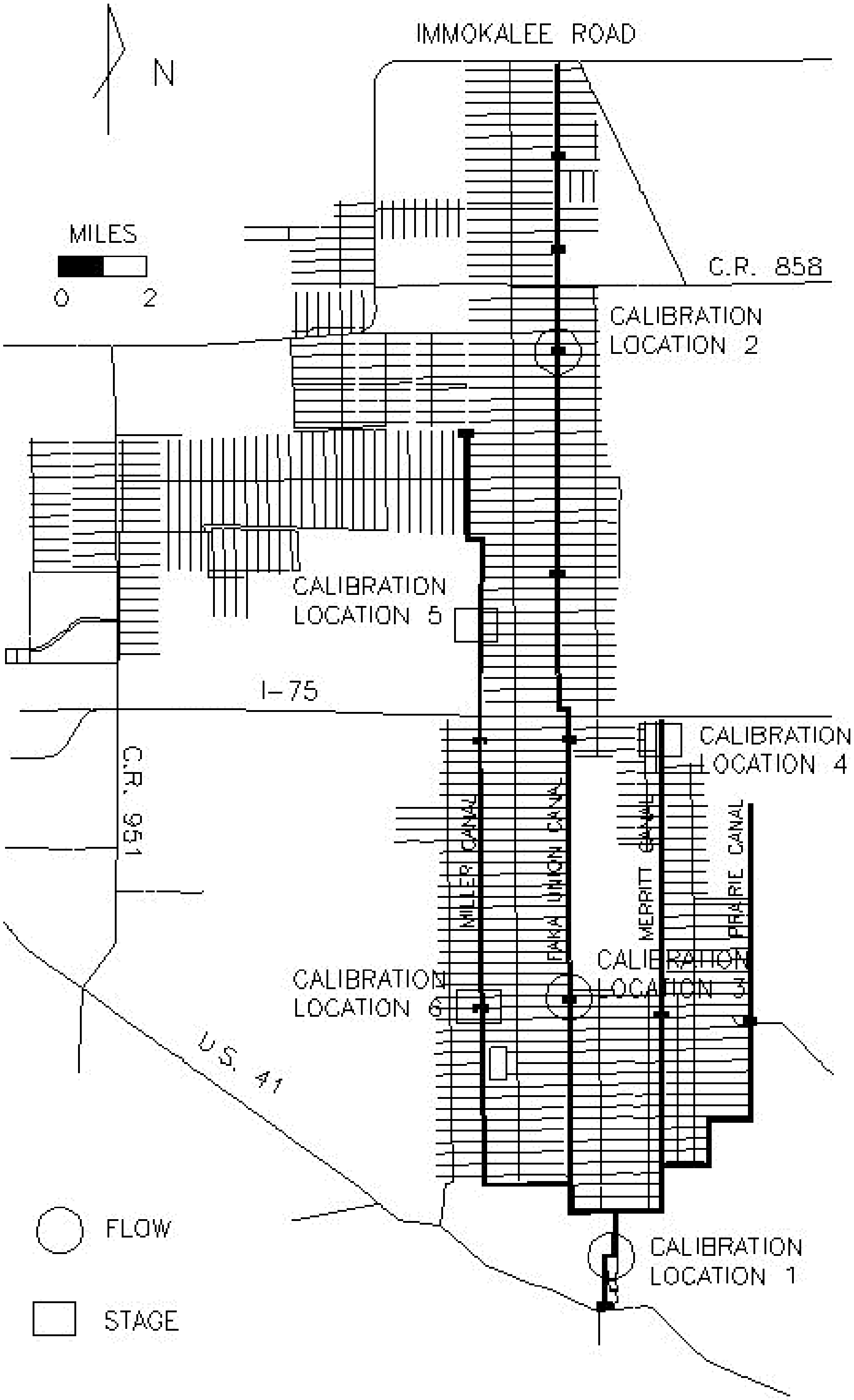


FIGURE 4. Calibration Locations

INSERT

TABLE 3

CALIBRATION LOCATIONS

	Location	Data Type	Period of Record
1.	Southern Faka Union Canal at FU#1	Flow	1969-1993
2.	North Faka Union Canal at FU#5	Flow	1978-1984
3.	South Central Faka Union Canal at FU#2	Flow	1978-1984
4.	Stumpy Strand-North Merritt Canal at 55th Ave SE	Stage	1991-1993
5.	North Miller Canal at 26th Ave SE	Stage	1981-1992
6.	South Miller Canal at Miller#1	Stage	1986-1992 (random)

calibration locations and Table 3 summarizes their data availability. For continuous process hydrologic -hydraulic simulation, it is recommended that calibration be based on at least three to five years of observed data in order to evaluate parameters under a variety of conditions. In addition, a simulation period of several years reduces the impact of any bias due to initial conditions. The time periods used for calibration were based solely on the availability of data. One drawback of the longer simulation period (i.e. greater than five years) is that it is difficult to find a longer time period where residential and agricultural land use developments have not influenced the runoff characteristics of the basin. This is the case for some calibration locations. However, it was decided to use all available data to provide a great variety of meteorological conditions. For instance, stage data at Miller Canal Weir No. 1 was collected randomly at approximately seven to ten-day intervals. Therefore, using all seven years of observed data for this station allowed more data points to be compared.

3-2.2 Land and Channel Segmentation

Land segmentation is determined by several factors including the spatial variability of weather data, soil and land characteristics, location of calibration data, and spatial resolution requirements. Maps of soils, topography and land use of the study area were overlaid and used to delineate the subbasins into land segments with similar characteristics. Land use and soils were considered particularly important. In addition, infrared satellite image and photograph data were analyzed.

For the purposes of generating the land related model input parameters, four general soil types and eleven land use categories were identified for the pervious land segmentation (PLS). The soil categories were formulated by generalizing a detailed soils map of the study area on the basis of recently completed soil survey of Collier County by USDA Soil Conservation Service. The four dominant soil categories are:

1. Non-Hydric

   Examples of specific soil types found in this category are Immokalee Fine Sands, Hallandale Fine Sands and Oldsmar Fine Sands. These soils have a top layer of four to six inches. They are rarely ponded and the water table can range from six to more than 40 inches below the surface.

2. Depressional

Examples of this soil type are Holopaw and Okeelanta Soils Depressional, the Boca, Riviera, Limestone Substratum and Copeland Fine Sand Depressional, the Chobee, Winder and Gator Soils Depressional, and the Riviera, Limestone Substratum-Copeland Fine Sands. The top layer ranges from five to 13 inches thick and can have a muck layer of up to 25 inches thick. These soils are naturally ponded six to nine months out of the year.

3. Prairie

Soils included in this category are Pennsucco (marl prairie) and Ochopee Fine Sandy Loam, Prairie (marl). The top layer is about five inches thick. With high rainfall, it may be ponded for seven to 30 days.

4. Hydric

Soil types included in this general category are the Malabar Fine Sands, the Basinger Fine Sands, the Riviera Fine Sands-Limestone Substratum, the Holopaw Fine Sands, the Hallandale and Boca Fine Sands (Slough) and the Ochopee Fine Sandy Loam. The top layer is two to five inches thick. With heavy rainfall, this soil type can be ponded for seven to 30 days.

The information on land use and land cover complex categories were used to optimize initial parameter estimates. The following dominant categories were selected:

1. Pasture/Old Fields

This category includes areas that were once farmed or used for pasture and now are overgrown with grasses. (Mostly present in NGGE)

2. Non-Forested Uplands/Pine with a Light Canopy (Scattered)

   These areas consist of non-hydric soil but are not thick pine forests. Sandy soil, higher elevation areas and high infiltration are common characteristics. Vegetation is generally 6-10 feet high (e.g. wax myrtle, scrub).

3. Pine Forest

   These areas consist of non-hydric soil with a dominant pine canopy.

4. Cypress with Pine and/or Exotics

   These areas contain mostly hydric soil but may have non-hydric soil. Here it is assumed pine and other exotic species are invading the cypress. These areas may have extensive, heavy invasion.

5. Agriculture

   These areas are used for citrus, tomato or other vegetable crops.

6. Impervious

   This category includes roofs and paved roads but does not include non-paved roads.

7. Non-Forested Slough and/or Wet Prairie and/or Pond

   These areas usually contain depressional or prairie soil, although there may be some other hydric soil. An example in this category is Lucky Lake Strand which comprises the headwaters of Merritt Canal.

8. Cypress

   These are primarily depressional areas of high water table with hydric soils and a dominant cypress canopy.

9. Prairie with or without Scattered Cypress

   These areas have dry prairie vegetation and may have scattered cypress. Soil is depressional or prairie.

10. Prairie with Cabbage Palm or Pine

    These areas usually have hydric soils but may also have prairie or depressional soils. The Cabbage Palm and Pine are assumed to be invading the prairie.

11. Mixed Swamp Forest

    These are moderate depressional areas in hydric soils with common vegetation dominated by a mix of Cypress, Maple, Bay and Oak.

Initially, the hydrology of the watershed was proposed to be simulated in 185 PLS to account for the extensive variety of land characteristics of the basin and to show a more realistic flow path of the surface and subsurface water as it flowed from one land area (or PLS) to the next. However, such level of detail and refinement works better on smaller watersheds. With each PLS requiring numerous input parameters, some of which are sensitive calibration parameters, it becomes necessary to limit segmentation of the watershed to larger PLS's. This provides a clearer picture of the sensitivity of the calibration parameters and how they affect the basin runoff. Consequently, the division of SGGE study area into PLS was modified to 35 PLS for model calibration and is shown in Figure 5.

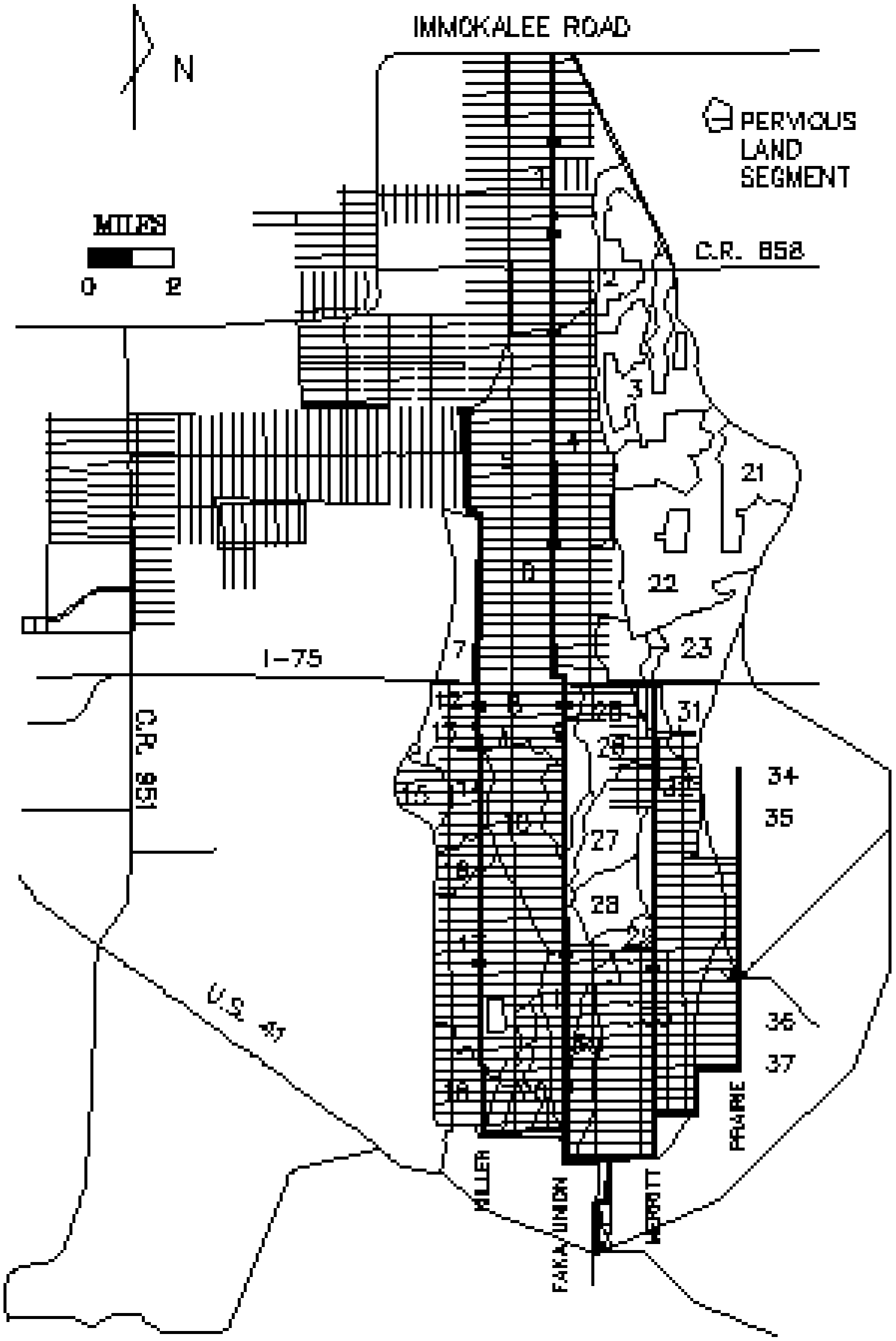


FIGURE 5. Pervious Land Segments for the Faka Union Canal Watershed

Channel segmentation is dependent upon the homogeneity of basic channel geometry, location of stream gauges and spatial resolution requirements. Each reach should have similar hydraulic characteristics, identified critical points in the canal and with flow travel time within the individual reaches approximating the simulation time step. Initially, reaches in the canals were divided at each weir and inflow points. The reaches were further divided so that each reach had a similar cross-section and, therefore, similar stage-storage-discharge characteristics. The slopes vary throughout the reaches. However, it was assumed that the reaches have reasonably homogeneous bottom slopes. Calibration data is available at five weirs in the system which correspond to the reach boundaries. Reaches were not further divided to equate flow time through individual reaches to the simulation time step. Shown in Figure 6 are the total number of reaches (32) for the Faka Union canal system.

The RCHRES module uses a function table (FTABLE) to specify the hydraulic properties of a reach. The U. S. Army Corps of Engineer's standard step backwater computation program HEC-2 and cross-section data in the Black, Crow and Eidsness study were used to generate the FTABLES for this study. Coded cross-sections were available from the COE Feasibility Study and weir structures were added using original design drawings and field surveys of weir structures Merritt No. 1 and Prairie No. 1. A survey of the upper portions of the Miller Canal and a field observation of the culverts in the Miller Canal on 28th Avenue SE were also incorporated. Two rating curves were used to represent wet and dry season operation of the stop logs in the water control structures.

3-2.3 Calibration and Verification

3-2.3a Need for and Nature of Model Calibration

Many of the algorithms contained in HSPF are conceptual mathematical approximations of complex natural phenomena. Therefore, before the model could be used to reliably simulate

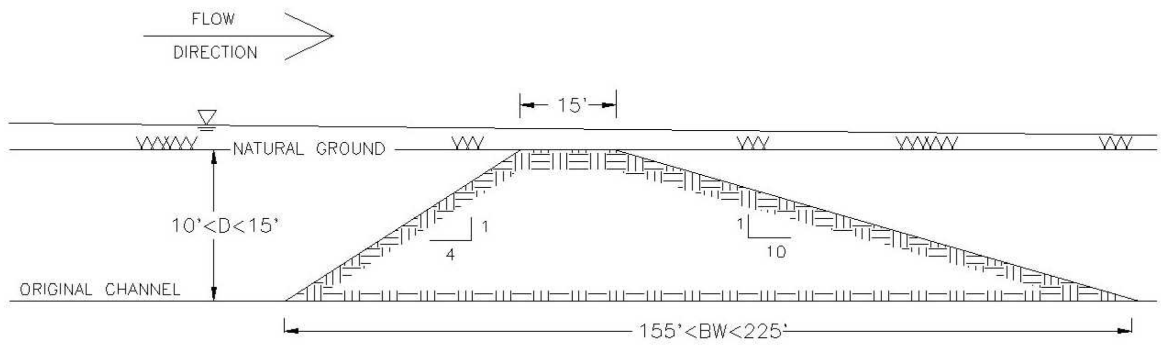


FIGURE 6 Typical Earthen Plug

streamflow behavior under alternative hypothetical basin development conditions, it is necessary to calibrate the model, that is, to compare simulation model results with factual historic data and, if a significant difference was found, to make parameter adjustments so as to adjust or calibrate the model to the specific natural and man-made features of the basin. While the model is general in that it is applicable to a wide range of geographic and climatic conditions, its successful application to any given water resources system, such as the SGGE basin, very much depends on the calibration process in which pertinent data on the natural resource and man-made features of the basin are used to adapt the model to the local conditions. A schematic representation of the model calibration process as used in this study is shown in Figure 7.

Since the model is designed to be applicable to many different water management configurations, these parameters provide the mechanism to adjust the simulation for specific topographical, hydrologic, edaphic, land use, and stream channel conditions. The large majority of the input parameters are adapted from known watershed characteristics. Parameters that cannot be precisely determined from known watershed features must be evaluated through calibration with recorded data.

The HSPF modules used for the model simulation of SGGE that contain parameters requiring calibration are the Pervious Land sub-model (PERLND) and Reach-Reservoir sub-model (RCHRES).

A set of 27 input parameters for each PLS was used for the PERLND module simulation. In the RCHRES module six parameters plus a function table or FTABLE was used for each reach.

3-2.3b Calibration Results

The calibration of the SGGE model utilized six streamflow and stage recording stations. The approach to the calibration sequence was to find an overall calibration of the whole basin using data

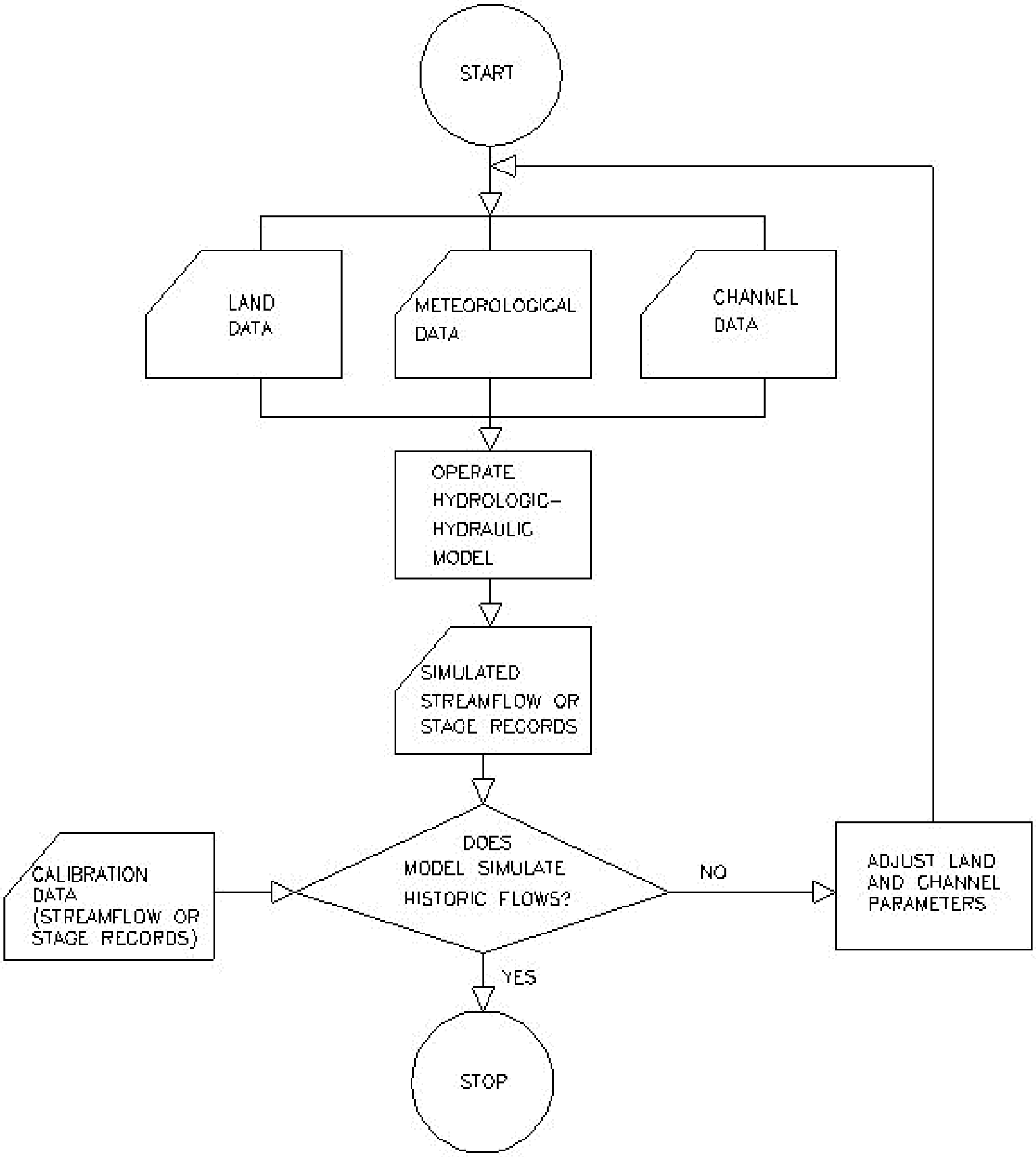


FIGURE 7. Schematic Representation of the Model Calibration Process

near the outlet of the basin and subsequently improve individual subbasin calibration without disturbing previous calibration results. The outlet of the SGGE watershed at Faka Union Canal Weir No. 1 was chosen as the first calibration location. Streamflows at the weir, which receives runoff from the entire basin, were calibrated.

The initial parameters were chosen after careful study of several sources. The HSPF User's Manual presented the specific algorithms used in the HSPF and allowable ranges of values for the parameters. Consultation with Dr. Norm Crawford, principal author of the program, at a HSPF training workshop provided typical ranges for the PERLND parameters. The HSPF Application Guide provided a discussion of the general behavior of a few key parameters for the PERLND module and RCHRES modules. Information was also available from three previous studies that utilized the HSPF model. These studies were: "Continuous Simulation of Surface and Subsurface Flows in Cypress Creek Basin, Florida, using Hydrological Simulation Program-Fortran" by Caroline Hicks; "Hydrologic Study of the Water Control District of South Brevard for Present Conditions and the Construction of L-74N Under the Upper St. Johns River Basin Plan" by the St. Johns River Water Management District; and the "East Side Green River Watershed Hydrologic Analysis" by Northwest Hydraulic Consultants Inc. The SCS Soil Survey for Collier County was used for initial estimates of upper zone nominal storage (UZSN), lower zone nominal storage (LZSN), and the index to mean infiltration rate (INFILT). Two key parameters, LZSN and INFILT, were assigned progressively lower values, which indicate greater runoff potential, in the southern portions of the basin due to lower elevations and the presence of "C" and "D" hydrologic soil groups. Recommended default values for evapotranspiration parameters were used and the deep fraction and active groundwater evapotranspiration parameters were set to zero and monthly variation of parameters were not used initially. Initial storage conditions were adjusted after the first run to more closely simulate the initial meteorological conditions.

Part of the Fakahatchee Strand State Preserve contributes runoff to the SGGE canal system. Field studies have shown that groundwater moves from east to west from the Preserve to the Prairie Canal, the easternmost canal of the Faka Union Canal system. Because of this, shallow groundwater was routed from the Preserve to the Prairie Canal. However, due to topography, surface runoff and interflow were not routed to the Prairie Canal but rather in a south to southwest direction. Therefore, surface and interflow from the Preserve were considered as cross-basin flows in the water balance equation for outflow through the Faka Union Canal.

The model output was analyzed by first establishing a water balance at the outlet of the basin where inflows nearly equaled outflows. Further analysis was done by comparing both runoff volumes and shapes of hydrographs. A regression analysis of observed and simulated flows and stages was performed by double mass curve fit and also by using the method of least squares.

A. Streamflows at Faka Union No. 1 (Basin Outlet)

A water balance check or mass balance is a necessary first step in calibration. This assures all inflows are accounted for and the model is set up correctly. The specific hydrologic components of the final simulated water budget are shown below:

SIMULATED OUTFLOWS				INFLOWS
DEEPFR + (in)	TAET + (in)	RUNOFF (in)	= TOTAL (in)	PRECIPITATION (in)
1.52	36.74	21.53	59.79	59.72

DEEPFR = Fraction of groundwater that is lost to deep percolation
TAET = Total simulated Evaporation

The outflows from the system closely match the inflows to the system. The final calibrated water budget becomes the simulated existing conditions to which the various alternatives are compared. All subsequent calibration performed for remaining subbasins within the SGGE watershed were done without interfering with this balance significantly.

The time period for calibrating the model at Faka Union Canal Weir No. 1 included years 1970 through 1984. The model calibration results are shown in Figures 8 and 9 that compare observed and simulated streamflow on an annual and monthly basis.

After 1975, a deviation was observed between simulated and recorded streamflows at Faka Union Canal near Weir No. 1. One reason is that over the 15-year simulation period, the model generated streamflows under somewhat constant or static watershed conditions using parameters that are assumed to remain constant over time. During continuous process simulation although many parameters were varied monthly, year to year progressive changes of watershed characteristics were not reflected in them. Changes in canal hydraulics were, however, simulated with multiple FTABLES in some strategic reaches. The recorded data reflect changes occurring on the watershed and therefore, affected runoff characteristics. After examining the average yearly rainfall and the average runoff recorded at the Faka Union Canal gauge near Weir No. 1 (Table 4), it is evident there is a discrepancy between higher precipitation years corresponding with higher recorded runoff. The conflicting rainfall-runoff relationship and the deviations of simulated streamflows after 1975 result from changes to the canal cross-sections (scour, sedimentation and aquatic vegetation), water control structures, and groundwater table over time. Most recently, the above mentioned changes to the hydraulic performance of the canal system are less pronounced since a very aggressive maintenance program has been in place since 1990. Additionally, changes to the water control structures are

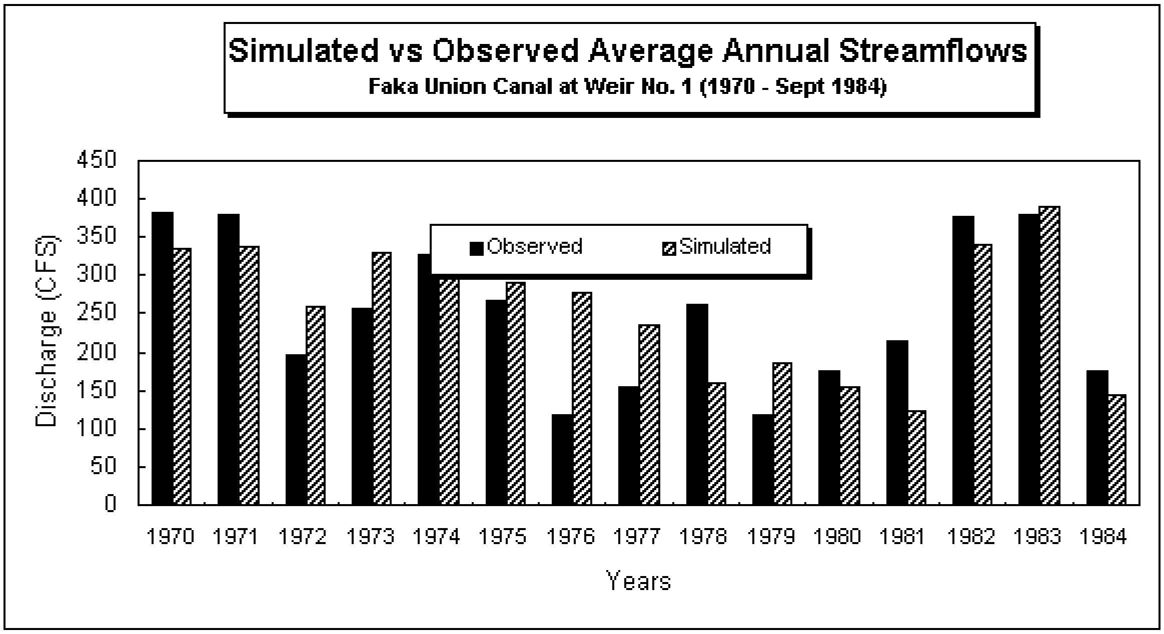


Figure 8

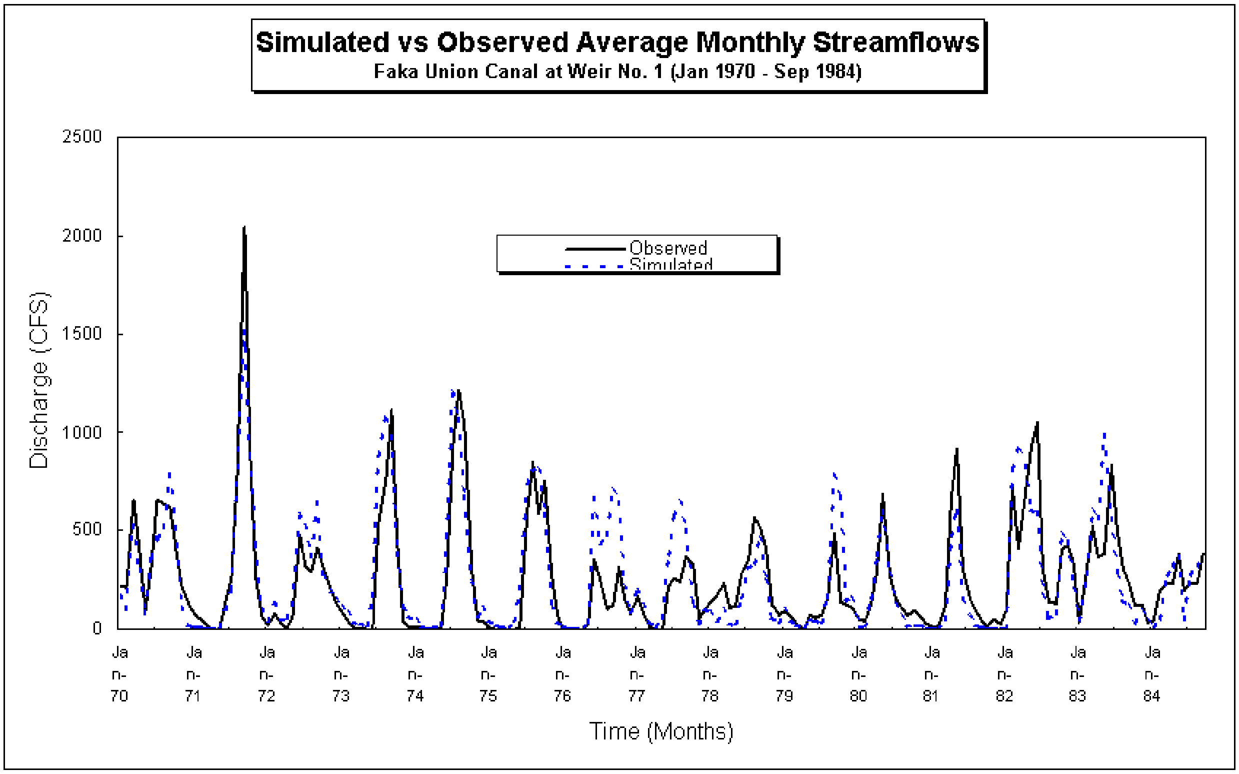


Figure 9

TABLE 4

AVERAGE RAINFALL/RUNOFF NEAR FAKA UNION CANAL OUTLET

Year	Rainfall Total (in)	Average Runoff (cfs)
1970	67.07	381
1971	64.08	380
1972	63.50	198
1973	65.45	255
1974	60.02	324
1975	61.71	263
1976	65.71	118
1977	54.94	155
1978	54.56	260
1979	57.05	119
1980	51.42	176
1981	45.49	213
1982	69.14	375
1983	76.01	380

presently well documented.

The groundwater table recorded an abrupt decline in the early years following the construction of the Faka Union Canal system. The first five years show the best correlation between simulated and observed values. Groundwater level affects certain HSPF parameters such as INFILT, LZSN and possibly DEEPFR and AGWRC as well, all of which are assumed to remain constant over the simulation period.

A regression analysis of simulated and observed flows using the method of least squares resulted in a R^2 value of 0.73. R^2 is a measure of the reliability of the correlation of two data sets. The closer R^2 is to a value of 1, the better the correlation between data sets. A double mass curve for the simulated streamflows at Faka Union No. 1 is shown in Figure 10. Overall, the calibration results for the entire watershed are satisfactory considering the changes in the characteristics of the watershed over the long calibration period.

B. Streamflows at Faka Union No. 5

Streamflows at Weir No. 5 was calibrated for a period of five years, starting January 1, 1979 and ending December 31, 1983. This provided a cycle of both wet (1982-1983) and dry (1981) years to be simulated. The controlling rainfall stations are Corkscrew Swamp Sanctuary and Silver Strand Grove.

The overall calibration results at this station were somewhat less satisfactory than desired. Figures 11 and 12 show simulated versus measured annual and monthly streamflows. This subbasin was extremely difficult to calibrate. No adjustments could be made to the parameters to closely simulate all five years. There are a few probable reasons for the difficulty in calibrating this subbasin.

One explanation is the changing hydraulic characteristics of the canal. The Faka Union Canal

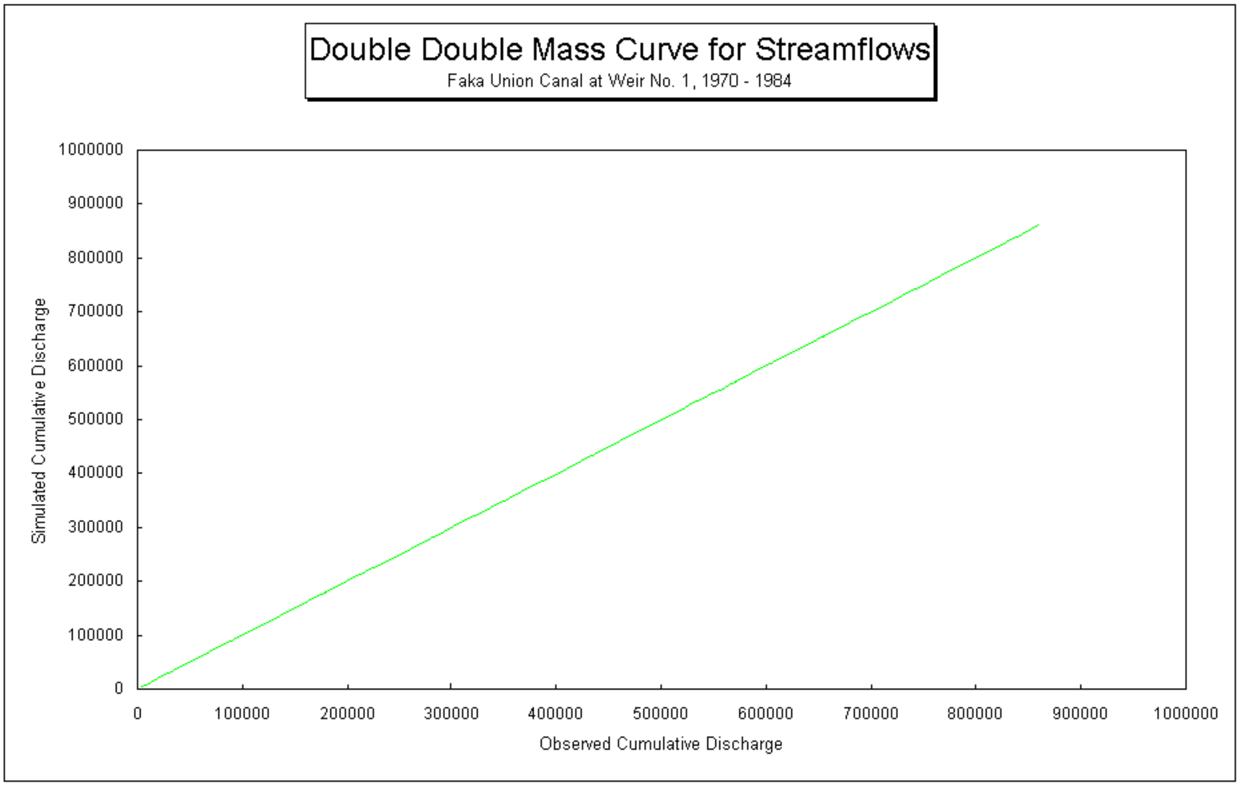

Double Double Mass Curve for Streamflows
Faka Union Canal at Weir No. 1, 1970 - 1984
Simulated Cumulative Discharge
Observed Cumulative Discharge
0
100000
200000
300000
400000
500000
600000
700000
800000
900000
1000000

Figure 10

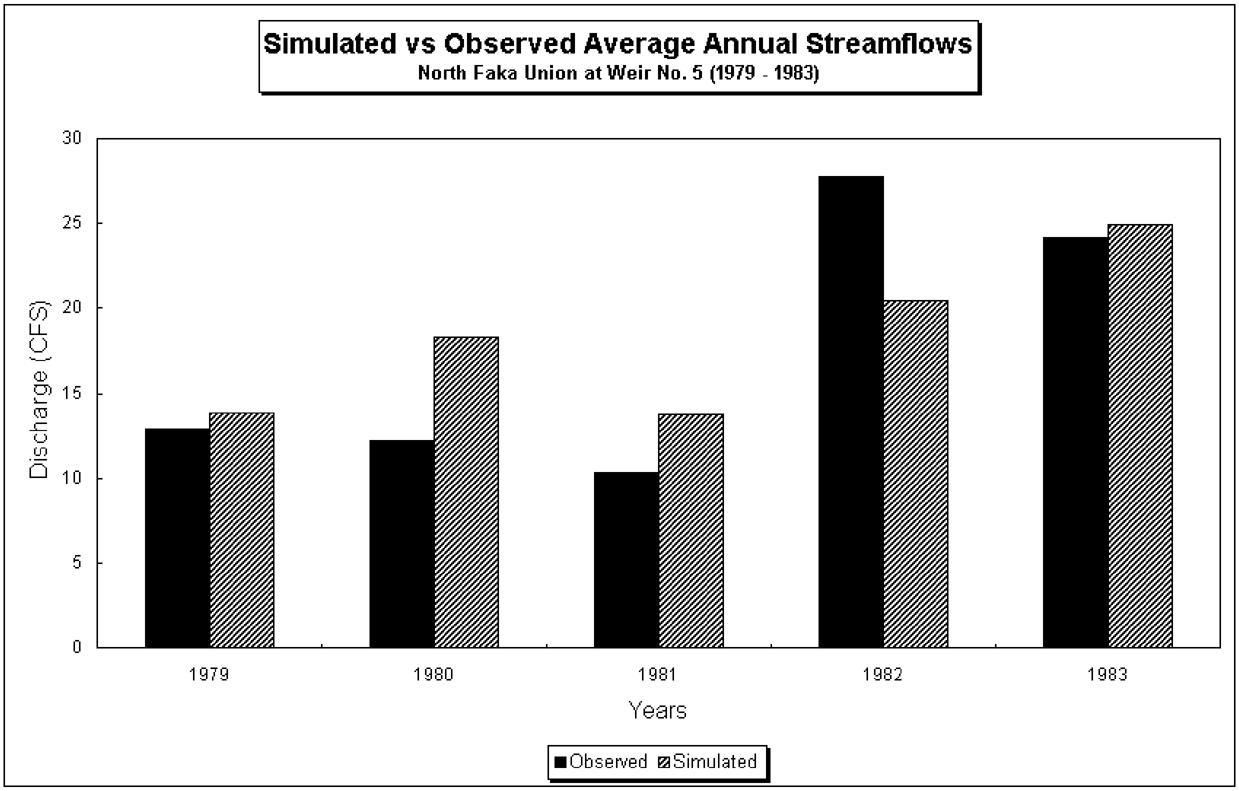

Simulated vs Observed Average Annual Streamflows
North Faka Union at Weir No. 5 (1979 - 1983)
30
25
20
15
10
5
0
Discharge (CFS)
1979
1980
1981
1982
1983
Years
■Observed ▨Simulated

Figure 11

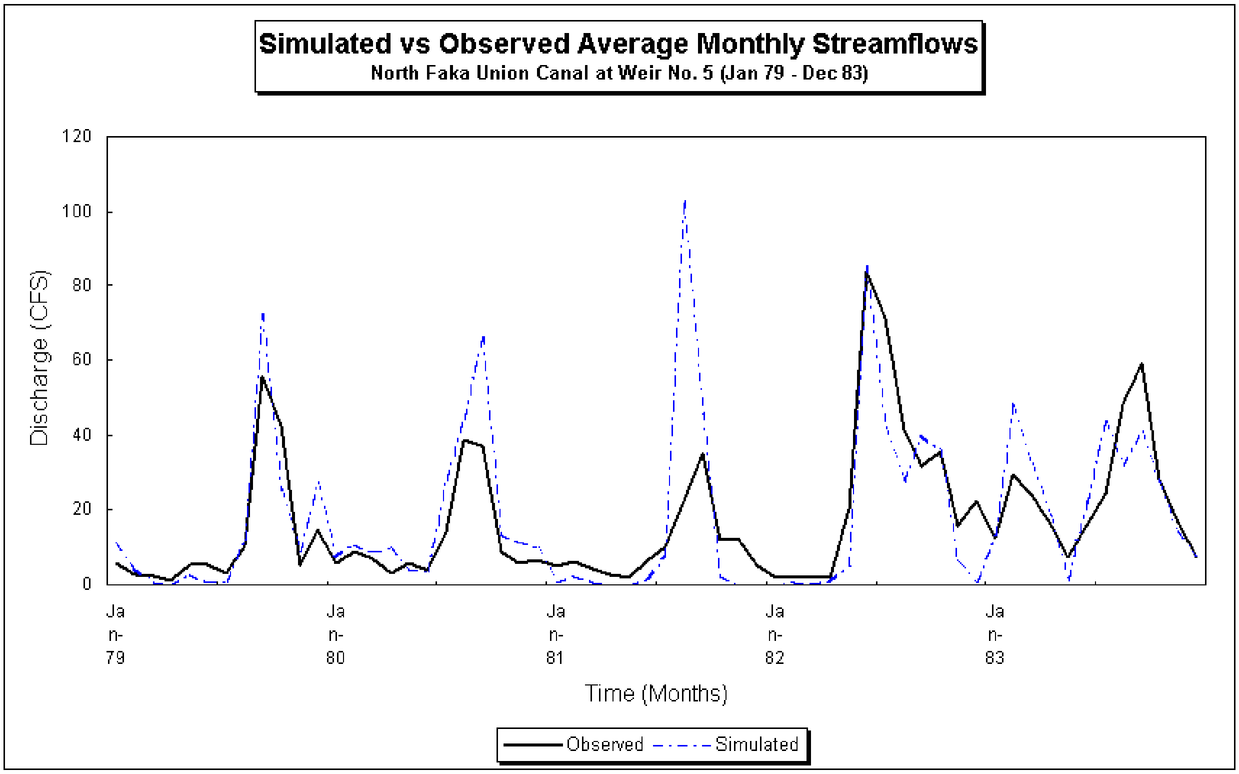


Figure 12

Weir No. 5 was renovated in 1983. In 1983, additional stoplogs were added to the original v-notch weir to allow for more storage. All other factors equal, the additional storage capacity in this portion of the canal would result in lower observed discharge in 1983. It is to be noted, that in 1983, the rainfall was higher (74 inches) than the rainfall received in 1982 (68 inches). But the observed runoff for 1983 was lower than the observed runoff for 1982. Similarly, the v-notched weir contained removable wooden boards, which were alternately removed and inserted several times unrecorded during parts of the calibration period. Accurate records of operation of the boards for the earlier years were not available. Vegetation growth is also a factor in the hydraulic performance of the canal. It is suspected that little aquatic weed control was performed during this time.

Secondly, accurate measured flow data is the key to good calibration results. The flow data at Faka Union No. 5 is classified as poor by the USGS. The USGS accuracy classifications are as follows: "excellent" means that about 95 percent of the daily discharges are within five percent; "good" within 10 percent; and "fair" within 15 percent. "Poor" means that daily discharges have less than "fair" accuracy. The reasons for the low classification are probably due to the above mentioned factors. Additionally, the discharge measurements used for calibration were extrapolated from rating curves that related to the observed stage values with discharge. The frequency of some discharge measurements were very widely distributed and did not adequately reflect the operation of stop logs
at the water control structures.

The City of Naples wellfield lies just south of this weir. Some improvement in the simulated dry season flows was obtained when withdrawals from the City of Naples wellfield were represented in the RCHRES block as an additional “outflow” from the canal. The effects of the City's wellfield on the discharge characteristics of Faka Union Canal is not directly modeled as the withdrawals are from the Lower Tamiami Aquifer, a storage zone deeper than those simulated by HSPF. One of the primary sources of recharge of the Lower Tamiami Aquifer is leakage from the Water Table Aquifer. This is accounted for in HSPF by assuming the fraction lost from the system by deep percolation in the DEEPFR parameter. However, the amount lost either remains constant over time or varies with the current available groundwater storage. Higher available storage results in a greater volume being lost to deep percolation or other losses. Groundwater storage is at its highest during the wet season which may not correspond to heavy withdrawals from the wellfield which are higher during the dry season. Therefore, the recharge was represented as an additional outflow column in the FTABLES of the RCHRES block.

A regression analysis of simulated and observed flows using the method of least squares resulted in a R^2 value of 0.60. A double mass curve for the simulated streamflows at Faka Union No. 5 is shown in Figure 13.

C. Streamflows at Faka Union No. 2

The time period for calibrating the model at Faka Union Canal weir No. 2 included years 1978 through 1983. Figures 14 and 15 show simulated versus measured annual and monthly streamflows. A regression analysis of simulated and observed flows using the method of least squares resulted in a R^2 value of 0.83. A double mass curve for the simulated streamflows at Faka Union No. 2 is shown in Figure 16.

