SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Peer Review Panel Draft Report:

DRAFT

Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream Estuaries

June 9, 2008

Executive Summary

The purpose of this document is to summarize the technical information contained in the Picayune Strand Restoration project implementation report and other sources of information to establish clear relationships among freshwater flows discharged from the watershed and inland and estuarine ecologic responses. Expected improvements include reversion to historic wetland plant and animal communities, reestablishment of sheet flow towards coastal estuaries, reduction of harmful surge flows through the Faka Union Canal into Faka Union Bay, improved habitat for fish and wildlife including threatened and endangered species.

The South Florida Water Management District (SFWMD) intends to use this information as the basis for quantifying water for the protection of fish and wildlife. Water for protection of fish and wildlife means water for ensuring a healthy and sustainable native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood and population variation. The fish and wildlife for which a water reservation may be set are native communities of fish and wildlife that use the habitat in its healthy state.

The Water Resources Development Act of 2000 requires the reservation or allocation of water needed to meet the goals and objectives of CERP projects. A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. Under Florida law, Section 373.223(4), FAC, the reservation is composed of a quantification of the water to be protected, which includes a seasonal and a location component. The water quantified for protection of fish and wildlife will be reserved by rule. As part of the rule development process, an independent expert panel will review the information contained in this report, the project implementation report, and other documents and will make an assessment of whether current best available information supports the proposed correlation between hydrology and the protection of fish and wildlife.

Implementation of the Picayune Strand Restoration project will result in the retention of water on and subsequent redistribution of water from the project area. Much of the water retained on project lands will reestablish historic wetland values and is beneficial to the natural system. This water made available by the project is necessary to improve the ecological functions of Picayune Strand. To analyze project effects on water retained within the project boundary and adjacent areas that benefit hydrologically by the project, targets for the volumes of water retained on the natural areas under pre-drainage and with-project conditions were calculated. The target for Picayune Strand is the pre-drainage condition.

Based on an analysis of the information presented in this document, while the project will improve the hydrology within the terrestrial portions of the Picayune Strand, the water needed for the protection of fish and wildlife will not be fully realized. As a result, all the water entering the project from the three canals located at the northern boundary of the project (Merritt, Miller and Faka Union) are considered necessary for protection of fish and wildlife. The project is effective in redistributing the flows across the southern estuary while reducing the existing harmful excessive flows into Faka Union Bay. The analysis shows that during wet conditions the project will discharge water above what is considered to be necessary for the protection of estuary fish and wildlife. However, during average and dry conditions, all of the discharges are less than or equal to the natural system targets for protection of fish and wildlife. At some point in the future, the reservation will be reviewed and revised if needed in light of changed conditions as required by Florida Statutes Section 373.223(4).

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Section 1. Introduction

1.1 Purpose and Scope of this Document

The purpose of this document is to summarize the available technical information contained within the Picayune Strand Restoration Final Integrated Project Implementation Report and Environmental Impact Statement (USACE and SFWMD 2004), referred to as the project implementation report, and other specific, related sources of information used to establish relationships among 1) overland freshwater flows and the ecological response of terrestrial wetlands and 2) freshwater flows discharged from the watershed and estuarine ecologic response. The South Florida Water Management District (SFWMD) intends to use this information as the basis for quantifying water for the protection of fish and wildlife.

This document highlights key pieces of technical information contained in the project implementation report used by SFWMD staff to establish the relationship between the inland and estuarine hydrology and its associated effects on fish and wildlife. The information contained in this document provides brief descriptions of 1) pre-drainage and existing hydrological and ecological conditions within the watershed and 2) ecological attributes of the system and their associated hydrologic performance measures. It also includes a summary of simulated hydrologic conditions within the project area and outflows to the downstream estuaries for 1) pre-drainage condition and 2) the existing condition (2000) with the project features implemented (with-project). Finally, it quantifies the water to be reserved under state law.

It is the intent of the SFWMD to use the technical relationships and evaluations identified in this document and the project implementation report as the basis of a water reservation rule. An independent expert panel will review the information contained in this report and related documents and will make an assessment of whether best currently available technical information supports the relationship between the waters anticipated to result from the completed project and the anticipated fish and wildlife response.

The SFWMD is undertaking the reservation of water for Picayune Strand Restoration as a result of commitments made for Comprehensive Everglades Restoration Plan (CERP) implementation in Section 601(h) of the Water Resource Development Act of 2000 (WRDA 2000), in Sections 385.26-27 of the Programmatic Regulations for Implementation of the Comprehensive Everglades Restoration Plan (DOD 2003), and for the purpose of ensuring that each CERP project meets its intended benefits for the natural system. These provisions require the identification of water for the natural system including water to be reserved or allocated. This identification includes water available to the natural system prior to project implementation (water that the state has agreed to protect but is not mandated to protect by Section 601(h) of WRDA 2000) and water made available for the natural system as a result of the project (water that is required to be protected by Section 601(h) of WRDA 2000). The SFWMD has elected to use its reservation authority (Section 373.223(4), FAC) to protect both water available to the natural system prior to project implementation and water made available by the project and will undertake this protection in a single rulemaking process.