After examining flows at the outlet of the basin and at Faka Union Weir No. 2 which receives runoff from the central part of the basin, there was evidence that groundwater flows in an east to west pattern into the Faka Union Canal both at a location just east of the north Faka Union Canal, near Stumpy Strand, and also just east of the Faka Union Canal between Faka Union Canal Weirs No. 2

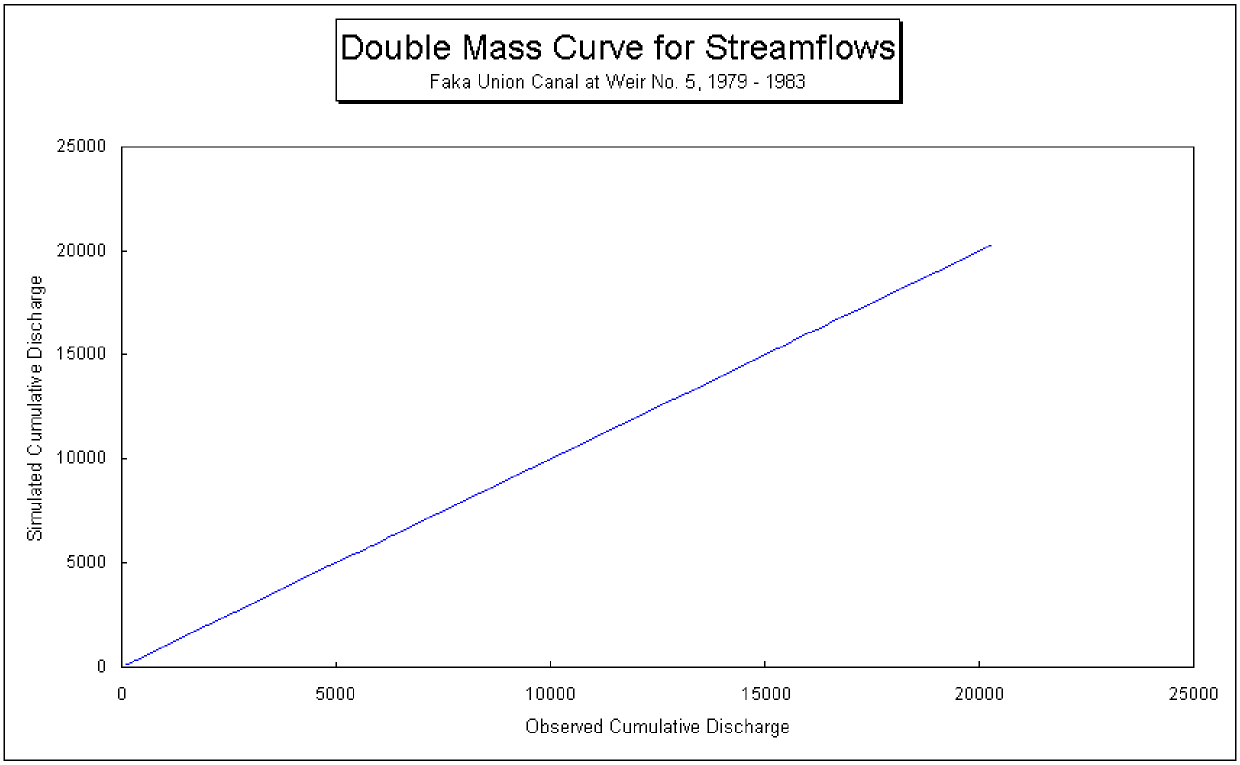

Double Mass Curve for Streamflows
Faka Union Canal at Weir No. 5, 1979 - 1983
Simulated Cumulative Discharge
Observed Cumulative Discharge
0
5000
10000
15000
20000
25000
0
5000
10000
15000
20000
25000

Figure 13

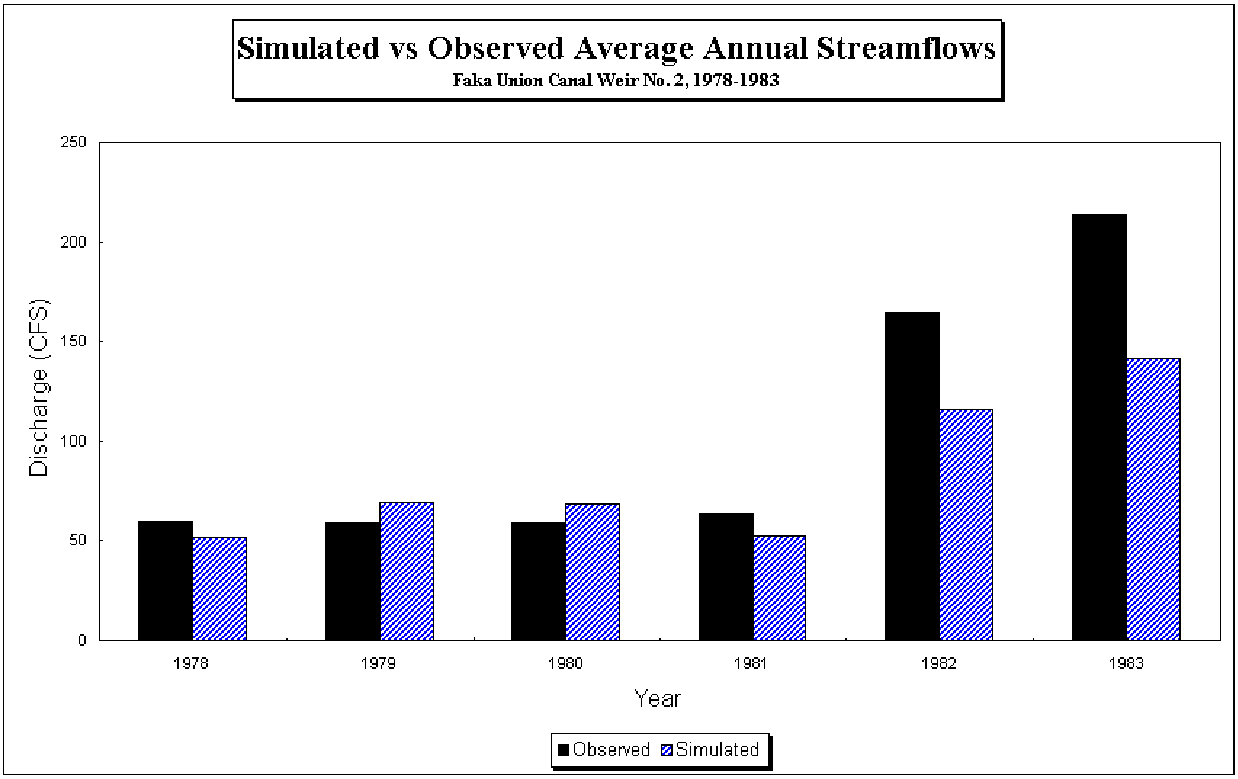

Simulated vs Observed Average Annual Streamflows
Faka Union Canal Weir No. 2, 1978-1983
Discharge (CFS)
250
200
150
100
50
0
1978
1979
1980
1981
1982
1983
Year
■ Observed
▨ Simulated

Figure 14

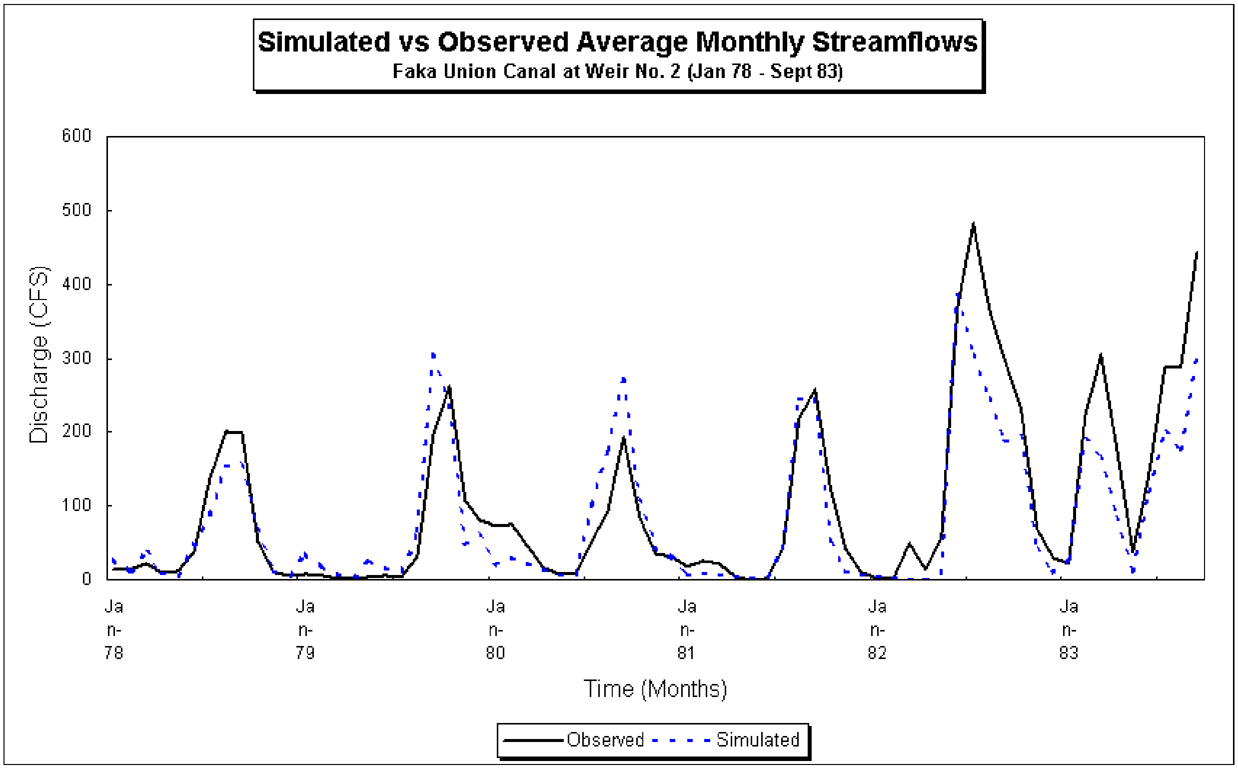

Simulated vs Observed Average Monthly Streamflows
Faka Union Canal at Weir No. 2 (Jan 78 - Sept 83)
600
500
400
300
200
100
0
Discharge (CFS)
Jan-78
Jan-79
Jan-80
Jan-81
Jan-82
Jan-83
Time (Months)
Observed
Simulated

Figure 15

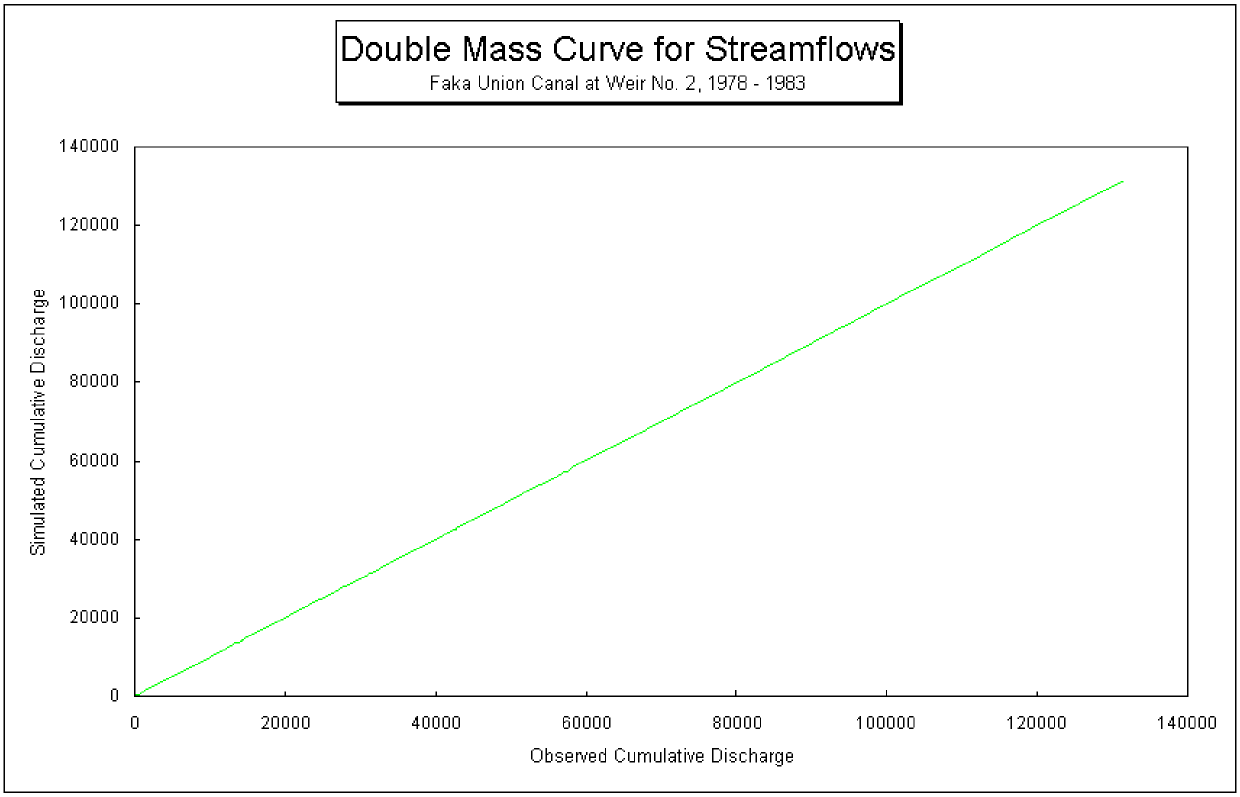


Figure 16

and 3. Simulated flow volumes at the outlet of the basin were close to observed volumes for years 1982 and 1983 but simulated flow volumes at Faka Union No. 2 for the same period were significantly lower than observed. This suggested that perhaps a greater area contributed runoff to the Faka Union Canal above Weir No. 2. After parameters were adjusted for the central portion of the basin and flow volumes still remained low, the watershed boundary for this subbasin was extended to include areas east of Faka Union Canal between Weirs No. 2 and 3. This resulted increase in some flow at Faka Union No. 2 but still remained low. A portion of groundwater flow from the Stumpy Strand area was then routed to the Faka Union Canal instead of the Merritt Canal and resulted in improved simulation.

D. Stages at Merritt Canal at 55th Avenue Southeast

In the remaining calibration locations observed stage records rather than streamflow measurements were used. Stages on the Merritt Canal were calibrated for a period of one year, starting December 1991 and ending November 30, 1992. Figure 17 show simulated versus measured monthly stages. A regression analysis of simulated and observed stages using the method of least squares resulted in a R^2 value of 0.96. A correlation curve for the simulated versus observed stages for Merritt Canal at 55th Ave SE is shown in Figure 18. The use of a shorter calibration period for the Stumpy Strand-Lucky Lake Strand subbasin is a contributing factor for the better correlation between simulated and observed stages.

E. Stages at Miller Canal at 26th Avenue Southeast

The time period for calibrating the model at Miller Canal at 26th Ave SE included nine years from May 1983 through May 1992. Figures 19 and 20 show simulated versus measured annual and monthly stages. A regression analysis of simulated and observed stages using the method of least

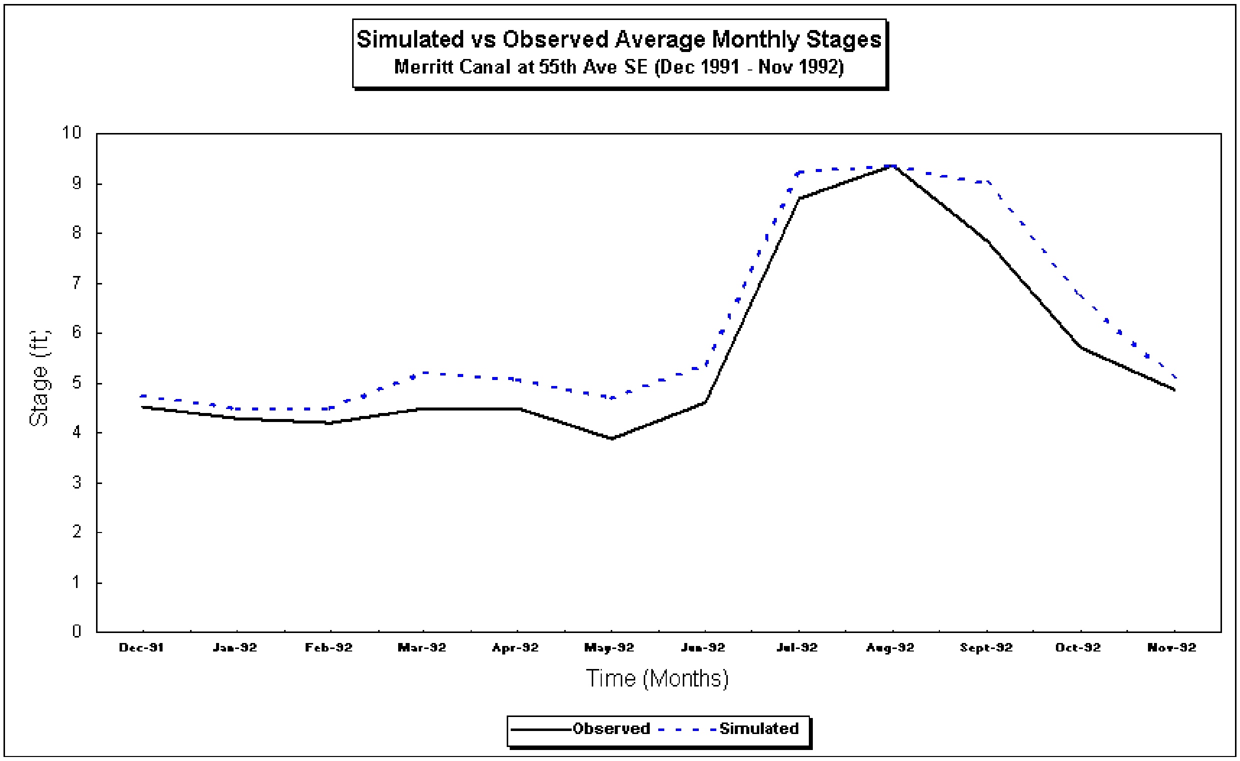

Simulated vs Observed Average Monthly Stages
Merritt Canal at 55th Ave SE (Dec 1991 - Nov 1992)
Stage (ft)
10
9
8
7
6
5
4
3
2
1
0
Dec-91
Jan-92
Feb-92
Mar-92
Apr-92
May-92
Jun-92
Jul-92
Aug-92
Sept-92
Oct-92
Nov-92
Time (Months)
Observed
Simulated

Figure 17

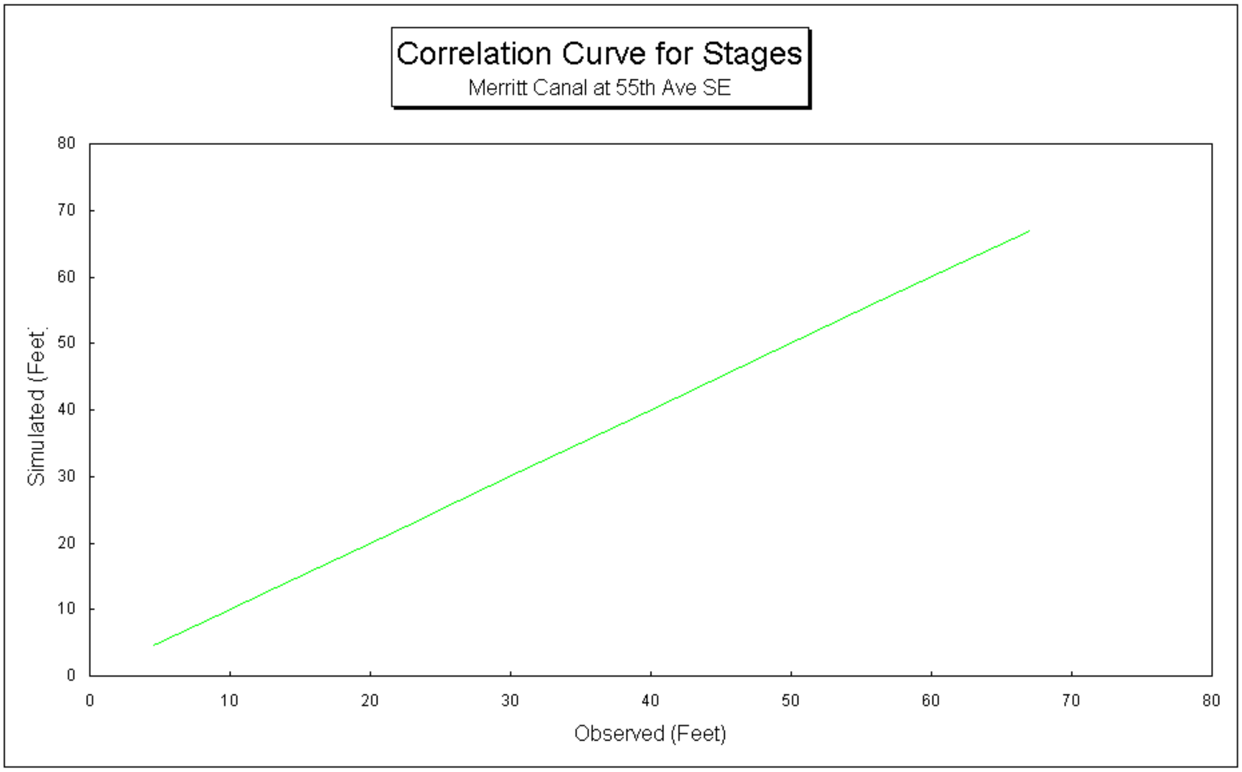
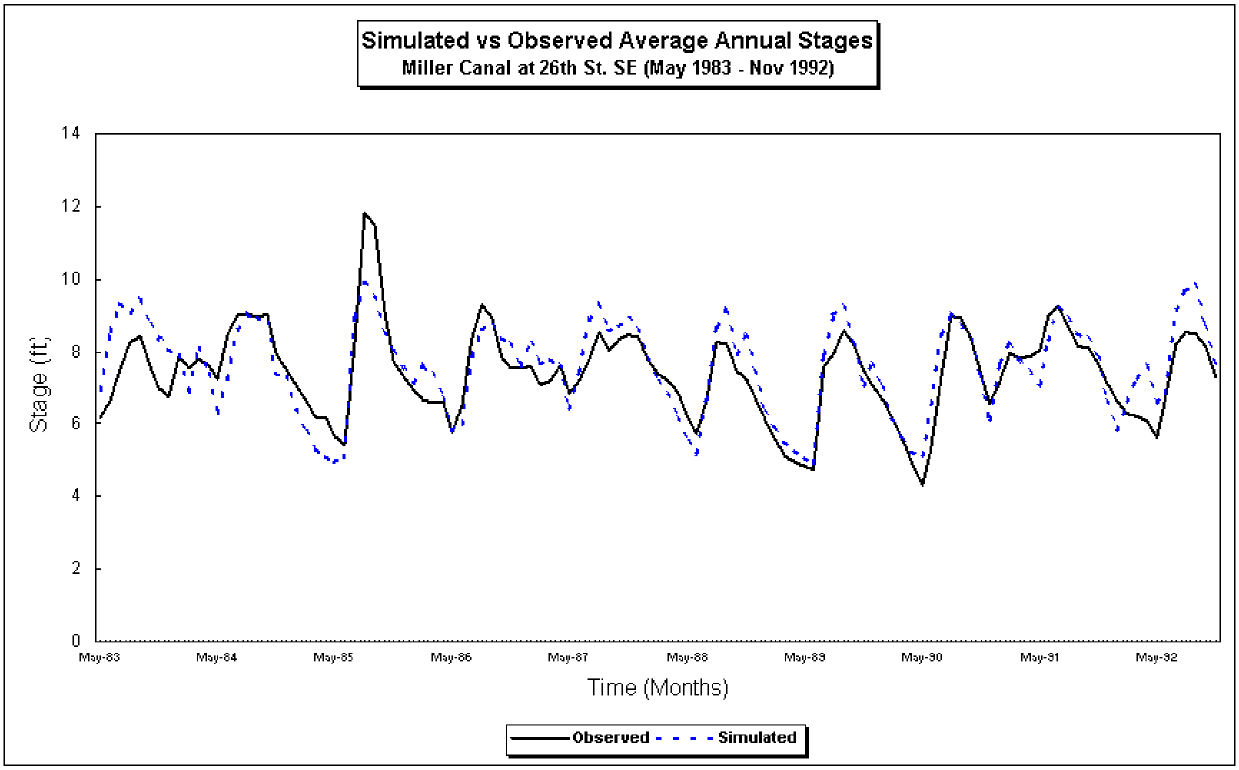

Correlation Curve for Stages
Merritt Canal at 55th Ave SE
Simulated (Feet)
Observed (Feet)
0
10
20
30
40
50
60
70
80

Figure 18



Simulated vs Observed Average Annual Stages
Miller Canal at 26th St. SE (May 1983 - Nov 1992)
Stage (ft)
0
2
4
6
8
10
12
14
May-83
May-84
May-85
May-86
May-87
May-88
May-89
May-90
May-91
May-92
Time (Months)
Observed
Simulated

Figure 19

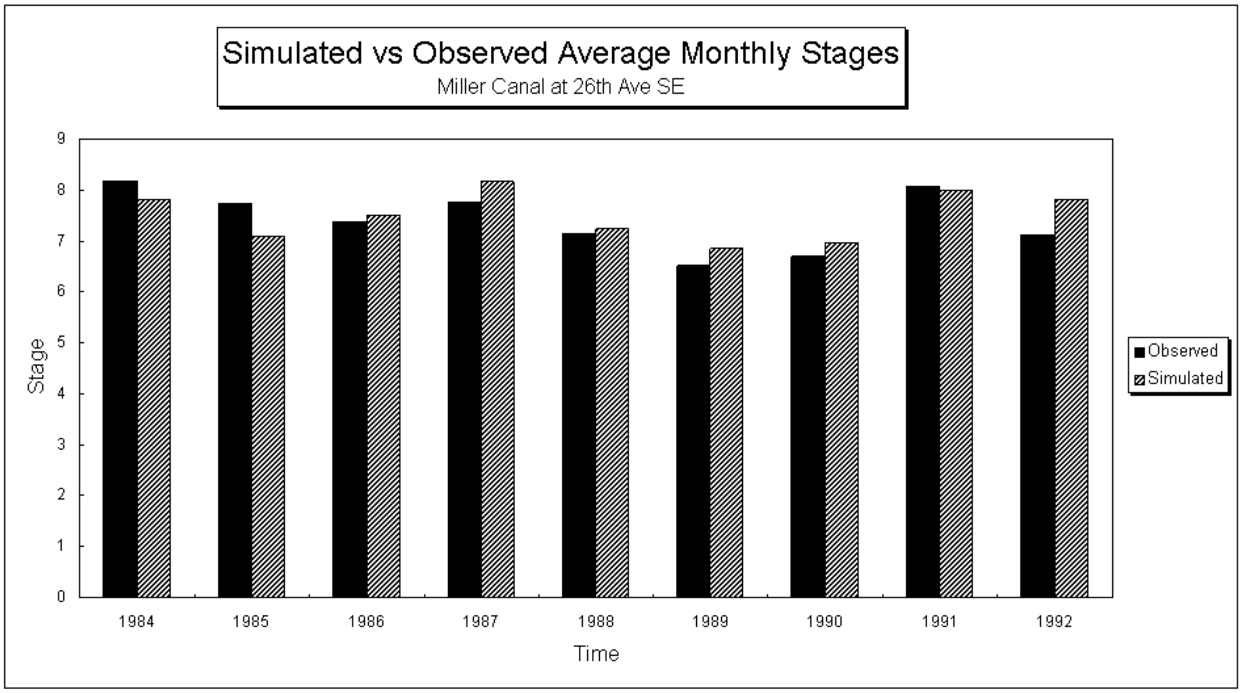


Figure 20

squares resulted in a R^2 value of 0.69. A correlation curve for the simulated versus observed stages at Miller Canal at 26th Ave SE is shown in Figure 21.

F. South Miller Canal at Miller No. 1

The calibration period at Miller Canal at Weir No. 1 started January 1986 and ended December 1992. Figures 22 and 23 show simulated verses measured annual and monthly canal stages. A regression analysis of simulated and observed stages using the method of least squares resulted in a R^2 value of 0.39. A correlation curve for the simulated versus observed stages is shown in Figure 24. The stage records at this location were collected randomly with an average frequency of once a week. Continuous data collection is preferred for calibration and the random nature of the data is a likely cause of the low correlation between simulated and observed stages.

G. Summary of Calibration Results

The overall performance of the model was enhanced significantly by the inclusion of factors such as time variant changes in the hydraulic properties of the canals and weirs. Progressive changes in canal hydraulics due to scour, sedimentation, aquatic weed growth and undocumented operation of water control structures posed greater challenges in the calibration process.

The weirs in the drainage system have undergone changes. Wooden boards were alternately removed and inserted in the v-notched weirs several times and these operations were unrecorded. A water level report by Stanley W. Hole and Associates in 1976 reported that sand cement bags were added to the crests of Miller Weir No. 1 and Faka Union Weir No. 2 increasing their elevation approximately two feet. In 1983, several weirs including Faka Union Weirs No. 5, 4, and 2 and Miller Weirs No. 1 and 3 were renovated. A limited representation of the historic transient discharge characteristics were simulated by using multiple FTABLES in the RCHRES block of the program.

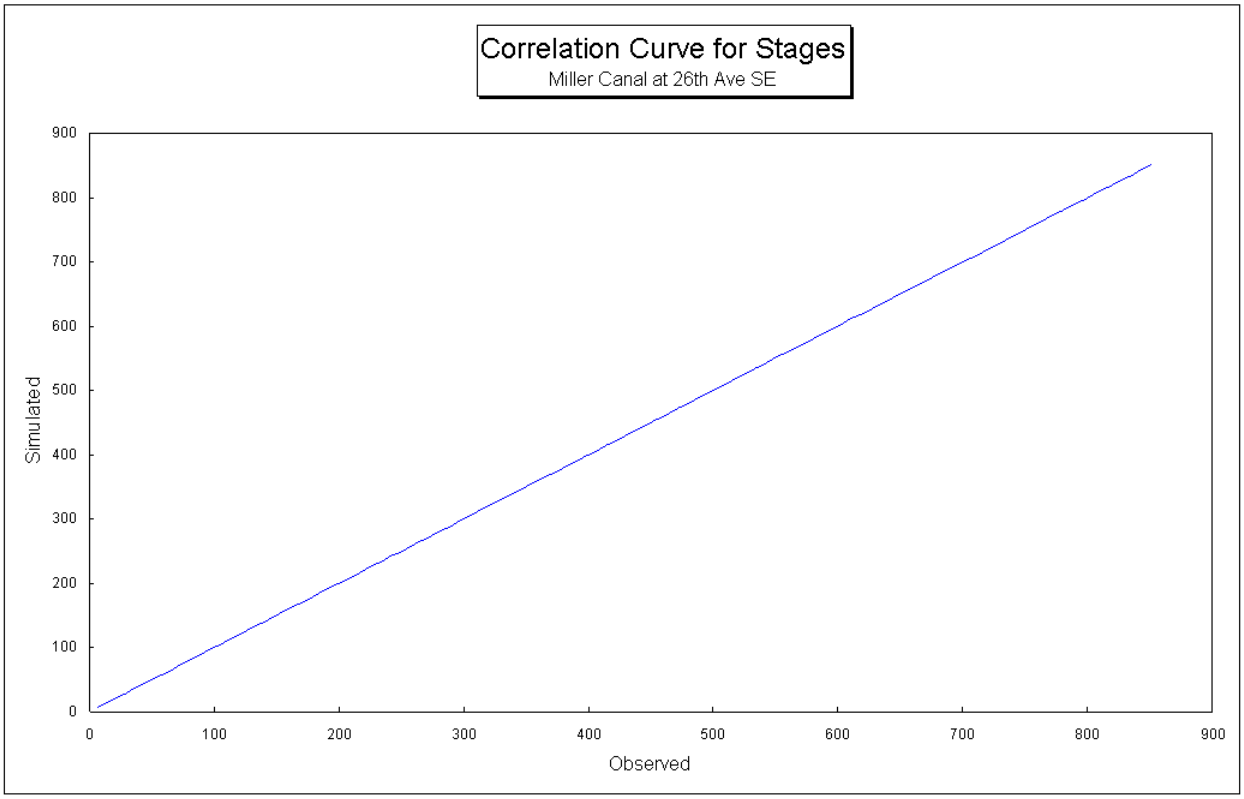


Figure 21

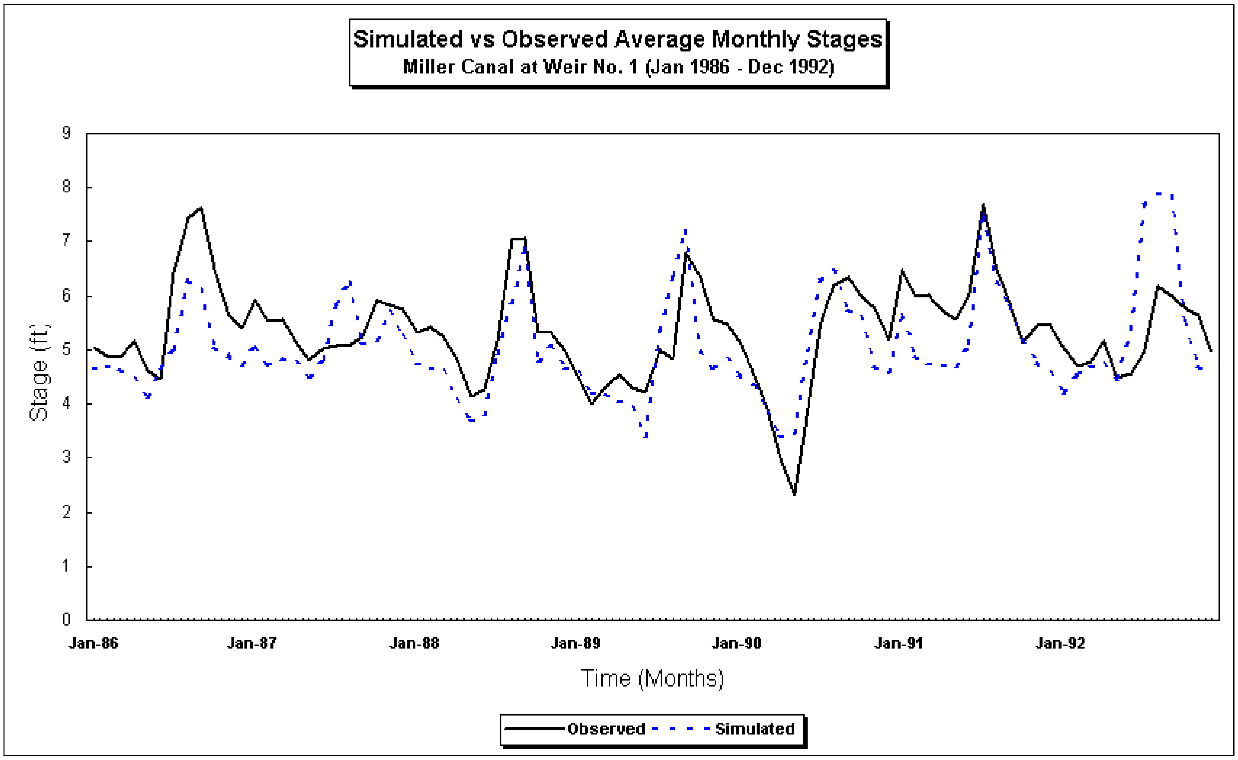

Simulated vs Observed Average Monthly Stages
Miller Canal at Weir No. 1 (Jan 1986 - Dec 1992)
Stage (ft)
9
8
7
6
5
4
3
2
1
0
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)
Observed
Simulated

Figure 22

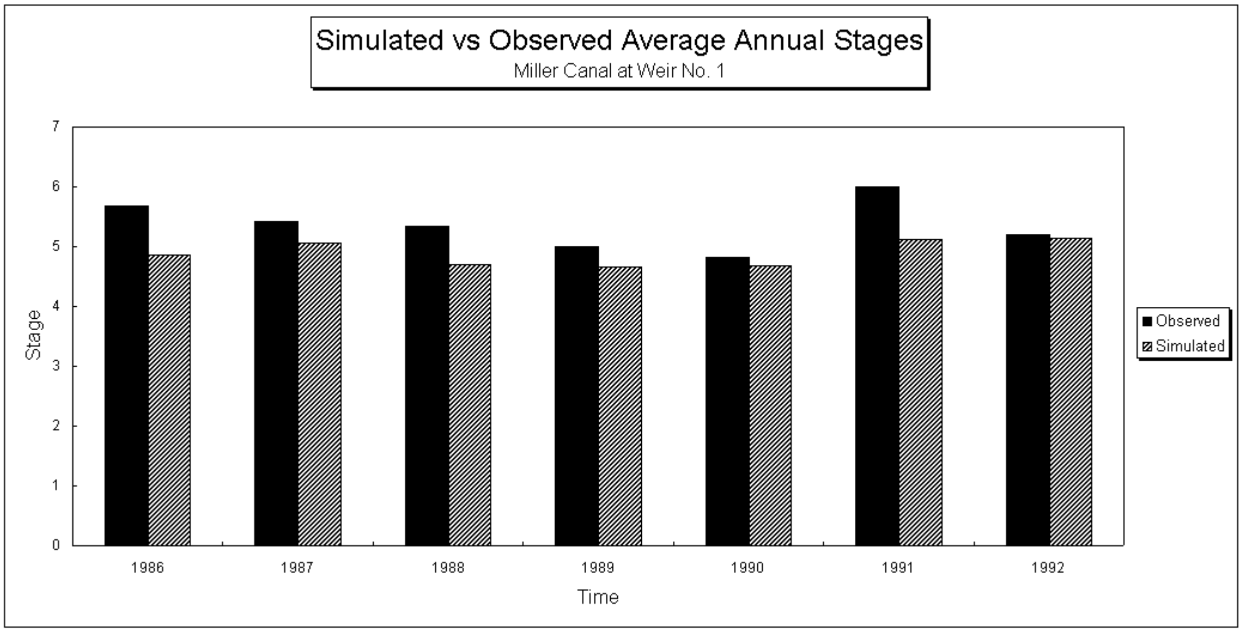

Simulated vs Observed Average Annual Stages
Miller Canal at Weir No. 1
Stage
0
1
2
3
4
5
6
7
1986
1987
1988
1989
1990
1991
1992
Time
■ Observed
▨ Simulated

Figure 23

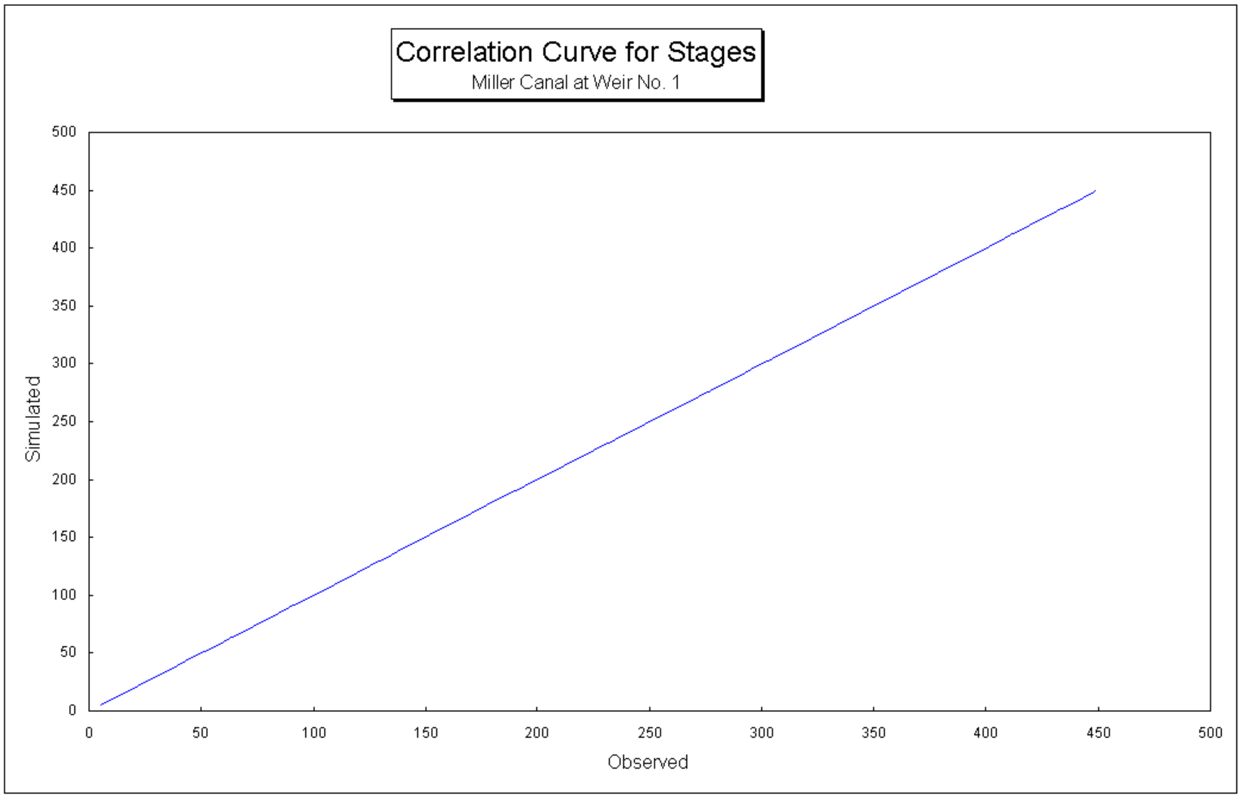


Figure 24

Typical wet and dry season weir crest elevations were used. However, it is impossible to chronologically account for every change to each weir structure due to incomplete records of operation logs and also the necessary limitations in the model.

Excessive weed growth in the canals affect the hydraulic capacities of the canals and consequently the recorded discharges at the outlet of the basin. A study on the conditions of the Faka Union and Miller Canals south of Alligator Alley, prepared by Stanley W. Hole and Associates in the summer of 1976, mentioned vegetative growth in both canals and particularly heavy growth in the Faka Union Canal. With the exception of the Faka Union Weir No. 5 location, the calibration locations near the headwaters of the canals showed better correlations than those further downstream.

3-2.3c Final Calibration Parameters

The final set of calibration parameters used for the simulation of SGGE is shown in Table 5. A list of parameter abbreviations from the HSPF program is shown in Appendix A.

3-2.3d Sensitivity Analysis of Model Parameters

Precipitation and evapotranspiration are direct determinants of water availability and therefore, the simulation in HSPF is very sensitive to the magnitude of precipitation. A thorough search for all available rainfall records resulted in the use of six different rainfall stations that surround the SGGE area. Due to the convective nature of scattered summer thunderstorms, rainfall at any given location can be spatially variable to a considerable extent. An example of this is evident when the model output was examined for August 13, 1981. The Corkscrew Swamp Sanctuary rainfall records report 3.75 inches of rain for that day; however, USGS discharge records for the Faka Union Weir No. 5 approximately nine miles southeast of the rainfall station show only a modest increase in discharge from 15 to 21 cfs over the next few days. On May 16, 1982 USGS

TABLE 5

FINAL PARAMETERS FOR HSPF SIMULATION OF SGGE

Parameter Set 1

PLS	FOREST	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
1	0	8	0.09	1660	0.00061	1.0	0.980
2	0	8	0.04	1660	0.00032	0.0	0.940
3	0	4	0.04	1660	0.00019	0.0	0.940
4	0	4	0.04	1660	0.00016	0.0	0.940
5	0	8	0.09	1660	0.00014	0.0	0.960
6	0	6	0.09	1660	0.00012	0.0	0.960
7	0	6	0.09	1660	0.00033	0.0	0.960
8	0	4	0.09	1660	0.00035	0.0	0.940
9	0	4	0.04	1660	0.00014	0.0	0.940
10	0	2	0.04	1660	0.00008	0.0	0.940
11	0	2	0.04	1660	0.00032	0.0	0.940
12	0	4	0.10	1660	0.00013	0.0	0.940
13	0	4	0.09	1660	0.00013	0.0	0.940
14	0	4	0.04	1660	0.00002	0.0	0.940
15	0	4	0.10	1660	0.00019	0.0	0.940
16	0	4	0.04	1660	0.00002	0.0	0.940
17	0	4	0.04	1660	0.00038	0.0	0.940
18	0	6	0.09	1660	0.00021	0.0	0.940
19	0	2	0.04	1660	0.00021	0.0	0.940
20	0	2	0.04	1660	0.00030	0.0	0.940
21	0	8	0.09	1660	0.00013	0.0	0.940
22	0	4	0.04	1660	0.00012	0.0	0.940
23	0	4	0.04	1660	0.00032	0.0	0.940
24	0	4	0.04	1660	0.00018	0.0	0.940
25	0	4	0.04	1660	0.00025	0.0	0.940
26	0	4	0.04	1660	0.00013	0.0	0.940
27	0	2	0.04	1660	0.00008	0.0	0.940
28	0	2	0.04	1660	0.00008	0.0	0.940
29	0	2	0.04	1660	0.00008	0.0	0.940
30	0	4	0.04	1660	0.00042	0.0	0.920
31	0	4	0.06	1660	0.00032	0.0	0.940
32	0	4	0.04	1660	0.00018	0.0	0.940
33	0	4	0.04	1660	0.00008	0.0	0.920
34	0	4	0.04	1660	0.00032	0.0	0.940
35	0	6	0.06	1660	0.00032	0.0	0.940
36	0	4	0.04	1660	0.00020	0.0	0.920
37	0	4	0.04	1660	0.00020	0.0	0.920

PLS = Pervious Land Segment
FOREST = fraction of winter forest transpiration
LZSN = lower zone nominal soil storage (in)
INFILT = index to mean infiltration rate (in/hr)
length of overland flow plane (ft)

SLSUR = slope of overland flow plane
KVARY = groundwater recession behavior parameter (1/in)
AGWRC = active groundwater recession LSUR = coefficient (1/day)

TABLE 5 (Continued)

Parameter Set 2

PLS	PETMAX	PETMIN	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
1	40.	35.	2.0	2.0	.30	0.0	0.40
2-3	40.	35.	2.0	2.0	.05	0.0	0.40
4	40.	35.	2.0	2.0	.50	0.0	0.40
5-6	40.	35.	1.0	2.0	.10	0.0	0.40
7	40.	35.	1.0	2.0	.03	0.0	0.40
8-9	40.	35.	2.0	2.0	.03	0.0	0.40
10	40.	35.	2.0	2.0	.03	0.0	0.60
11	40.	35.	2.0	2.0	.03	0.0	0.70
12-13	40.	35.	2.0	2.0	.03	0.0	0.40
14	40.	35.	2.0	2.0	.03	0.0	0.60
15	40.	35.	2.0	2.0	.03	0.0	0.40
16	40.	35.	2.0	2.0	.03	0.0	0.60
17-18	40.	35.	2.0	2.0	.03	0.0	0.70
19	40.	35.	2.0	2.0	.03	0.0	0.40
20	40.	35.	2.0	2.0	.03	0.0	0.70
21-22	40.	35.	2.0	2.0	.03	0.0	0.40
23-24	40.	35.	2.0	2.0	.03	0.0	0.40
25-26	40.	35.	2.0	2.0	.03	0.0	0.40
27-29	40.	35.	2.0	2.0	.03	0.0	0.60
30	40.	35.	2.0	2.0	.03	0.0	0.70
31-32	40.	35.	2.0	2.0	.03	0.0	0.40
33	40.	35.	2.0	2.0	.03	0.0	0.70
34	40.	35.	2.0	2.0	.03	0.0	0.40
35	40.	35.	2.0	2.0	.03	0.0	0.60
36-37	40.	35.	2.0	2.0	.03	0.0	0.70

PETMAX = air temperature which signals a change in ET calculation (F), only used if snow is considered
PETMIN = air temperature which signals a change in ET calculation (F), only used if snow is considered
INFEXP = exponent in infiltration equation
INFILD = ratio of max/min infiltration rate
DEEPFR = fraction of groundwater lost to deep aquifer
BASETP = fraction of ET from active groundwater outflow
AGWETP = fraction of ET from active groundwater storage

TABLE 5 (Continued)

Parameter Set 3

PLS	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
1	0.100	1.80	0.70	5.00	0.90	0.50
2	0.100	0.50	0.70	5.00	0.95	0.30
3	0.150	0.50	0.70	5.00	0.95	0.70
4	0.150	0.50	0.70	5.00	0.95	0.80
5	0.150	0.50	0.70	5.00	0.90	0.80
6	0.150	0.50	0.70	5.00	0.90	0.80
7	0.100	0.50	0.70	5.00	0.90	0.60
8	0.150	0.50	0.70	5.00	0.95	0.80
9	0.150	0.50	0.70	5.00	0.95	0.80
10	0.150	0.50	0.70	5.00	0.95	0.70
11	0.150	0.50	0.70	5.00	0.95	0.70
12	0.150	0.50	0.70	5.00	0.95	0.70
13	0.150	0.50	0.70	5.00	0.95	0.70
14	0.100	0.50	0.70	5.00	0.95	0.40
15	0.150	0.50	0.70	5.00	0.95	0.70
16	0.150	0.50	0.70	5.00	0.95	0.70
17	0.150	0.50	0.70	5.00	0.95	0.70
18	0.150	0.50	0.70	5.00	0.95	0.70
19	0.100	0.50	0.70	5.00	0.95	0.40
20	0.150	0.50	0.70	5.00	0.95	0.70
21	0.100	0.50	0.70	5.00	0.95	0.30
22	0.150	0.50	0.70	5.00	0.95	0.70
23	0.150	0.50	0.70	5.00	0.95	0.70
24	0.100	0.50	0.70	5.00	0.95	0.40
25	0.150	0.50	0.70	5.00	0.95	0.80
26	0.150	0.50	0.70	5.00	0.95	0.70
27	0.150	0.50	0.70	5.00	0.95	0.70
28	0.100	0.50	0.70	5.00	0.95	0.40
29	0.150	0.50	0.70	5.00	0.95	0.70
30	0.200	0.50	0.70	5.00	0.95	0.90
31	0.150	0.50	0.70	5.00	0.95	0.80
32	0.150	0.50	0.70	5.00	0.95	0.40
33	0.150	0.50	0.70	5.00	0.95	0.90
34	0.150	0.50	0.70	5.00	0.95	0.70
35	0.150	0.50	0.70	5.00	0.95	0.40
36	0.200	0.50	0.70	5.00	0.95	0.90
37	0.100	0.50	0.70	5.00	0.95	0.40

CEPSC = interception storage capacity (in)
NSUR = Manning's n for overland flow
UZSN = upper zone nominal soil storage (in)
INTFW = interflow inflow parameter
IRC = interflow recession rate (1/day)
LZETP = lower zone evapotranspiration parameter

TABLE 5 (Continued)

Monthly Variable Parameter - LZETP

PLS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
2	0.2	0.2	0.2	0.2	0.2	.05	.05	.05	.05	.05	0.2	0.2
3	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
4-6	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.4
7	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3
8-13	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4
14	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
15-17	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.4
18	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.4
19	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
20	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
21	0.2	0.2	0.2	0.2	0.2	.05	.05	.05	.05	.05	0.2	0.2
22	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
23	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
24	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
25	0.6	0.7	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.6
26	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
27	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
28	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
29	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
30	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7
31	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4
32	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
33	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7
34	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
35	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
36	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7
37	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3

TABLE 5 (Continued)

Parameters for Initial Conditions

PLS	CEPS	SURS	UZS	IFWS	LZS	AGWS	GWVS
1	0.00	0.0	0.0	0.0	6.0	1.7	0.00
2	0.00	0.0	0.0	0.0	6.0	1.7	0.00
3	0.00	0.0	0.0	0.0	6.0	3.5	0.00
4	0.00	0.0	0.0	0.0	6.0	2.0	0.00
5	0.00	0.0	0.0	0.0	6.0	1.7	0.00
6	0.00	0.0	0.0	0.0	6.0	2.0	0.00
7	0.00	0.0	0.0	0.0	6.0	2.0	0.00
8	0.00	0.0	0.0	0.0	5.0	1.7	0.00
9	0.00	0.0	0.0	0.0	5.0	2.0	0.00
10	0.00	0.0	0.0	0.0	4.0	2.0	0.00
11	0.00	0.0	0.0	0.0	4.0	2.0	0.00
12	0.00	0.0	0.0	0.0	4.0	1.7	0.00
13	0.00	0.0	0.0	0.0	4.0	2.0	0.00
14	0.00	0.0	0.0	0.0	4.0	2.0	0.00
15	0.00	0.0	0.0	0.0	4.0	1.7	0.00
16	0.00	0.0	0.0	0.0	4.0	2.0	0.00
17	0.00	0.0	0.0	0.0	3.0	2.0	0.00
18	0.00	0.0	0.0	0.0	4.0	2.0	0.00
19	0.00	0.0	0.0	0.0	3.0	2.0	0.00
20	0.00	0.0	0.0	0.0	3.0	2.0	0.00
21	0.00	0.0	0.0	0.0	6.0	1.7	0.00
22	0.00	0.0	0.0	0.0	6.0	3.0	0.00
23	0.00	0.0	0.0	0.0	4.0	2.0	0.00
24	0.00	0.0	0.0	0.0	4.0	3.0	0.00
25	0.00	0.0	0.0	0.0	4.0	1.7	0.00
26	0.00	0.0	0.0	0.0	4.0	2.0	0.00
27	0.00	0.0	0.0	0.0	4.0	1.7	0.00
28	0.00	0.0	0.0	0.0	4.0	2.0	0.00
29	0.00	0.0	0.0	0.0	3.0	1.7	0.00
30	0.00	0.0	0.0	0.0	4.0	2.0	0.00
31	0.00	0.0	0.0	0.0	4.0	2.0	0.00
32	0.00	0.0	0.0	0.0	4.0	3.0	0.00
33	0.00	0.0	0.0	0.0	3.0	2.0	0.00
34	0.00	0.0	0.0	0.0	4.0	2.0	0.00
35	0.00	0.0	0.0	0.0	3.0	2.0	0.00
36	0.00	0.0	0.0	0.0	4.0	2.0	0.00
37	0.00	0.0	0.0	0.0	3.0	2.0	0.00

CEPS = interception storage at the start of the simulation (in)
SURS = surface storage at the start of the simulation (in)
UZS = upper zone soil storage at the start of the simulation (in)
IFWS = interflow storage at the start of the simulation (in)
LZS = lower zone soil storage at the start of the simulation (in)
AGWS = active groundwater storage at the start of the simulation (in)
GWVS = index to groundwater slope at the start of the simulation (in)

discharge records report an increase in discharge from 2 to 19 cfs, however rainfall records at the Corkscrew Swamp Sanctuary report no rainfall on or around that day. This abrupt increase in discharge may have resulted from opening of stop logs at the weir which was not recorded.

Since groundwater outflow or baseflow is what makes up most of the canal discharge during the dry season, the HSPF submodel that simulates groundwater inflow, outflow and storage is the primary means to model dry season flow in the study area. The inflow to groundwater is direct infiltration plus percolation from the upper zone that does not travel to the lower zone plus an optional external lateral groundwater inflow. The outflows from groundwater are deep percolation to inactive groundwater, groundwater outflow to streams and evaporation from groundwater. The outflow is calculated by:

AGWO = KGW*(1.0 + KVARY*GWVS)*AGWS

where KGW = 1.0 - (AGWRC)**(DELT60/24)

AGWO = active groundwater outflow

KGW = groundwater outflow recession parameter, per interval

KVARY = parameter which can make active groundwater storage to outflow relation nonlinear in per inch

GWVS = index to groundwater slope in inches

AGWS = active groundwater storage at the start of the simulation in inches

AGWRC = daily recession constant of groundwater flow, if KVARY or GWVS = 0.0 That is, the ratio of current groundwater discharge to groundwater discharge 24-hr earlier

DELT60 = hr/interval

The major parameters that affect the modeling of shallow groundwater flow are AGWRC and KVARY. Minor adjustments to the AGWRC caused significant changes in runoff hydrograph shapes. The AGWRC was varied from 0.998 to 0.945. With AGWRC = 0.998, active groundwater storage was high and outflow was slowly released. With high values of AGWRC, groundwater tends to be retained in storage rather than being released as groundwater outflow. Reasonable runoff volumes could only be achieved with AGWRC equal to lower values such as 0.945. The runoff hydrograph shape tended to be fatter and shorter and match better with the observed hydrographs.

With KVARY = 1.0, the modeler has the option to make groundwater recession rates variable. By making KVARY = 1.0, the GWVS variable is activated. In the model, GWVS is increased each interval (in this case each day) by the inflow to active groundwater and decreased by three percent each day. The overall effect of activating the GWVS variable seems to increase baseflow during wet periods and decrease base flow during drier periods. In this case, with KVARY = 1.0, wet season flows were greatly over estimated. Spring flows seemed to be better represented and dry season flows remained unchanged. Overall, it seems that in using the variable recession rate through the KVARY and GWVS parameters, GWVS is highly influenced by the wet season antecedent conditions and is increased too much and as a result, wet season flows are overestimated. Dry season flows are not affected because after several days or even months with no significant rainfall, the GWVS is decreased to zero and ceases to be of any help in producing groundwater outflow during the dry season. Therefore, KVARY was set to zero for all but PLS No. 1 and the AGWRC was set to fairly low values ranging from 0.92 to 0.96 with one PLS set to 0.98. By making AGWRC lower, reasonable runoff volumes were achieved. However, groundwater did not remain in storage when direct infiltration from precipitation ceased during the dry season and percolation inflow from soil storage diminished. The groundwater storage decreased to zero and was no longer able to produce outflow. As a result, dry season runoff tended to be under estimated by the model.

A study by Caroline Hicks called "Continuous Simulation of Surface and Subsurface Flows in Cypress Creek Basin, Florida, Using Hydrological Simulation Program-Fortran (HSPF)" investigated the ability of HSPF to successfully model groundwater flow in Florida. According to that report (Hicks, 1985), "The physical behavior of the watershed which the model was not successfully simulating was the depletion of the Surficial Aquifer during successive dry months. If rainfall is not available to replenish the Surficial Aquifer, ET and leakage to deep groundwater can reduce the water table level until it drops below the level of the stream bed. When rainfall occurs after such a depletion, water must fill the surficial storage to the threshold level of the stream bed before runoff will be observed. The active groundwater storage zone of the model does not recognize a threshold level of storage below which outflow will not occur. Any water entering the active groundwater storage zone must eventually leave as either evapotranspiration or outflow to a stream; no minimum level of storage is maintained."

In general, there are two types of calibration parameters in the PERLND module of HSPF; those whose adjustments affect volume runoff totals and those whose adjustments affect only the hydrograph shape without affecting total runoff volumes. The following parameters are generally used to change volume totals: upper zone nominal storage (UZSN), lower zone nominal storage (LZSN), various evapotranspiration (ET) parameters such as lower zone evapotranspiration parameter (LZETP), active groundwater evapotranspiration parameter (AGWETP), and baseflow evapotranspiration parameter (BASETP), and fraction of groundwater to deep aquifer (DEEPFR). The infiltration parameter (INFILT) affects both runoff volumes and hydrographs. The principal parameters that affect the hydrograph shape but not volumes are the interflow recession coefficient (IRC), interflow inflow parameter (INTFLW), active ground water recession coefficient (AGWRC), and the variable groundwater recession rate coefficient (KVARY).

The effect of AGWRC and KVARY has been previously discussed. With the exception of DEEPFR, the parameters that influence the runoff volumes are those that also influence the total ET amounts. The INFILT parameter allows the modeler to shift the water losses from runoff to ET and vice versa. The LZETP parameter facilitates the modeling of ET by helping to characterize vegetation type and other factors that determine ET losses from the lower soil storage zone. This parameter was input on a monthly basis to account for seasonal variation. Higher values increase ET and decrease runoff. The AGWETP and BASETP have a similar effect. An AGWETP value of 0.7 was suggested for wetland areas. However, through the calibration process, a value of 0.4 was used because higher values caused too much water to be lost to ET and runoff volumes to be too small. Increasing the LZSN also increases the ET and lowers the runoff. A major portion of the actual ET comes from the lower soil moisture zone and increasing LZSN will increase simulated ET. Increasing LZSN also tends to lower runoff peaks. DEEPFR is the fraction of groundwater that is lost to inactive groundwater and therefore, is not available for runoff or ET. Increasing DEEPFR will reduce runoff because less groundwater will be available for outflow.

Hydrograph shape of a selected storm can be adjusted with the INTFLW and IRC parameters and with minor adjustments to UZSN and INFILT parameters. Increasing UZSN will reduce peaks considerably and will represent watersheds that have significant subsurface and interflow components. Low UZSN values are indicative of highly responsive watersheds where the surface runoff component is dominant (Donigian, 1984).

Initially the UZSN and LZSN values were obtained using information from the SCS soil survey. The upper zone of the soil corresponds somewhat to what the SCS soil survey describes as the surface layer of the soil which can vary in thickness from two to five inches. This thickness multiplied by the soil's water holding capacity gave a starting value for UZSN. The final UZSN parameter was increased slightly to reduce high flows. The LZSN parameter values were obtained using information about the substratum layer of the soil from the SCS soil survey. This thickness extended between 35 to 52 inches below the ground surface. The initial values calculated were raised through the calibration process to increase ET and decrease runoff.

The INFILT parameter governs the division of precipitation into various components (surface, interflow and groundwater). The initial INFILT parameter was selected on the basis of the permeability of the soil given by SCS soil survey. The typical values for INFILT range from 0.008 to 1.0 and the original value of six was greatly reduced to a calibrated values between 0.04 and 0.10. High values indicate high infiltration which is the case in the study area where sandy soils predominate. However, all of the precipitation was rapidly going directly to groundwater flow and as a result, there was no surface flow component. Although many of the soils found in the study area have permeabilities of 6 in/hr or greater, the infiltration parameter had to be reduced to allow some surface flow. Although some parameters such as INFILT are physically meaningful, they may not correspond on a one to one basis with their physical counterparts (in this case, permeability). The UZSN and LZSN parameter are also examples of this. Both of these parameters were adjusted after initial estimates were made based on SCS soils information.

The FTABLES or function tables describe the hydraulic performance of the canals. Initially the HEC-2 program output and cross section profiles from the Black, Crow and Eidsness study were used to develop these tables. However, it was observed that large changes in stage elevation were occurring with relatively small changes in discharge values and summer peak discharges were consistently under estimated. After several unsuccessful attempts to change this with PERLND parameter alone, rating curves based on USGS stage and discharge records were used to adjust the FTABLES. The new FTABLES resulted in better correlation of both discharge volumes and hydrographs. Additional columns were added to the Faka Union Canal FTABLES to represent the time variant impediments to flow (both aquatic weeds and flashboards) and groundwater seepage from the Faka Union Canal near the City of Naples wellfield. The use of multiple columns did improve the results of the simulation.

Changes to the parameters governing surface flow length of overland flow (LSUR) and Manning's n for overland flow (NSUR) did not prove to be nearly as sensitive as changes to the subsurface and groundwater parameters. This could be attributed to the fact that the surface component of runoff is a much smaller percentage of total runoff than the groundwater outflow component. Generally the effect of these two parameters diminishes as the simulation time step increases from hourly to daily and as the watershed areas become larger.

3-2.3e Verification of the Model

The model was tested for verification using a seven-year simulation period of 1985 to 1992 with the flow data collected at Faka Union Weir No. 1. This station was used for verification because it records the outflow from the entire watershed and has continuous records of outflow from 1969. The period 1985 to 1992 was chosen because this period covers a representative cycle of drought and wet years including the relatively dry years of 1988-1990 and the wet years of 1991-1992. The results as shown in Figure 25 were similar to the calibration results at weir No. 1 for 1970 to 1984. The overall evaluation of model performance to simulated SGGE is discussed in the next section.

3-3. EVALUATION OF MODEL PERFORMANCE

3-3.1 Presence of Seasonal Variable High Groundwater Table in South Florida Hydrology

One unique element in South Florida hydrology is a seasonally varying water table with a large amplitude. During the wet season the piezometric head can come up very close to, or above the land surface. The parameters that can be varied seasonably in HSPF are interception storage capability(CEPSC), upper zone soil nominal storage(UZSN), manning's n for overland flow (NSUR), interflow parameter(INTFW), interflow recession parameter(IRC) and lower zone soil evaporation parameter(LZETP). These parameters account for changing evaporation/transpiration rates from vegetation, leaf cover and agricultural practices such as plowing. A varying groundwater table is not thought to change surface runoff volumes significantly due to its location a fair distance below ground. Changing soil moisture levels are considered to affect surface runoff significantly, although changing soil moisture conditions are usually assumed to result from rainfall events rather than by a rising groundwater table and resulting fully saturated soil conditions. These assumptions do not hold true for the wetlands in south Florida. Throughout a typical year, the water table may vary by

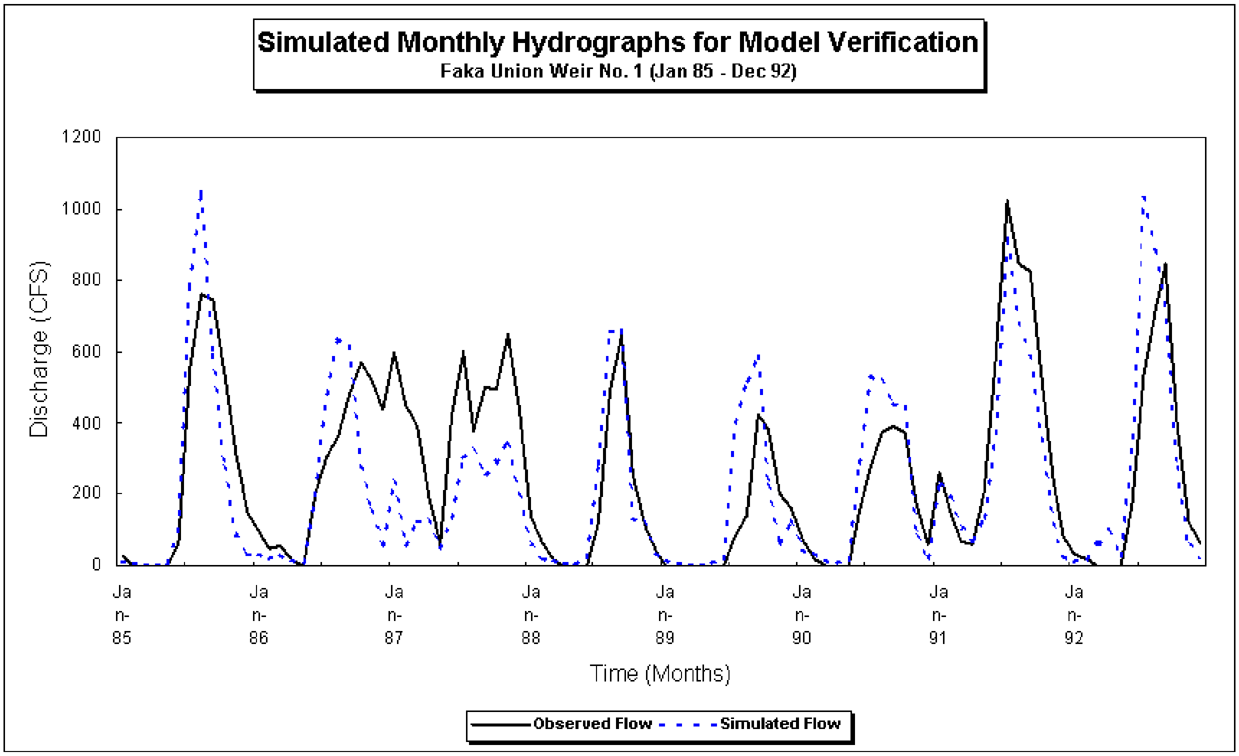


Figure 25

several feet, rising above the land surface during the wet season and dropping during the dry season. These cyclic groundwater levels affect such hydrologic processes as soil storages, evapotranspiration from the upper and lower zones of soil horizon, runoff and direction of shallow groundwater flow. Some seasonal variation of parameters is allowed in HSPF (i.e. seasonal canopy changes), but not to the extent that it can model a seasonal high water table.

Head differences between the canal water levels and the adjacent groundwater levels vary seasonally and as a result, changes in groundwater flow direction can occur. A good example of this change in flow direction in SGGE occurs in the western portion of the Fakahatchee Strand State Preserve and in the area east of Faka Union Canal between Faka Union Canal Weir No. 5 and I-75.

During the wet season when the groundwater levels are high, groundwater may move in a south to southwest direction. As dry season progresses, the groundwater movement may shift direction to an east-west pattern, draining directly into one of the north-south canals. A surficial groundwater movement vector, based on three dimensional finite difference modeling of western Collier County, is illustrated in Figure 26. In the HSPF model of SGGE, one direction must be chosen for the entire simulation period and a seasonal shift in the groundwater flow direction cannot be simulated.

3-3.2 Sheetflow Hydraulics

When the water table rises above the land surface and large land areas are flooded, the existing Pervious Land (PERLND) module of HSPF does not model the sheetflow characteristics adequately. The extremely flat slopes and depressional storages stretch the assumptions of the surface runoff model as flow on an inclined plane. A typical expanse of natural south Florida wetland has the ability to store an enormous amount of water. The existing overland flow algorithms do not represent the storage effects of these wetlands and thus over estimate the runoff peaks. During the calibration process, the parameters were adjusted to increase infiltration and groundwater flow and runoff peaks were matched better. Also evaporation from overland flow is not represented in the model, because in a typical non-wetland area, overland flow exists for a brief time period (hours) during or immediately following a rainfall event. In wetland areas where overland flow may last weeks, evaporation should be accounted for. Further enhancement to the PERLND module to account for these unique features of south Florida wetlands has been proposed in a recently undertaken study by the District. The enhanced program can be applied later to update the SGGE model.

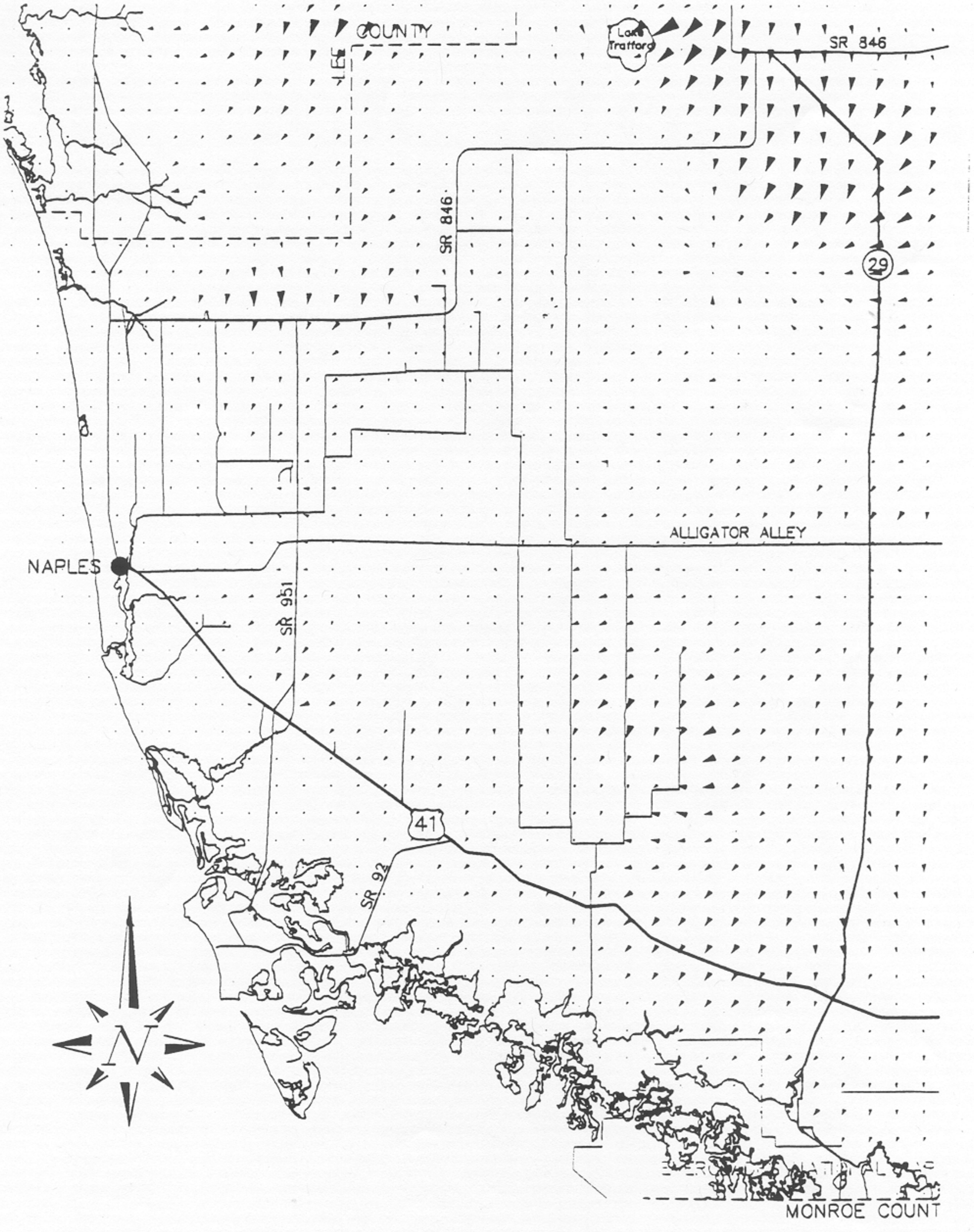


FIGURE 26. Surficial Aquifer Horizontal Movement During Dry Season
(Bennett, Michael W., April 1992)

3-3.3 Reach-Reservoir (RCHRES) Module of HSPF

The outflow hydrograph is sensitive to the function tables (FTABLES) which represents the stage-storage-outflow characteristics of the canals. The runoff hydrographs were better matched at Miller Canal at 26th Avenue SE than at Miller Canal Weir No. 1, a location farther downstream. As the runoff is routed through the canals, inadequate accounting of storage and discharge relationships along canal reach and flat topography might have resulted in loss of some accuracy. The modification of the RCHRES module to dynamically route flows through canals with flat bed slopes and various control structures should enhance the simulation of flow characteristics in South Florida canals.

3-3.4 Assumptions in Alternative Analysis

Though the application of the PERLND and RCHRES modules of HSPF provides a fair representation of the existing SGGE hydrology, the alternatives analysis creates new challenges. Traditional applications of HSPF have included reservoir operations analysis, stormwater management plan development and water quality studies related to waste treatment, urban and/or agricultural management practices. The task of representing alternative measures for restoration of wetland hydrology of SGGE is a unique application. The spreader channel along the north boundary of SGGE is simulated as a reach discharging into a land segment as lateral inflows. (Refer to Chapter 4, Section 4-1.2c) This is not the conventional direction of flow in the runoff hydrologic cycle. A necessary assumption for representing the spreader channel in this way is that the water from the spreader is spread out evenly over the entire land segment and not along a "line" as in the real physical world.

As the hydrology of SGGE is restored, one might assume certain HSPF parameters as infiltration factor (INFILT) and those representing soil storages would be different due to the new nearly saturated or saturated conditions. However, these are calibrated parameters and it is very difficult to accurately determine the required modification to these parameters.

HSPF does not simulate hydroperiods directly. Instead it simulates various storage zones, including soil storages, which represent the water holding capacity of the soil layers. There is not, however, a clear relationship between soil storages and wetland hydroperiods, particularly when an area becomes fully saturated and inundated. Consequently, the RCHRES module was used to provide estimates of hydroperiods given reflooded conditions. A more precise methodology for analyzing wetland hydroperiods is desirable.

3-3.5 Overall Complexity of Modeling SGGE

The SGGE hydrologic regime is complex in that there are strong interactions between the surface runoff processes, and high groundwater table levels, areas of surface inundation, and even canal water levels. The hydraulics in the canals are influenced by backwater effects, unrecorded structural and canal alterations, well pumpage, and adjacent groundwater levels. The modeling of these complexities were limited by the current version of HSPF in representing unique South Florida hydrologic conditions such as the overland runoff and infiltration components for high groundwater table. It is hoped that the proposed modification to the PERLND and RCHRES modules to simulate wetland storage characteristics and dynamic flood routing would enhance representation of a complex hydrologic regime like SGGE.

3-4. ASSESSMENT OF HYDROLOGIC CONDITIONS FOR THE SGGE REGION

Based on the detailed investigation and foregoing hydrologic-hydraulic modeling of the SGGE region, the following observations of the existing hydrologic conditions were made:

1. The canals largely control the present hydrology of SGGE. Any sheetflow that exists is quickly intercepted by a swale and directed to one of the four main canals. During the dry season, the canals collect groundwater from the adjacent land and discharge it into the Gulf of Mexico. The average discharge from the Faka Union Canal at the outlet of the basin is 260 cfs with average wet season flows of 460 cfs. Using a drainage area of 189 square miles, the runoff amounts to 18.7 inches per year.

2. The surficial groundwater flow directions vary seasonally. During dry periods, the Faka Union Canal system influences the Surficial Aquifer as far as Stumpy Strand and Fakahatchee Strand. The surficial groundwater flows west into the Faka Union Canal both at a location just east of the north Faka Union Canal near Stumpy Strand and also just east of the Faka Union Canal between weirs No. 2 and 3. Additionally, groundwater flows from the western portion of the Fakahatchee Strand State Preserve into the Prairie Canal. During the wet season when the groundwater levels are high and the soils are saturated, the Faka Union Canal system has a smaller contributory drainage area due to the absence of a gradient for groundwater outflow to the stream.

3. The shallow groundwater flow pattern in the SGGE area behaves somewhat like surface and interflow in that it peaks similarly. Generally groundwater flow is thought to behave in a gradually varying way, however, much better calibration results were obtained by having a fairly low active groundwater recession coefficient (AGWRC) which causes a rapid release of groundwater and produces noticeable groundwater peaks. However, it was also noticed that groundwater release

slows down during the dry season, even somewhat abruptly. HSPF <u>does</u> allow a time varying groundwater recession rate to be used, although the recession rate cannot be <u>arbitrarily</u> chosen. The algorithm used is that the amount of groundwater outflow is increased as there is inflow but also decreased by a set amount each day.

4. As the dry season approaches it appears that the groundwater flow at Faka Union Canal near Weir No. 1 receded at a faster rate during the early years (1970 to 1975) after the canals were built than later years (1976 to 1984). This indicates that the construction of the canals not only increased surface runoff, but also increased the rate of groundwater outflow, perhaps causing groundwater peaks that were not present before the canals were built.

5. Better calibration results were obtained at Faka Union Weir No. 5 when a higher value for deep fraction (DEEPFR) was used. DEEPFR represents the fraction of groundwater lost to the deep aquifer, and also could represent groundwater lost to wellfield pumpage. This indicates that the City of Naples wellfield located between Weirs No. 5 and 4 is benefitting by recharge from the Faka Union Canal.

4. PLAN DEVELOPMENT

4-1. DEVELOPMENT OF ALTERNATIVE RESTORATION PLANS

4-1.1 Criteria for Plan Development

Within the purview of the developed hydrologic-hydraulic model, alternative structural/nonstructural measures to modify the existing water management system of SGGE were evaluated to accomplish the following objectives of the project:

1. Wetland hydroperiod restoration (pre-Golden Gate Estates development),
2. Surface water sheetflow restoration,
3. Replacement of concentrated shock load discharges to estuaries with distributed sheetflow,
4. Improved water storage and aquifer recharge,
5. Enhanced surface water deliveries to the adjacent Fakahatchee Strand State Preserve,
6. Reduction of over-drainage of Fakahatchee Strand,
7. Reduction of over-drainage of the adjacent Florida Panther National Wildlife Refuge,
8. Maintenance of existing flood protection for areas north of I-75.

The criteria in identifying a set of restoration alternatives were geared toward developing a hydrologic regime that is compatible with achieving these objectives. Plans were formulated on the assumption that the entire extent of the lands identified under the CARL Program will be under public ownership of the State of Florida.

Although it is not listed as one of the objectives, there is an “uplands” criteria which involves preservation of the hydroperiod of existing uplands. It is important to clarify the definition of uplands and their corresponding hydroperiod regime. This study uses as a reference a study called "The Big Cypress National Preserve" (Duever et al., 1986) which describes various vegetation communities found in the Big Cypress National Preserve located nine miles to the east of SGGE. Much of the vegetation that is found in the Preserve is very similar to that which is found in SGGE. For the purpose of this study, "uplands" are defined to be "Pine Forests" as described in the above reference. Pine forests are divided into two primary types, distinguished by their dominant under story vegetation. The hydroperiod regime for both of these forests is described as follows. "...dry or only shallowly inundated conditions with a short hydroperiod of about 20-60 days annually (Duever et al., 1978). Klein et al. (1970) found that maximum water levels usually just reached the surface of the soil. Pine forests with a saw palmetto under story are generally found on drier sites, while those with a mixed grass under story are on wetter sites (Duever et al., 1986)." Normal maximum water depths are shown as less than six inches. This criteria is used to determine whether upland hydroperiods are preserved (not exceeded) under the restoration scenarios.

In order to quantify the system's response with respect to the hydrologic and hydraulic evaluation of the alternatives, various model outputs were analyzed. The various storage zones (upper zone soil, lower zone soil and groundwater storage) were analyzed. Also considered were the runoff volumes at Faka Union Weir No. 1 and over the entire basin. A simplified approach was used to estimate general hydroperiods for the SGGE area. The base conditions to which the alternatives were compared was the current system for which the model is calibrated as well as pre-development conditions. A 23-year simulation was run (1970-1992) for both the existing system and the alternatives.

4-1.2 Identification of Alternatives

Several previous studies suggested weir type water control structures on the canals as the primary means for reduction of overdrainage and restoration of the overall hydrology of SGGE. Weir structures would meet the objectives of increased water storage and aquifer recharge, but they would not eliminate the freshwater point load discharge into Faka Union Bay and fully restore wetland hydroperiods. Therefore, they do not meet all the objectives of the project and alternatives of this type were not investigated further. Five alternative restoration measures were formulated to accomplish the stated objectives of the project and are described below.

4-1.2a Alternative 1: Diversion Structure

This alternative considers the interim plan investigated earlier by the Big Cypress Basin. It includes a flow diversion structure with three 48-inch diameter gated culverts and a spreader channel located approximately one mile north of Faka Union Canal Weir No. 1 (see Figure 27). The culverts will divert up to 50 percent of the existing base flow to the spreader channel. The dissipated flows will be conveyed through public lands owned by the Fakahatchee Strand State Preserve (Florida Department of Environmental Protection) to distribute through the bridges under U. S. 41. These diverted flows will be dissipated and filtered through wet prairies as sheetflow to the Faka Union Bay. This is a partial plan, and not expected to achieve the full range of objectives identified for the SGGE restoration project.

4-1.2b Alternative 2: Spreader Channel and Canal/Road Removal Plan

This alternative, as shown in Figure 28, considers one spreader channel immediately below I-75 extending from the western boundary of the SGGE study area eastward nearly to the western boundary of the Fakahatchee Strand State Preserve. This plan also considers removal of all roads and canals south of Alligator Alley with provision of pumps on the Miller, Faka Union and Merritt Canals for flood control of the NGGE. This alternative is intended to provide insight to

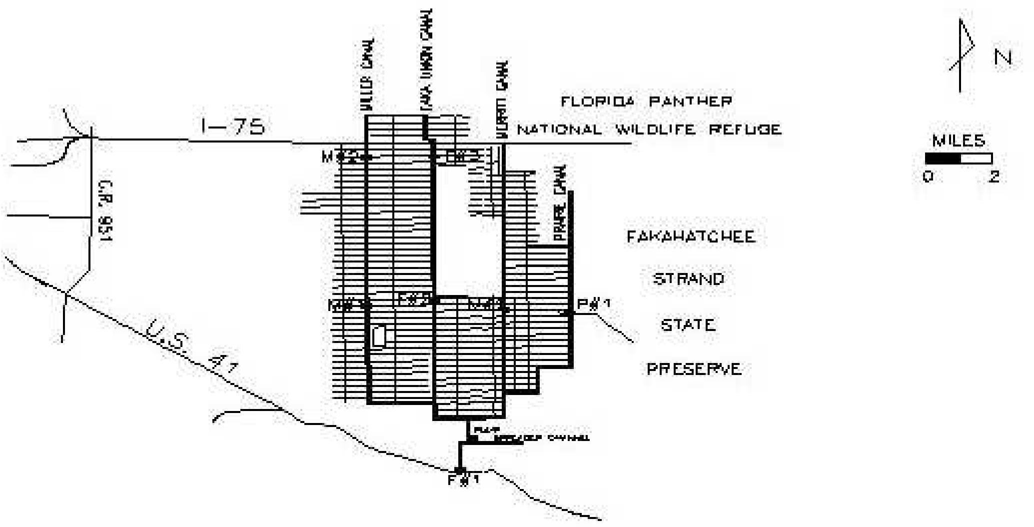


FIGURE 27. Conceptual Plan of Alternative 1 – Faka Union Diversion Structure

predevelopment conditions had there been no development south of I-75, although canal and roads will continue to exist north of I-75. Major system response information for SGGE such as runoff volumes and rates and relative soil storages were examined. Evaluation of NGGE runoff was part of the results analyzed in this alternative.

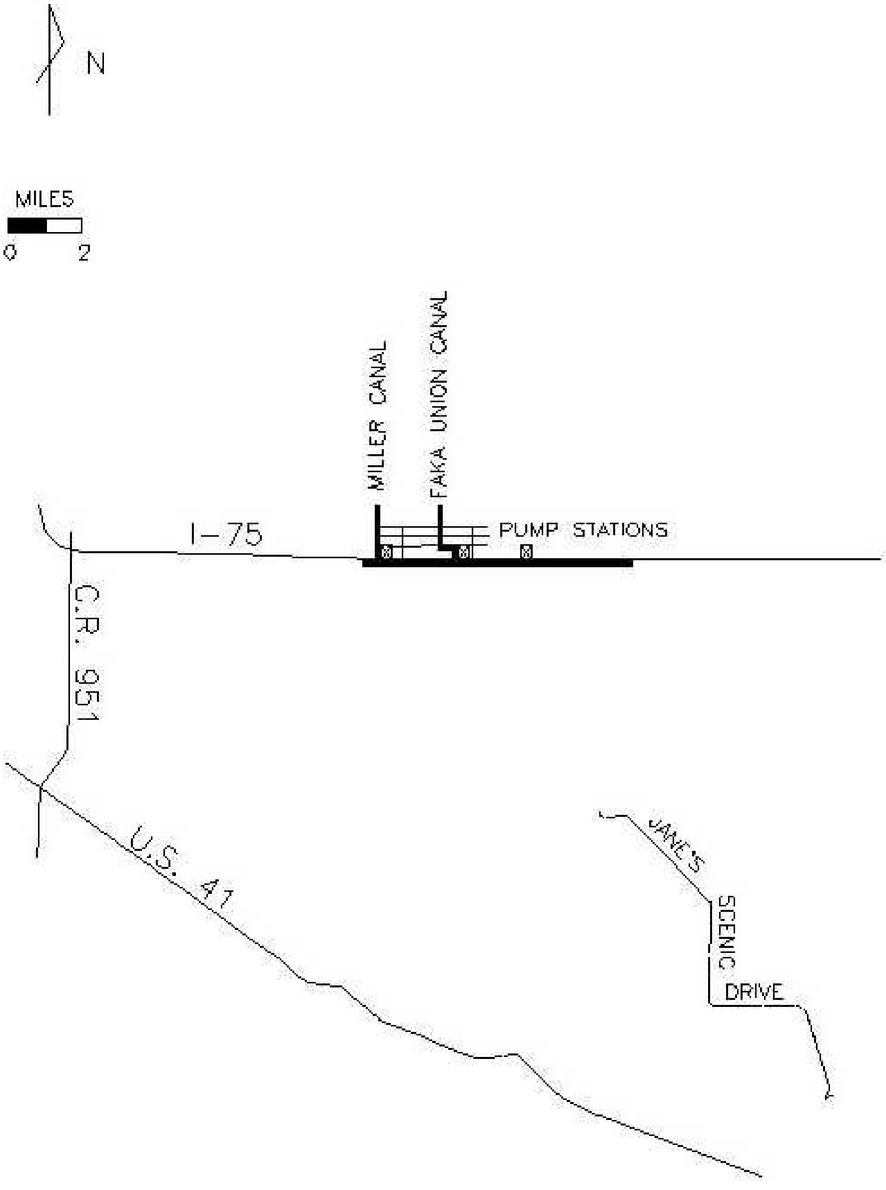


FIGURE 28. Conceptual Plan of Alternative Two – Spreader Channel and Canal-Road Removal Plan

4-1.2c Alternative 3: Spreader Channels, Canal Blocks and Selected Road Removal Plan

Three configurations of structural elements were formulated for Alternative 3, all of which have some common key components. These are (a) spreader channels, (b) pump stations on each of the three major north-south canals which contribute drainage from NGGE, © removal or grading down of selected roads and old tram lines, (d) canal plugs and roadside swale blocks, (e) elimination of canal maintenance south of the spreader channel locations, and (f) continuation of the groundwater level monitoring program. These elements are described in detail below.

(a) Spreader Channels

A typical spreader channel, shown in Figure 29, accepts pumped flow from one of the three main incoming north-south canals and spreads the water over a broad east-west front. The pumps discharge into a stilling basin to reduce the flow velocities as they enter the spreader.

The purpose of the spreader channel is twofold. First, it must receive flow from the north-south canals and redirect this flow in an east-west direction. Secondly, it must redistribute the flow in a broad shallow front across the land surface, usually by overtopping its downstream (in this case south) bank and discharging onto the land surface. If only the first purpose was important, a channel cross-section similar to the current GAC canals could be used. However, the backwater effects of raising the water surface elevation in the spreader channel high enough to allow overtopping and

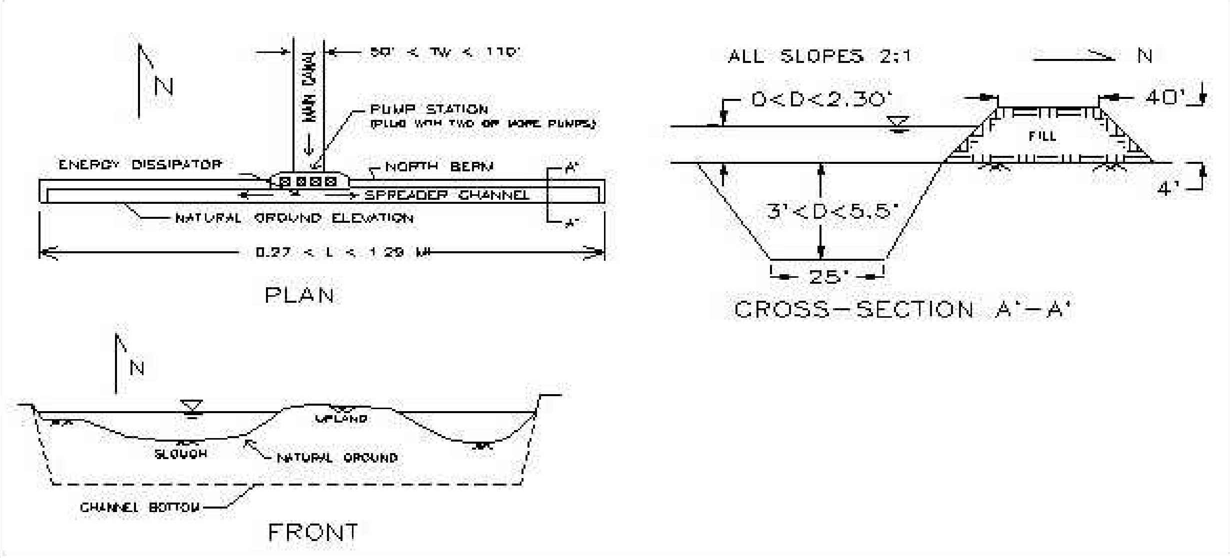


FIGURE 29. Typical Spreader Channel

discharge onto the land surface would compromise flood protection for the upstream portions of the north-south canals. In order to maintain flood protection north of I-75, two water levels must be maintained and separated in the canal with the downstream or south end at the necessary higher level (i.e. at or slightly above ground) and the upstream or north end at the lower level.

The proposed spreader is a relatively shallow channel. As shown in Figure 30, the water surface elevation is "stepped up" by pumping into the spreader channel and the water then flows by gravity onto the land surface by overtopping the spreader banks. The bed of the spreader channel is sloped to allow the water to reach the remote ends of the spreader channel. Water is prevented from backing up to the north by a north berm and by natural topography. A seepage ditch collects the seepage and returns it to the spreader channel.

Earlier studies of the SGGE canal system suggested possible spreader channels on the Prairie Canal and near the outlet of the system along U.S. 41. However, the alternatives considered in this study propose complete removal of channelized flow south of I-75. Therefore, any additional spreader channel located south of the initial spreader channels would be impractical due to lack of channelized inflow available at these locations. Consequently, restoration elements of that type were not considered in any of the alternatives.

The spreader channels discharge into the headwaters of several major flowways (or sloughs) in SGGE. Flood conveyance through the SGGE sloughs is a significant constraint for design of the spreader channels. These flowways have an optimal water stage (and corresponding conveyance capacity) with respect to the requirements of local flora and fauna. One must limit design flows to what the sloughs can convey at a reasonable stage. Higher design flows mean higher water stages in the sloughs and surrounding areas, which may not meet the criteria of restoring historic

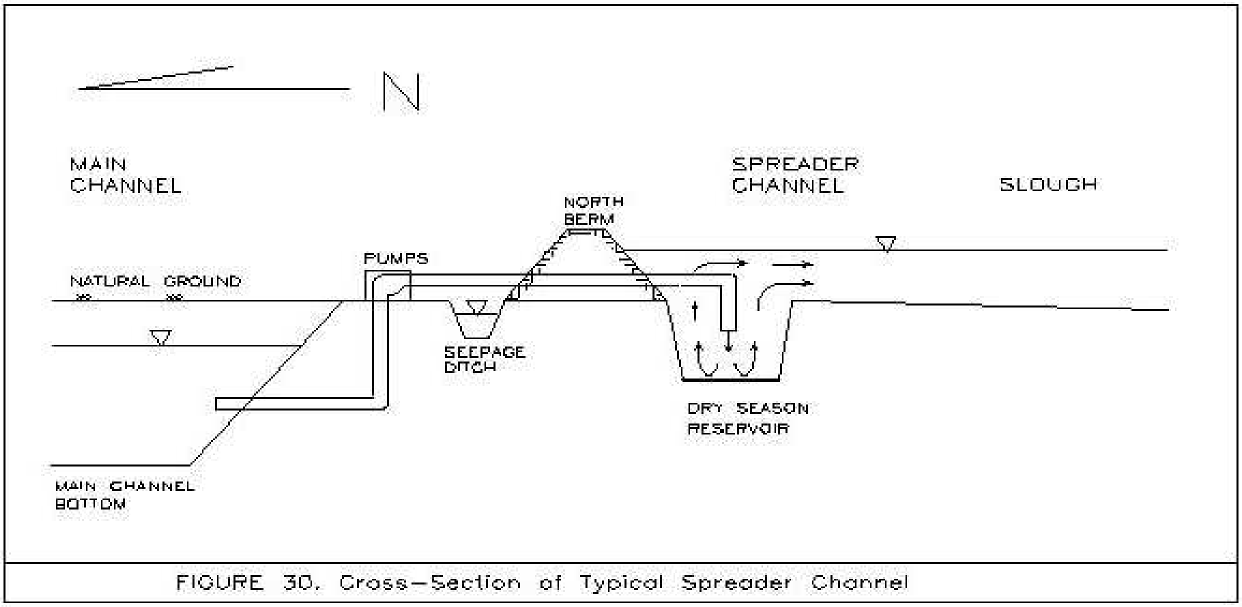


FIGURE 30. Cross–Section of Typical Spreader Channel

(pre-Golden Gate Estates) hydroperiods. This constraint is taken into account in the design of the pump station/spreader channel system.