Source materials, the majority of which were taken from the project implementation report, are provided here. The reader is encouraged to review the source documents for additional details. The documents are as follows:

- Picayune Strand Restoration Final Integrated Project Implementation Report and Environmental Impact Statement (USACE and SFWMD 2004) www.evergladesplan.org/pm/projects/docs_30_sgge_pir_final.aspx
- Picayune Strand Restoration Project Baseline Report (Chuirazzi and Duever 2008): my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_SFER/PORTLET_SFER/TAB2236041/VOLUME1/appendices/v1_app_7a-2.pdf
- Big Cypress Basin Integrated Hydrologic-Hydraulic Model documentation (DHI 2002): my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_REGIONALSERV/PORTLET_BCBPROJECTS/FINALREP/PDF/TABLE_CONTENTS.PDF
- Operation Schedule of Water Control Structures (SFWMD 2007): my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_REGIONALSERV/PORTLET_BCBPROJECTS/STRUCTURE_OP_PAMPLET_BCB_2007_COLOR.DOC
- Hydrologic Restoration of Southern Golden Gate Estates – Conceptual Plan (SFWMD 1996): my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_REGIONALSERV/PORTLET_BCBPROJECTS/SGGEREPORT.PDF
- A Conceptual Model of Ecological Interactions in the Mangrove Estuaries of the Florida Everglades (Davis et al. 2005): www.evergladesplan.org/pm/recover/recover_docs/cems/cem_eg_mangrove.pdf
- Big Cypress Regional Ecosystem Conceptual Ecological Model (Duever 2005: www.evergladesplan.org/pm/recover/recover_docs/cems/cem_big_cypress.pdf
- Total System Conceptual Ecological Model (Ogden et al. 2005a): www.evergladesplan.org/pm/recover/recover_docs/cems/cem_total_system.pdf
- Use of Conceptual Ecological Models to Guide Ecosystem Restoration in South Florida (Ogden et al. 2005b): www.evergladesplan.org/pm/recover/recover_docs/cems/cem_use_of_cems.pdf
- Lower West Coast Water Supply Plan 2005-2006 Update (SFWMD 2006): my.sfwmd.gov/portal/page?_pageid=1874,4166896,1874_4166893:1874_4165845&_dad=portal&_schema=PORTAL
- Preliminary Assessment of the Groundwater Resources of Western Collier County (SFWMD 1986): my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_TECH_PUBS/PORTLET_TECH_PUBS/DRE-220.PDF
- Coastal Environmental Impacts Brought About by Alteration to Freshwater Flow in the Gulf of Mexico (Sklar and Browder 1998): available on web board.
- Picayune Strand Restoration Project: Faka Union/Miller Pump Stations-Levees, Canals and Roads Technical Review Briefing presentation (NOVA Consulting, Inc. 2008): available on web board.
- Assessment of Salinities and Bio-Abundances Resulting from Runoff into Faka Union Bay for CERP Scenarios (Wang and Browder 2008): available on web board.

- Analysis of Freshwater Discharge at Faka Union Bay and Rainfall at Immokalee Time Series in the Period 1985-2002 (Garcia and Wang DATE): available on web board.
- Biological Models (Browder DATE?): available on web board.

1.2 Document Structure

This document is organized into 9 main sections. This section described the purpose and scope of this document. The basis for determining the water reservation and the approach used are provided in Section 2. Section 3 defines the project area and describes the project. Section 4 describes the pre-drainage and existing system. Section 5 identifies the valued ecosystem components within the ecosystem along with their hydrologic requirements. Section 6 presents the hydrologic performance measures and their linkage to the valued ecosystem components. Section 7 describes the model used to define pre-drainage (target) and with-project hydrologic conditions. Section 8 presents the modeling results and summarizes the portion of existing and with-project water to be reserved for protection of fish and wildlife. Section 9 contains references cited within this report.

Section 2. Basis for Water Reservation and Approach

2.1 What is a Water Reservation?

A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or the public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, which includes a seasonal and a location component. For purposes of this report, the SFWMD will be adopting a water reservation for the protection of fish and wildlife for the Picayune Strand and its downstream estuaries by rule. The technical information and recommendations in this document serve as the basis for the quantification of water for the protection of fish and wildlife that will be adopted through the rulemaking process.

The SFWMD has committed to protect the quantities of water necessary for each CERP project to meet its objectives. For this project, this quantity of water is identified in Section 12 of the project implementation report. Section 601(h)(4) of WRDA 2000 requires the state to reserve or allocate the water made available from a CERP project using the authority granted to the State of Florida under Chapter 373 F.S. before a project cooperation agreement with the US Army Corps of Engineers to construct the project can be executed. In addition, the SFWMD has agreed to use its water reservation or allocation authority to protect existing water for the natural system that is needed for each CERP project. The SFWMD has the ability to use either water reservation or other allocation tools to protect the water identified in the Picayune Strand Restoration project implementation report (USACE and SFWMD 2004). The SFWMD has determined that utilization of a water reservation is the most appropriate tool for protecting water identified for the natural system for this project. A more detailed discussion of the federal authorities applicable to CERP projects can be found in Section 12 of the project implementation report.

2.2 State Authority for Establishing Water Reservations

The state law on water reservations, in F.S. Section 373.223(4), provides for the following:

> *The governing board or the department, by regulation, may reserve from use by permit applicants, water in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review and revision in the light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.*

When water is reserved under this statute, it is not available to be allocated for use under a consumptive use permit and is protected for the natural system. For purposes of this document, water for protection of fish and wildlife means water for "ensuring a healthy and sustainable, native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood and population variation." (Assoc. of Florida Cmty. Developers, et al. v. Dep't of Envtl. Prot., et al., DOAH Case No. 04-0880RP, (Div. of Admin. Hrgs Final Order Feb. 24, 2006). The fish and wildlife for which a water reservation may be set are existing native communities of fish and wildlife that use the habitat in its healthy state.

In quantifying water to be reserved, existing legal uses of water are protected so long as they are not contrary to the public interest. An existing legal use is a water use that is authorized under a SFWMD or Florida Department of Environmental Protection (FDEP) consumptive use permit under Part II of Chapter 373, F.S, or is exempt from consumptive use permit requirements under Chapter 373, F.S or SFWMD or FDEP rules.

The FDEP Rule 62-40.474 regarding water reservations provides for the following:

> *62-40.474 Reservations.*
>
> *(1) The governing board or the department, by rule, may reserve water from use by permit applicants, pursuant to section 373.223(4), F.S., in such locations and quantities, and for such seasons of the year, as in its judgment may be required for the protection of fish and wildlife or the public health and safety. Such reservations shall be subject to periodic review at least every five years, and revised if necessary in light of changed conditions. However, all presently existing legal uses of water shall be protected so long as such use is not contrary to the public interest.*
>
> *(a) Reservations may be used for the protection of fish and wildlife to:*
>
> *1. Aid in a recovery or prevention strategy for a water resource with an established minimum flow or level;*
>
> *2. Aid in the restoration of natural systems which provide fish and wildlife habitat;*
>
> *3. Protect flows or levels that support fish and wildlife before harm occurs;*
>
> *4. Protect fish and wildlife within an Outstanding Florida Water, an Aquatic Preserve, a state park, or other publicly owned conservation land with significant ecological value; or*
>
> *5. Prevent withdrawals in any other circumstance required to protect fish and wildlife.*
>
> *(b) Reservations may be used for the protection of public health and safety to:*
>
> *1. Prevent sinkhole formation;*
>
> *2. Prevent or decrease saltwater intrusion;*
>
> *3. Prevent the movement or withdrawal of groundwater pollutants; or*
>
> *4. Prevent withdrawals in any other circumstance required to protect public health and safety.*

> *(2) Reservations shall, to the extent practical, clearly describe the location, quantity, timing, and distribution of the water reserved.*
>
> *(3) Reservations can be adopted prospectively for water quantities anticipated to be made available. When water is reserved prospectively, the reservation rule shall state when the quantities are anticipated to become available and how the reserved quantities will be adjusted if the actual water made available is different than the quantity anticipated.*
>
> *(4) The District* [SFWMD] *shall conduct an independent scientific peer review of all scientific or technical data, methodologies, and models, including all scientific and technical assumptions employed in each model, used to establish a reservation if the District determines such a review is needed. As part of its determination of the necessity of conducting a peer review, the District shall consider whether a substantially affected person has requested such a review.*

These regulations provide programmatic guidance to the SFWMD in developing the water reservation rule for which this technical document serves as the basis.

2.3 Process Steps and Activities

This document has been created in support of the Florida Statutes Chapter 120 and Sections 373.044 and 373.113 rule development authorities. Figure 5 summarizes the general steps that occur during the rule development process. The first step has been accomplished. The SFWMD Governing Board authorized publication of a notice of rule development of a reservation for the water for the natural system identified for the Picayune Strand Restoration project in February 2008.

This document fulfills the second step in Figure 1. The SFWMD has made the determination to have this document, which contains the technical underpinnings used to identify the water needed for the protection of fish and wildlife, peer reviewed by an independent scientific panel as part of the rule development process. As a result of this public process, the final peer review report may be used for revising or refining this document, as necessary.

A public rule development process for stakeholders and interested persons will be conducted to present findings of the peer review and provide the public opportunities to participate in the drafting of rule language, including specific language quantifying the volume, timing and distribution of water needed for the protection of fish and wildlife and provisions restricting consumptive use permit allocations. Once the draft rule language has been finalized and the technical document revised if needed, the SFWMD Governing Board will have the opportunity to authorize the notice of rulemaking, and subsequently hold a public hearing adopting the final rule.