(b) Pump Stations

As indicated above, the pump stations are an integral part of the spreader channel system. With the elimination of the gravity drainage system south of I-75 in the Faka Union basin, pumping stations are necessary to maintain and possibly enhance flood protection for areas north of I-75 within this basin. It is suggested that these pump stations be located directly upstream of the spreader channels to minimize the fill required for berm construction and to reduce the friction head loss as the flow travels form the pump to the spreader channel. The pumps are sized to pass an average daily discharge equivalent to peak canal discharge of a 10-year return frequency storm event and increase the head sufficiently to allow discharge from the spreader channels onto the land surface (design head of 5.5 to 6.5 feet). The size of the pumps required are related to their location in

SGGE. The farther south the pumps are placed, the larger the pump must be to accommodate the larger flows.

The sizing of the pumps is critical to the success of the project, as the pumps will provide flood protection for a portion of NGGE. Therefore, a careful analysis of the flows from NGGE to SGGE across I-75 was made. As observed flow data on the canals near I-75 are not available, flood flow frequency analysis was performed on the simulated flows. A summary of flood flows at this location from this analysis and also from a few earlier analyses is presented in Table 6. Stage and flow measurements taken in the vicinity of I-75 would improve the accuracy of flood flow predictions.

Backpumping capabilities for the pump stations is included in the plan. Backpumping into the upper reaches of the canal system near the City of Naples' and County's wellfield would meet the project goal of improving water supply storage. Increased canal storage and aquifer recharge north of the pump stations will also be achieved by maintenance of water levels to within one to two feet of ground surface during the dry season by adjusting the operation schedule of the pumps. These levels will be a significant improvement over the existing storage capability of structures Miller No. 2 and Faka Union No. 3, both with a weir crest elevation of 6.2 NGVD.

TABLE 6

FLOOD FREQUENCY ANALYSES FOR FLOWS ACROSS I-75

Gulf America Corporation
Date of Analysis: 1965
Method of Calculation: Rational Formula

	Miller Bridge	Faka Union Bridge	Merritt Bridge
Drainage Area(sq. mi.):	7.5	30	4.5
10- year discharge (cfs):	450	1180	346
25-year discharge (cfs):	NA	NA	NA

Black, Crow & Eidsness
Date of Analysis: 1974
Method: SCS Flood Peak Formula

	Miller Bridge	Faka Union	Merritt Bridge
Drainage Area (sq. mi.):	10	62	3
10-year discharge (cfs):	418	1342	194
25-year discharge (cfs):	529	1726	243

Greiner Engineering Sciences, Inc.
Date of Analysis: 1983
Method: USGS Stream Gage Analysis & Extrapolation

	Miller Bridge	Faka Union	Merritt Bridge
Drainage Area (sq. mi.):	--------------48-------------		74
10-year discharge (cfs):	-------------590-------------		415
25-year discharge (cfs):	-------------800-------------		560

U.S. Army Corps of Engineers
Date of Analysis: 1986
Method: HEC-1

	Miller Bridge	Faka Union	Merritt Bridge
Drainage Area (sq. mi.):	NA	NA	NA
10-year discharge (cfs):	550	1540	NA
25-year discharge (cfs):	590	1890	NA

This Study
Date of Analysis: 1995
Method: HSPF Continuous Simulation

	Miller Bridge	Faka Union	Merritt Bridge
Drainage Area (sq. mi.):	10	62	3
10-year discharge (cfs):	128	417	160

25-year discharge (cfs):	180	499	238

All configurations of this alternative have three pump stations, one located on each major north-south canal. The proposed pump stations for the Miller and Merritt Canals include two pumps each, while the pump station for the Faka Union canal has four pumps. The capacities of the pumps, however, are dependent on the volumetric rate of flow at that point in the canal. All pump stations include backup generators and seepage pumps. Additionally, two portable pumps are available for operation when a pump needs maintenance and is not operational.

(c) Road Removal

Given that there are approximately 290 miles of roads in SGGE, their complete removal is neither economically feasible nor necessary to achieve reestablishment of sheetflow. The criteria for selection of a particular segment of road for removal were based on those roads that intercepted major flowways, those located at the north end of SGGE and those roads having the greatest environmental impact. The major flowways were determined using information from topographic maps, soils and vegetation maps, aerial photographs, satellite images and field inspections.

The roads crossing major flowways were considered top priority for removal. Removal of roads beginning at the north end ensures a flowway from the spreader channels and prevents any backing up of water. As the water flows south, and farther from development and I-75, the lesser is the impact from any damming effect of the roads. The paved roads tend to be wider and possibly higher than the side dirt roads, some of which have overgrown to merely a narrow path. Therefore, the paved roads were considered to have a greater impact on the environment.

Old logging tram lines are scattered throughout SGGE and are an impediment to sheetflow.

Using the road removal as a guide, the tram paths are proposed to be leveled where they intercept a major flowway.

(d) Canal Plugs/Swale Blocks

The canals in SGGE have been responsible for the overall degradation of the hydrology and ecology of the area, more so than the roads, due to their ability to intercept the upper part of the Water Table Aquifer. Therefore, complete elimination of channelized flow south of I-75 is suggested through placement of canal plugs. Canal locations that intercept major flowways are considered a top priority location for installation of canal plugs. The suggested material for the plugs is spoil and crushed limerock which is available from the adjacent canal banks and roads designated for removal. The mild slopes of the plugs provide stability when overtopping occurs during wet periods and create both shallow and deep water habitat for wildlife and fish. The configuration of a typical earthen plug is shown in Figure 31. Much of the open water area in the canals will remain. Only less than one percent of the 540 acres of open water canals will be filled in for the plugs. Open stretches of water in the plugged canals will vary in length from 1,320 feet to two miles between plugs with many reaches of one quarter to one mile in length. Additionally, roadside swales should be blocked at the point where it enters the canal at each plug site. Without these blocks, flow would back up into the swale, cross the road to the downstream swale and discharge back into the canal, bypassing any block in the canal.

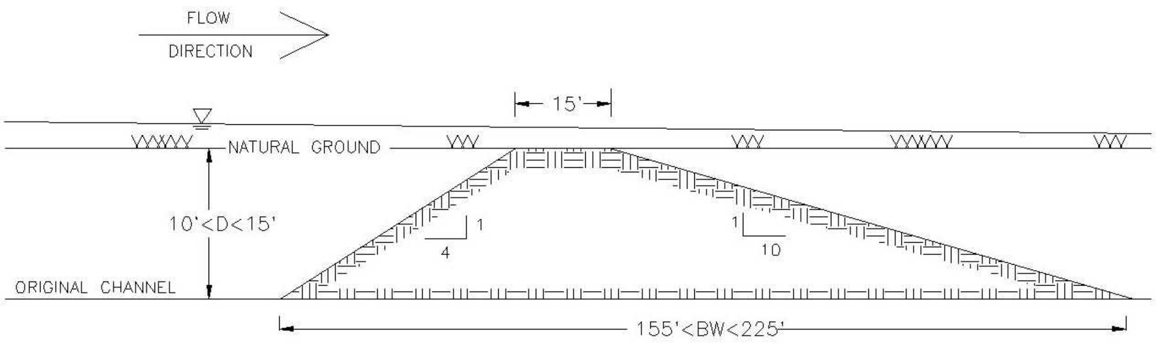


FIGURE 31. Typical Earthen Plug

(e) Elimination of Canal Maintenance South of the Spreader Channels and Removal of Existing Weir Structures

Elimination of the ongoing aquatic weed control activities for canal maintenance in the major canals would further restrict the conveyance capacity of the remnant canals and help to reduce channelized flow. Since the canals south of I-75 would cease to act like canals, the weir structures would become obsolete. The affected weirs would be Miller No.1, Faka Union No. 2, Merritt No.1 and Prairie No.1. Faka Union No.1 would remain unaffected. The concrete portion and sheet piles of these structures could be left intact if they pose no environmental problem, however, the steel walkways and gates may be salvaged.

(f) Groundwater Level Monitoring Program

The current groundwater monitoring wells maintained by the USGS and the Fakahatchee Strand State Preserve staff should be continued and possibly enhanced to provide comparison data for investigation of the success or efficiency of the restoration efforts relative to the pre-restoration conditions.

A. Alternative 3A

The configuration of Alternative 3A is shown in Figure 32. Structural elements include two spreader channels, three pump stations (total of eight pumps), removal of 114 miles of roads, and installation of 11 canal plugs. Nonstructural elements include elimination of canal maintenance south of the spreader locations and continuation of a groundwater level monitoring program.

The first spreader channel abuts I-75 and extends 4.85 miles eastward from Everglades Boulevard to approximately one and a half miles east of Merritt Canal. The inflow to this spreader would be the discharges from the Faka Union Canal and the north Merritt Canal. The spreader is located approximately 200 feet south of I-75. The second spreader channel collects flows from the Miller Canal and extends 1.65 miles from the western boundary of SGGE to Everglades Boulevard and is located approximately one and a half miles south of I-75. Several upland areas exist just south of I-75 within a mile of Miller Canal. Locating the spreader south of these uplands would prevent water from circumventing the islands and backing up to the west. As part of the analysis of this alternative, a groundwater flow model was developed to evaluate the spreader channel's influence on I-75.

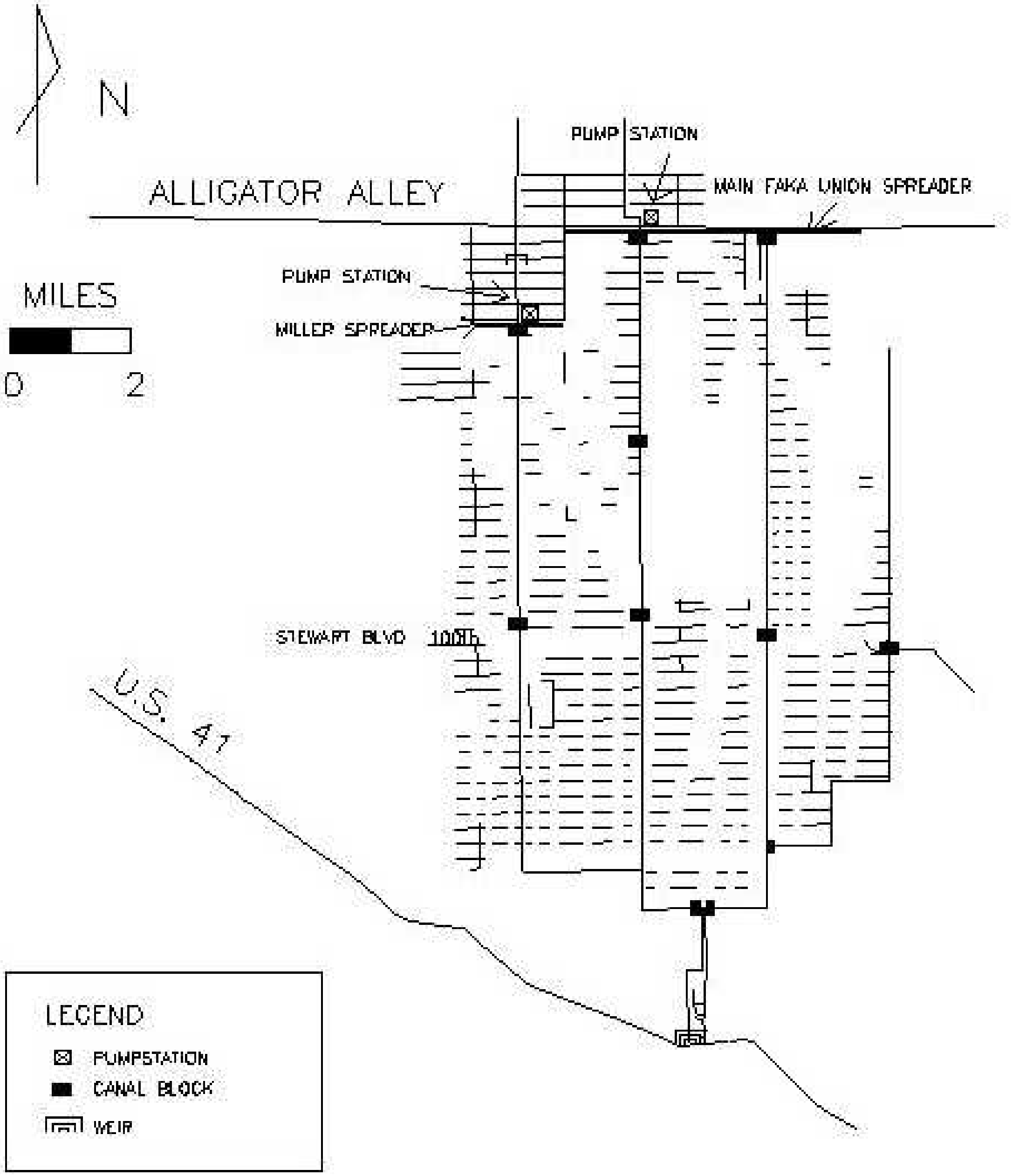


FIGURE 32 Conceptual Plan of Alternative 3A – Two Spreader Channels Canal Plugs and Partial Road Removal

The Miller Canal pump station involves two 90 HP pumps that have the combined capacity to move the design flow of 200 cfs and raise the head by five and a half feet. The Faka Union Canal pump station has four 115 HP pumps that together can pass 417 cfs with an increase in head of six and a half feet. The Merritt Canal pump station has two 85 HP pumps designed to pass a total flow of 160 cfs with a six and a half feet head. It is expected these pumps will operate approximately four months of the year. This alternative requires the smallest pumps because they are farthest north.

This alternative also includes 114 miles of road removal and installation of 11 canal plugs. The concept of this plan originated from earlier studies done by the Golden Gate Estates Redevelopment Committee and later evaluated by the COE in which a few strategically placed plugs were suggested. Canal maintenance south of the spreaders would be eliminated in this plan and groundwater level monitoring would continue.

B. Alternative 3B

The primary structural elements in Alternative 3B are shown in Figure 33. The major modifications from Alternative 3A are the location of the spreader channels and pump stations, the number of canal blocks and the miles of road removal.

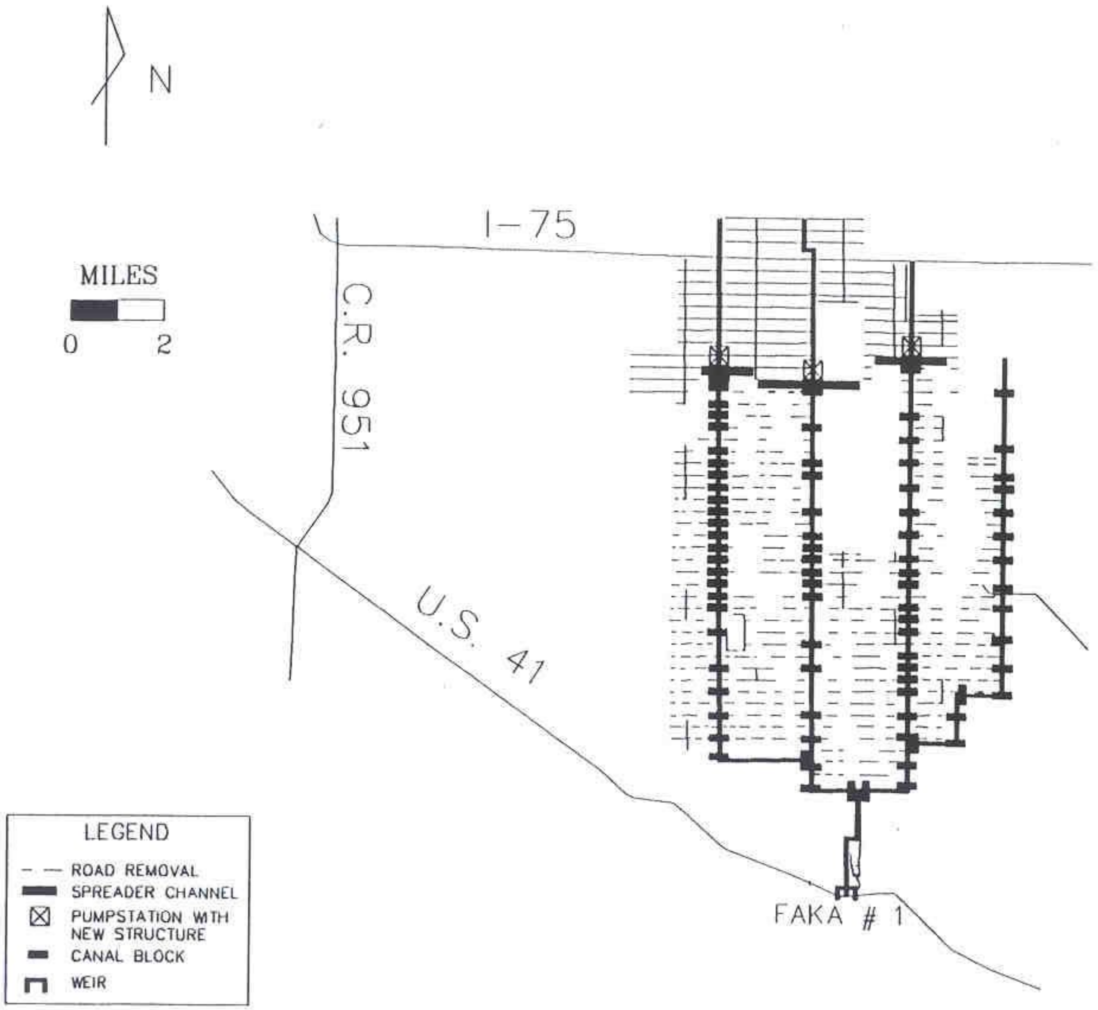


FIGURE 33. Conceptual Plan of Alternative 3B – Three Spreader Channels, Canal Plugs and Partial Road Removal

The spreader channels were located farther south, approximately two and a quarter miles south of Alligator Alley. The main reasons for shifting the spreaders south were (1) concern of the effects of the groundwater mound generated by the spreader on I-75 and (2) presence of non-hydric soils near I-75. The spreader channel of the Miller Canal parallels 64th Avenue SE with an east-west length of one mile. The Faka Union Canal spreader parallels the south side of 66th Avenue SE with an east-west length of two and a quarter miles. The Merritt Canal spreader parallels 62nd Avenue SE and equals approximately one and a half miles in length.

The Miller Canal pump station requires two 90 HP pumps to pass the design flow of 200 cfs with a five and a half feet head increase. The Faka Union Canal pump station has four 135 HP pumps that together can pass 500 cfs with an increase in head of six and a half feet. The Merritt Canal pump station has two 90 HP pumps designed to pass 165 cfs with a six and a half feet head. It is expected these pumps will also operate approximately four months of the year. This alternative requires the largest pumps because they are farthest south.

Alternative 3B involves removal of 128 miles of road, a slight increase from Alternative 3A. The number of canal blocks are significantly increased from 11 to 82. Open stretches of water that are several miles long provide localized drainage, especially during the dry season and early in the wet season when canal stages are low. Therefore, increased canal blocks would inhibit drainage notably. Canal maintenance south of the spreaders would be eliminated and groundwater level monitoring would continue.

C. Alternative 3C

Alternative 3C, shown in Figure 34, is very similar to 3B except the pump station and spreader channel for the Merritt Canal is located farther north. This reduces the size of the pumps

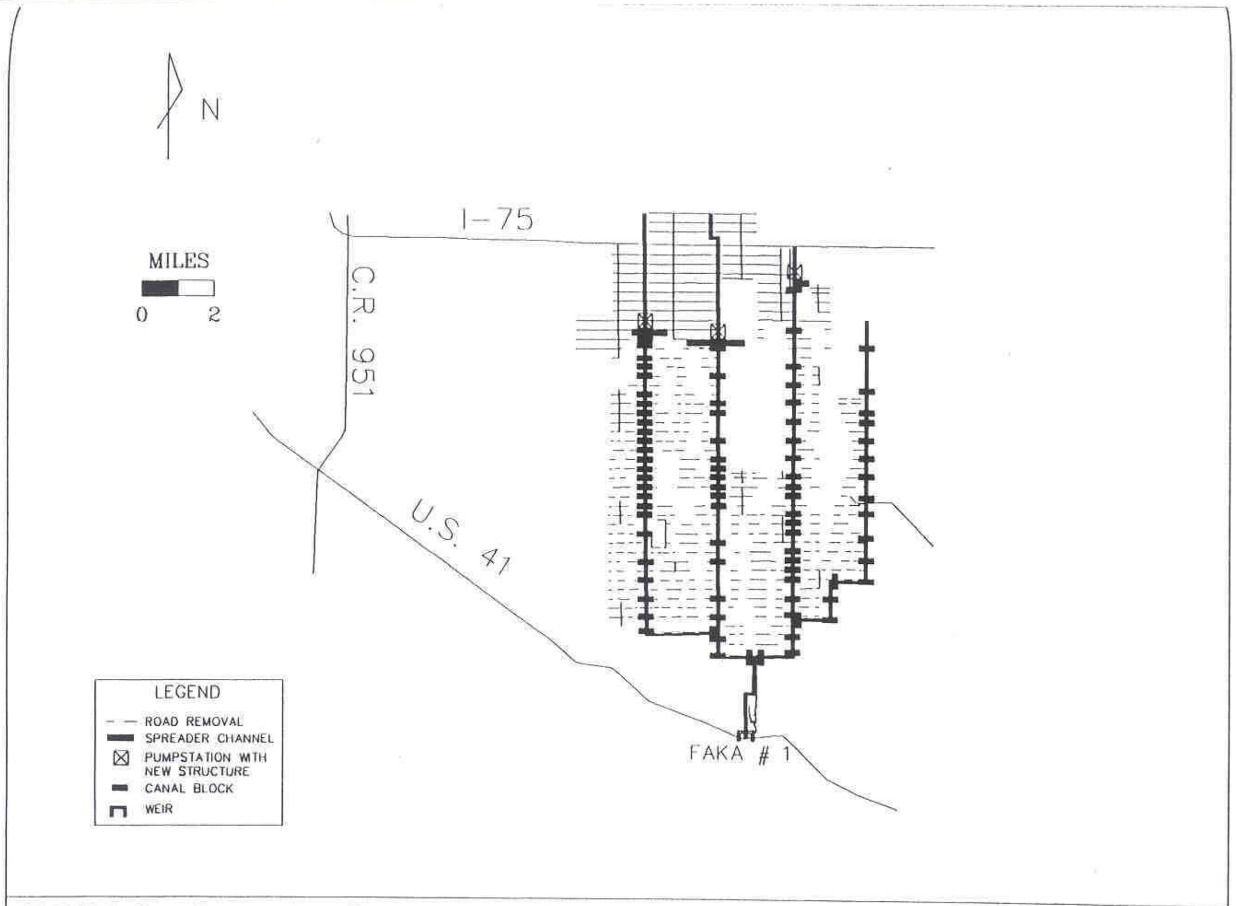


FIGURE 34. Conceptual Plan of Alternative 3C – Three Spreader Channels, Canal Plugs and Partial Road Removal

but requires an additional canal plug and two more miles of road removal.

The Miller Canal spreader channel parallels 64th Avenue SE for a length of 4,488 feet. The Faka Union Canal spreader parallels the south side of 66th Avenue SE with an approximate east-west length of one and a third miles. The Merritt Canal spreader parallels 54th Avenue SE and equals approximately 1,425 feet in length.

The Miller Canal pump station requires two 90 HP pumps to pass the design flow of 200 cfs with a five and a half feet head increase. The Faka Union Canal pump station has four 135 HP pumps that together can pass 500 cfs with an increase in head of six and a half feet. The Merritt Canal pump station has two 85 HP pumps designed to pass 160 cfs with a six and a half feet head. It is expected these pumps will operate approximately four months of the year.

Alternative 3C involves 130 miles of road removal, a slight increase from Alternative 3B, and installation of eighty-three canal plugs. Canal maintenance south of the spreaders would be eliminated and groundwater monitoring would continue.

4-1.3 Cost Analysis of Plans

Cost estimates for the implementation of the five alternatives are presented below. All costs are in 1995 dollars. The unit rate cost values of the construction costs are adapted from the SFWMD Construction and Land Management Department's 1995 cost indices for similar construction projects.

4-1.3a Estimates of First Costs

An estimate of the first costs for each of the alternatives is outlined in Tables 7 through 11.

4-1.3b Estimates of Annual Operation and Maintenance

An estimate of the annual operation and maintenance costs for each alternative is shown in Table 12.

TABLE 7

FIRST COST ESTIMATE IN 1995 DOLLARS FOR ALTERNATIVE 1 DIVERSION STRUCTURE WITH THREE 48-INCH GATED CULVERT WITH SPREADER CHANNEL

DESCRIPTION	**QUANTITY UNIT**	**EQUIPMENT**		**LABOR**		**MATERIAL**		**TOTAL ($)**
		Unit Cost	**Total**	**Unit Cost**	**Total**	**Unit Cost**	**Total**	
1. MOB/ DEMOB	L.S.							7,500
2. Equipment Rental	L.S.							5,000
3. Canal Excavation	1500 C.Y.	2		1				4,500
4. Detour Road	L.S.							10,000
5. Site Fencing	L.S.							2,500
6. Clearing	L.S.							5,000
7. General Site Work	L.S.							5,000
8. Pump								
a) 36" (30,000 GPM) Pump	1	1500		1500		40,000		43,000
b) Motor & Drive	1	300		700		10,000		11,000
c) Pipe	25 ft.	30		50		150		5,750
d) Flap Gate	1	300		400		4,000		4,700
e) Service Platform	1							10,000
9. Electrical								
a) Control Panel	1	300		2000		10,000		12,300
b) Float Controls	1	100		1000		2,000		3,100

DESCRIPTION	**QUANTITY UNIT**	**EQUIPMENT**		**LABOR**		**MATERIAL**		**TOTAL ($)**
c) Raceways	L.S.							5,000
d) Testing	L.S.							2,000
e) Service	L.S.	*		*		*		
10. Sand Cement Endwalls	1000 c.f.					7		7,000
11. Excavation/ Backfill for Pump	L.S.							3,000
Subtotal								146,350
O&P Bond @ 18%								26,343
TOTAL								172,693

* Not included at this time.

TABLE 8

FIRST COST ESTIMATE IN 1995 DOLLARS FOR ALTERNATIVE 2[1]

SPREADER CHANNEL WITH REMOVAL OF ROADS AND FILLING OF CANALS

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
1.	Canal Plugs & Swale Blocks				
	a) Fill (including hauling, grading & compaction)[2]				
	Prairie	931,627	C.Y.		
	Merritt	1,554,276	C.Y.		
	Faka Union	3,521,564	C.Y.		
	Miller	1,645,209	C.Y.		
	Total	7,652,676	C.Y.	8.00	61,221,408
				Subtotal	61,221,408
2.	Spreader Channels				
	Main Spreader				
	a) Mobilization/Demobilization	1	L.S.	20,000.00	20,000
	b) Clearing	94.54	AC.	14,275.00	1,349,559
	c) Excavation & Fill (including grading & compaction)	293,627	C.Y.	4.00	1,174,508
	d) Riprap				
	12" layer (large)	276	C.Y.	45.00	12,420
	6" layer (bedding)	138	C.Y.	30.00	4,140
				Subtotal	2,540,627

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
3.	Pump Stations				
	Main Spreader				
	a) Pumps (Merritt) 80 cfs (85 HP)	2	L.S.	84,000.00	168,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	75,000.00	75,000
	d) Pumps (Faka) 105 cfs (115 HP)	4	L.S.	103,000.00	412,000
	e) Installation and Sitework	1	L.S.	65,040.00	65,040
	f) Backup Generator	1	L.S.	140,000.00	140,000
	g) Pumps (Miller) 65 cfs (70 HP)	2	L.S.	72,500.00	145,000
	h) Installation and Sitework	1	L.S.	57,600.00	57,600
	I) Backup Generator	1	L.S.	80,000.00	80,000
	j) Portable Pump 500 cfs (530 HP)	1	L.S.	405,500.00	405,500
	k) Portable Pump 150 cfs (160 HP)	1	L.S.	144,500.00	144,500
	l) Seepage Pump 25 cfs (20 HP)	2	L.S.	40,000.00	80,000
				Subtotal	1,830,240
4.	Road and Tram Removal				
	a) Mobilization/Demobilization	2	L.S.	20,000.00	40,000
	b) Demolition of Paving (3" thick)	539,733	S.Y.	4.00	2,158,932
	c) Excavation of Limerock Road	954,311	C.Y.	4.00	3,817,244
	d) Tram line leveling	29,630	C.Y.	3.00	88,890
				Subtotal	6,105,066
5.	Weir Structure Removal (gates only, no concrete)				
	Gated Structure Removal (Prairie #1, Merritt #1, Faka Union #2, & Miller #1)	4	L.S.	5,000.00	20,000
				Subtotal	20,000
	Subtotal				71,717,341
	Contingency @ 15%				10,757,601
	TOTAL				**82,474,942**

Notes:
1. Cost Estimate does not include land acquisition costs, permit fees, and extension of electric utility lines.
2. All fill estimates include 20% extra for spills.

TABLE 9

FIRST COST ESTIMATE IN 1995 DOLLARS FOR ALTERNATIVE 3A[1]

TWO SPREADER CHANNELS/ ROAD REMOVAL/CANAL PLUGS

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
1.	Canal Plugs & Swale Blocks				
	a) Fill (including hauling, grading &				
	compaction)[2]	3,770	C.Y.		
	Prairie	6,468	C.Y.		
	Merritt	17,174	C.Y.		
	Faka Union	4,488	C.Y.		
	Miller	31,900	C.Y.	8.00	255,200
	Total	11	PER	1,500.00	16,500
	b) Dewatering		PLUG		
	c) Riprap	3,784		45.00	170,280
	12" layer (large)	1,892	C.Y.	30.00	56,760
	6" layer (bedding)	121	C.Y.	4.00	484
	d) Swale Blocks		C.Y.		
				Subtotal	499,224
2.	Spreader Channels				
	Main Spreader				
	a) Mobilization/Demobilization	1	L.S.	20,000.00	20,000
	b) Clearing	70.54	AC.	14,275.00	1,006,959
	c) Excavation & Fill (including				
	grading	219,091	C.Y.	4.00	876,364
	& compaction)				
	d) Riprap	180	C.Y.	45.00	8,100
	12" layer (large)	90	C.Y.	30.00	2,700
	6" layer (bedding)				
	Miller Spreader	1	L.S.	20,000.00	20,000
	a) Mobilization/Demobilization	24	AC.	14,275.00	342,600
	b) Clearing				
	c) Excavation & Fill (including	74,536	C.Y.	4.00	298,144
	grading				
	& compaction)	92	C.Y.	45.00	4,140
	d) Riprap	46	C.Y.	30.00	1,380
	12" layer (large)				
	6" layer (bedding)			Subtotal	2,580,387

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
3.	Pump Stations				
	Main Spreader				
	a) Pumps (Merritt) 80 cfs, 85 HP	2	L.S.	84,000.00	168,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	75,000.00	75,000
	d) Pumps (Faka) 105 cfs, 115 HP	4	L.S.	103,000.00	412,000
	e) Installation and Sitework	1	L.S.	65,040.00	65,040
	f) Backup Generator	1	L.S.	140,000.00	140,000
	g) Seepage Pump 25 cfs (20 HP)	1	L.S.	40,000.00	40,000
	Miller Spreader				
	a) Pumps - 100 cfs, 90 HP	2	L.S.	99,000.00	198,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	80,000.00	80,000
	d) Seepage Pump 25 cfs (20HP)	1	L.S.	40,000.00	40,000
	Portable Pumps				
	a) Portable Pump 500 cfs (530 HP)	1	L.S.	405,500.00	405,500
	b) Portable Pump 150 cfs (160 HP)	1	L.S.	144,500.00	144,500
				Subtotal	1,883,240
4.	Road and Tram Removal				
	a) Mobilization/Demobilization	2	L.S.	20,000.00	40,000
	b) Demolition of Paving (3" thick)	539,733	S.Y.	4.00	2,158,932
	c) Excavation of Limerock Road	265,956	C.Y.	4.00	1,063,824
	d) Tram line leveling	29,630	C.Y.	3.00	88,890
				Subtotal	3,351,646
5.	Weir Structure Removal (gates only, no concrete)				
	Gated Structure Removal (Prairie #1, Merritt #1, Faka Union #2, & Miller #1)	4	L.S.	5,000.00	20,000
				Subtotal	20,000
	Subtotal				8,334,497
	Contingency @ 15%				1,250,175

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
	TOTAL				**9,584,672**

Notes:

1. Cost Estimate does not include land acquisition costs, permit fees, and extension of electric utility lines.
2. All fill estimates include 20% extra for spills and compaction.

TABLE 10

FIRST COST ESTIMATE IN 1995 DOLLARS FOR ALTERNATIVE 3B[1]

THREE SPREADER CHANNELS/ROAD REMOVAL/CANAL BLOCKS

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
1.	Canal Plugs & Swale Blocks				
	a) Excavation & Fill (including grading & compaction)[2]	27,064	C.Y.		
	Prairie	59,927	C.Y.		
	Merritt	74,165	C.Y.		
	Faka Union	63,633	C.Y.		
	Miller	224,789	C.Y.	8.00	1,798,312
	Total	82	PER PLUG	1,500.00	123,000
	b) Dewatering				
	c) Riprap	27,301	C.Y.	45.00	1,228,545
	12" layer (large)	13,651	C.Y.	30.00	409,530
	6" layer (bedding)	902	C.Y.	4.00	3,608
	d) Swale Blocks			Subtotal	3,562,995
2.	Spreader Channels				
	Merritt Spreader				
	a) Mobilization/Demobilization	1	L.S.	20,000.00	20,000
	b) Clearing	23.27	AC.	14,275.00	332,218
	c) Excavation & Fill (including grading & compaction)	72,277	C.Y.	4.00	289,109
	d) Riprap	92	C.Y.	45.00	4,140
	12" layer (large)	46	C.Y.	30.00	1,380
	6" layer (bedding)				
	Faka Union Spreader	1	L.S.	20,000.00	20,000
	a) Mobilization/Demobilization	32.73	AC.	14,275.00	467,221
	b) Clearing				
	c) Excavation & Fill (including grading	101,640	C.Y.	4.00	406,560

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
	& compaction)	92	C.Y.	45.00	4,140
	d) Riprap	46	C.Y.	30.00	1,380
	12" layer (large)				
	6" layer (bedding)	1	L.S.	20,000.00	20,000
	Miller Spreader	14.55	AC.	14,275.00	207,701
	a) Mobilization/Demobilization				
	b) Clearing	45,173	C.Y.	4.00	180,692
	c) Excavation & Fill (including				
	grading	92	C.Y.	45.00	4,140
	& compaction)	46	C.Y.	30.00	1,380
	d) Riprap			Subtotal	1,960,061
	12" layer (large)				
	6" layer (bedding)				
3.	Pump Stations				
	Merritt				
	a) Pumps - 83 cfs, 90 HP	2	L.S.	87,000.00	174,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	75,000.00	75,000
	d) Seepage Pump 25 cfs (20 HP)	1	L.S.	40,000.00	40,000
	Faka Union - 125 cfs, (135 HP)	1	L.S.	75,000.00	75,000
	a) Pumps	4	L.S.	137,000.00	548,000
	b) Installation and Sitework	1	L.S.	65,040.00	65,040
	c) Backup Generator	1	L.S.	140,000.00	140,000
	d) Seepage Pump 25 cfs (20 HP)	1	L.S.	40,000.00	40,000
	Miller				
	a) Pumps - 100 cfs (90 HP)	2	L.S.	99,500.00	199,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	80,000.00	80,000
	d) Seepage Pump	1	L.S.	40,000.00	40,000
	Portable Pumps				
	a) Portable Pump 500 cfs (530 HP)	1	L.S.	405,500.00	405,500
	b) Portable Pump 150 cfs (160 HP)	1	L.S.	144,500.00	144,500
				Subtotal	2,066,240
4.	Road & Tram Line Removal				
	a) Mobilization/Demobilization	3	L.S.	20,000.00	60,000
	b) Demolition of Paving (3" thick)	448,213	S.Y.	4.00	1,792,853
	c) Excavation of Limerock Road	350,436	C.Y.	4.00	1,401,742
	d) Tram line leveling	29,630	C.Y.	3.00	88,890
				Subtotal	3,343,485
5.	Weir Structure Removal (gates only, no				

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
	concrete)				
	Gated Structure Removal (Prairie #1, Merritt #1, Faka Union #2, & Miller #1)	4	L.S.	5,000.00	20,000
				Subtotal	20,000
	Sub-total				
	Contingency @ 15%				10,952,781
					1,642,917
	TOTAL				**12,595,698**

Notes:

1. Cost Estimate does not include land acquisition costs, permit fees, and extension of electric utility line.
2. All fill estimates include 20% extra for spills and compaction.

TABLE 11

FIRST COST ESTIMATE IN 1995 DOLLARS FOR ALTERNATIVE 3C[1]

THREE SPREADER CHANNELS/ROAD REMOVAL/CANAL BLOCKS

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
1.	Canal Plugs & Swale Blocks				
	a) Fill (including hauling, grading & compaction)[2]				
	Prairie	27,064	C.Y.		
	Merritt	61,563	C.Y.		
	Faka Union	74,165	C.Y.		
	Miller	63,633	C.Y.		
	Total	226,425	C.Y.	8.00	1,811,400
	b) Dewatering	86	PER	1,500.00	129,000
	c) Riprap		PLUG		
	12" layer (large)	27,504		45.00	1,237,680
	6" layer (bedding)	13,753	C.Y.	30.00	412,590
	d) Swale Blocks	946	C.Y.	4.00	3,784
			C.Y.		
				Subtotal	3,594,454

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
2.	Spreader Channels				
	Merritt Spreader				
	a) Mobilization/Demobilization	1	L.S.	20,000.00	20,000
	b) Clearing	3.93	AC.	14,275.00	56,101
	c) Excavation & Fill (including grading & compaction)	32,184	C.Y.	4.00	128,736
	d) Riprap				
	12" layer (large)	92	C.Y.	45.00	4,140
	6" layer (bedding)	46	C.Y.	30.00	1,380
	Faka Union Spreader				
	a) Mobilization/Demobilization	1	L.S.	20,000.00	20,000
	b) Clearing	18.76	AC.	14,275.00	267,799
	c) Excavation & Fill (including grading & compaction)	58,274	C.Y.	4.00	233,096
	d) Riprap				
	12" layer (large)	92	C.Y.	45.00	4,140
	6" layer (bedding)	46	C.Y.	30.00	1,380
	Miller Spreader				
	a) Mobilization/Demobilization	1	L.S.	20,000.00	20,000
	b) Clearing	12.36	AC.	14,275.00	176,491
	c) Excavation & Fill (including grading & compaction)	38,397	C.Y.	4.00	153,588

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
	d) Riprap				
	12" layer (large)	92	C.Y.	45.00	4,140
	6" layer (bedding)	46	C.Y.	30.00	1,380
				Subtotal	1,092,371
3.	Pump Stations				
	Merritt				
	a) Pumps - 80 cfs, 85 HP	2	L.S.	84,000.00	168,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	75,000.00	75,000
	d) Seepage Pump 25 cfs (20 HP)	1	L.S.	40.000.00	40,000
	Faka Union				
	a) Pumps -125 cfs, 135 HP	4	L.S.	137,000.00	548,000
	b) Installation and Sitework	1	L.S.	65,040.00	65,040
	c) Backup Generator	1	L.S.	140,000.00	140,000
	d) Seepage Pump 25 cfs (20 HP)	1	L.S.	40,000.00	40,000
	Miller				
	a) Pumps - 100 cfs, 90 HP	2	L.S.	99,500.00	199,000
	b) Installation and Sitework	1	L.S.	57,600.00	57,600
	c) Backup Generator	1	L.S.	80,000.00	80,000
	d) Seepage Pump 25 cfs (20 HP)	1	L.S.	40,000.00	40,000
	Portable Pumps				
	a) Portable Pump 500 cfs (530 HP)	1	L.S.	405,500.00	405,500
	b) Portable Pump 150 cfs (160 HP)	1	L.S.	144,500.00	144,500
				Subtotal	2,060,240
4.	Road Removal & Tram Leveling				
	a) Mobilization/Demobilization	3	L.S.	20,000.00	60,000
	b) Demolition of Paving (3" thick)	452,906	S.Y.	4.00	1,811,624

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT COST	ESTIMATE COST ($)
	c) Excavation of Limerock Road	351,316	C.Y.	4.00	1,405,264
	d) Tram Leveling	29,630	C.Y.	3.00	88,890
				Subtotal	3,365,778
5.	Weir Structure Removal (gates only, no concrete)				
	Gated Structure Removal (Prairie #1, Merritt #1, Faka Union #2, & Miller #1)	4	L.S.	5,000.00	20,000
				Subtotal	20,000
	Subtotal				10,132,843
	Contingency @ 15%				1,519,926
	TOTAL				**11,652,769**

Notes:

1. Cost Estimate does not include land acquisition costs, permit fees and extension of electric utility lines.
2. All fill estimates include 20% extra for spills and compaction.

TABLE 12

COST ESTIMATE OF ANNUAL OPERATION AND MAINTENANCE

($)	1	2	3A	3B	3C
PUMP OPERATION[1]	25,980	76,005	81,435	93,070	89,973
MAINTENANCE[2]	3,000	13,000	13,000	9,700	4,800
TOTAL	**28,980**	**89,005**	**94,435**	**102,770**	**94,773**

Notes:

1. Pumping Cost:

Alternative 1 67cfs for 4 mo. equals 5,196 MG/yr x $5/MG =	$ 25,980
Alternative 2 196cfs for 4 mo. equals 15,201 MG/yr x $5/MG =	$ 76,005
Alternative 3A 210cfs for 4 mo. equals 16,287 MG/yr x $5/MG =	$ 81,435
Alternative 3B 240cfs for 4 mo. equals 18,614 MG/yr x $5/MG =	$ 93,070
Alternative 3C 232cfs for 4 mo. equals 17,995 MG/yr x $5/MG =	$ 89,973

2. Maintenance Cost:
@ $2,000 per mile of spreader channel

4-1.3c Summary of Costs

A summary of the costs involved in the implementation of each alterative is presented in Table 13.

4-1.3d Phased Implementation Costs and Funding

Due to the large size of this restoration project, it would be cost effective and advantageous to the ecology of SGGE to implement the plan in phases. This would allow for a more gradual ecological change of the area and allow for minor adjustments to be made throughout the project. Alternative 1 is a smaller project and does not involve phases. Alternative 2 requires all three north-south canals to be altered at one time, however, the Prairie Canal can be plugged in the first phase. Removal of the roads between the Merritt and Prairie Canals can also be done in this phase. The remainder of the work would be done in the second phase. Alternative 3A can be split into two phases. Phase 1 would include plugging the Prairie Canal and removing the road segments between Merritt and Prairie canals. Phase 2 would involve construction of the remainder of the project. Alternatives 3B and 3C could be split into three phases. The first phase would involve plugging of the Prairie Canal and road and tram removal between Merritt and Prairie Canals. It would also involve removal of part of the Prairie No. 1 structure. No spreader channels would be constructed in this phase. The second phase involves placement of the Merritt pump station and spreader channel, canal plugs in the Merritt Canal, road and tram removal between Faka Union and Merritt Canals. The third and final phase would involve placement of the Faka Union and Miller pump stations and spreader channels, canal plugs in the Faka Union and Miller Canals and completion of road and tram

TABLE 13

COST SUMMARY

	1	2	3A	3A	3C
FIRST COST	172,693	82,474,942	9,584,672	12,595,698	11,652,769
AMORTIZED FIRST COST[1]	12,546	5,991,805	696,326	915,077	846,574
ANNUAL O&M	28,980	89,005	94,435	102,770	88,835
TOTAL ANNUAL	**41,526**	**6,080,810**	**790,761**	**1,017,847**	**935,409**

Notes:

1. Amortization based on project life of 30 years with 6 % interest rate.

removal. A cost estimate for each phase is illustrated below.

ALTERNATIVE	1	2	3A	3B	3C
PHASE 1	$172,693	$9,014,733	$837,729	$1,350,813	$1,626,559
PHASE 2	N/A	$73,460,209	$8,746,943	$3,603,240	$2,693,608
PHASE 3	N/A	N/A	N/A	$7,641,645	$7,332,602

Part of the funding for the initial cost of the project can be absorbed by in-kind services of the Florida Division of Forestry (FDOF) who currently manages the public lands within SGGE. Using FDOF's staff and equipment, the road and tram removal portion of the project could be accomplished. Stockpiling the fill at the plug locations would eliminate hauling costs and reduce the costs further. The funding required for the remainder of the project would involve construction of the pump stations and spreader channels and installation of the canal plugs.

4-1.4 Summary of Alternatives

A summary of the restoration alternatives considered is shown in Table 14.

TABLE 14

SUMMARY OF RESTORATION ALTERNATIVES

Alternative	**1**	**2**	**3A**	**3B**	**3C**
Spreader Channels (Total Miles)	1 (1.5)	1 (6.5)	2 (6.5)	3 (4.85)	3 (2.4)
Pumps (#) (Total Horsepower)	1 (75)	8 (770)	8 (810)	8 (900)	8 (890)
Road Removal (miles)	None	290	114	128	130
Canal Plugs (Total cu yd earth fill)	None (0)	All Canals (7,652,676)	11 (31,900)	82 (224,789)	83 (226,425)
SGGE Canal Maintenance	Yes	No	No	No	No
Groundwater Monitoring	Yes	Yes	Yes	Yes	Yes
Cost Estimate ($) **a) Total Contract** **b) Using FDOF equipment and labor**	 172,693 172,693	 82,474,942 45,759,172	 9,584,672 6,105,426	 12,595,698 8,353,057	 11,652,769 7,381,291

4-2. HYDROLOGIC AND HYDRAULIC AND GROUNDWATER FLOW SIMULATION OF ALTERNATIVES

The final task of the model application process is to simulate the performance of the previously identified alternatives in order to compare their effectiveness in achieving the desired objectives of the project. Of critical importance in the alternatives analysis is incorporating all the effects of the proposed alternatives in the model in terms of specific changes to the model parameters, inputs and/or system representation and defining the output to be used in the comparison. The application of the PERLND and RCHRES modules to represent alternative configurations of pumps, spreader channels, canal blocks and road removal, provided unique challenges different from the traditional applications of HSPF. The model representation of the alternatives was formulated in the RCHRES and NETWORK modules of the calibrated HSPF model of SGGE and their performance was modeled for the entire period of simulation. The detailed description of the HSPF input modifications is summarized below.