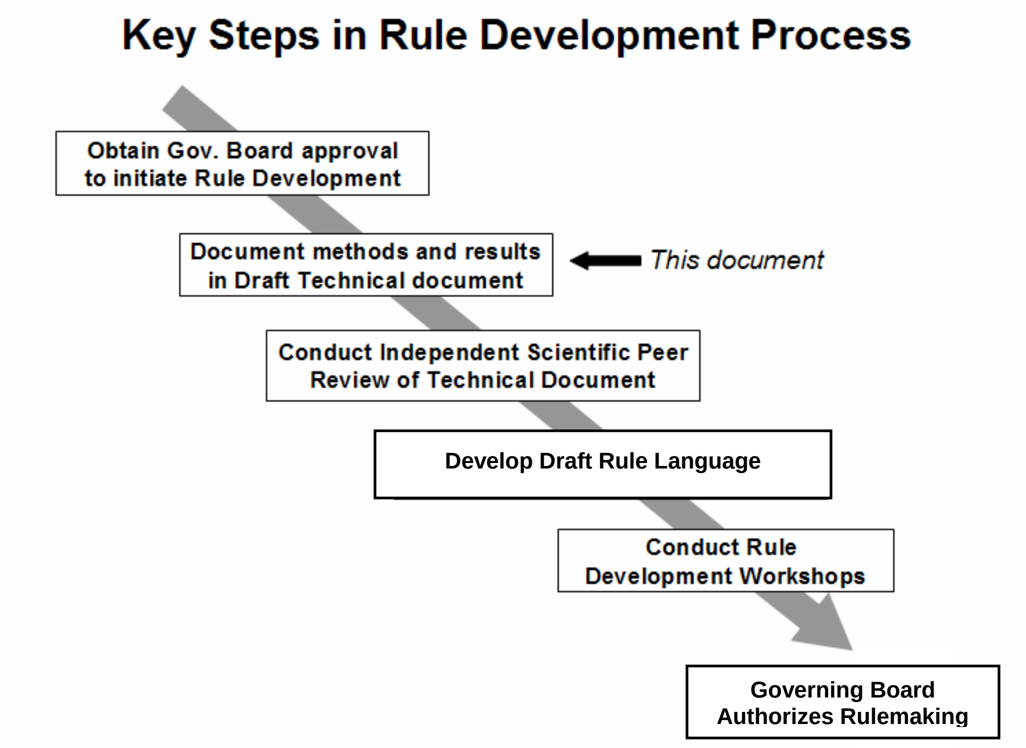


Figure 1. Process steps for developing technical information in support of a rule

2.4 Technical Approach

The technical approach applied by the SFWMD to quantify water needed for the protection of fish and wildlife within Picayune Strand was based on the Picayune Strand Restoration project implementation report (USACE and SFWMD 2004). Identification of water for inland freshwater wetlands and estuarine enhancement and protection is based on the premise that water contributing to meeting targets of hydrologic performance measures will ensure a healthy sustainable population of fish and wildlife that can remain healthy and viable through natural cycles of drought, flood and population variation, and can continue into the future as a healthy, sustainable population.

The approach is as follows:

- Identify the pre-drainage condition. This is the condition the Project is designed to achieve or its goal.
- Develop conceptual ecological models describing the natural system and anthropogenic effects upon the system, including stressors and attributes.
- Determine valued ecosystem components using the attributes from the conceptual ecological models as a basis.
- Develop performance measures and targets to evaluate how simulated hydrology affects valued ecosystem components.
- Re-aggregate the same model simulations and results used for the project implementation report to identify the quantity and location of water necessary for the protection of fish and wildlife in the inland freshwater wetlands and downstream estuaries.

Section 3. Picayune Strand Restoration Project Area and Scope

3.1 Project Area

Picayune Strand Restoration is a CERP project that will rehydrate a failed 1960s subdivision, known as Southern Golden Gate Estates, by removing the infrastructure of roads and canals and restoring its pre-drainage hydrology. Picayune Strand is located in southwestern Collier County. It is surrounded by preserves and wildlife areas that will be linked and enhanced by the restored conditions within the project area, creating a combined natural area that will function as a single connected regional ecosystem (Figure 2). The regional ecosystem includes estuaries, freshwater wetlands and uplands.

3.2 Existing Features

The Southern Golden Gate Estates subdivision included almost 20,000 platted parcels with 279 miles of roads and 48 miles of drainage canals (Figure 3) (USACE and SFWMD 2004). The project involves rehydrating the 55,247-acre (about 94 square miles) subdivision by removing the infrastructure of roads and canals and restoring its pre-drainage hydrology. An extensive canal system was excavated to drain surface waters and provide fill for the road system. Roads are impeding overland sheetflow. Within the project area there have historically been four large drainage canals flowing from north to south. From west to east, they include the Miller, Faka Union, Merritt and Prairie Canals. The Prairie Canal is, at the time of writing of this document, partly plugged and the lands in the vicinity of that canal are progressively rehydrating. The Miller, Merritt and Prairie Canals merge with Faka Union Canal near the south end of the project area. The three remaining canals are trapezoidal in shape and have an average excavated depth of approximately 10 feet from the top of the bank to the bottom of the channel. The surface widths range from 45 feet to more than 200 feet. The canals have overdrained the area, resulting in the reduction of aquifer recharge, greatly increased freshwater point source discharges to receiving estuaries to the south, invasion by nuisance vegetation, loss of ecological connectivity and associated habitat, and increased frequency of forest fires.

3.3 Achievement of Project Objectives

The combination of improved hydrology, more natural fire regime, and appropriate exotic vegetation control can be expected to reestablish the major pre-drainage characteristics of Picayune Strand plant communities (USACE and SFWMD 2004). Expected improvements include reversion to historic plant and animal communities, reestablishment of sheet flow through Picayune Strand towards coastal estuaries, reduction of harmful surge flows through the Faka Union Canal into Faka Union Bay, improved freshwater overland flow and seepage into other bays of the Ten Thousand Islands region, improved aquifer recharge, decreased frequency and intensity of forest fires, improved habitat for fish and wildlife including threatened and endangered species, reductions in invasive native and exotic species, and increased spatial extent of wetlands.

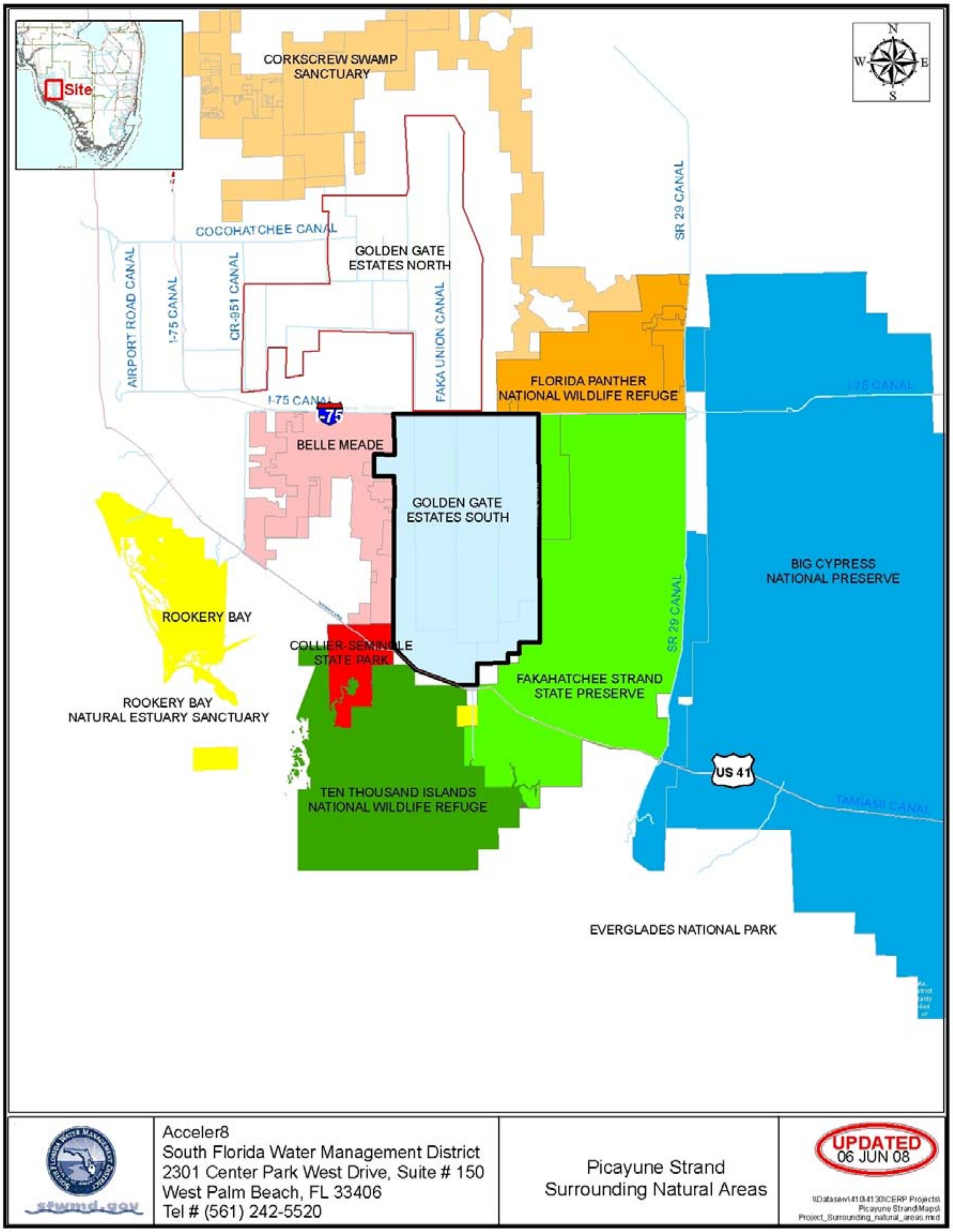


Figure 2. Picayune Strand Restoration project and surrounding area

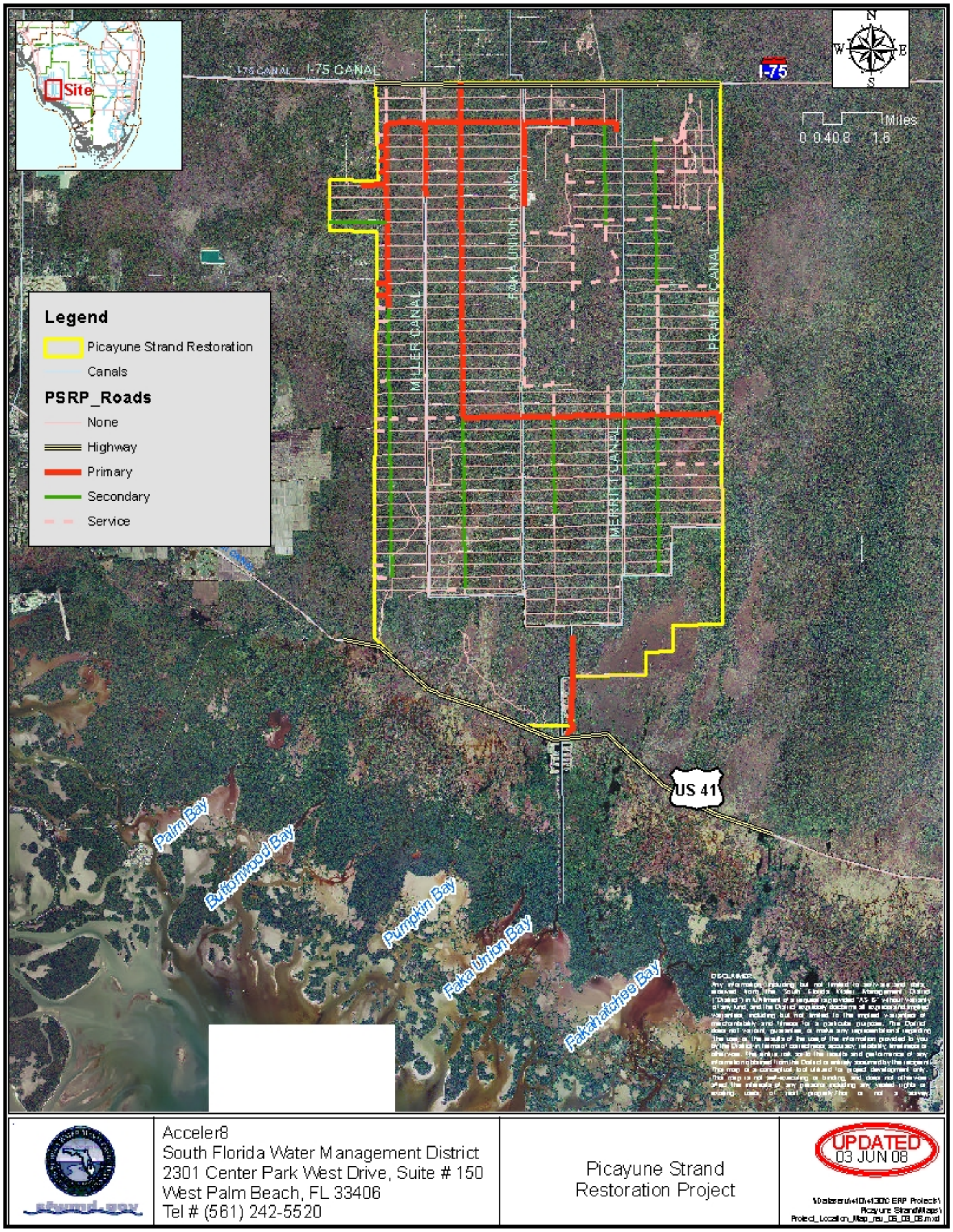


Figure 3. Southern Golden Gates Estates subdivision infrastructure and downstream estuaries

3.4 Project Features

Based on the project objectives and as described in the project implementation report (USACE and SFWMD 2004), the conceptual design of the hydrologic features of the area will be accomplished by removing 227 miles of roads, plugging 42 miles of canals, and installing three pump stations and spreader channels to reestablish overland sheet flow across the area (Figure 4). Canal plugs will be placed south of the pump stations in the Miller, Faka Union and Merritt Canals, and in the entire length of the Prairie Canal, preventing the canals from transporting water southward to the estuaries. Source material for canal plugs and swale blocks will be spoil from original canal and swale excavations, and demolition and degrading of the roads. Approximately 52 miles of existing road will remain. These roads will be modified with a mix of low water crossings to allow water to flow over them and with culverts to allow water to flow under them. Spreader channels will be located immediately downstream of the pump stations and will distribute flows below tieback levees to mimic historic sheet flow. However, in the northwest corner of the project, 17,720 acres will not receive flows so as to provide habitat for upland species. In addition to enhancing hydration, the project pump stations will provide flood protection for surrounding developed areas including Northern Golden Gates Estates by maintaining the same canal stages existing today, while levees will protect developments such as Port of the Islands. Additional culverts will be placed under U.S. 41 to allow water sheet flowing across the landscape to continue flowing southward to the estuaries of the Ten Thousand Island National Wildlife Refuge, improving timing and volume of freshwater flows to the estuaries of Palm, Blackwater, Buttonwood, Pumpkin, Faka Union and Fakahatchee Bays (Figure 3).