Alternative 1 was represented in HSPF by creating a new reach for the spreader channel and having this reach discharge into a land segment as a surface lateral inflow. A user defined input time series represented the flows being diverted from the main channel into the spreader channel.

The major model input to represent Alternative 2 was changed by simulating the single spreader channel as a RCHRES and routing the outflow to a pervious land segment (PLS). As no further RCHRES was considered thereafter, the simulation for the downstream segments was performed only by the PERLND module. The runoff from the land segments was routed from one PLS to another along the alignments of the historical drainage patterns as surface, interflow and groundwater lateral inflows, until the runoff left the boundary of the basin.

To simulate the elements of Alternative 3A, two new reaches were created to represent the spreader channels and these reaches discharged into the land segments directly to the south as was done for Alternative 2. The runoff from the land segments was then routed from one pervious land segment (PLS) to another as surface, interflow and groundwater lateral inflow until it reached a historical flowway. The flowways themselves were represented by five newly created reaches as wide and shallow channels. The plugged canals were represented as "ponds" in the model with interconnection occurring only when one pond overflowed to another as the water surface rose above the crest of the canal plugs.

Alternative 3B was represented in HSPF as follows. Instead of routing PLS outflow from one reach to another, the outflow was directed to the canals as was done for existing conditions. The canals were represented as the existing canals plus an additional wide shallow floodplain, and the flows in the canals south of I-75 were permitted to overtop their banks and spill onto the land. The reaches are actually a combination of the existing canals and large floodplains having the potential to store substantial amounts of water. It is expected that after the restoration is complete these canals will still fill up first during the early part of the wet season before sheetflow will occur. Even with the canal and swale blocks, there will be substantial groundwater movement towards the canals if a head difference exists, as during the transition period between wet and dry seasons. The hydroperiods were estimated by observing the duration and depths of the overbank flows. Since PLS outflows were not routed to downstream PLS, the simulated soil and groundwater storages did not change. The spreader channels also discharged into reaches rather than into PLS. The plugged canals function again as “ponds”, interconnecting only when the upstream segment fills up.

Alternative 3C is very similar to Alternative 3B, the main difference being the location of the Merritt spreader channel slightly farther north. The modifications to the HSPF input involve changes to the northernmost reaches in the system, however, south of these reaches the input is exactly the same. These slight changes to the input do not produce any noticeable change in the model output and Alternatives 3B and 3C are modeled in a similar manner. As a result, the comparison of this alternative with Alternative 3B is mainly a comparison of cost and area of rehydration. Soil and groundwater storages, hydroperiods and runoff volumes are similar between Alternatives 3B and 3C.

The model output analysis included the soil and groundwater storages, runoff volumes and water stages in the reaches. An overall water budget was determined for each alternative. A few other outputs were examined for a full rehydration of SGGE including flows across U.S. 41 and Stewart Boulevard, and the time required to fill the plugged canal segments before overtopping would occur.

A significant amount of research has been done on the natural ecosystems of southwest Florida and their corresponding hydrology. Information is available from many sources regarding the hydrology of typical major vegetation communities such as cypress, pinelands, fresh and saltwater marshes, prairies and hardwood hammocks that are found throughout southwest Florida, including in SGGE. Using this wealth of information that has been collected over recent years, we can identify the specific criteria that will define a successful hydrologic restoration of SGGE. This predetermined criteria is used to compare each alternative’s effectiveness in re-establishing the pre-development hydrology of SGGE and its various ecosystems.

Because HSPF does not model hydroperiods directly, hydroperiods are estimated by analyzing the duration of stages simulated in the RCHRES module. Some accuracy is lost in the necessary assumptions made for modeling purposes. For example, the cross sectional area used in the computation of the overbank flows was approximated and assumed to be of constant cross section throughout the length of the reach. Additionally, relatively small changes in topography (inches) result in large changes in hydroperiods and vegetation. Obtaining accurate topographic data to this scale for such a large area is extremely expensive and time consuming. The time and the depth of overbank stages were found to be sensitive to both surface roughness (Manning's n value) and slope of the overbank.

The purpose of the groundwater flow simulation was to determine the effect of the elevated water levels in the spreader channels on I-75 which borders SGGE to the north, and specifically, to determine the distance between I-75 and the spreader channel for which no seepage would occur under I-75. After examining the hydraulic properties of the aquifer system, it is unrealistic to assume that no seepage will occur. As long as a head difference exists between the water levels in the spreader channels and the I-75 ditch, leakage from the spreaders toward the I-75 ditch will occur. This seepage is collected by a seepage collection ditch and is pumped back into the spreader.

Groundwater flow simulation in HSPF is limited to the upper portion of the shallow aquifer which has a contribution to streamflow. A more detailed groundwater model needed to be developed to predict the seepage towards I-75. A two dimensional and three dimensional MODFLOW groundwater model was constructed based on the Collier County regional groundwater flow model.

With an assumption of separation distance between I-75 and the spreader channel being short in comparison with the lengths of the spreaders and the I-75 ditch, a two dimensional cross-section of unit width was used to analyze groundwater seepage for scenarios of Alternatives 2 and 3A. The three separate spreaders in Alternatives 3B and 3C form a typical three dimensional groundwater flow system, for which a separate analysis was done. Detailed hydrogeologic structures and hydraulic characteristics of the aquifer system of Collier County have been reported in SFWMD reports TP 86-1 (Knapp, et. al., 1989) and 92-04 (Bennett, 1992) and input data for the local model was interpolated from the regional model. Two memoranda describing in detail the task description, model setup and initial results analysis are included in Appendix E.

4-3. EVALUATION OF ALTERNATIVE PLANS

The formulation of a recommended hydrologic restoration plan is based on the hydrologic and hydraulic performance of each alternative, as well as the estimate of least cost. An economic benefit analysis under each alternative scenario to estimate the benefit to cost ratio was beyond the scope of this study.

4-3.1 Hydrologic Performance of Alternative 1

Area of Rehydration

Alternative 1 is a partial restoration plan to take advantage of presently available public lands. Alternative 1 was intended as an interim plan and does not achieve all the objectives of the project. It would rehydrate a small portion of SGGE as shown in Figure 35.

Water Budget and Runoff

The overall basin runoff in Alternative 1 for the study area remains the same as existing conditions, however, point discharge at the Faka Union Weir No.1 is reduced from an average annual of 260 cfs to 120 cfs. Alternative 1 is intended primarily to reduce the voluminous point discharges of freshwater to the Faka Union Bay Estuary. Significant flows (average wet season = 460 cfs) will continue to be discharged at the Faka Union Canal outlet during the wet season. A reduction of 140 cfs of freshwater discharge contributes towards enhancing the ecologic health of the estuary. The

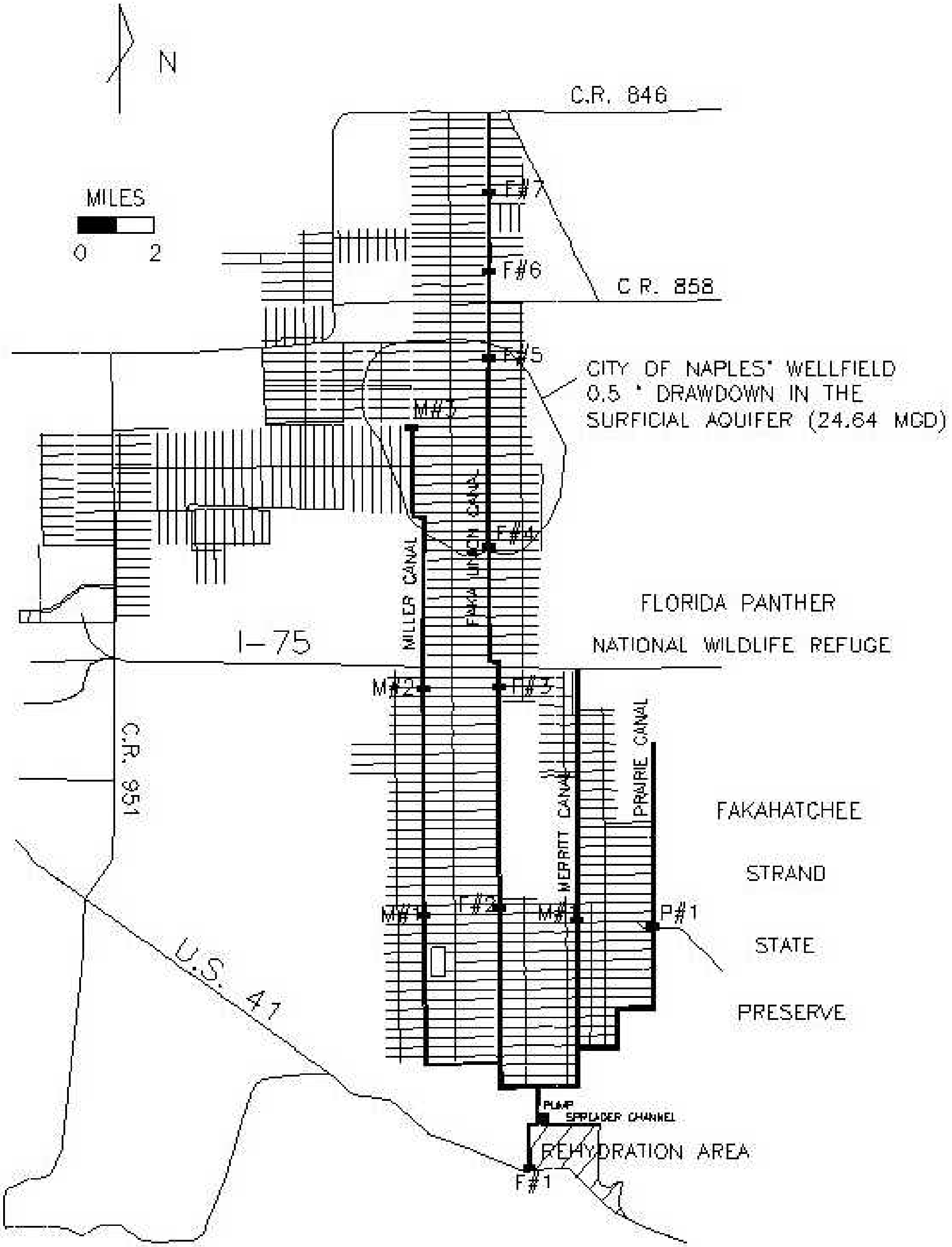


FIGURE 35. Area of Rehydration for Alternative One

sheetflow created enhances the functioning of the adjacent wetlands. A runoff hydrograph at Faka Union Weir No. 1 for this alternative is shown in Figure 36.

Soil and Groundwater Storages/Hydroperiods

The representation of Alternative 1 by routing large volumes of channel outflow to a relatively smaller PLS results in unreasonable inflow depths and artificially high soil storage and runoff values. In the subsequent alternatives as the receiving PLS areas become larger, the inflow depth is more reasonable. As such, the effect on soil storage and hydroperiods for Alternative 1 are not comparable to the results of the other two alternatives.

Flood Control for Northern Golden Gate Estates (NGGE)

The limited scope of this alternative affects water levels on currently publicly owned land in SGGE. There will be no impact on upstream flood stages and flood control for NGGE under this alternative.

Additional Study of This Alternative

The feasibility of this interim plan was further evaluated by the Construction and Land Management Department (CLM) of the District. Five alternatives for diverting freshwater from the Faka Union Canal to adjacent wetlands were evaluated. Although the sheetflow created would enhance the adjacent wetlands and reduce the freshwater shock loads to the estuary, CLM recommended not to proceed with construction of this alternative due to marginal benefits associated with relatively high costs. A memorandum updating the feasibility study for this plan is included in Appendix G.

4-3.2 Hydrologic Performance of Alternative 2

Area of Rehydration

Alternative 2 would provide rehydration for all of SGGE, western Fakahatchee Strand and the eastern portion of Belle Meade, as well as increased aquifer recharge in a portion of NGGE, while maintaining existing flood protection for NGGE (see Figure 37).

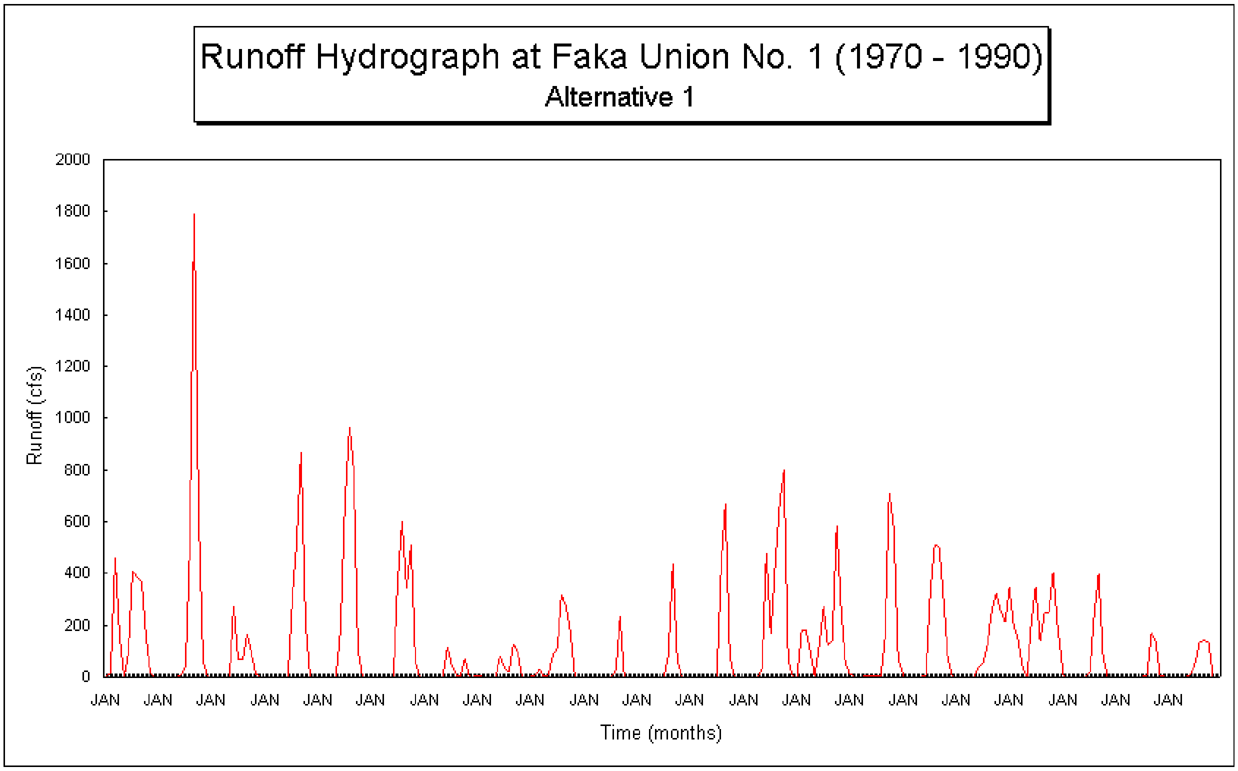


Figure 36

Most of the area that is impacted by the SGGE restoration project is within the boundaries of two CARL projects. However, an approximately 1.3 square mile area of privately owned land in eastern Belle Meade, not currently within the Belle Meade or Save Our Everglades CARL project boundary, intercepts a prominent and well-defined flowway (Figure 37). Inclusion of this property within a CARL boundary would be the optimal solution from a water management perspective. If this is not feasible, other alternatives should be considered to still ensure water storage, flow and water treatment as well as habitat values through these lands. Urban and recreational uses that require any drainage, however, are not recommended for these lands. It would be extremely difficult and expensive to establish and maintain a lower groundwater table necessary for development. This would also be in direct conflict with restoring natural hydrology and would nullify the restoration effort in this area.

Water Budget and Runoff

Evaporation and percolation showed a slight increase of one inch per year while total runoff decreased by this amount. Although total runoff did not decrease significantly, all the runoff is non-channelized flow. Runoff at Faka Union Weir No. 1 is zero because all canals are filled in this alternative.

It should be noted that simulation of Alternative 2 did not show much reduction in runoff. Runoff was reduced more for Alternative 3B, which proposed a plan involving partial elimination of the SGGE canal and roadway system. This is mainly due to the way Alternative 2 was simulated in HSPF. Since all canals south of I-75 were to be removed, the RCHRES module of the program (the module that simulates canal reaches) was only used for NGGE. The outflows from the land segments were routed to other land segments as lateral inflows. Evaporation was calculated in the PERLND module. Alternatives 3A through 3C were modeled using both PERLND and RCHRES modules since canal segments were maintained in these alternatives. The runoff from the land segments in Alternatives 3A through 3C was routed to reaches represented by the RCHRES module of the program. Once there, the runoff was subjected to an additional increase in overall evaporation

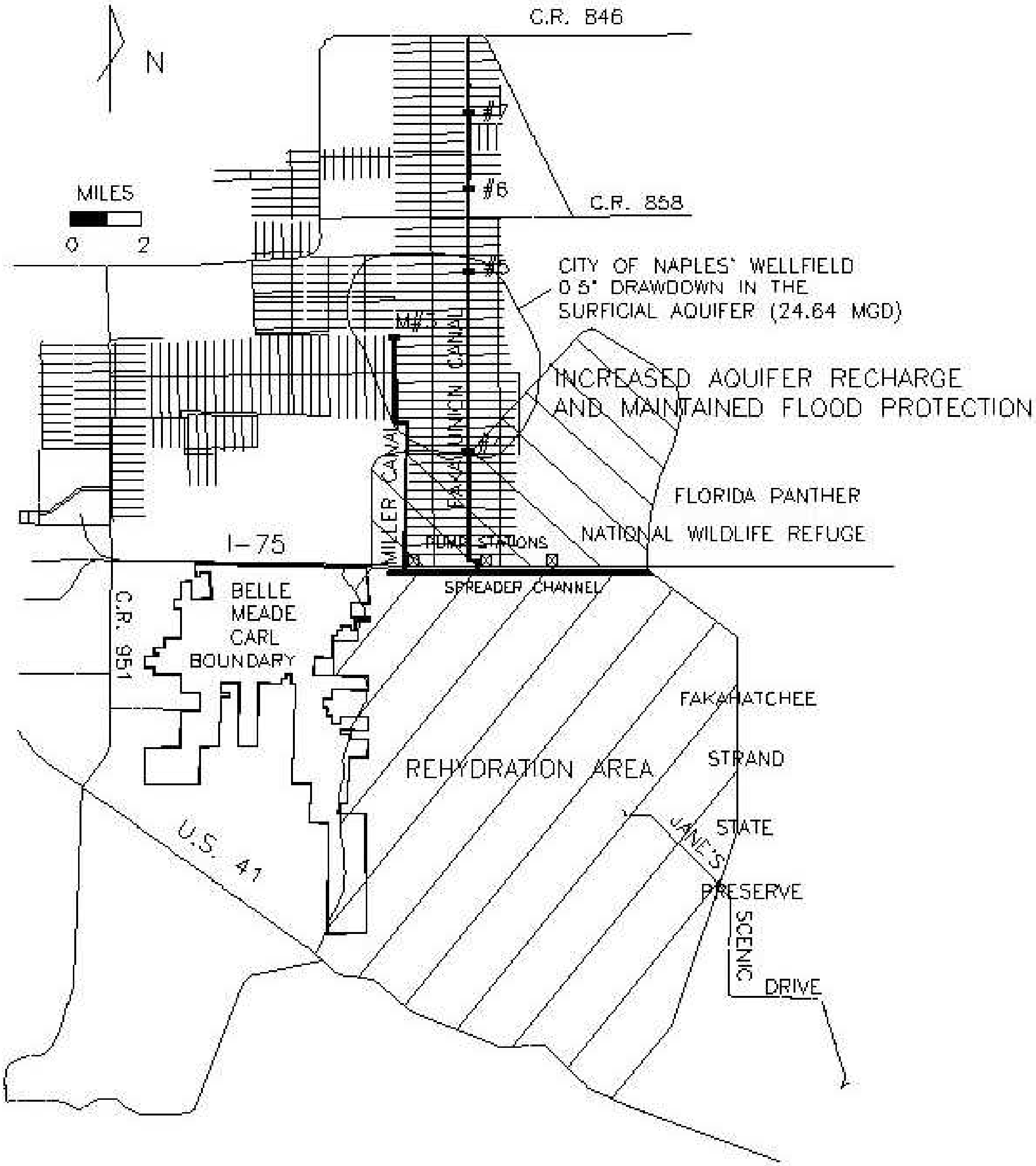


FIGURE 37. Area of Rehydration for Alternative Two

and decrease of overall runoff. The reaches used in Alternate 3A were not as extensive as in Alternatives 3B and 3C.

Soil and Groundwater Storages/Hydroperiods

Figures 38 through 49 show the average daily soil storages in the upper and lower soil zones and the active groundwater storage zone for existing and Alternative 2 conditions for those land segments south of I-75 for each month of the simulation period from January 1970 to December 1992. Average daily upper zone soil storage increased by ten percent, lower zone by six percent and active groundwater storage increased 205 percent. The active groundwater storages for Alternative 2 were extended up to three months longer over existing threshold conditions.

Hydroperiods were determined by observing the duration and depths of the overbank stages simulated in the RCHRES module of HSPF. As stated before, the RCHRES module was not used in the simulation of this alternative, so this approach to estimate hydroperiods was not reasonable. There is a relationship between the storage zones in HSPF and the surficial groundwater levels. A study involving an application of HSPF on a watershed near Tampa, Florida (Hicks, 1985) concluded that there is "a significant correlation between the behavior of the HSPF active groundwater zone and

the actual groundwater behavior represented by the shallow well elevation data." The relationship

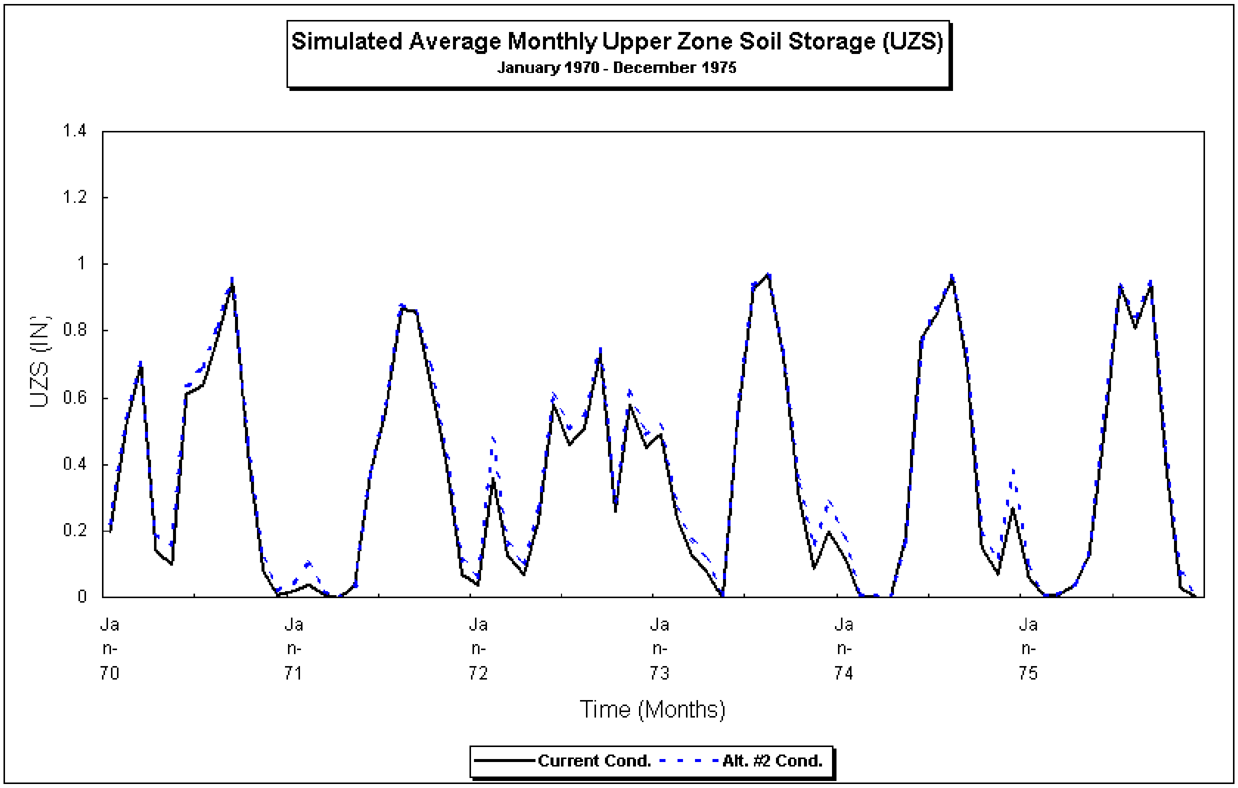

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1970 - December 1975
1.4
1.2
1
0.8
0.6
0.4
0.2
0
UZS (IN)
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
Current Cond.
Alt. #2 Cond.

Figure 38

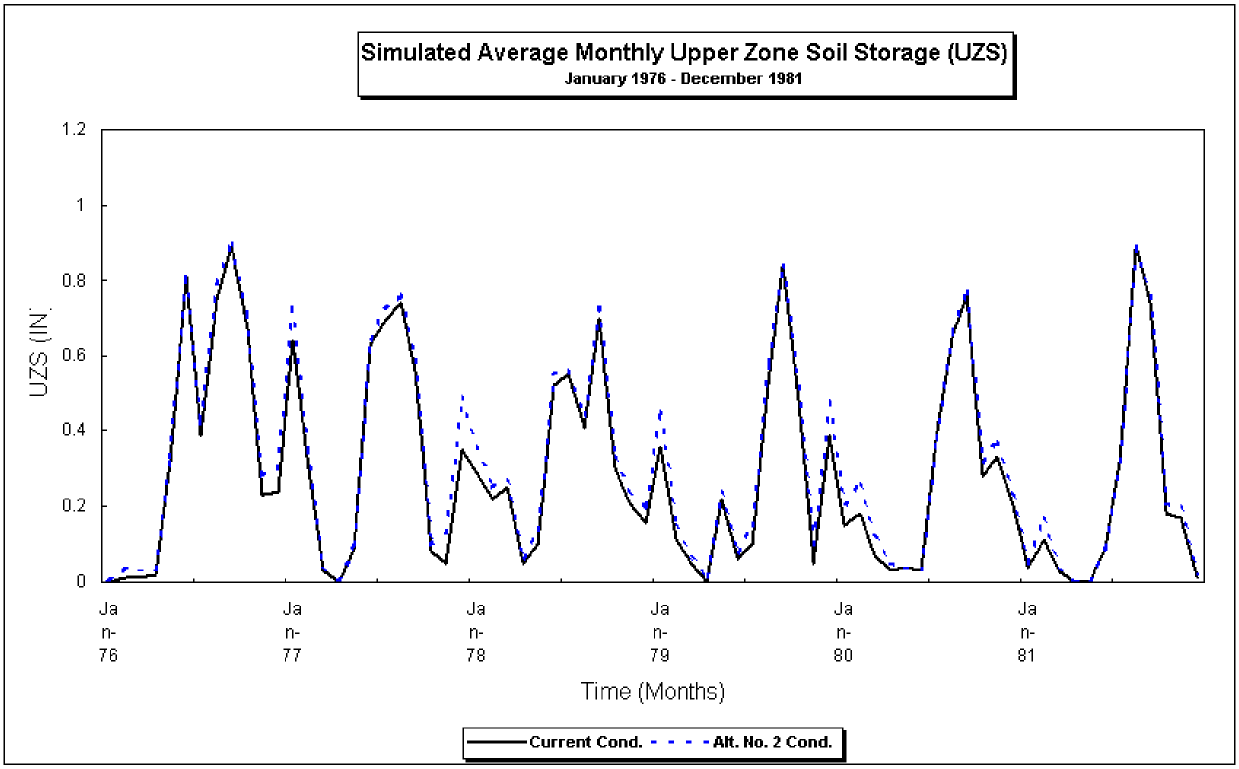

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1976 - December 1981
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 39

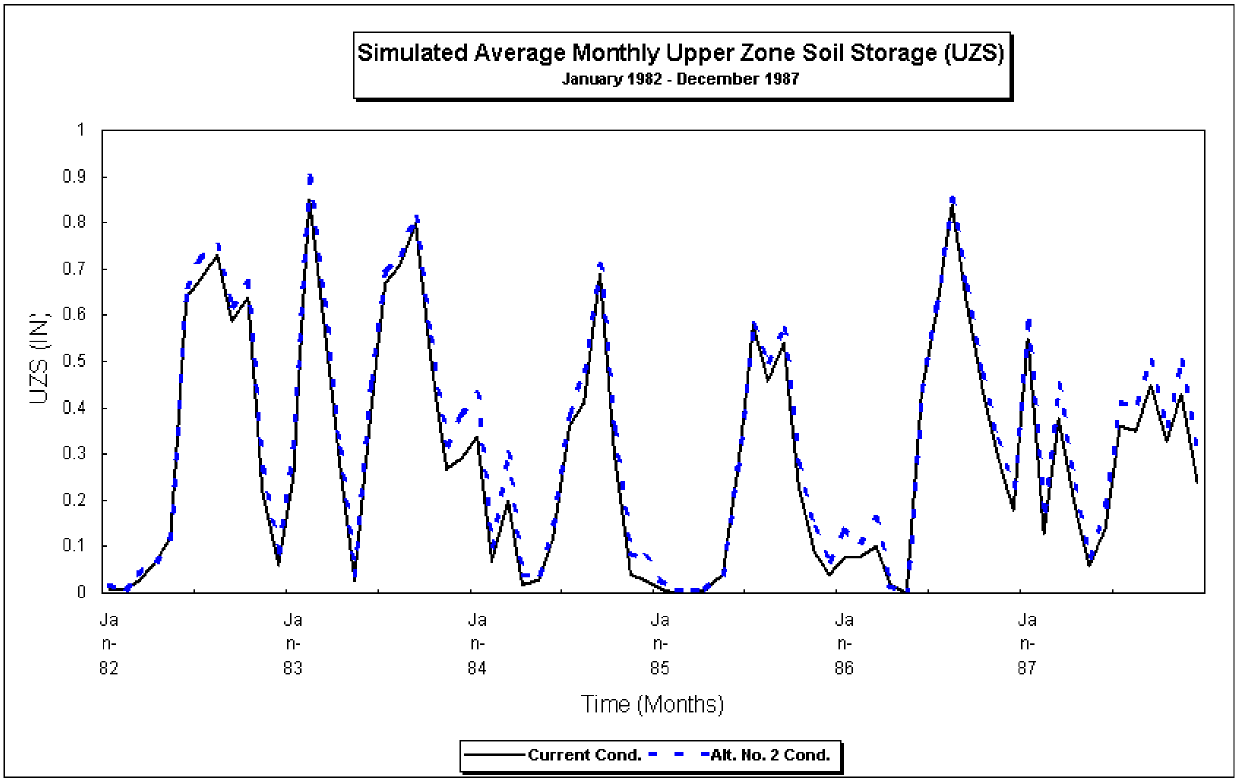

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1982 - December 1987
UZS (IN)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 40

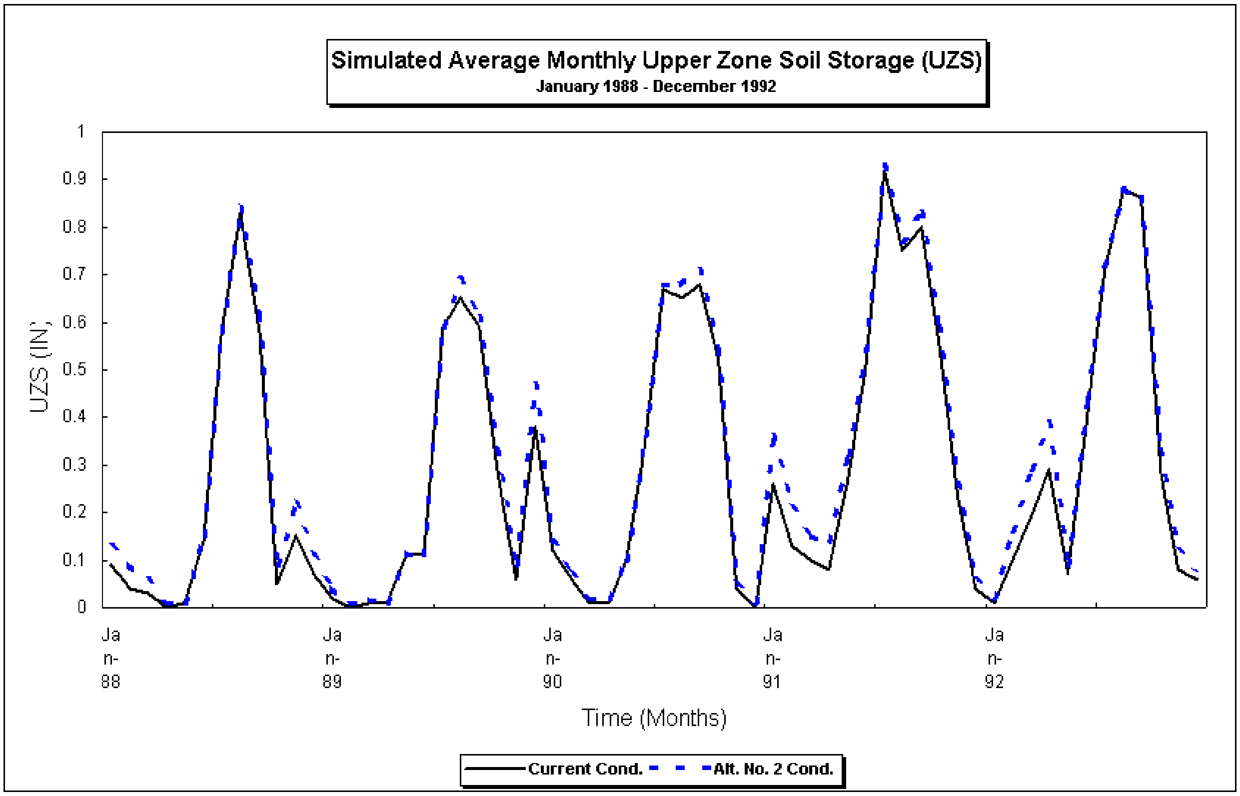

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1988 - December 1992
UZS (IN)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 41

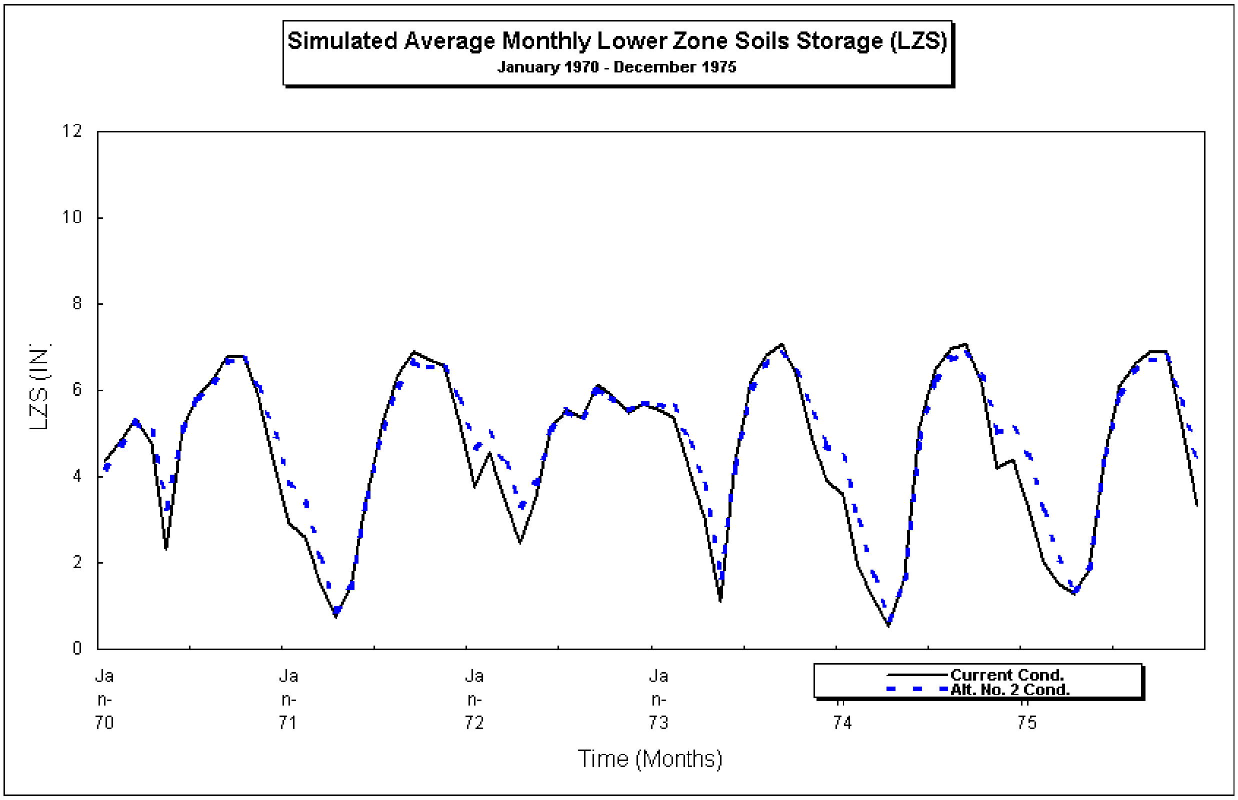

Simulated Average Monthly Lower Zone Soils Storage (LZS)
January 1970 - December 1975
12
10
8
6
4
2
0
LZS (IN
Jan-70
Jan-71
Jan-72
Jan-73
74
75
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 42

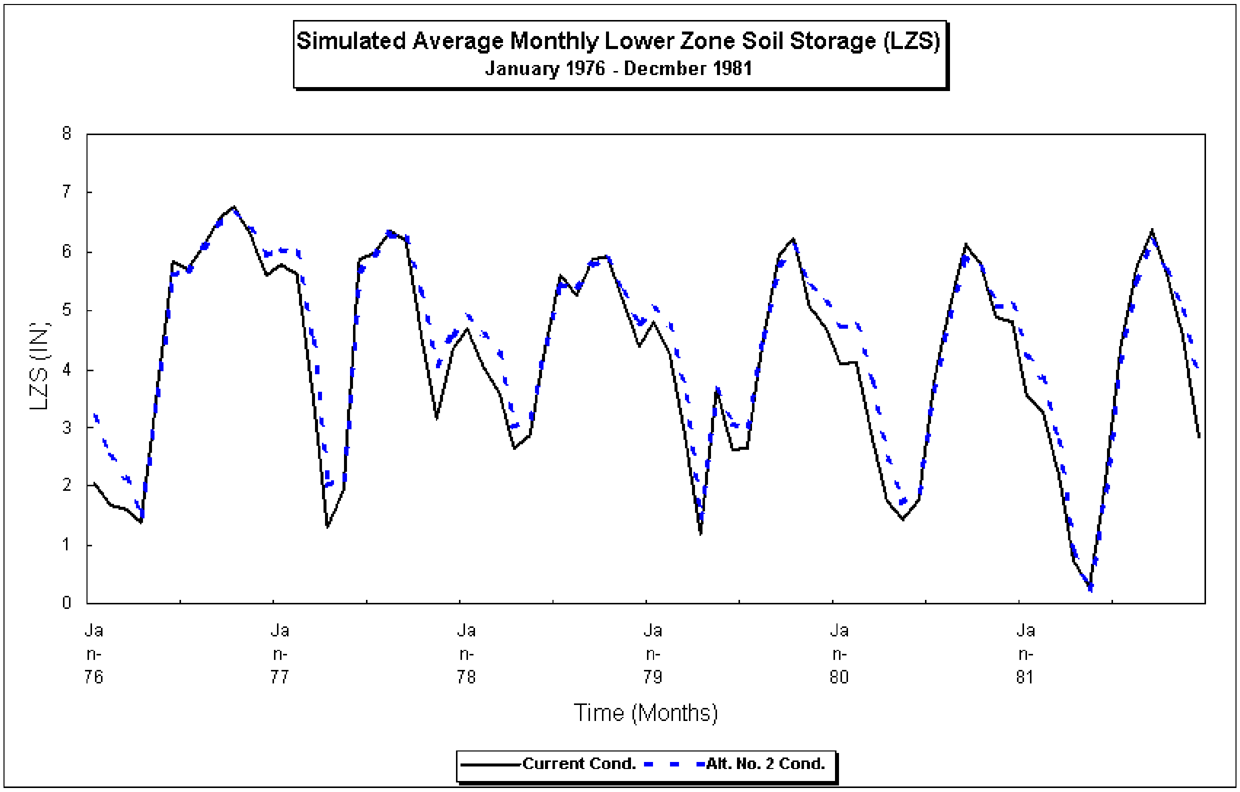

Simulated Average Monthly Lower Zone Soil Storage (LZS)
January 1976 - Decmber 1981
LZS (IN)
8
7
6
5
4
3
2
1
0
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 43

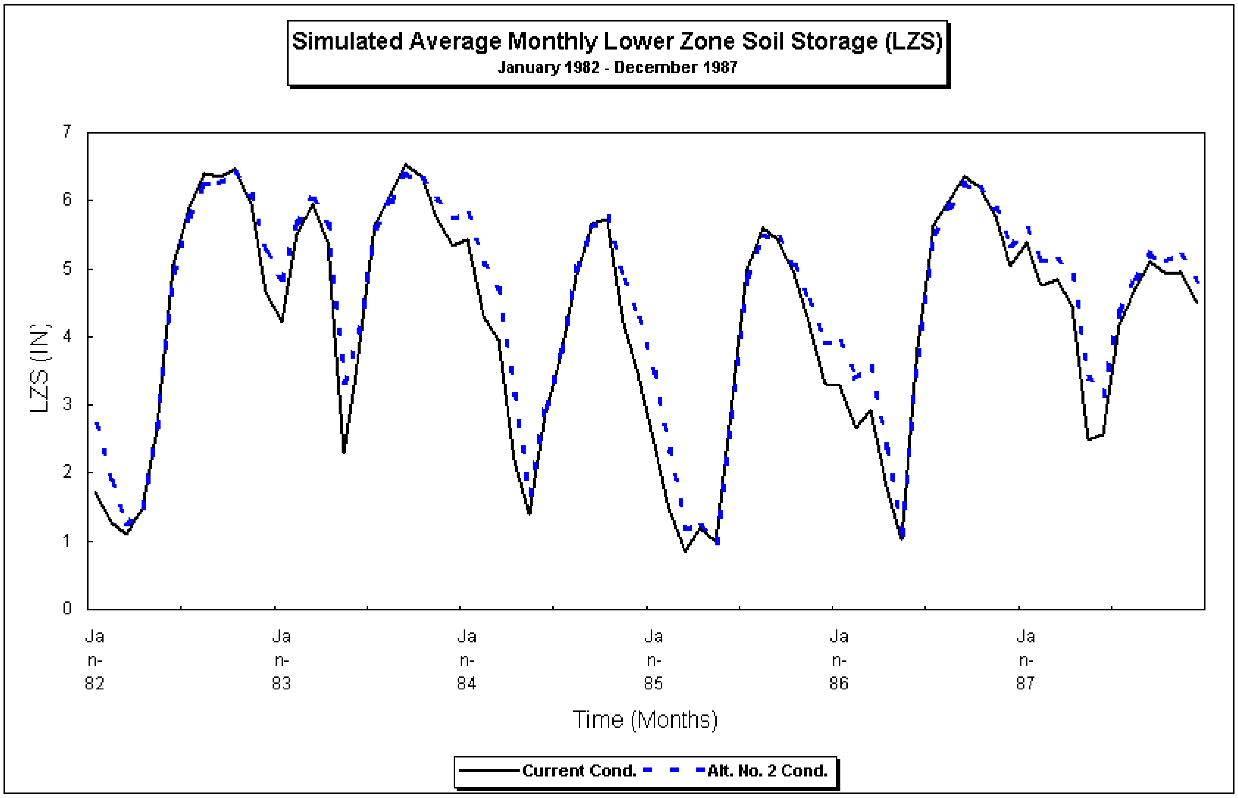

Simulated Average Monthly Lower Zone Soil Storage (LZS)
January 1982 - December 1987
LZS (IN)
7
6
5
4
3
2
1
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 44

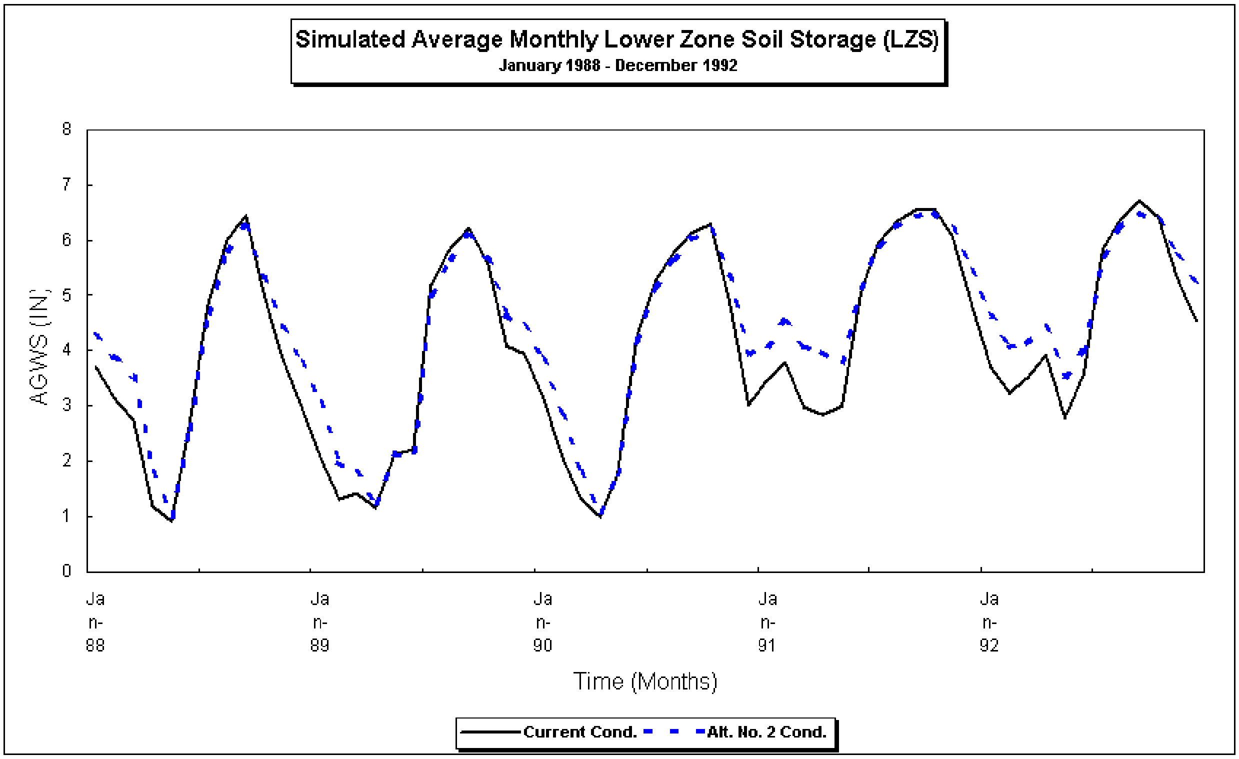

Simulated Average Monthly Lower Zone Soil Storage (LZS)
January 1988 - December 1992
AGWS (IN)
8
7
6
5
4
3
2
1
0
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 45