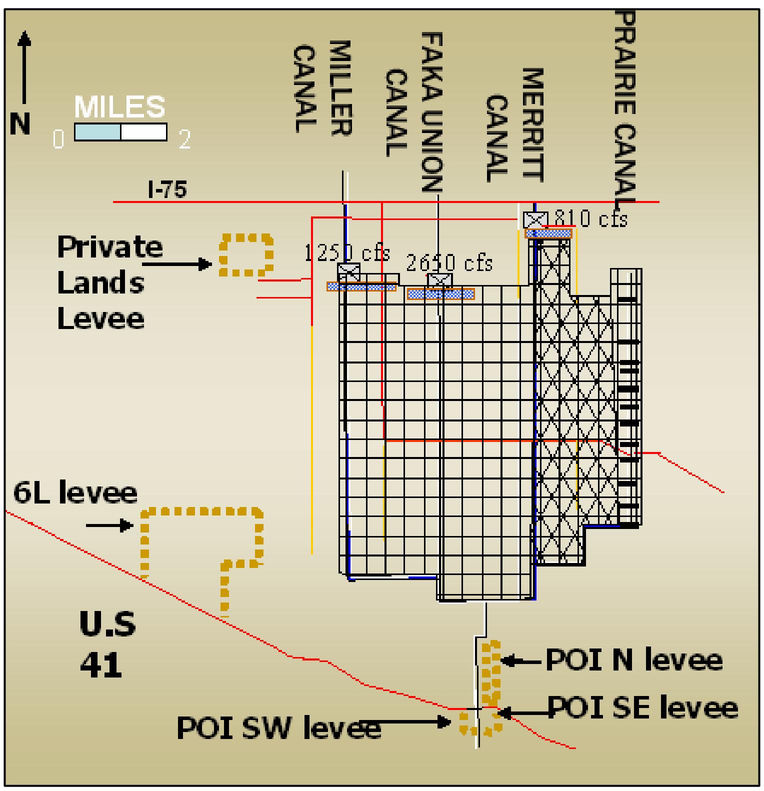


Figure 4. Construction features of Picayune Strand Restoration

3.4.1 Operational Strategy

The Miller, Faka Union and Merritt Canals will continue to convey water from Northern Golden Gate Estates to the project area. Under the project, three pump stations will be constructed along each of the canals to aid in delivery of existing flows from the north into the project area. The pump station capacities are 1,250 cfs for the Miller Canal, 2,650 cfs for the Faka Union Canal, and 810 cfs for Merritt Canal (SFWMD 2007). At the pump stations, the water will be pumped into spreader canals that will direct flows in an east-west direction. As the water spills over the spreader canal weirs, historic sheet flow within the project area will be restored. The pump stations, in conjunction with the spreader canals, tieback levee and proposed improvements to US Hwy 41, will be used to restore the former wetlands to the south while maintaining flood protection to Northern Golden Gate Estates to the north, private lands within Belle Meade to the west and the Port of Islands area to the south. The pump stations will be operated so that they maintain drainage that existed in December 2000, as per WRDA 2000. They will not increase drainage of existing wetlands in Northern Golden Gate Estates or decrease the level of flood protection in adjacent lands.

The optimum canal stages, which will be different during the wet and dry seasons, are shown in Table 1. For operational purposes, the wet season is defined as beginning on May 1 of each year, and the dry season begins on October 15. The term “optimum” refers to the water levels associated with water management operations adopted by the SFWMD. The operation of the pump stations will be monitored to mimic these seasonal adjustments.

Table 1. Optimum canal stages upstream of the canal pump stations

	Optimum Canal Stages (feet, NAVD 88)	
Pump Station	**Wet Season**	**Dry Season**
Miller	4.9	5.15
Faka Union	4.9	5.15
Merritt	5.2	8.0

Section 4. Description of the Picayune Strand Watershed and Downstream Estuaries

4.1 Physiographic Setting

The Picayune Strand Restoration project is located southwest of the Florida Panther National Wildlife Refuge (NWR), north of the Ten Thousand Islands NWR, east of the South Belle Meade State Conservation and Recreation Lands (CARL) Project, west of the Fakahatchee Strand Preserve State Park, and northeast of Collier-Seminole State Park and Rookery Bay National Estuarine Research Preserve (Figure 2). The areas of the South Belle Meade CARL project, known simply as Belle Meade, and the Picayune Strand Restoration project have been combined by the State of Florida to form Picayune Strand State Forest. These federal and state preserves and parks surrounding the Picayune Strand Restoration area will be linked and enhanced by restored conditions within this area. The combined natural area will be able to function as one connected regional ecosystem.