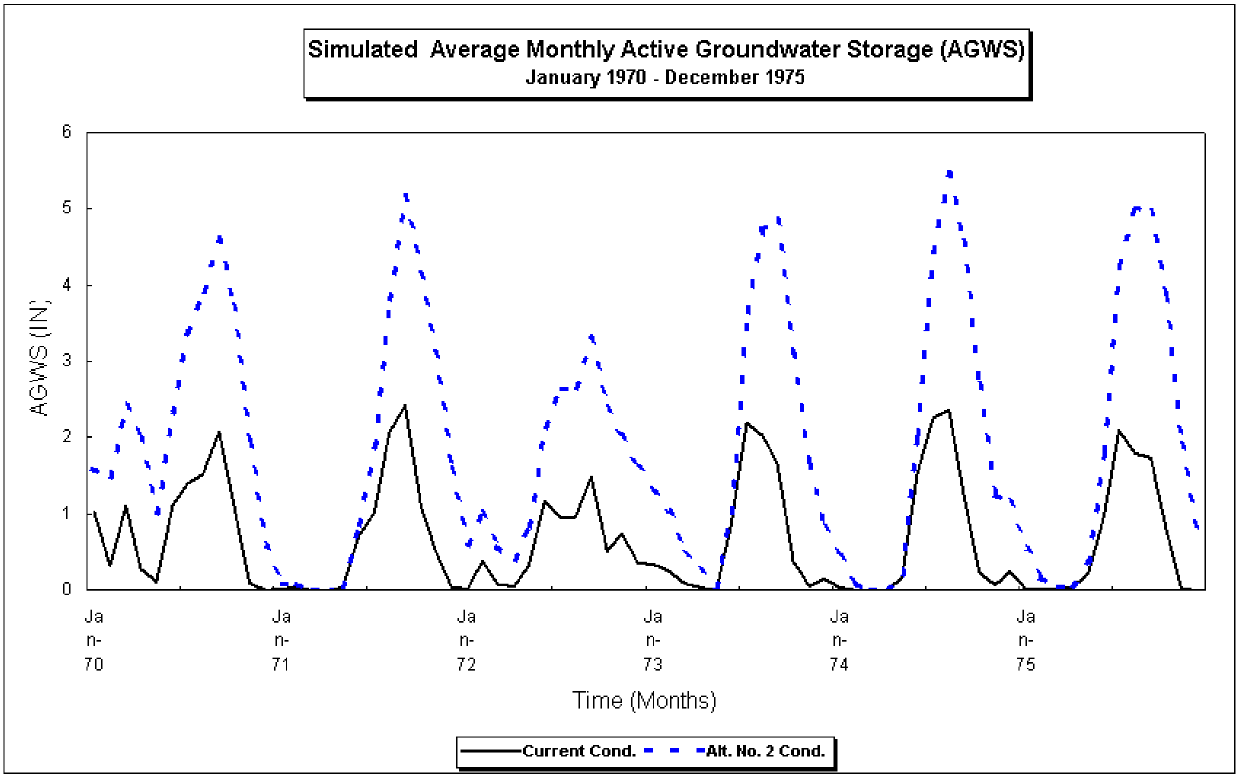

Simulated Average Monthly Active Groundwater Storage (AGWS)
January 1970 - December 1975
AGWS (IN)
6
5
4
3
2
1
0
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 46

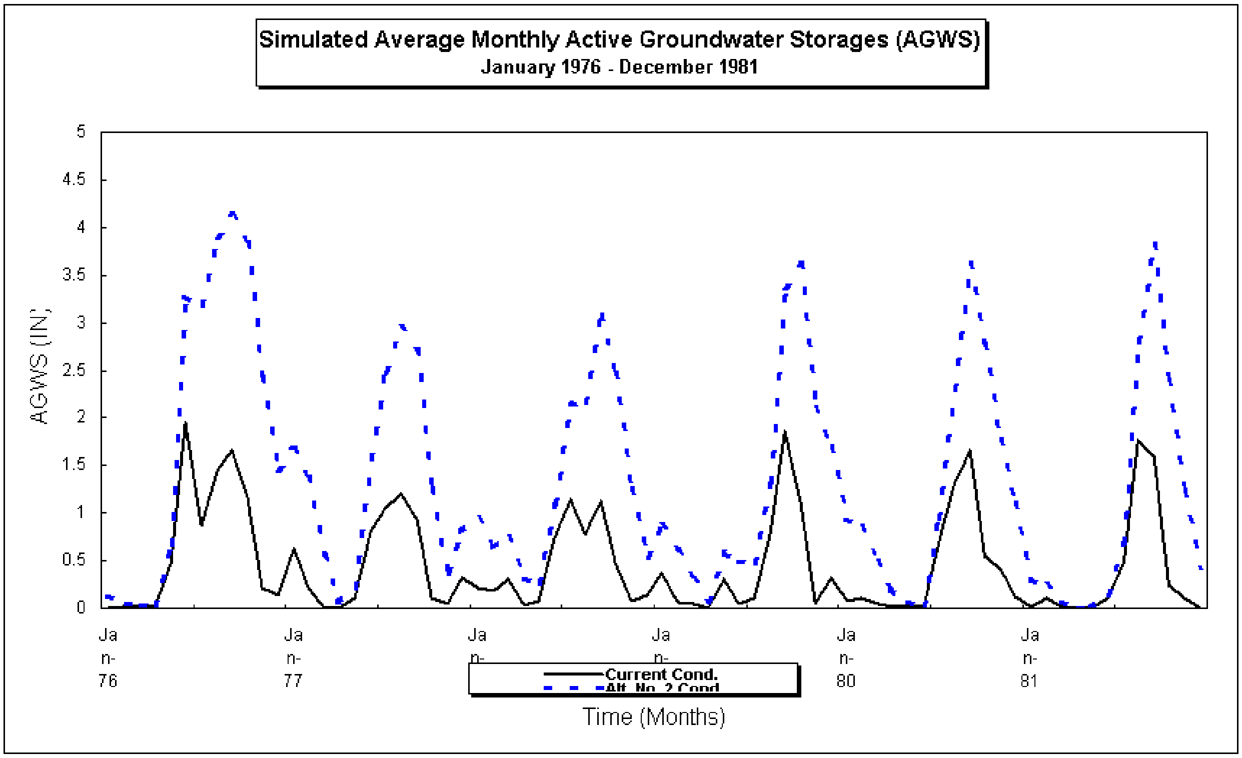

Simulated Average Monthly Active Groundwater Storages (AGWS)
January 1976 - December 1981
AGWS (IN)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-76
Jan-77
Jan-
Jan-
Jan-80
Jan-81
Current Cond.
Alt. No. 2 Cond.
Time (Months)

Figure 47

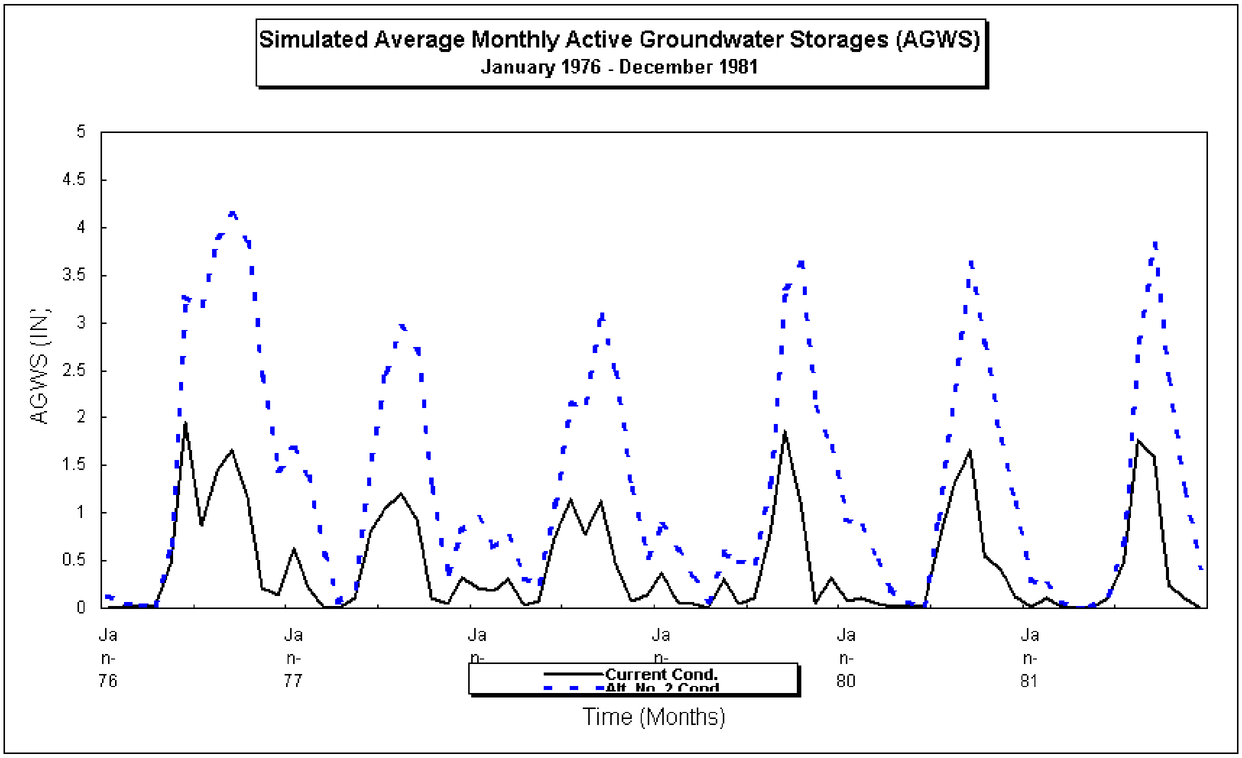

Simulated Average Monthly Active Groundwater Storages (AGWS)
January 1976 - December 1981
AGWS (IN)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-76
Jan-77
Jan-
Jan-
Jan-80
Jan-81
Current Cond.
Alt. No. 2 Cond.
Time (Months)

Figure 48

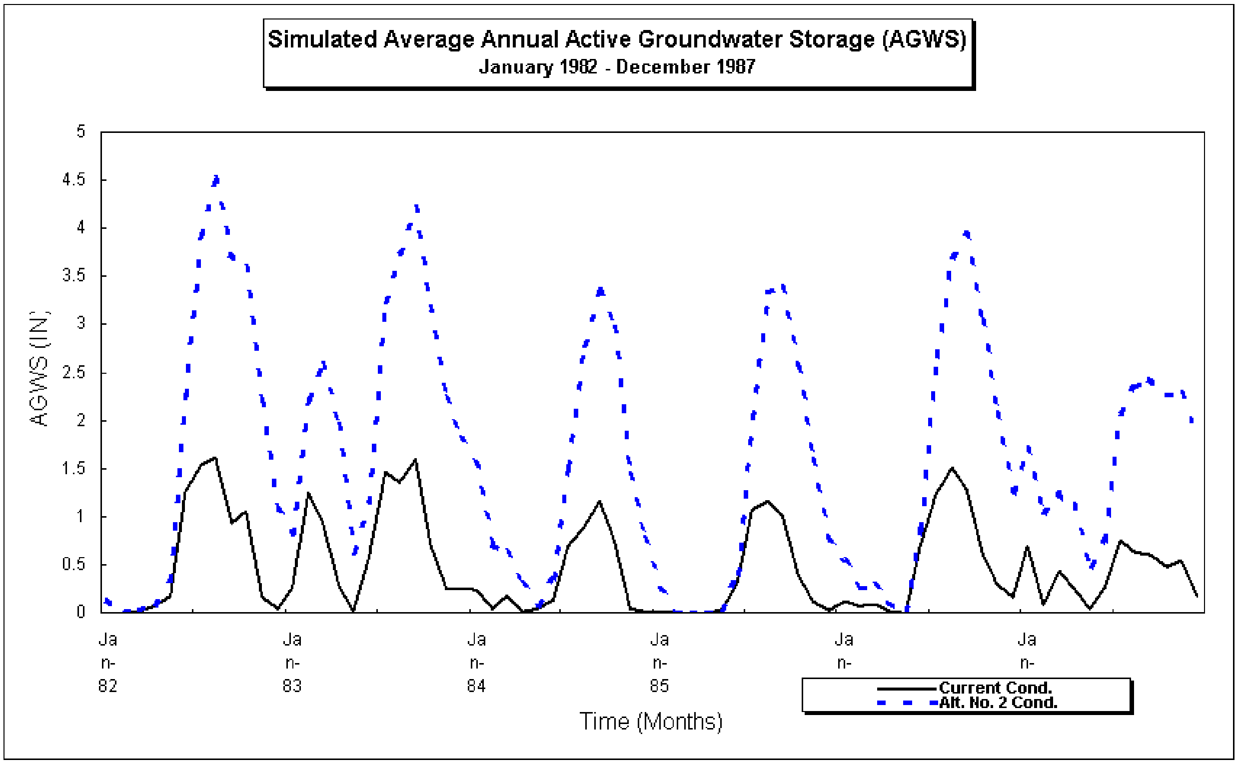

Simulated Average Annual Active Groundwater Storage (AGWS)
January 1982 - December 1987
AGWS (IN)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-
Jan-
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 48

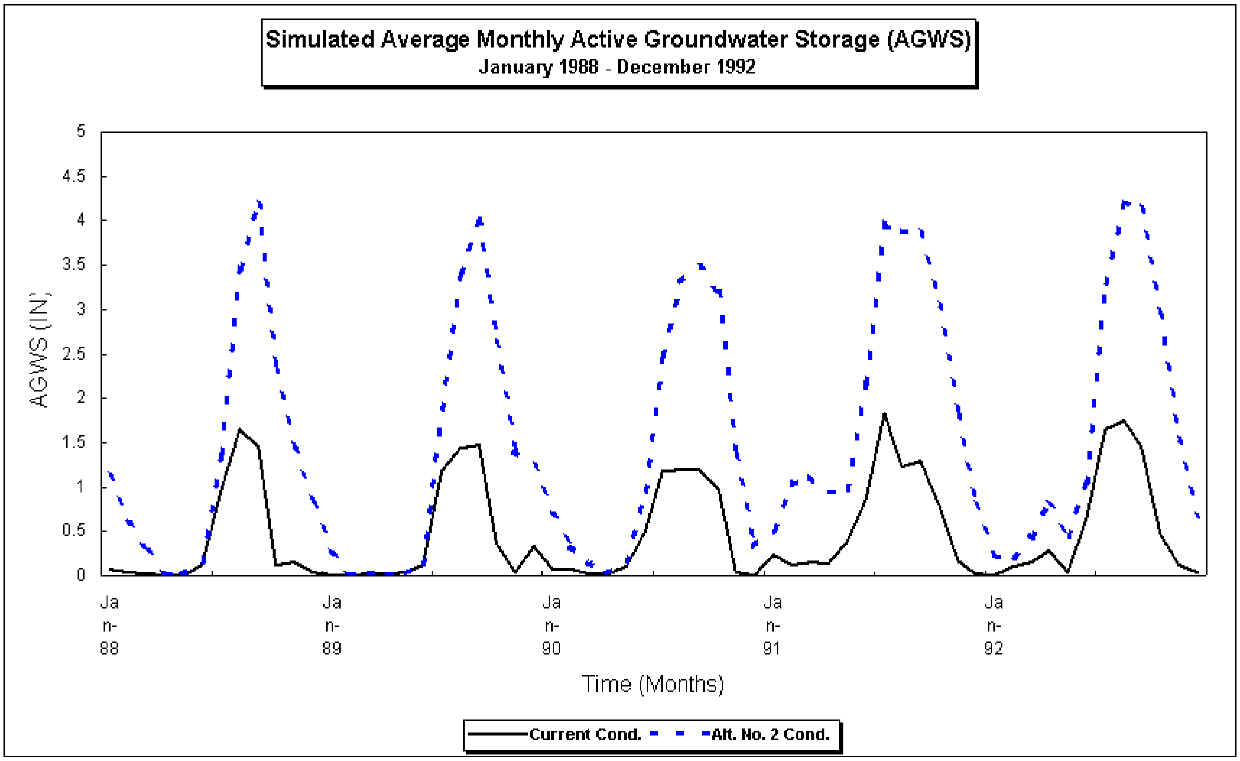

Simulated Average Monthly Active Groundwater Storage (AGWS)
January 1988 - December 1992
AGWS (IN)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)
Current Cond.
Alt. No. 2 Cond.

Figure 49

is not one to one, however. The average increase in active groundwater storage divided by an average soil porosity of 0.11 gives an increase in active groundwater storage of ten inches, an upper zone storage increase of 0.3 inches and a lower zone increase of 2.4 inches. This gives a total increase in water storage of 12.7 inches.

Based on the most current topographic and vegetation maps, average maximum wet season water depths in the sloughs directly downstream from the main spreader cannot exceed approximately one foot if historic hydroperiods for wetland and upland areas are to be restored. Average maximum wet season flows that will discharge from the spreader channels is 286 cfs and results in a maximum water depth of 0.93 foot. This indicates that the hydroperiod criteria is not exceeded, that is, the water levels will not be wetter than historical levels.

Flood Control for NGGE

For Alternative 2, as with the other alternatives, the flood protection for the areas north of I-75 would be maintained by the pumps.

4-3.3 Hydrologic Performance of Alternative 3A

Area of Rehydration

Alternative 3A considers two separate segments of the Main spreader channel and the Miller Canal spreader is proposed to be moved southward approximately one and a quarter miles south of I-75 (see Figure 50). The extreme northwest corner of SGGE would be left out of the rehydration area, although this area would still benefit from increased aquifer recharge due to higher maintained canal water levels. A portion of NGGE would benefit from increased aquifer recharge if the pumps were used to maintain water levels with a freeboard of one to two feet, while existing flood protection would continue for NGGE.

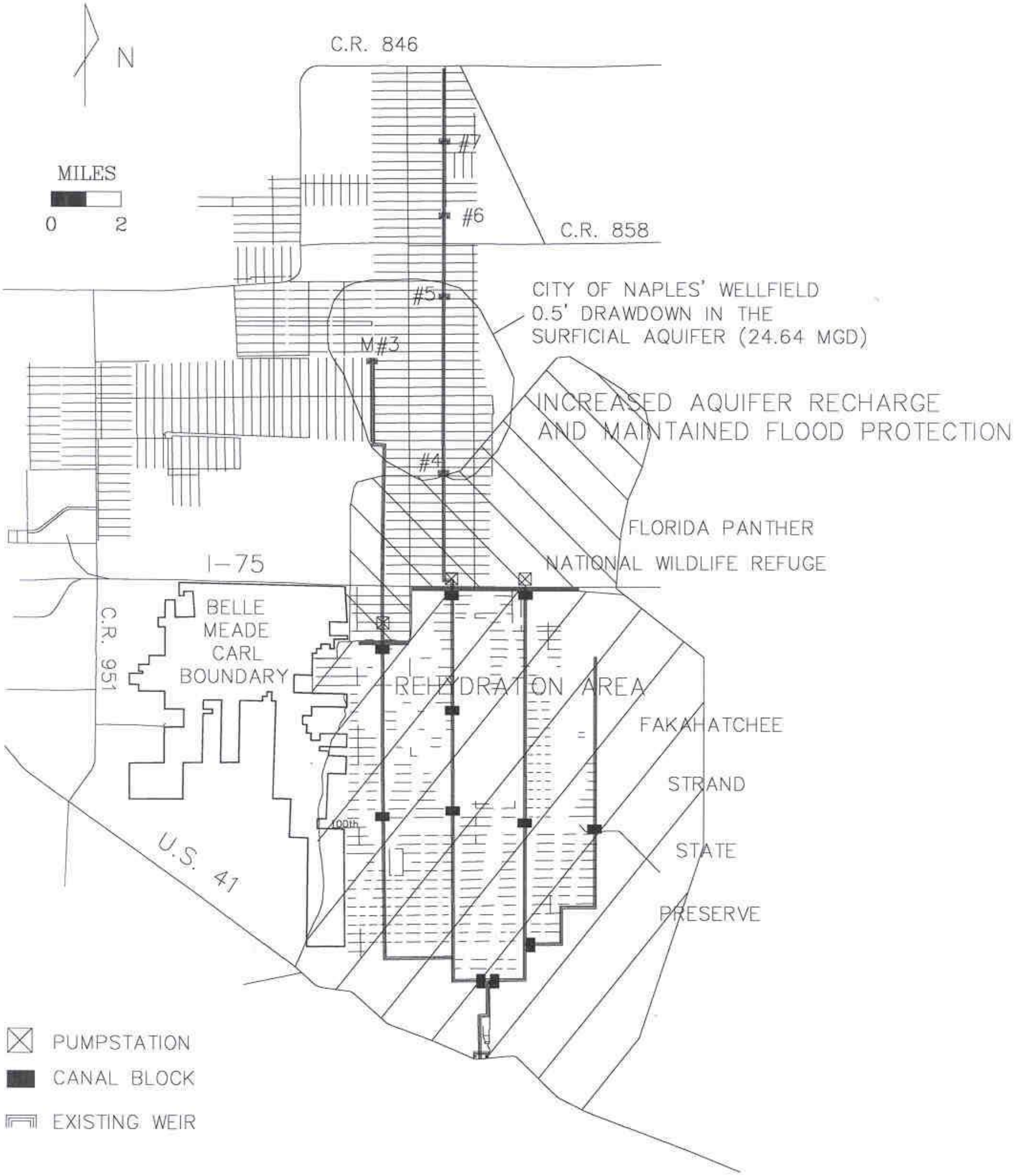


FIGURE 50. Area of Rehydration for Alternative 3A

Approximately 1.25 square miles of privately owned land in eastern Belle Meade is within the rehydration area and is not within a CARL project boundary. As explained previously, these areas intercept a major flowway which conveys water out of SGGE and are an integral part of the restoration project. Due to importance of these areas from a water management perspective, inclusion of these areas into a CARL project boundary is recommended.

Water Budget and Runoff

This alternative produced a slight decrease in runoff (one inch) from existing conditions. Channelized runoff consists of a small contribution (average annual = 2 cfs) from the Faka Union Canal near the outlet where approximately the last two miles of canal remain intact. Plugging this portion of the canal would be cost prohibitive due to its large cross-section and somewhat inaccessibility by existing roads. Overall basin runoff is comprised mainly by non-channelized runoff. A runoff hydrograph at Faka Union Weir No.1 for this alternative is shown in Figure 51.

Soil and Groundwater Storages/Hydroperiods

Figures 52 through 63 show the average daily soil storages in the upper and lower soil zones and the active groundwater storage zone for those land segments south of I-75 under Alternative 3A scenario for the entire period of simulation. The upper zone soil storage increased by six percent, lower zone soil storage increased by four percent and active groundwater storage increased by 62 percent. The active groundwater storage under Alternative 3A was extended up to two months longer than existing conditions. By dividing soil and groundwater storages by an average soil porosity of 0.11 gives a total increase in water storage of 5.7 inches.

Proper estimation of hydroperiods require accuracy of topographic data in the order of inches. For many areas in SGGE, the soils and topographic data did not correlate well. Typical areas

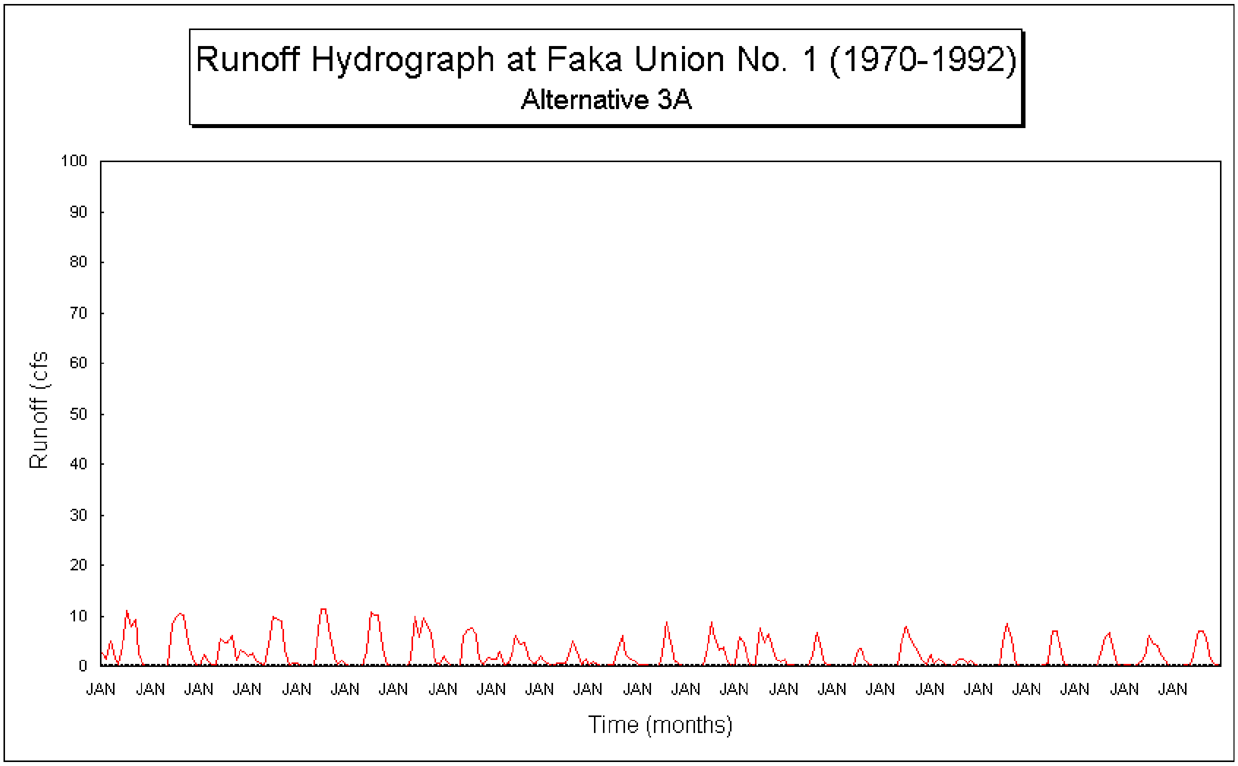


Figure 51

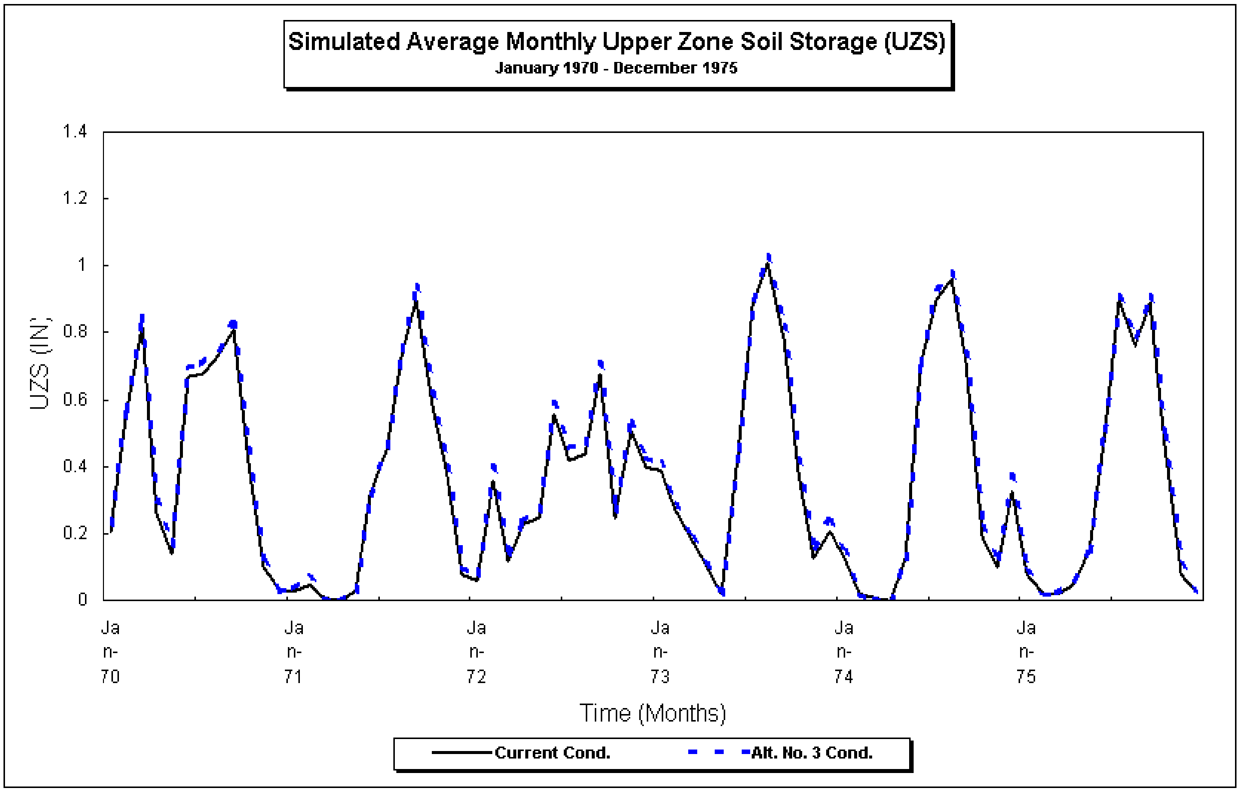

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1970 - December 1975
UZS (IN)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 52

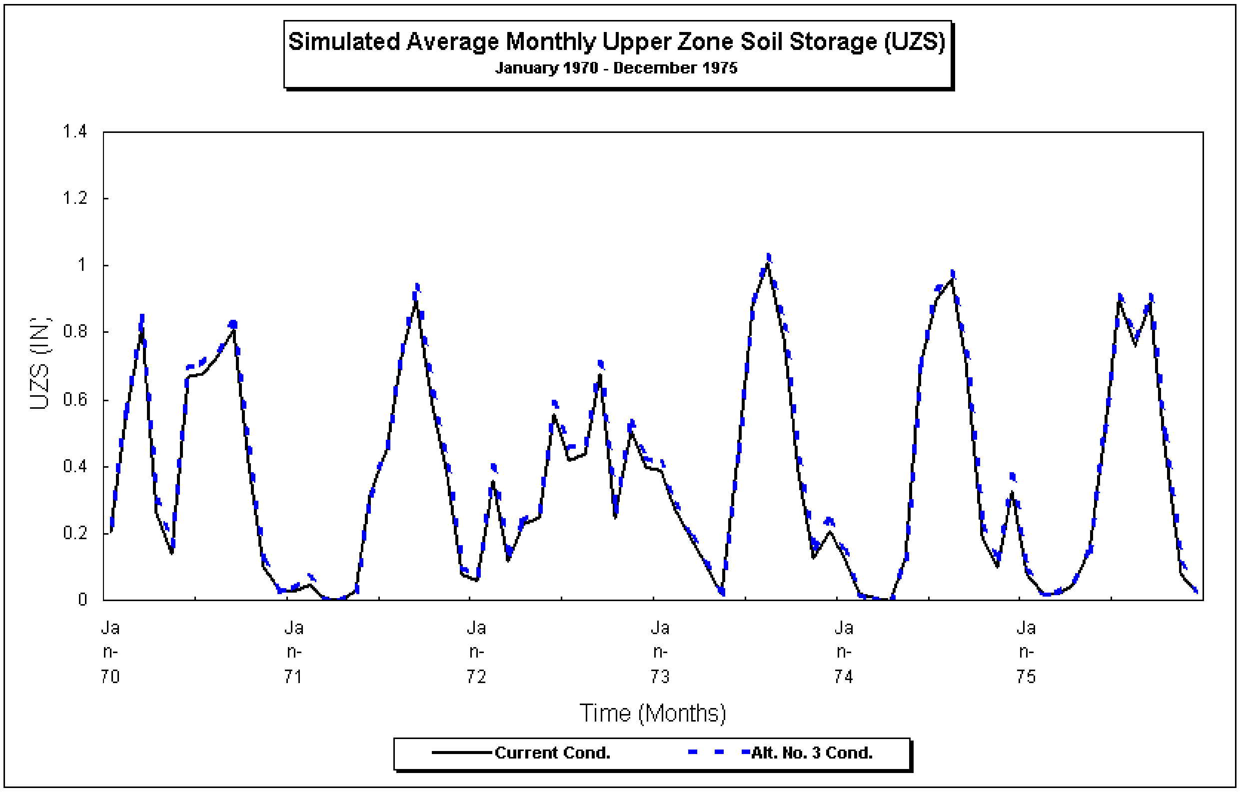

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1970 - December 1975
UZS (IN)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 53

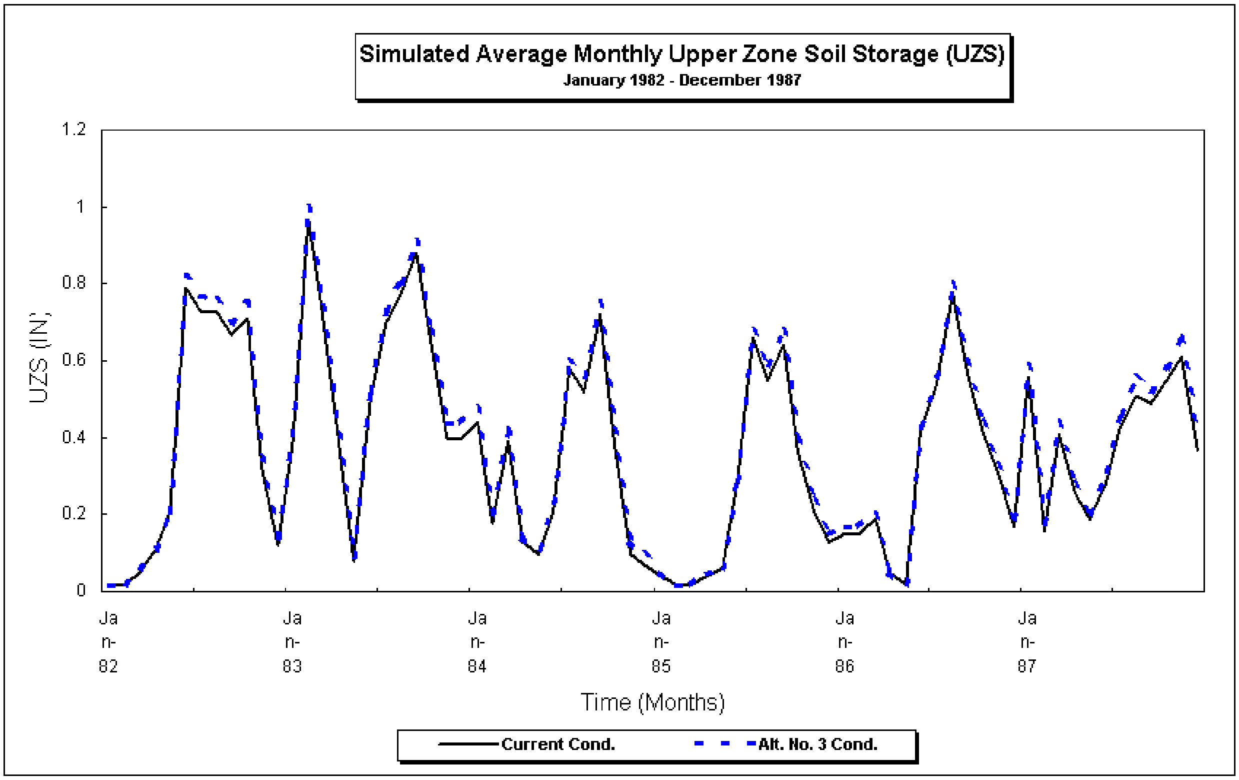

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1982 - December 1987
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 54

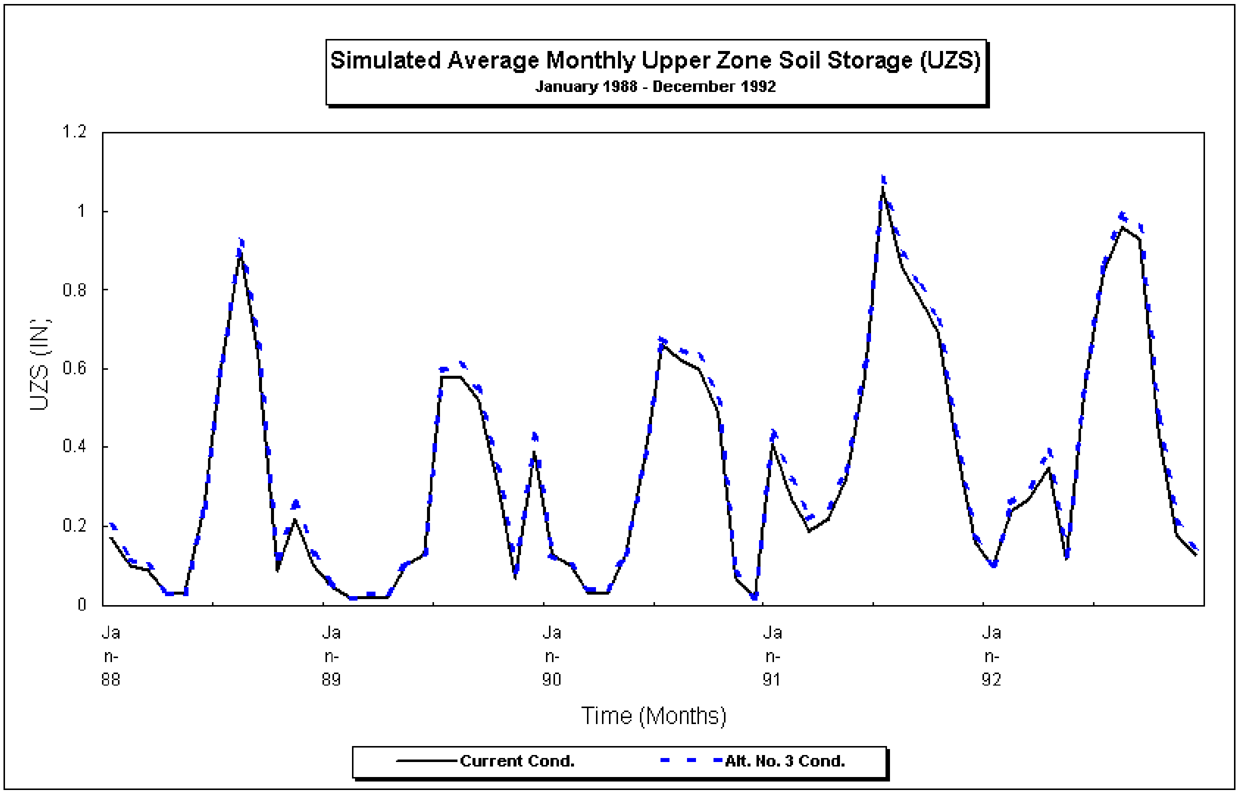

Simulated Average Monthly Upper Zone Soil Storage (UZS)
January 1988 - December 1992
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 55

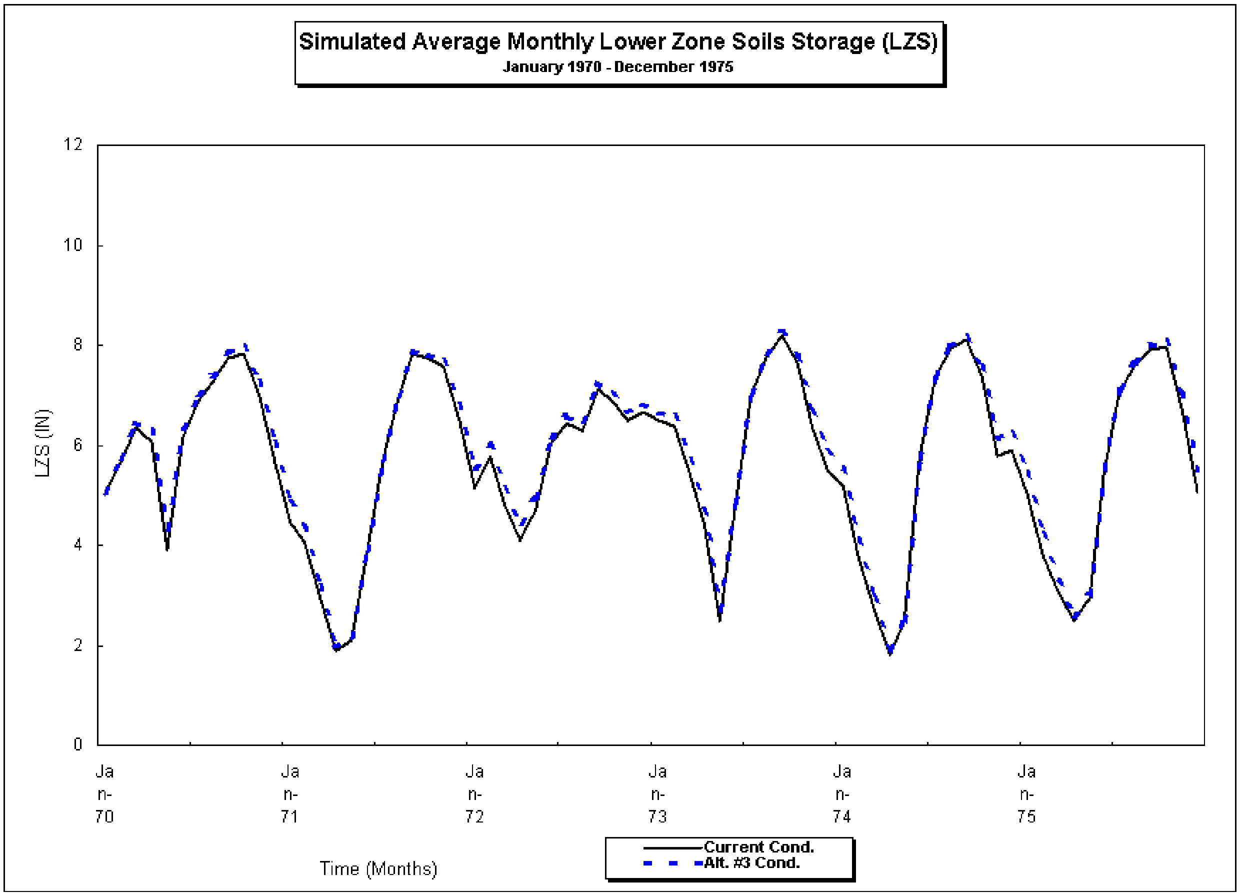

Simulated Average Monthly Lower Zone Soils Storage (LZS)
January 1970 - December 1975
LZS (IN)
0
2
4
6
8
10
12
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
Current Cond.
Alt. #3 Cond.

Figure 56

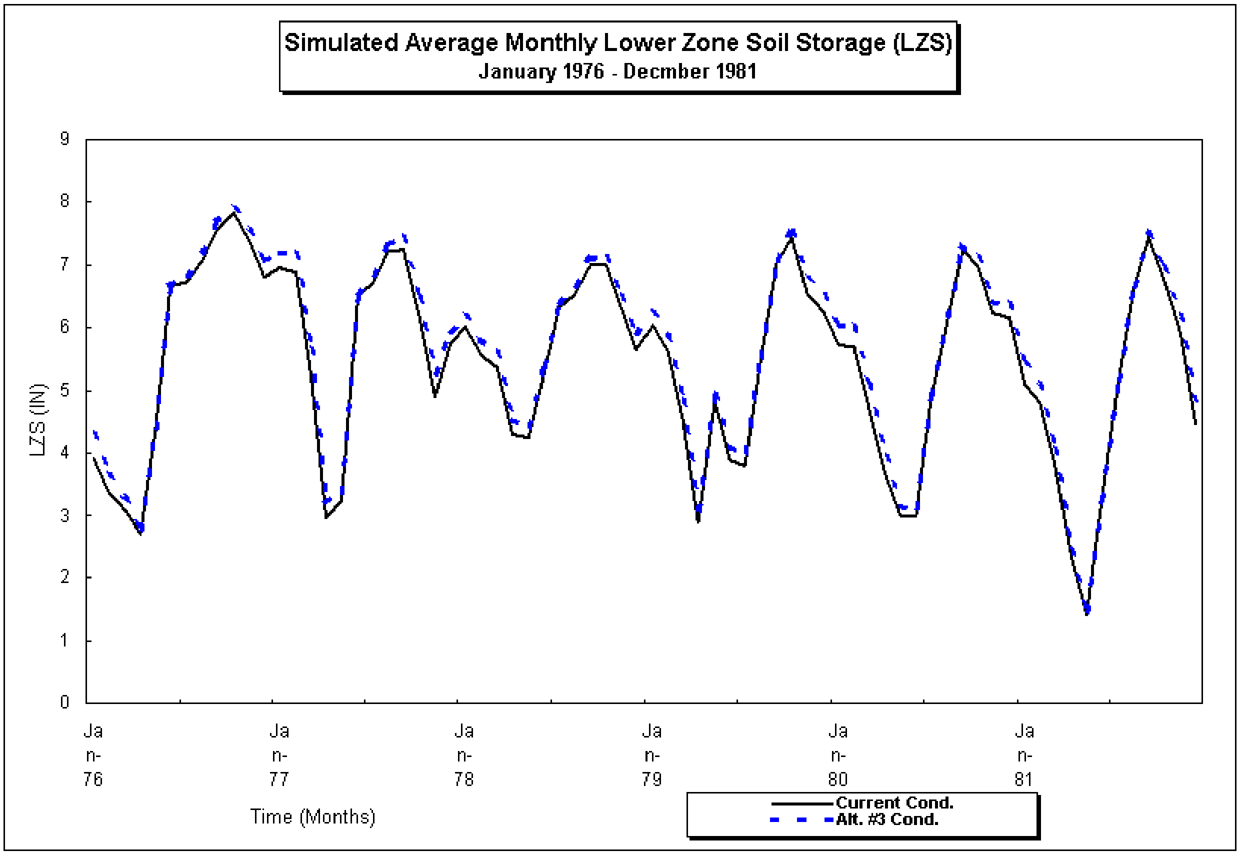

Simulated Average Monthly Lower Zone Soil Storage (LZS)
January 1976 - Decmber 1981
LZS (IN)
0
1
2
3
4
5
6
7
8
9
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)
Current Cond.
Alt. #3 Cond.

Figure 57

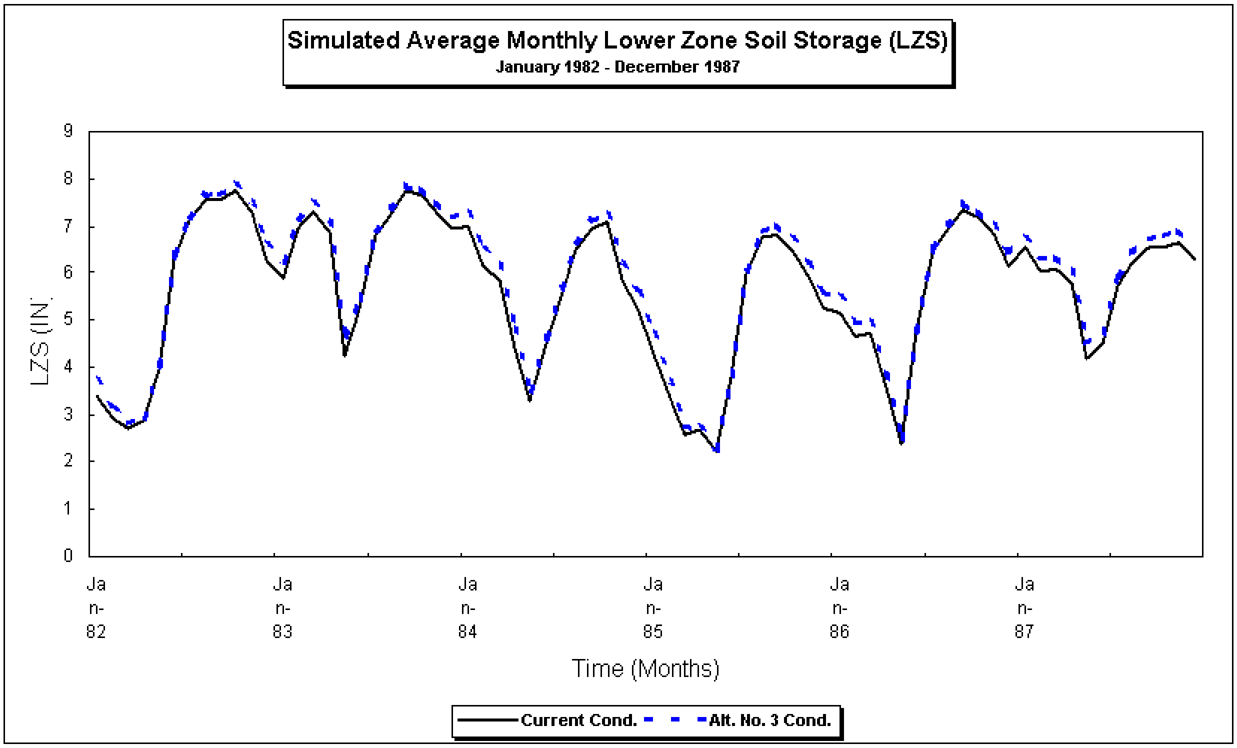

Simulated Average Monthly Lower Zone Soil Storage (LZS)
January 1982 - December 1987
LZS (IN)
9
8
7
6
5
4
3
2
1
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 58

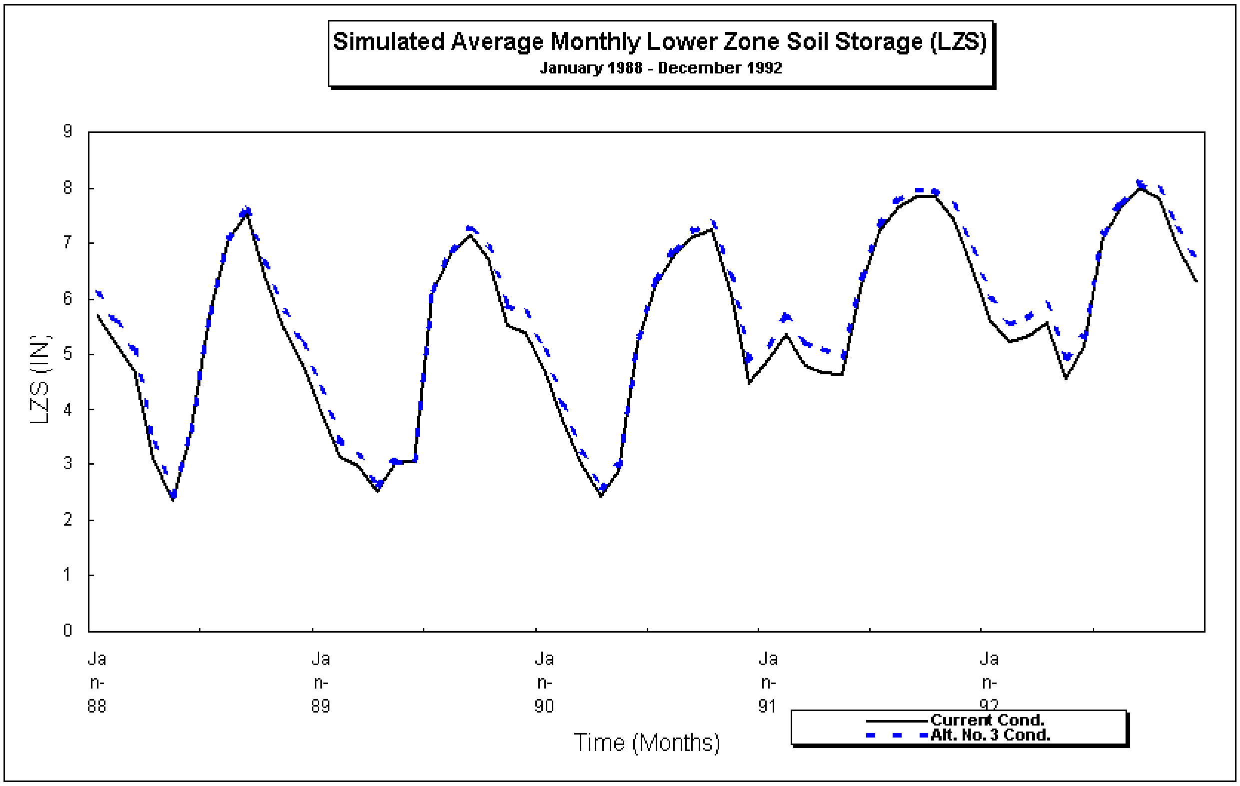

Simulated Average Monthly Lower Zone Soil Storage (LZS)
January 1988 - December 1992
9
8
7
6
5
4
3
2
1
0
LZS (IN)
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 59

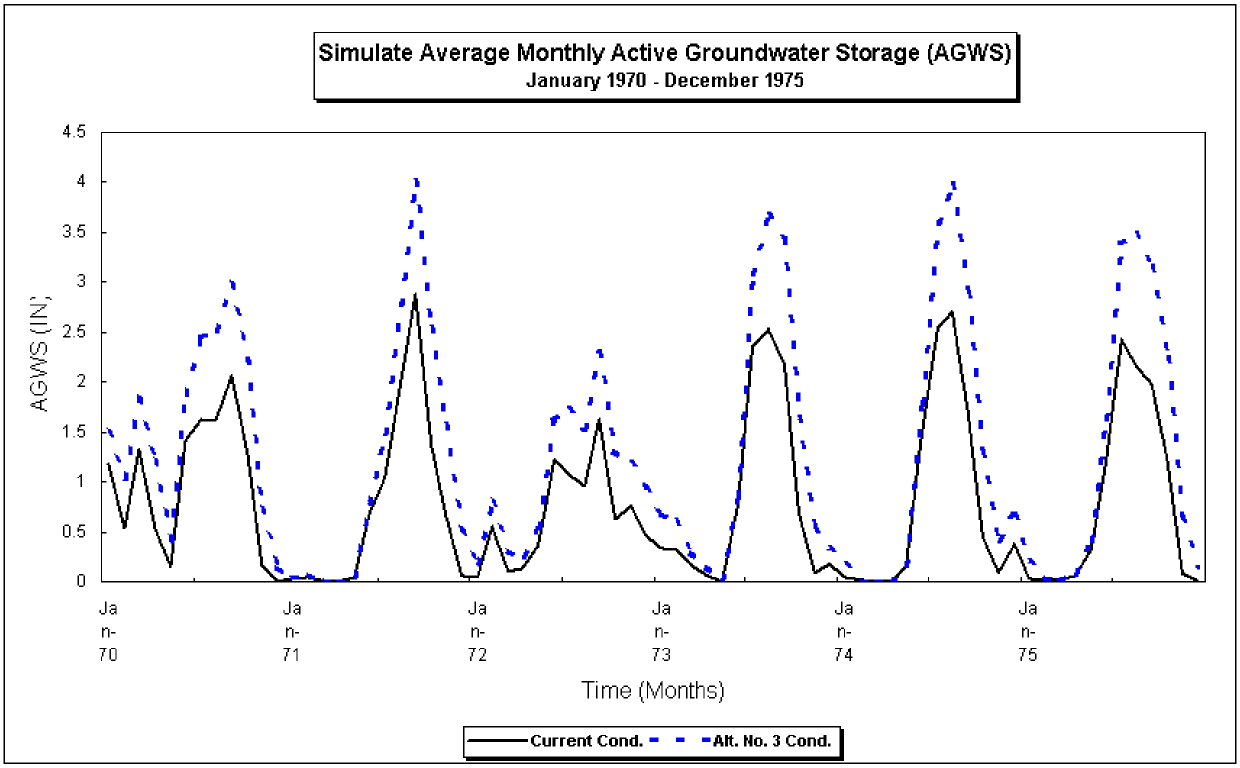

Simulate Average Monthly Active Groundwater Storage (AGWS)
January 1970 - December 1975
AGWS (IN)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
Current Cond.
Alt. No. 3 Cond.

Figure 60

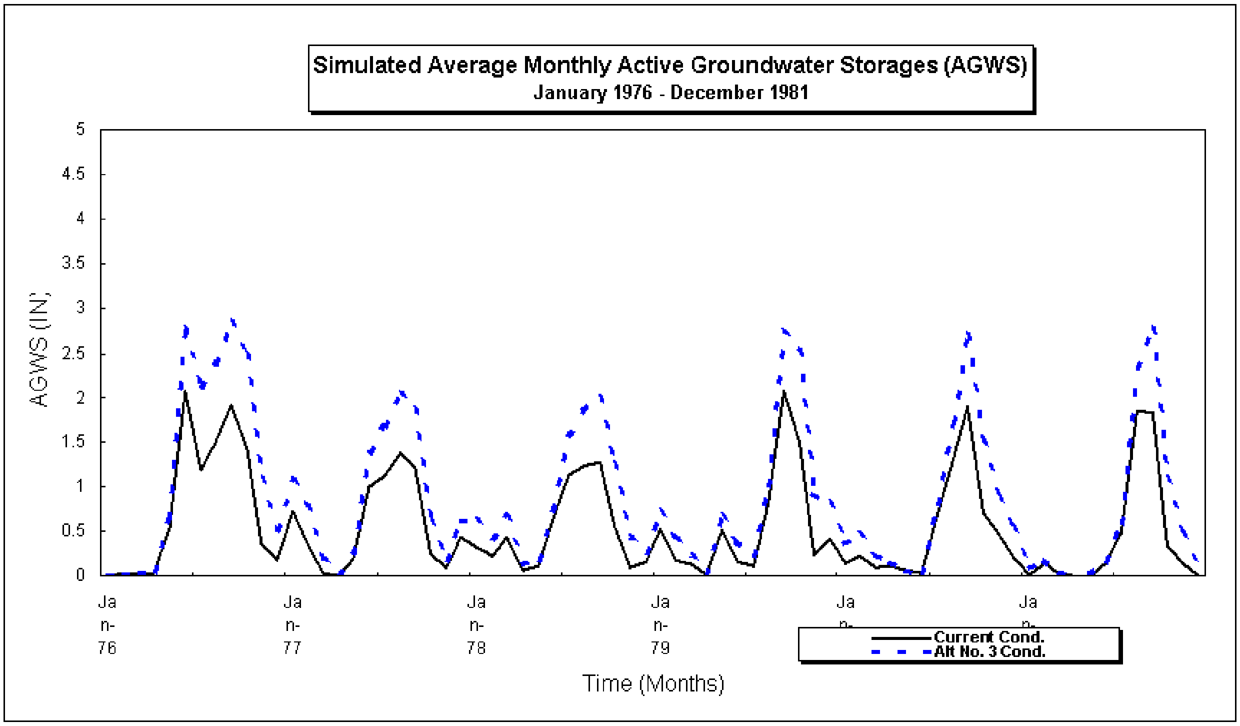

Simulated Average Monthly Active Groundwater Storages (AGWS)
January 1976 - December 1981
AGWS (IN)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-76
Jan-77
Jan-78
Jan-79
Jan-
Jan-
Current Cond.
Alt No. 3 Cond.
Time (Months)

Figure 61

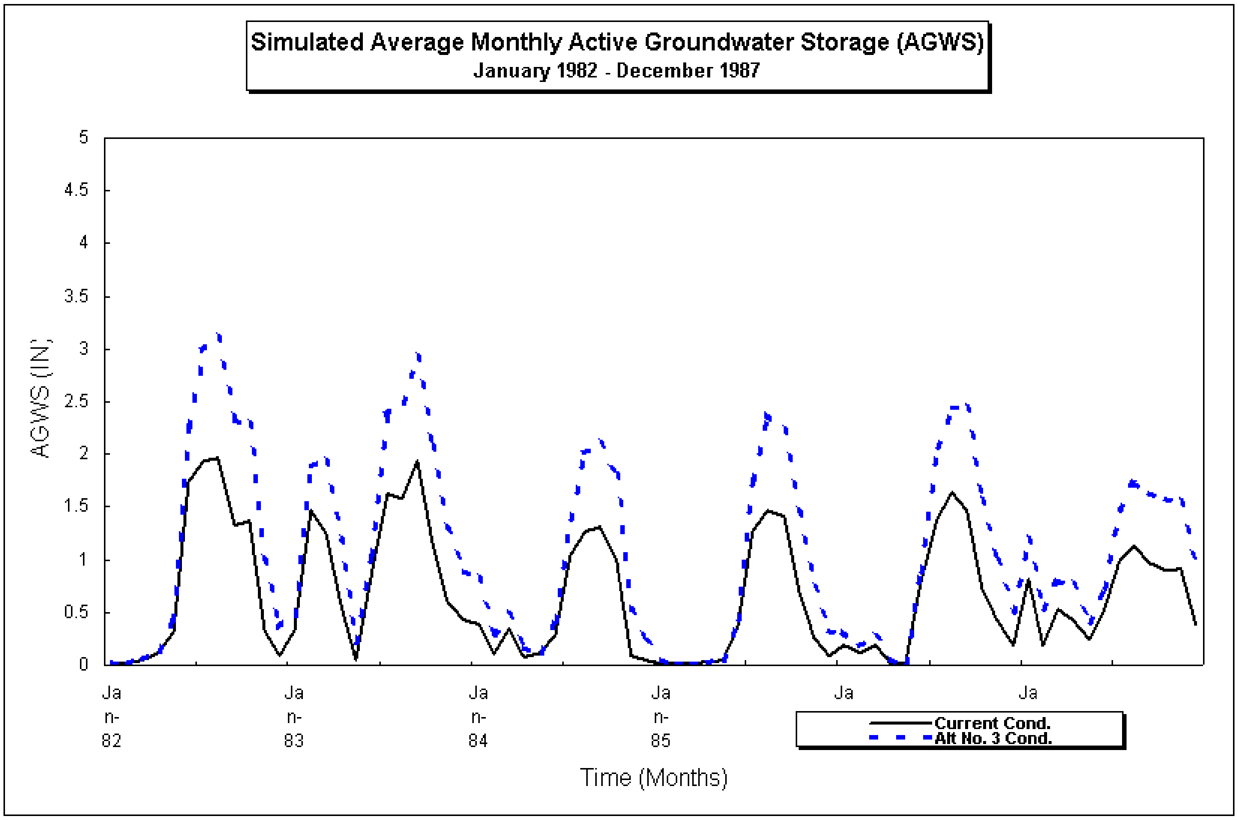

Simulated Average Monthly Active Groundwater Storage (AGWS)
January 1982 - December 1987
AGWS (IN)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan-82
Jan-83
Jan-84
Jan-85
Ja
Ja
Current Cond.
Alt No. 3 Cond.
Time (Months)

Figure 62

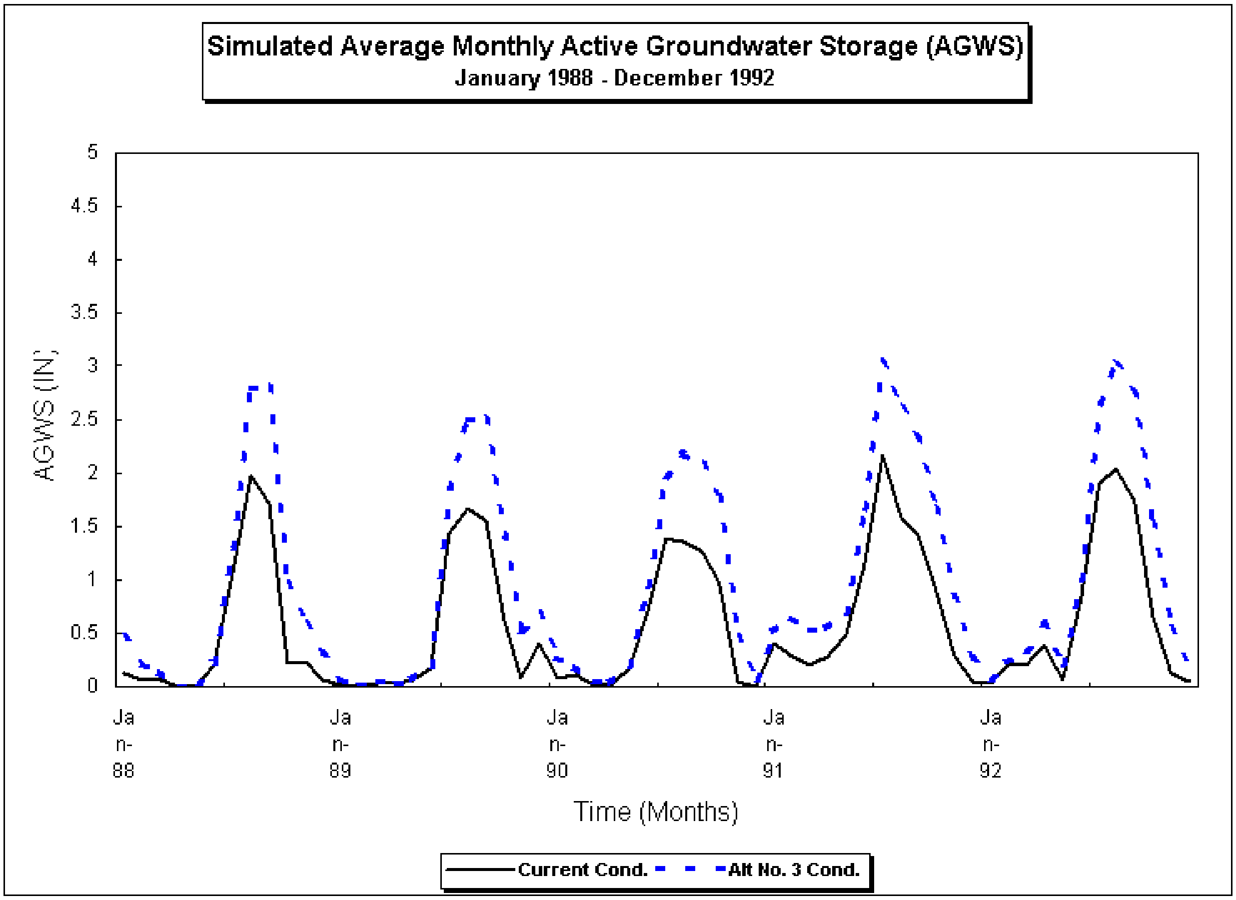


Figure 63

were selected where topographic and soils data agreed and thus were believed to be more accurate. Although depths and hydroperiods cannot be given for the entire SGGE area, any location within the area of rehydration, as shown previously in Figure 51, can expect a change in the hydrologic regime. Results from the RCHRES module show some average hydroperiods for a few typical areas in SGGE (see Figure 64).

Based on the most current topographic and vegetation maps, average maximum wet season water depths in the sloughs directly downstream from the Miller spreader cannot exceed approximately one foot if historic hydroperiods for wetland and upland areas are to be restored. Average maximum wet season water depths in the sloughs directly downstream from the Main spreader cannot exceed approximately one foot. Average maximum wet season flows that will discharge from the Miller and Main spreader channels are 69 and 243 cfs, respectively, and result in maximum water depths of 0.65 and 1.17 feet. This indicates that the hydroperiod criteria is exceeded downstream from the Main spreader, that is, it will result in wetter and longer hydroperiods than historical threshold levels in this area.

Flood Control for NGGE

Flood protection for areas north of I-75 would be maintained by the pump stations.

4-3.4 Hydrologic Performance of Alternative 3B

Area of Rehydration

The area of rehydration and aquifer recharge for alternative scenario 3B is shown in Figure 65. Approximately 1.1 square miles of privately owned land in eastern Belle Meade is within the rehydration area and is not within the Belle Meade CARL project boundary. These areas are an integral part of the restoration project and are recommended for inclusion in the Belle Meade or Save Our Everglades CARL project boundary for optimal water management.

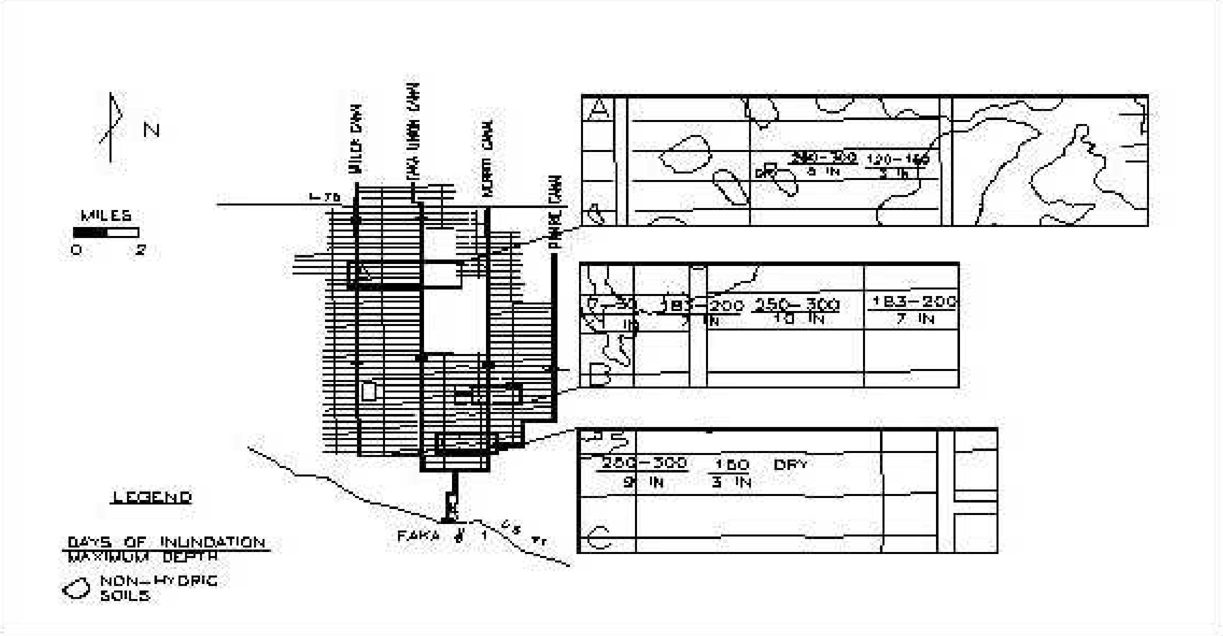


FIGURE 64. Average Hydroperiods for Select Areas for Alternative 3A

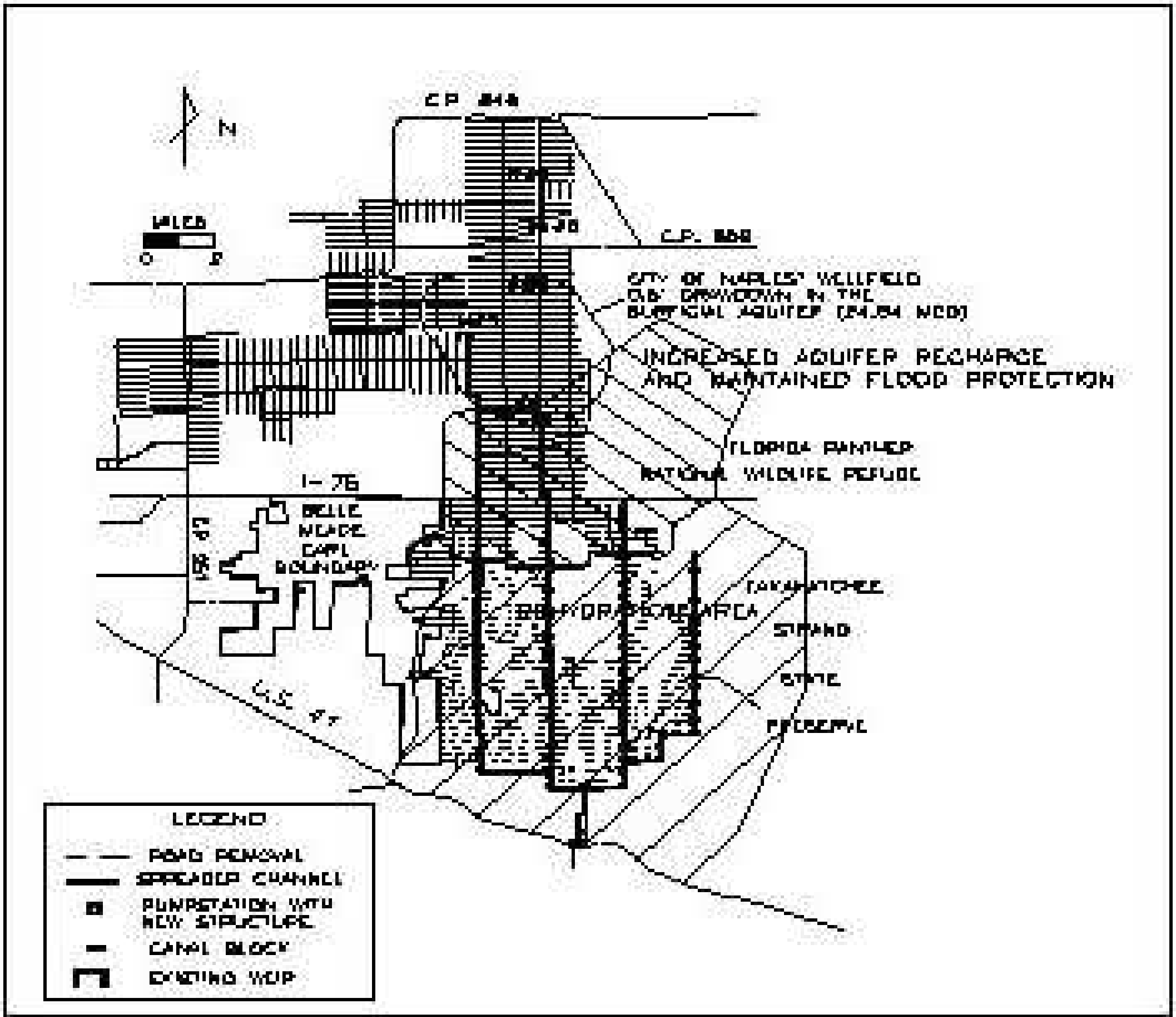


FIGURE 6B Area of Rehydration for Alternative 3B

Water Budget and Runoff

The water budget for this alternative shows a significant increase in evaporation (5 inches per year) and corresponding reduction in overall runoff. The channelized runoff amounting to an annual average of 2 cfs comes solely from the last two miles of the Faka Union Canal at the outlet. A runoff hydrograph at the Faka Union Weir No. 1 is shown in Figure 66.

Soil and Groundwater Storages/Hydroperiods

The changes in simulated soil and groundwater storages from existing conditions could not be evaluated by the model because PLS outflow was routed to canals rather than to other land segments. Soil and active groundwater storage outputs are available only in the PERLND module. After PLS outflows are routed to a stream reach, the RCHRES simulation does not provide soil moisture storage output. Hydroperiods were simulated by analyzing the stages of the overbank flows and typical hydroperiods that can be expected are shown for a few selected areas in Figure 67.

Based on the most current topographic and vegetation maps, average maximum wet season water depths in the sloughs directly downstream from the Miller and Merritt spreaders cannot exceed approximately one foot if historic hydroperiods for wetland and upland areas are to be restored. Average maximum wet season water depths in the sloughs directly downstream from the Faka spreader cannot exceed approximately 1.5 feet. Average maximum wet season flows that will discharge from the Miller, Faka Union and Merritt spreader channels are 69, 229 and 59 cfs respectively and result in maximum water depths of 0.65, 1.44 and 0.89 feet. This indicates that the hydroperiod criteria is not exceeded for this alternative.

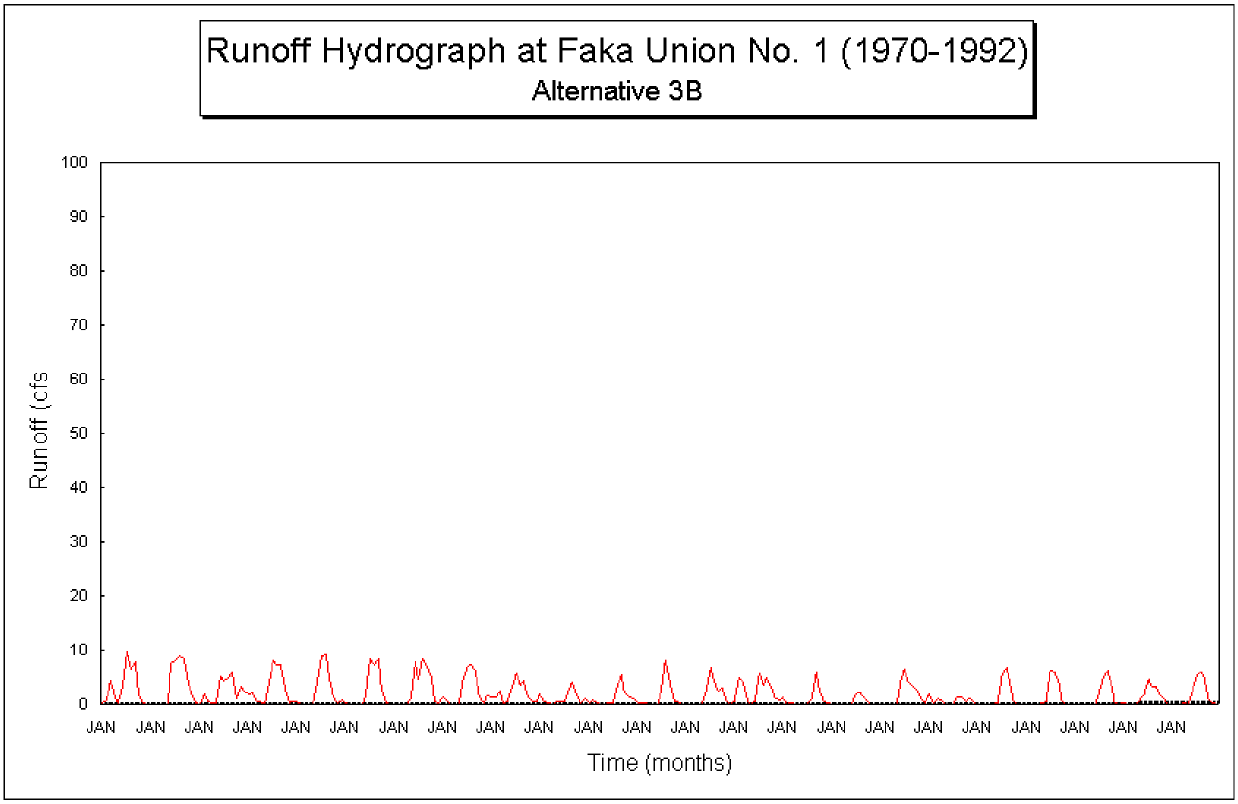

Runoff Hydrograph at Faka Union No. 1 (1970-1992)
Alternative 3B
100
90
80
70
60
50
40
30
20
10
0
Runoff (cfs
JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN JAN
Time (months)

Figure 66

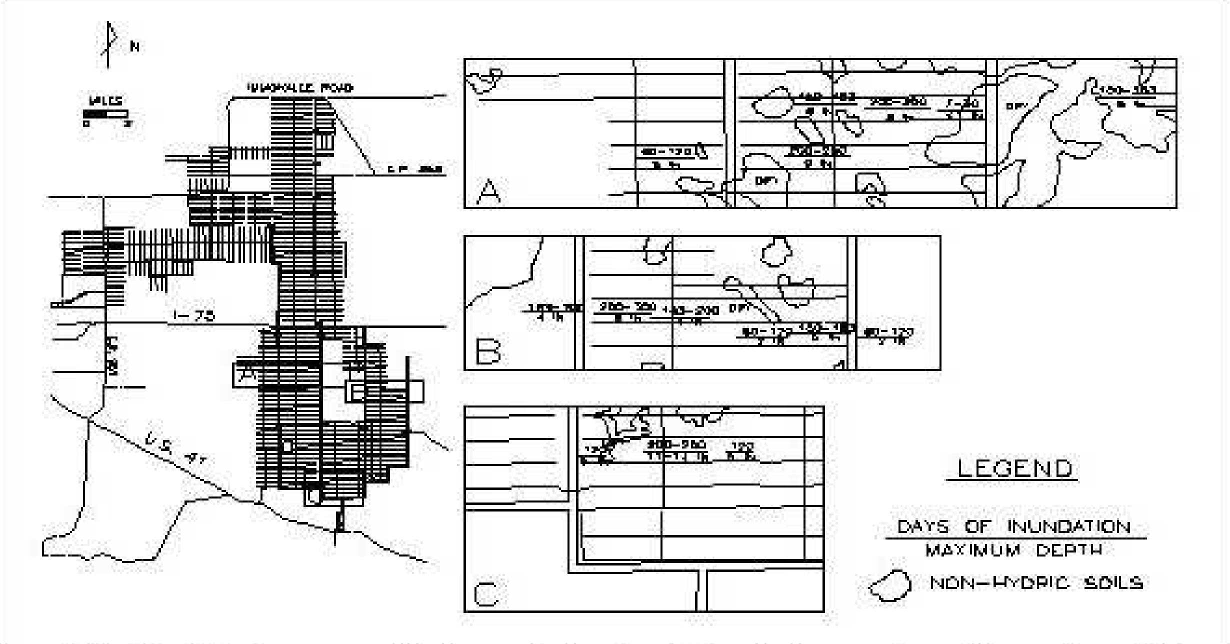


FIGURE 67. Average Hydroperiods for Select Areas for Alternative 3B

Flood Control for NGGE

Flood control for NGGE is maintained solely by the pump stations.

4-3.5 Hydrologic Performance of Alternative 3C

Area of Rehydration

The slight shift in the location of the Merritt spreader channel in Alternative 3C resulted in an increase in the extent of the rehydration area from Alternative 3B as shown in Figure 68. Approximately 1.1 square miles of privately owned land in eastern Belle Meade is within the rehydration area and is not within a CARL project boundary. These areas are an integral part of the restoration project and are recommended for inclusion in the Belle Meade or Save Our Everglades CARL project boundary for optimal water management.

Water Budget and Runoff

The changes in the water budget from existing conditions are similar to those of Alternative 3B. A runoff hydrograph at Faka Union No. is shown in Figure 69.

Soil and Groundwater Storages/Hydroperiods

As in Alternative 3B, the changes in soil and active groundwater storages were not evaluated by the model because PLS outflows were routed to canals. RCHRES simulation in HSPF does not provide soil moisture storage output.

Estimates of typical hydroperiod changes computed by stage duration of overbank flows are illustrated in Figure 67. Typical hydroperiods are similar to Alternative 3B. Based on the most current topographic and vegetation maps, average maximum wet season water depths in the sloughs directly downstream from the Miller spreader cannot exceed approximately one foot if historic hydroperiods for wetland and upland areas are to be restored. Average maximum wet season water

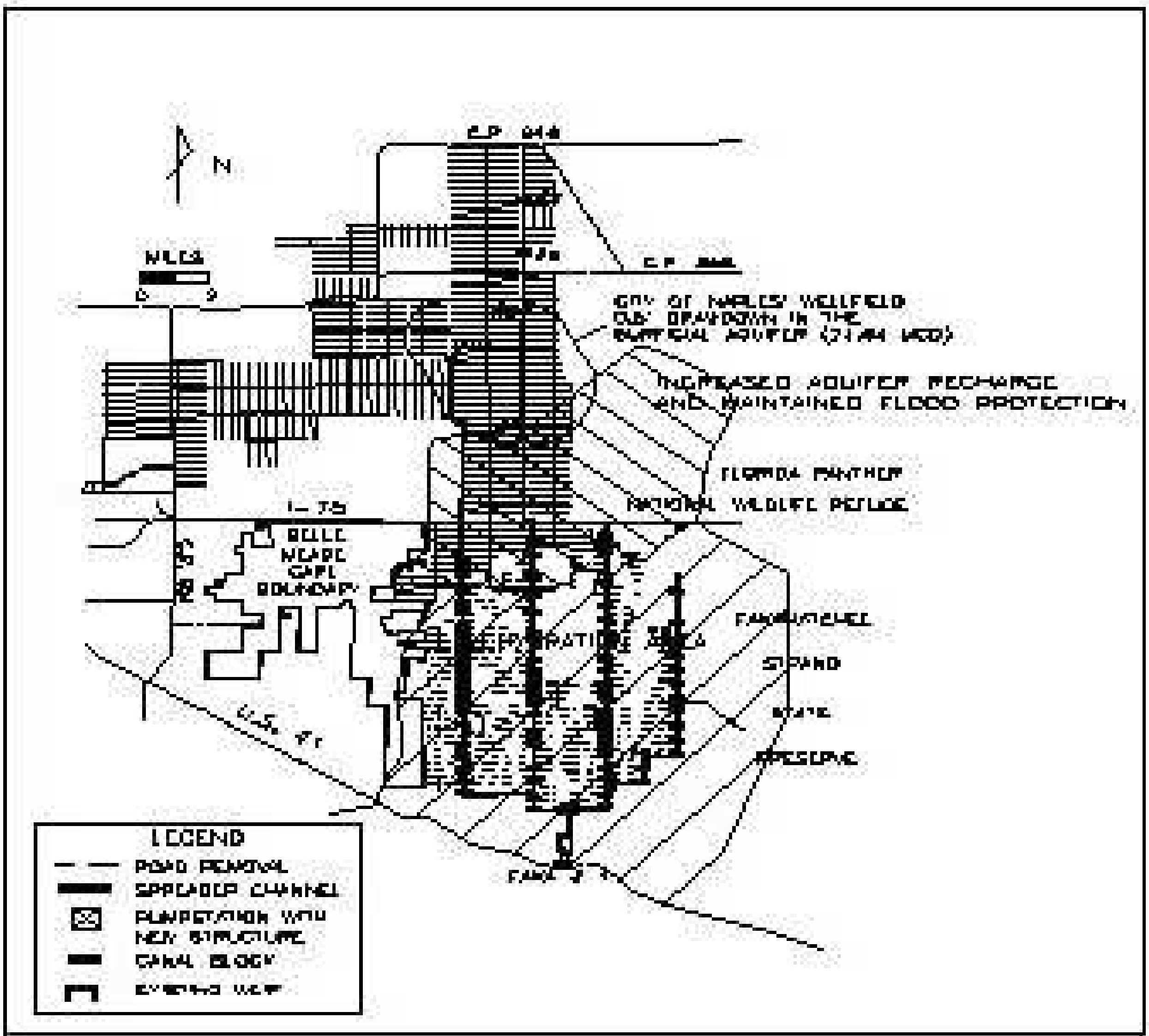


FIGURE 68. Area of Rehydration for Alternative 3C

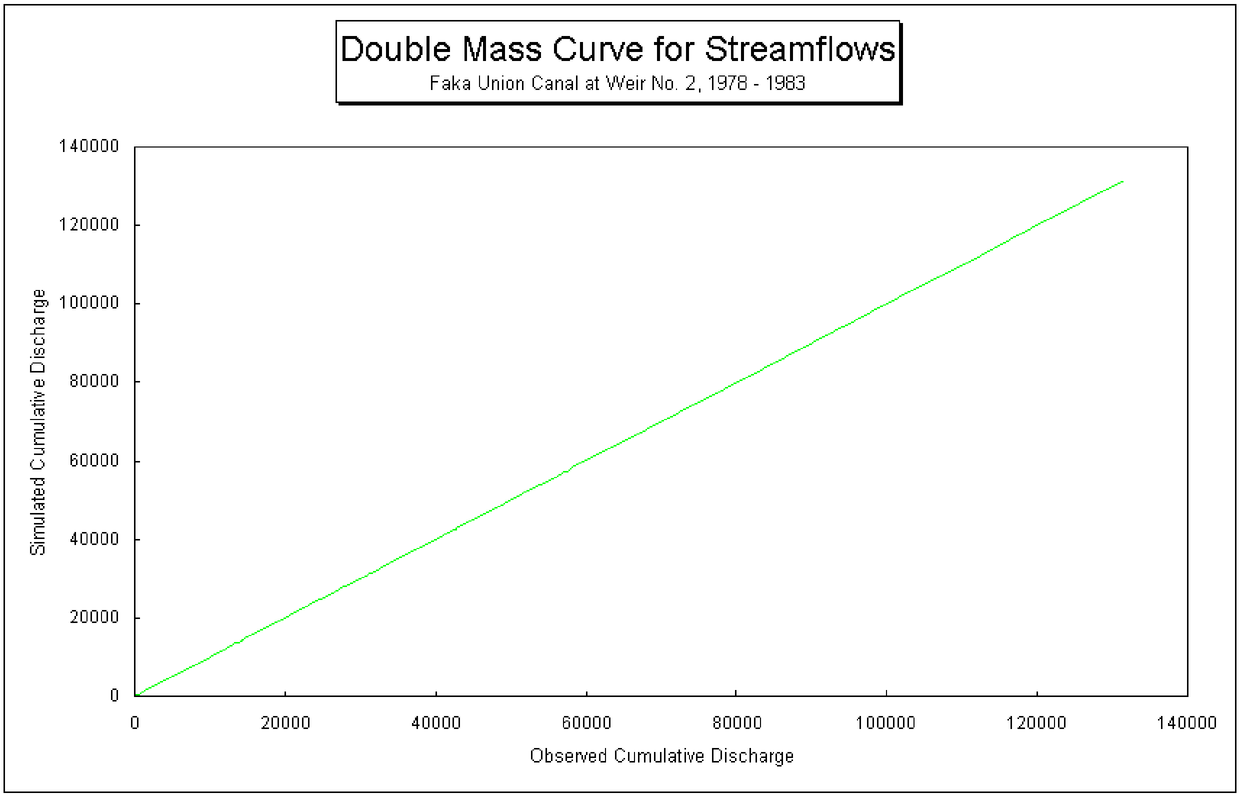


Figure 66

depths in the sloughs directly downstream from the Faka and Merritt spreaders cannot exceed approximately 1.5 feet. Average maximum wet season flows that will discharge from the Miller, Faka Union and Merritt spreader channels are 69, 229 and 49 cfs respectively and result in maximum water depths of 0.65, 1.44 and 1.06 feet. This indicates that the hydroperiod criteria is not exceeded. These levels indicate that additional water could be routed to the Miller and Merritt spreaders without violating the hydroperiod criteria, but the maximum level is reached for the Faka Union spreader.

Flood Control for NGGE

Flood control for NGGE is maintained by the pump stations.

4-3.6 Additional Hydrologic Analysis

Additional hydrologic analyses were performed for the full-scale rehydration of SGGE. The remaining canal segments will experience some periods when the canal levels will be lower than the adjacent groundwater levels. If a gradient exists between the groundwater levels and canal water levels, water will flow into the canals. Simulation indicated that the canals were filled after a week of typical wet season rainfall, an extremely quick response time. Three to five days were common. Even after a drought, canals were filled after 18 days. This indicates the remaining canal segments will not be a large impediment to sheetflow, and sheetflow will occur early in the wet season. Flows crossing U.S. 41 through the culverts were also examined under the restoration scenario. Given the absence of canals, distributed flows across U.S. 41 are expected to increase. The culverts under U.S. 41, however, have the capacity to pass larger flows than those simulated under the restoration scenarios. Figure 70 shows the spacial distribution of average annual simulated flows through the bridge culverts under simulated existing, restored and goal conditions. The flows contributing to the eastern areas of Faka Union Bay show an average annual increase in sheetflow discharge from 14 cfs to 68 cfs. This increased sheetflow into the Faka Union Bay will compensate for the reduced outflow from the Faka Union Canal. It is not desirable to maintain the existing average annual Faka Union Canal discharge of 260 cfs. Appendix D of the U. S. Army Corps of Engineer's report, "Feasibility Study of Golden Gate Estates" (1986), contains a summary of an environmental report evaluating the effects of a reduction in discharge from the Faka Union Canal on the productivity of the Faka Union Bay. This study concluded that "reducing canal discharge to approximately 100 to 150 cfs would substantially increase fish abundance and biomass (in the Bay)."

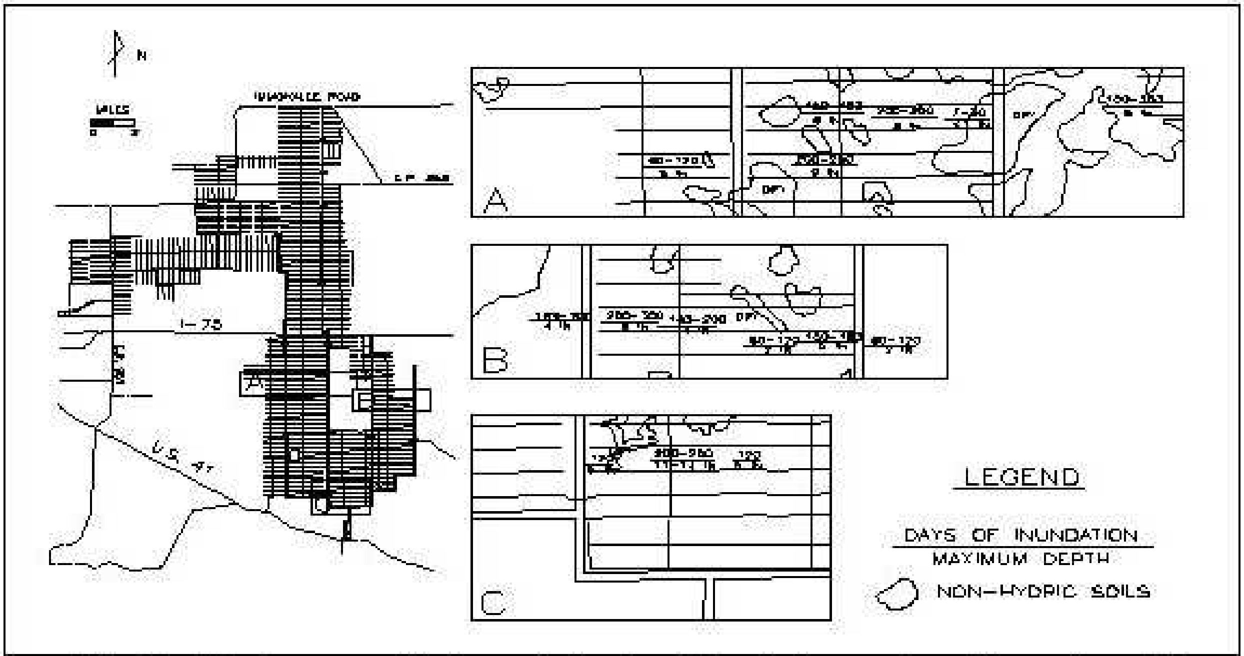


FIGURE 67. Average Hydroperiods for Select Areas for Alternative 3B

4-3.7 Groundwater Analysis for Alternative Plans

The hydraulic head difference between the elevated water levels in the spreader channels and any neighboring open water body, including the I-75 ditch will induce movement of groundwater and cause some seepage to the I-75 ditch. The leakage that occurs from the spreader channels will have both a horizontal and vertical direction component. Therefore, only part of the leakage reaches the I-75 ditch and becomes seepage. The remaining leakage percolates downwards into the aquifer system.

The amount of seepage volume that enters the I-75 ditch varies with both the stages in the spreader channels and the distance between the I-75 ditch and the spreaders. As the stages increase, the total seepage into the I-75 ditch increases. This relationship is expected. However, this increase

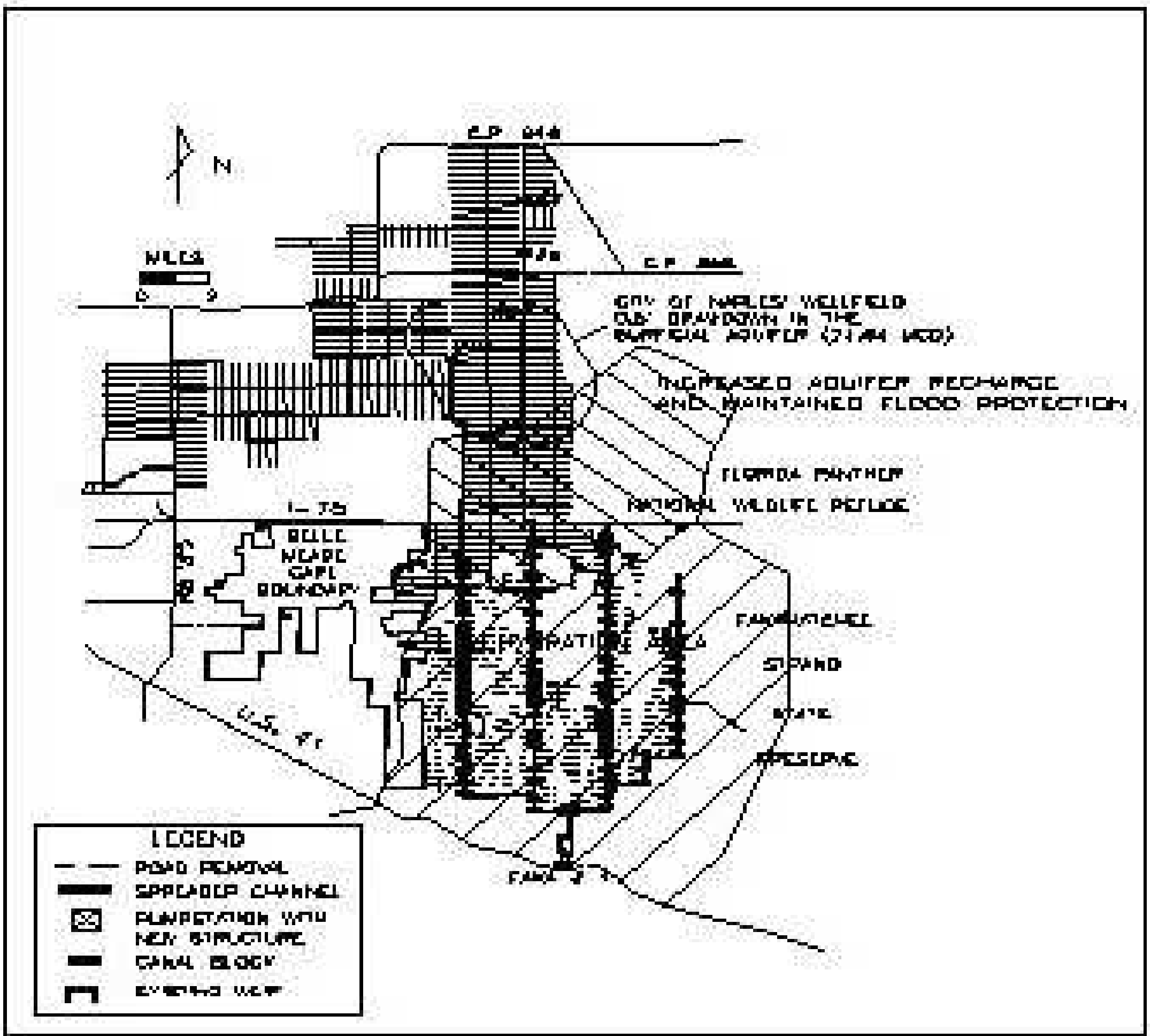


FIGURE 66. Area of Rehydration for Alternative 3C

occurs due to two factors. First the higher stages increase the rate of leakage from the spreaders and secondly they increase the extent of the I-75 ditch seepage zone (the area along the I-75 ditch that is affected by the spreader seepage).

The vertical percolation (that part of the leakage that does not become seepage to the I-75 ditch) plays a more important role as the distance increases. As the distance between the spreaders

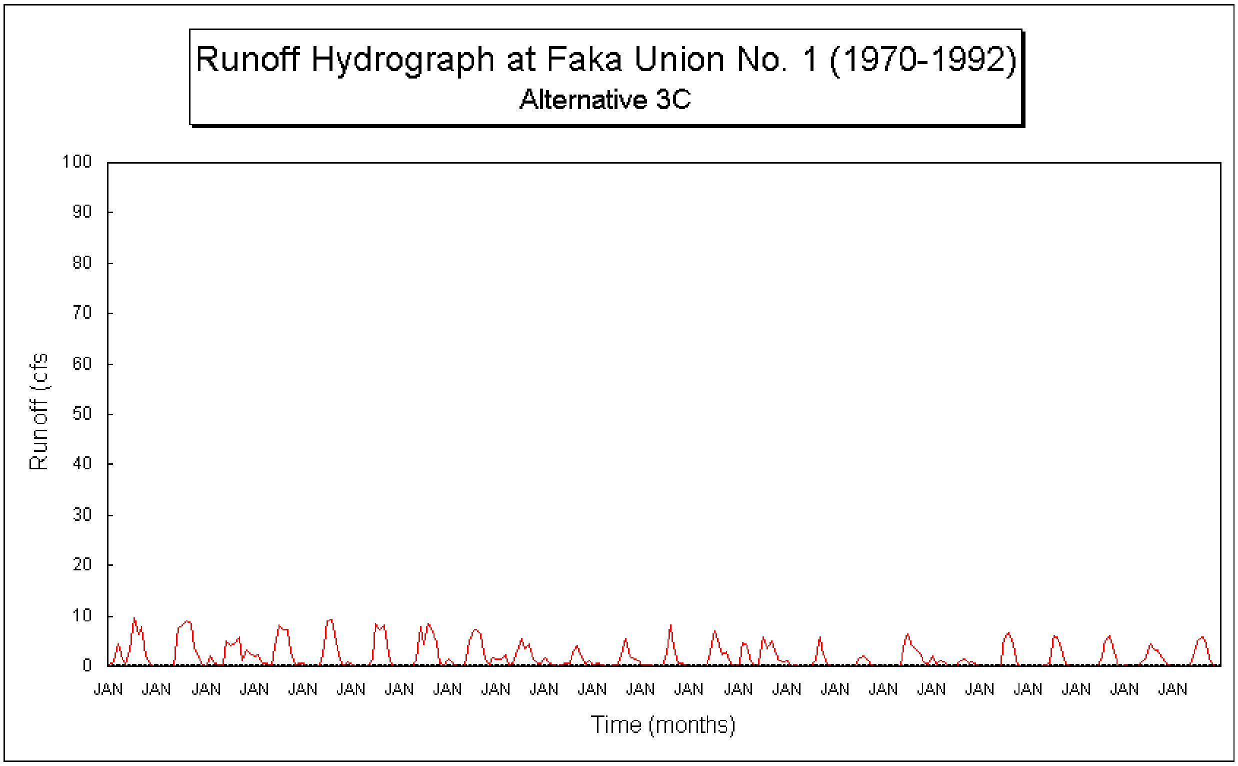


Figure 69

and I-75 increases, the seepage zone along the I-75 ditch increases, however, the seepage intensity decreases. The total seepage may increase or decrease depending on the combined effect of these two influences. The distance between the spreader channel and the I-75 ditch also affects the model assumptions which in turn affect the total seepage. When the separation distance is short in comparison with the lengths of the spreader channel and the ditch, the groundwater flow problem may be assumed as a two dimensional problem which results in a slightly higher total seepage volume than if analyzed as a three dimensional problem. With the three dimensional groundwater flow, the flow patterns are more spread out and a greater amount of leakage contributes to the Surficial Aquifer rather than seepage to I-75. Overall, seepage increases with higher stages, and shorter distances. The high hydraulic conductivities in this region and the presence of the Lower Tamiami Confining Unit will contribute seepage to the I-75 ditch. The groundwater analysis showed approximately 2 million gallons per day (MGD) of seepage from the spreader channels to the I-75 ditch in Alternative 3B. However, the total flow being pumped from NGGE to SGGE during a 10-year storm event is approximately 501 MGD. Therefore, the percentage of recycled water is less than one percent of the total flow. Even with the two dimensional flow analysis, where the spreader channel is within a mile of I-75, as in Alternative 3A, the percentage of recycled water is less than two percent (8 MGD). Practically, the manageable amount of seepage from the spreaders will be

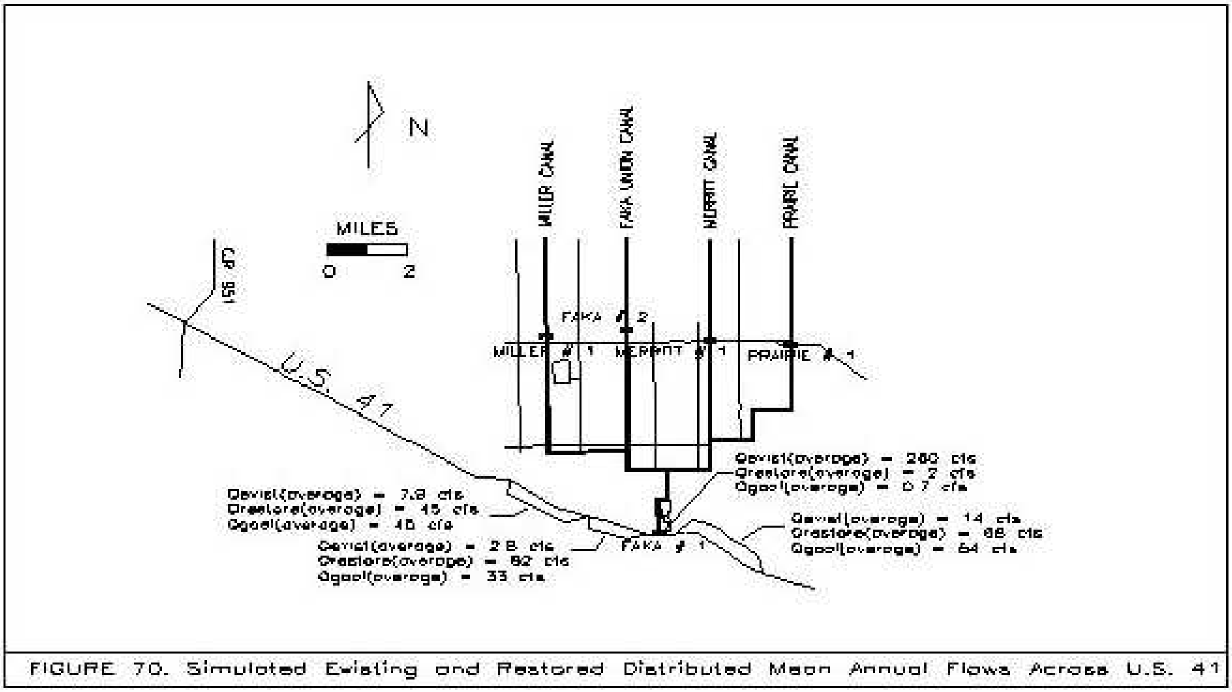


FIGURE 70. Simulated Existing and Restored Distributed Mean Annual Flows Across U.S. 41

intercepted by the I-75 ditch and the seepage collector ditch without rendering any adverse impact to I-75 and areas north of it.

4-3.8 Summary of Plan Evaluations

Alternatives 2 through 3C would achieve a restoration plan that rehydrates most of SGGE and increases aquifer recharge in part of NGGE. The City of Naples' wellfield would benefit from the increased aquifer recharge in all of the alternative plans except Alternative 1 especially if they were to expand their wells south of their existing ones. Alternative 2 provides full rehydration and restoration for the entire study area. Most of the area that is impacted by the SGGE restoration project is either under public ownership or within the boundaries of two CARL projects. However, a small area, as outlined previously, of privately owned land in eastern Belle Meade, not currently within the Belle Meade CARL project boundary, intercepts a prominent and well-defined flowway. Inclusion of this property within a CARL boundary would be the optimal solution from a water management perspective. If this is not feasible, other alternatives (such as flow easements, purchase of development right, etc.) should be considered to still ensure water storage, flow and water treatment as well as habitat values through these lands. Urban and recreational uses that require any drainage, however, are not recommended for these lands. It would be extremely difficult and expensive to establish and maintain a lower groundwater table necessary for residential development. This would also be in direct conflict with restoring natural hydrology and would nullify the restoration effort in this area.

Runoff will be reduced in Alternatives 2 through 3C because of the longer retention period of surface detention storage which allows for increased evaporation and groundwater recharge. The model simulation for Alternative 2 demonstrates the increase in evaporation from the soil storages due solely to an increase in the upper, lower and groundwater storage zones, while the model simulation of Alternative 3A through 3C illustrates the evaporation potential of an expansive wetland system that exists in SGGE. It is expected that runoff will be reduced up to approximately six inches as a result of the combination of these two factors in any alternative that restores sheetflows in SGGE. A total reduction in runoff of eight inches is required to achieve the pre-development criteria. The point load freshwater discharge from Faka Union Canal into the Faka Union Bay would be significantly reduced from an existing average annual flow of 260 cfs to 2 cfs in the large scale restoration plans. Alternative 2, with the complete elimination of the canal system, provides the maximum reduction of point flow. The Faka Union Bay, however, will receive increased distributed flow from surrounding coastal marshes that were cutoff from sufficient inflow by the canal system.

Generally, hydroperiods for north SGGE appear to be of sufficient duration and depth. Neither wetland nor upland hydroperiod regimes will be exceeded, that is, uplands won't be "flooded out." Analysis of hydroperiods of representative sections show the durations of inundation range from 0 to 300 days with maximum water depths of 14 inches. The higher water depths are confined to the deeper sloughs and some areas in SGGE would remain dry during an average rainfall year. Hydroperiods in northeast SGGE, including Picayune Strand, appear long in comparison with their depth. Larger growth cypress in the Picayune Strand area may require higher water depths. East of Faka Union Canal, the maximum water depths appear to be shallower than maximum water depths west of the Faka Union Canal. In the extreme south part of SGGE, maximum water depths are slightly low, however durations appear sufficient. Analysis of these results shows flows should be routed through historical flowways, especially Picayune Strand, and that road removal is critical to ensure water movement throughout SGGE. Flood conveyance through the SGGE sloughs is a significant constraint for design of the spreader channels and one must limit design flows to what the sloughs can convey at a reasonable stage. Based on the most current topographic and vegetation maps, historic hydroperiod criteria is not exceeded for the wetlands or uplands for any of the current scenarios and design flows except Alternative 3A.

The simulation of Alternative 2 is unique in that only the PERLND module was used for simulation. The routing of PLS outflows to downstream land segments resulted in an increase in soil and groundwater storages. This modeling strategy shows the change in soil moisture storages but does not provide an estimation of hydroperiods. Hydroperiods were simulated by analyzing the stages of the overbank flows for the canal segments in Alternatives 3A through 3C. It is expected that all alternatives that implement a hydrologic restoration will result in increased soil storages as modeled in Alternative 2 and hydroperiods similar to those predicted under Alternative 3. That is, all the alternatives, with the exception of Alternative 1, would provide for additional groundwater storage amounting to 25 billion gallons.

Alternative 1 is a partial restoration plan to take advantage of presently available public lands. Alternative 1 was intended as an interim plan and does not achieve all the objectives of the project. Alternative 2 is the ideal plan to restore the original hydrology of SGGE by filling all four canals and removing every single road. It meets the restoration goals most closely, however, with an estimated first cost of over 85 million dollars, this alternative is not economically feasible.

Alternatives 3A through 3C are very similar in their ability to meet the project's hydrologic restoration goals. Alternative 3A is the least costly of these three, however, it does not meet the uplands criteria. Alternatives 3B and 3C, of which 3C is the least cost alternative, closely meet all the objectives of the project.

A summary of the evaluated plans and their performance in meeting the predevelopment criteria is shown in Table 15. The pre-development criteria is defined as the estimated extent of the pre-development hydrologic conditions.

TABLE 15

EVALUATION SUMMARY

	PRE-DEVELOPMENT CRITERIA	1	2	3A	3B	3C
Area of Restoration in Study Area (mi2)	127	3	127	124	111	113
Reduction in Basin Runoff (in)	8	0	6	6	6	6
Average Yearly Runoff @ FU1(cfs)	0.7	130	0.7	2	2	2
Increase in Water Storage (in)	18 - 24	----	12.7	12.7	12.7	12.7
Phased Implementation	----	No	Yes (2)	Yes (2)	Yes (3)	Yes (3)
Estimated Hydroperiods - Days of Inundation	0-300	----	0-300	0-300	0-250	0-250
Estimated						

	PRE-DEVELOPMENT CRITERIA	1	2	3A	3B	3C
Hydroperiods - Maximum Depth of Inundation (inches)	0-30	----	0-14	0-10	0-14	0-14
Uplands Criteria (non-exceedance of hydroperiod)	----	Yes	Yes	No	Yes	Yes
First Cost ($)	----	172,693	82,474,942	9,584,672	12,595,698	11,652,769

4-3.9 Economic Benefits Evaluation

A quantitative economic benefit analysis under each alternative scenario to estimate the benefit to cost ratio was beyond the scope of this study. However, on the basis of qualitative assessment, the following prominent benefits of the project can be identified:

- The implementation of the SGGE restoration plan would improve the water quality of the coastal estuaries by converting the voluminous freshwater point discharges to the traditional overland sheetflow along a six-mile wide front into the Ten Thousand Islands Estuaries Aquatic Preserve, part of the western Everglades. The reintroduction of overland flow through coastal marshes would increase marsh and mangrove productivity, moderate salinity fluctuations, provide a desirable mix of fresh and saline water environment conducive to the survival and protection of juvenile fishes and shellfish beds, and would enhance the recreational and commercial fishery values of the region.
- Improved groundwater recharge will protect the City of Naples Eastern Golden Gate wellfield, provide for a long term water supply source and serve as a natural barrier to a saltwater intrusion.
- Adjacent sensitive lands, including the Fakahatchee Strand State Preserve and the Florida Panther National Wildlife Refuge, will benefit from this plan with enhanced habitat quality.
- With the implementation of the Picayune Stand State Forest, the overall recreational value of SGGE will be improved. The Division of Forestry's forestry management plan for the area will include specific sites for fishing, camping, hunting and general nature appreciation by the public. Hiking trails through representative plant communities is proposed. Much of

the open water area in the canals will remain. During the wet season, water levels will overtop the canal plugs causing the open stretches to merge and provide recreationally navigable waterways for airboats, canoes, etc.

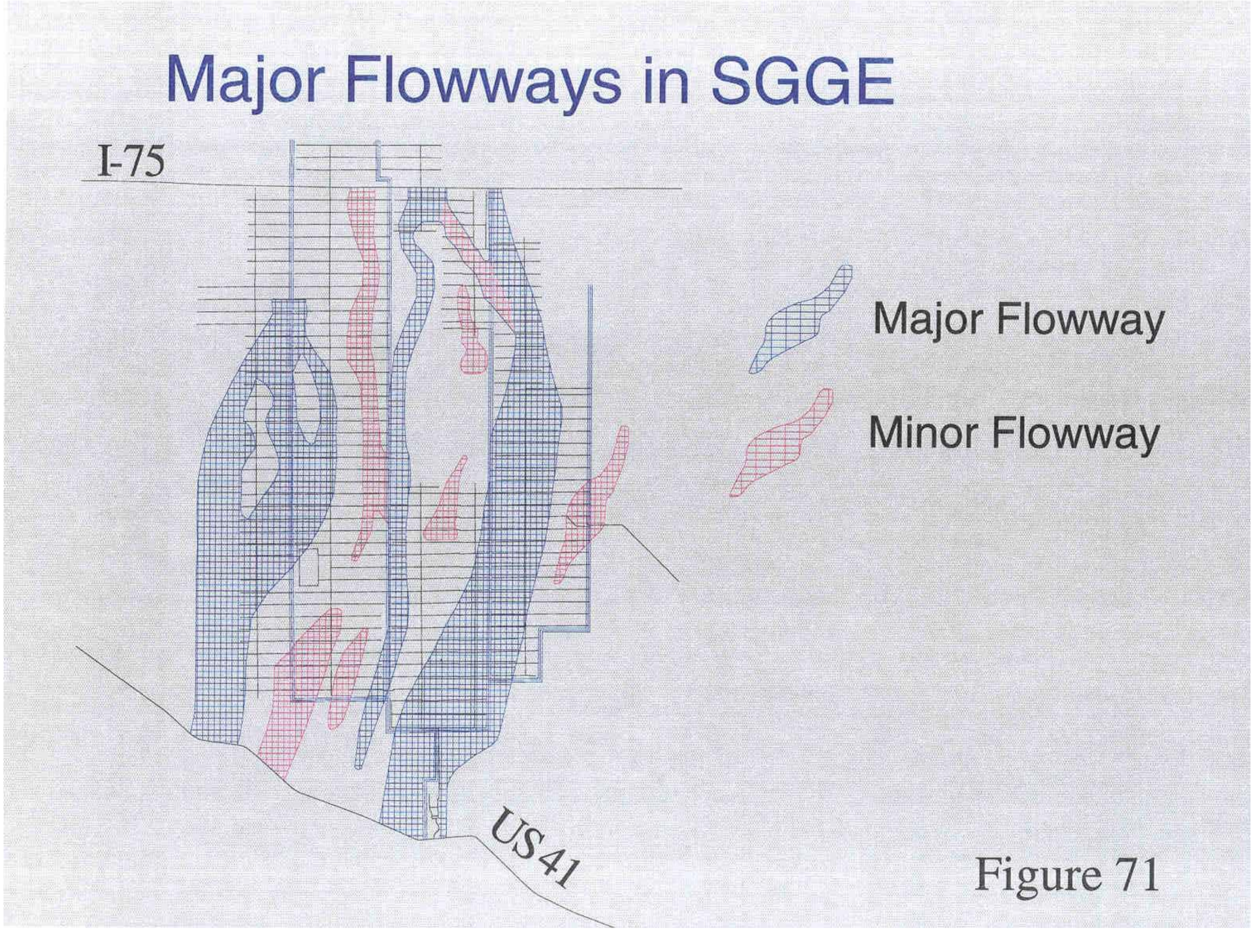
- The SGGE hydrologic restoration project provides an excellent opportunity to increase environmental awareness about the impacts of land development on the fringe of sensitive coastal wetlands.
- Continued maintenance of the existing level of service for flood control for northern Golden Gate Estates is a benefit of this plan.
- Elimination of canal maintenance south of the spreader channels as outlined in the restoration plans would produce savings for the Big Cypress Basin operation and maintenance program of approximately $593,000 annually. This is based on a direct proration of the 163 miles of canals in the 1996 budget. Additionally, the elimination of the need for repair and replacement of seven aging water control structures would result in annual savings of approximately $387,000 in 1995 dollars for the Big Cypress Basin capital improvement/replacement project fund.
- Tremendous costs associated with providing drainage to the urban development on a wetland environment of SGGE would be avoided.

The Big Cypress Swamp, of which SGGE is a part, is considered to have the best quality surface water in south Florida. It contains expansive areas of pristine wilderness and some of the most biologically diverse plant and animal communities on the North American continent. As a part of the “Save Our Everglades” program, the restoration of SGGE rests on the principles that our quality of life is inextricably linked to the health and viability of natural systems, and that both economy and the natural resources of south Florida depend on healthy natural systems, (Save Our Everglades Tenth Anniversary, Governor’s Office of Planning and Budgeting, 1993).

5. RECOMMENDED PLAN

On the basis of the above hydrologic-hydraulic, and economic evaluations, and assessment of impacts of five alternative restoration measures, the Alternative 3C plan involving construction of three pump stations, three spreader channels, 83 canal blocks and removal of selected segments of roads is recommended for implementation of the restoration of SGGE. Alternative 3C meets all of the hydrologic restoration objectives of the project at the least cost. Implementation of this alternative would accomplish the hydrologic restoration of SGGE by introducing sheetflow in SGGE, re-establishing the historical flowways (see Figure 71), reducing runoff by increased evaporation and groundwater recharge, and replacing point flow discharge through the Faka Union Canal with distributed flow along U.S. 41 into the tidal coastal marshes. In addition to implementing the structural/nonstructural elements of Alternative 3C, the following recommendations are included as part of the overall restoration plan for SGGE:

1. To accommodate the Florida Division of Forestry's (the management entity for the public lands in SGGE) needs for management of the area, including fire control, as well as to facilitate public access for recreational use of the area, Alternative 3C can be modified slightly to maintain a travel corridor through the project area. It is recommended this be accomplished by utilizing existing road beds combined with Low Water Crossings located at flowway crossings. A diagram showing the proposed route, which would connect Everglades Boulevard to Jane's Scenic Drive in the Fakahatchee Strand State Preserve, is shown in Figure 72. A drawing of a typical Low Water Crossing consolidated with limerock base in order to maintain the crossing for vehicular traffic is shown in Figure 73.



Major Flowways in SGGE

Figure 71

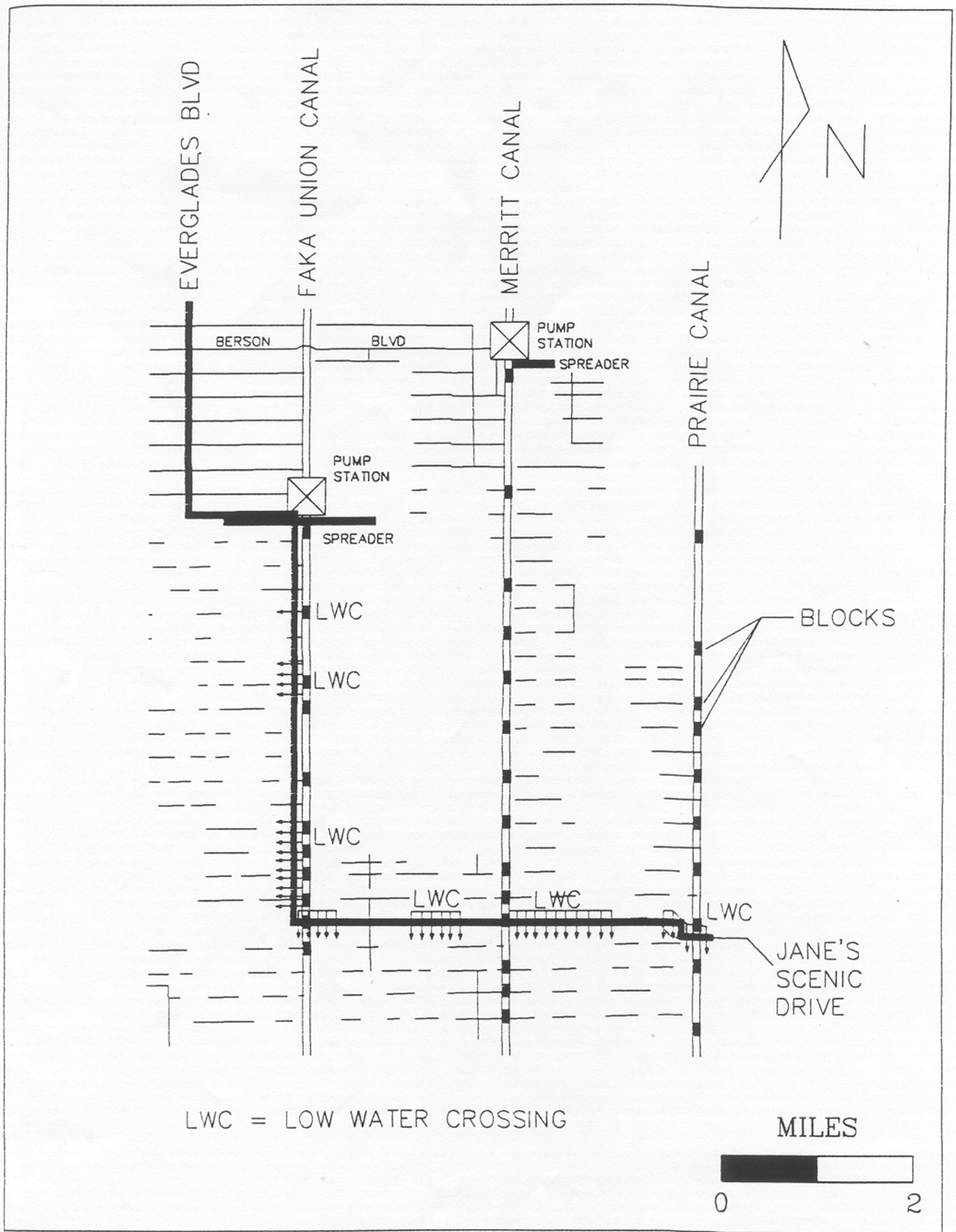
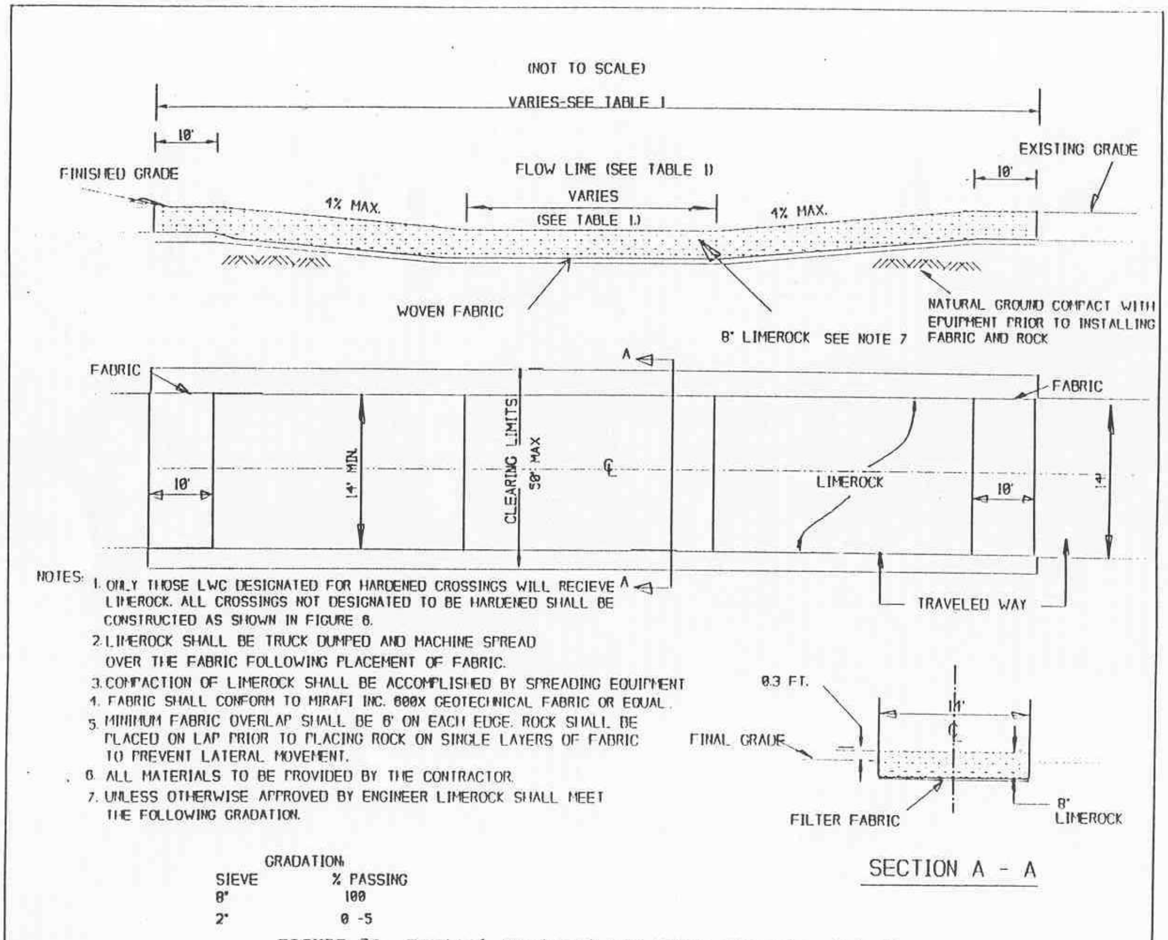


FIGURE 72. Proposed Travel Corridor Through SGGE



NOTES:
1. ONLY THOSE LWC DESIGNATED FOR HARDENED CROSSINGS WILL RECIEVE LIMEROCK. ALL CROSSINGS NOT DESIGNATED TO BE HARDENED SHALL BE CONSTRUCTED AS SHOWN IN FIGURE 6.
2. LIMEROCK SHALL BE TRUCK DUMPED AND MACHINE SPREAD OVER THE FABRIC FOLLOWING PLACEMENT OF FABRIC.
3. COMPACTION OF LIMEROCK SHALL BE ACCOMPLISHED BY SPREADING EQUIPMENT
4. FABRIC SHALL CONFORM TO MIRAFI INC. 600X GEOTECHNICAL FABRIC OR EQUAL.
5. MINIMUM FABRIC OVERLAP SHALL BE 6' ON EACH EDGE. ROCK SHALL BE PLACED ON LAP PRIOR TO PLACING ROCK ON SINGLE LAYERS OF FABRIC TO PREVENT LATERAL MOVEMENT.
6. ALL MATERIALS TO BE PROVIDED BY THE CONTRACTOR.
7. UNLESS OTHERWISE APPROVED BY ENGINEER LIMEROCK SHALL MEET THE FOLLOWING GRADATION.

GRADATION

SIEVE	% PASSING
8"	100
2"	0 -5

FIGURE 73. Typical Hardened Low Water Crossing Detail

2. Collection of additional streamflow data is recommended by the installation of surface water flow monitoring stations on the Miller, Faka Union and Merritt Canals at the three major inflow points into SGGE at I-75 as soon as possible. Abundant streamflow data improve the accuracy of flood flow estimation. Since flood protection for the Miller and Faka Union basins of NGGE will be provided by the pump stations, the sizing of the pumps, which are

based on flood flow predictions, is a key element of the plan.

3. Continuation and enhancement of the existing groundwater monitoring program should be an integral part of the SGGE restoration efforts for evaluating the effects of the overall restoration project.

4. Success criteria that outline short and long term measurable goals, both quantitatively and qualitatively, should be determined early in the project. Monitoring should start in the first phase of the restoration project and help identify if a goal is not being met.

5. The flowways in SGGE have an optimal water stage and corresponding conveyance capacity requirement with respect to the functioning of local flora and fauna. The design flows for the structural elements of this plan should be optimal so the stages in the flowways and associated hydroperiods do not exceed the historical criteria.

6. Restoration of wetlands, especially for a large upland-wetland ecosystem that exists in SGGE, is a complex process that involves maintaining adequate amounts of water during appropriate times of the year. In addition to the hydrologic and hydraulic considerations, other critical components entail soils and geomorphology, structural components, plant materials and design, monitoring and management. In order for the restoration effort to be successful, this task should be implemented using an interdisciplinary approach.

7. It is recommended that restoration should be implemented in a phased approach. This would allow for a more gradual ecological change of the area and allow for minor adjustments to be made throughout the project.

8. It is recommended that the issue related to the mitigation of impacts on an approximately

1.1 square mile area of land within the Belle Meade area be resolved so the restoration of SGGE can be implemented. This area is presently not included in either of the two CARL projects. From a water management perspective, the optimal solution is to include this area within a CARL project boundary.

9. It is recommended that the property that is owned by the Port of the Islands Development company may be surrounded by a perimeter dike and seepage collection ditch. This area neighbors the SGGE CARL project but is not within the project boundary. The dike and ditch will prevent sheetflow from entering this area. Proper drainage design for development within this property will still be required.

6. PLAN IMPLEMENTATION

6-1. PHASED RESTORATION

Phased implementation of the restoration would be financially and ecologically advantageous. Although the project would be separated into phases, each phase would involve most of the major “elements” of the plan, that is, pump stations, spreaders, plugs, road removal, etc. The identification of the phases is based primarily on the connectivity of the canals and their contributing subbasins. The Merritt and Prairie Canals are obvious first phase choices because they do not connect to NGGE canals and are fairly isolated. Miller and Faka Union Canals are not isolated canals as they extend into NGGE. Phased restoration will allow for minor midcourse correction in the rehydration plan if a certain restoration goal is not being met.

6-2. MANAGEMENT PLAN

The Florida Division of Forestry (FDOF) is responsible for managing the public lands within SGGE which is being designated as the Picayune Strand State Forest. The implementation of the SGGE hydrologic restoration plan will enhance the quality of the flora and fauna of the state forest. The FDOF is currently developing a management plan for the State Forest which will include recreational uses such as fishing, camping, general nature appreciation and possibly hunting. The management plan emphasizes conservation, nature appreciation and recreational use consistent with this diverse and inter-connecting ecosystem and natural resource. Recreational use of publicly acquired lands is an important objective of the CARL program.

7. CONCLUSIONS

The previous studies by the Army COE and others on the feasibility of modifying the existing water management features of the Faka Union Canal drainage basin for restoring the hydrology and ecology of the area were based on hydrologic-hydraulic analysis with event-based models. This study used a state-of-the-art methodology to simulate the continuous process hydrology of SGGE for a 23-year period and to predict the behavior of the water table and its effect on soil storage and surface water flow under five alternative scenarios. Although certain refinements are under study to better simulate south Florida hydrology, this model represents present state of the art technology for continuous process watershed modeling.

<u>The basic premise of development of this plan rests on the assumption that the entire extent of the SGGE lands as identified in the State of Florida's CARL acquisition program will be under public ownership of the State.</u> This study is, therefore, unique in that a hydrologic restoration plan is developed for all of SGGE.

Concurrently, development of a regional watershed management plan for Western Collier County has been undertaken by the Big Cypress Basin. This planning process is conducting a comprehensive evaluation of the surface water flow characteristics of Western Collier County as a singular watershed component for developing improved water management strategies for the region. One of the primary objectives of that plan is to enhance natural system functions and values on conservation lands. Some modifications of the elements of the SGGE restoration plan may be required in incorporating to the respective elements of the regional plan so as to achieve homogenous natural system values for the adjoining publicly owned conservation lands.

The hydrologic restoration plan formulated with this study is capable of achieving the objectives of the project. Restoration of the hydrology of SGGE is of vital importance in protecting the future water supplies and environmental resources of Collier County and southwest Florida. After nearly two decades of efforts by many organizations and individuals, this plan coupled with the land acquisition efforts of the CARL Program sets the stage for an implementable hydrologic restoration program for SGGE. It is recommended that the Big Cypress Basin Board continue its support of CARL acquisition efforts undertaken by the State of Florida so that practical restoration efforts can be implemented soon.

REFERENCES

AQUA TERRA Consultants et al, August 1994. Technical and Cost Proposal in Response to RFP No. C-5365 HSPF Modifications for Southern Florida Hydrology. Mountain View, California.

Bennett, Michael W., April 1992. Technical Publication 92-04, A Three-dimensional Finite Difference Groundwater Flow Model of Western Collier County, Florida. Hydrogeology Division. Department of Research and Evaluation. South Florida Water Management District. West Palm Beach, Florida.

Black, Crow and Eidsness, Inc., October 1974. Hydrologic Study of the G.A.C. Canal Network. Gainesville, Florida. Project No. 449-73-53.

Black, Crow and Eidsness, Inc. and CH2M Hill, April 1977. Hydrologic Investigations (An Engineering Report). Project No. 305-74-50. Gainsville, Florida.

CH2M Hill, July 1980. East Golden Gate Well Field Pumping Test Analysis for the City of Naples, Florida. Project No. NA30506.90. Gainesville, Florida.

--------, November 1978. Proposed Interim Modifications Golden Gate Estates Canal System. Project No. NA44900.75. Naples, Florida.

Connell, Metcalf & Eddy, August 1978. Hydraulic Study of the Lower Golden Gates Estates Drainage Canal Network in Collier County, Florida. Project No. 7046.00. Coral Gables, Florida.

Crawford, Norman A. Hydrocomp, Inc., Redwood City, California -- Personal communication, 1994.

Donigian, Anthony S. et al, June 1984. Application Guide for Hydrological Simulation Program-Fortran (HSPF). Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, Georgia, p. 77, 84, 93

Duever, Michael J. Et al, 1986. The Big Cypress National Preserve. National Audubon Society, New York, New York.

Environmental Science and Engineering, Inc., February 1979. Golden Gate Estates Groundwater and Septic Tank Investigation, Collier County, Florida. Project No. 78503. Gainsville, Florida.

Golden Gate Estates Study Committee, 1977. Golden Gate Estates Redevelopment Study, Collier County, Florida.

Gore, Dr. Robert, January 31, 1990. Fire, Rain Plus Man, The Express, Naples, Florida.

Hicks, Caroline N., 1985. Continuous Simulation of Surface and Subsurface Flows in Cypress Creek Basin, Florida, Using Hydrological Simulation Program-Fortran (HSPF). Pub. No. 86, University of Florida Water Resource Research Center, Gainsville, Florida, p. 141
Duever, Michael J. et al, 1986. The Big Cypress National Preserve. Research Report No. 8 of the National Audubon Society, New York, New York.

Kenner, W.E., 1966. Runoff in Florida. Map Series No.22, U.S. Geological Survey.

Maloney, Frank E., 1979. Legal Ramifications of Implementation of the Interim Action Program in Golden Gate Estates, Collier County, Florida.

--------, June 1975. Report on Water Resources Problems of Western Collier County, Florida As Affected by the GAC Corporation's Canal System in its Golden Gate Development Project. University of Florida, Gainsville, Florida.

Nath, Ananta K., Abbott, Gail C. And Gadipudi, Rao, 1995. Evaluation of Wetland Restoration Measures by Continuous Simulation in Proceedings of the International Conference on Water Resources Engineering, San Antonio, Texas.

Nelson, Jennifer and Tony Venditti, 1992. The Restoration of Golden Gates Estates. Prepared for Dr. Berrin Tassel, Florida International University, Miami, Florida.

Stanley W. Hole & Associates, June 1977. Report on Acceptance and Flooding Golden Gate Estates. Naples, Florida.

Swayze, L. J. and B. F. McPherson, 1977. The Effect of the Faka Union Canal System on Water Levels in the Fakahatchee Strand, Collier County, Florida. Water Resources Investigation 77-61, USGS, U. S. Government Printing Office, 19 pp.

U.S. Army Corps of Engineers, Jacksonville District, 1986. Golden Gate Estates, Collier County, Florida Feasibility Report.

--------, 1980. Reconnaissance Report, Golden Gate Estates. Jacksonville, Florida.

Wang, Flora C., 1977. "Impacts of Drainage Canals on Surface and Subsurface Hydrology of Adjacent Areas in South Florida." In Cypress Wetlands for Water Management, Recycling and Conservation, 4th Annual Report.

Wang, Flora C. and Allen R. Overman, 1981. "Impacts of Surface Drainage on Ground Water

Hydraulics." Paper No. 80163 of the Water Resources Bulletin.

Wang, John D. and Joan Browder. "Canal Discharge Impacts on Faka Union Bay." In Hydraulics and Hydrology in the Small Computer Age, Vol. 1, Ed. Waldrop, W.R. American Society of Civil Engineers, New York, New York, 10017-2398, pp. 141-146.

APPENDIX A

LIST OF HSPF ACRONYMS

AGWETP	fraction of ET from active groundwater storage
AGWO	active groundwater outflow
AGWRC	daily recession constant of groundwater flow if KVARY or GWVS = 0 the ratio of current groundwater discharge to groundwater 24 hours earlier
AGWS	active groundwater storage at the start of the simulation
ANNIE	program by USGS, more interactive and efficient system of time data mgmt
ARM	Agricultural Runoff Model
BASETP	fraction of ET from active groundwater outflow
CEPSC	interception storage capacity (in)
CEPS	interception storage at the start of the simulation
DBHYDRO	SFWMD hydrologic database
DEEPFR	fraction of groundwater lost to deep aquifer
DELT 60	hr/interval
ET	Evapotranspiration
FOREST	fraction of winter forest transpiration
FTABLE	function table for 6 modules of RCHRES
GWVS	index to groundwater slope at the start of the simulation
HSPF	Hydrologic Simulation Program-Fortran. Developed for EPA to simulate watershed hydrology and water quality
HYDR	hydraulic behavior simulation
IMPLND	Impervious Land Module
INFEXP	exponent in infiltration equation
INTFLW	interflow inflow parameter
IFWS	interflow storage (in)
INFILD	ratio of max/min infiltration rate
INFILT	index to infiltration capacity
INTFW	interflow inflow parameter
IRC	interflow recession rate (1/day)
KGW	groundwater outflow recession parameter, per interval
KVARY	parameter which can make groundwater storage to outflow relation nonlinear in per inches
LSUR	length of overland flow plane in feet
LZETP	lower zone evapotranspiration parameter
LZS	lower zone soil storage at the start of the simulation
LZSN	lower zone soil storage in inches
NETWORK	network block of HSPF program
NPS	non-point source
NSUR	Manning's n for overland flow
PERLND	pervious land module

PETMAX	air temperature which signals a change in ET calculation only used if snow is considered
PETMIN	air temperature which signals a change in ET calculation only used if snow is considered
PLS	pervious land segment
PWATER	Pervious Land-Water Budget Simulation
RCHRES	Reach-Reservoir
RFAVGM	Program that averages daily rainfall at selected stations
RO	Runoff
SLSUR	slope of Overland Flow Plane
SUPY	Water Supply
SURS	surface storage at the start of the simulation (in)
TAET	total simulated evapotranspiration
UZS	upper zone soil storage at the start of the simulation
UZSN	upper zone nominal soil storage (in)
WDM	Watershed Data Management, program ANNIE file

APPENDIX B

APPENDIX C

HSPF data input files are available on disk at the Big Cypress Basin office, 6167 Jane’s Lane, Naples, Florida 33942.