To the south of the project and adjacent areas is the Ten Thousand Islands region. Estuaries within the Ten Thousand Islands region include the following ebays, from west to east (Figure 3): Palm Bay, Blackwater Bay, Buttonwood Bay, Pumpkin Bay, Faka Union Bay, and Fakahatchee Bay.

4.2 Climate

The Picayune Strand Restoration area undergoes about a 6-month dry season (November through April) and a 4-month wet season (June through September), with May and October being transition months. The average annual temperature is about 75 degrees Fahrenheit, with record extremes ranging from 105 degrees in late spring to 25 degrees in winter. Annual rainfall for nearby Naples averages 53 inches. Within Collier County, annual rainfall varies from a low of 30 inches to a high of 105 inches. Nearly 80 percent of the annual rainfall occurs during the wet season and transition months. Most of the rainfall is returned to the atmosphere by evaporation from soil and free water surfaces, as well as transpiration through plants. Under natural conditions, the combined process of evapotranspiration accounted for an approximate loss of 45 inches of water per year. Thus, only about 8 inches of average annual precipitation was available for surface runoff and groundwater recharge. Predrainage, natural surface runoff in the project area has been reported to be on the order of 0 to 10 inches annually (Kenner 1966).

4.3 Soil

The 1954 Collier County Soil Survey (Leighty et al. 1954) indicated several soils that might be found within the project area. Most of the area has black or dark-gray, mucky, and fine sand or peaty muck; others areas have brown peat. Duever (1984) classified four major soil groups - rock, sand, marl and organics - in the Big Cypress National Preserve. These major soil groups are found in the Picayune Strand Restoration Project area and historically were subject to intermittent or prolonged flooding and are characterized as poorly or very poorly drained. Organic soils accumulate in depressions that are inundated for much of the year creating a unique environment with increased species diversity (Duever 2005). Organic soils accumulate very slowly, about 0.5 meters per 1,000 years, but can be lost in less than a decade when exposure to air is increased and in a few days when consumed by fires (Duever 2005). Soils throughout the project area vary in thickness over limestone. If the thickness of the soil layer above the limestone is greater than four feet, soil forming processes occur to either form stain layers or cause mineral movement within clay layers above the limestone. South of the four major canals that drain the project area, soils in the wet prairies have marl over sandy deposits on rock.

4.4 Hydrogeology

The geology of the area consists of a Surficial Aquifer System, Lower Tamiami Aquifer and the Sandstone Aquifer. The Surficial Aquifer System includes the water table aquifer and some portion of the Lower Tamiami Aquifer that extends down to approximately 80 feet. The Lower Tamiami Aquifer provides most of the consumptive water use upstream of the project. It has varying degrees of confinement with the overlying water table aquifer. The water table aquifer is well connected with the canal systems and responds rapidly to rainfall, the only source of recharge, and canal drainage. For more information, see the Preliminary Assessment of the Groundwater Resources of Western Collier County (SFWMD 1986).

4.5 Pre-drainage Hydrology and Natural Flow Patterns

The range of annual fluctuation in water levels above and below ground and the duration of inundation are the primary factors influencing plant communities within the Picayune Strand area, although frequent fires and substrate are also factors (Harper 1927, Klein et al. 1970, Craighead 1971, Duever 1984, Duever 2005). The flat topography created minimal gradients, resulting in a gentle, broad, slow-moving overland sheetflow a few inches to a few feet deep across most of the area during much of the wet season. Water flowed in a general southerly direction, curving slightly to the south-southwest as it approaches the coast. Predrainage, natural surface runoff in the area has been reported to be up to 10 inches annually (USACE and SFWMD 2004). Seasonal flooding occurred several months of the year (USACE and SFWMD 2004) and wetland hydroperiods were maintained well into the dry season (SFWMD and NRCS 2003). Typical ranges were from 1 to 2 feet above ground surface at the height of the wet season to 3 feet below ground surface in the late dry season. During the dry season isolated pools were formed as sheetflow receded below the ground surface. This natural sheetflow system absorbed floodwater, promoted groundwater recharge, sustained wetland vegetation, rejuvenated freshwater aquifers, assimilated nutrients, and removed suspended materials. While hydrology is the prime determinant for whether there are upland, wetland or aquatic plant communities on a particular site, fire interacts with hydrology to determine the successional stages of these communities, i.e. whether they are herbaceous, shrub, coniferous forest or hardwood forest. In addition, substrates influence the species composition and productivity of these communities, and the occurrence of certain substrates is associated with the interaction of geologic substrates, fire and hydrology.

The Ten Thousand Islands Region included the tidally influenced rivers, the receiving bays, and the shallow coastal islands offshore, which extended to the limit of significant freshwater influence. Under pre-drainage conditions, freshwater reached the Ten Thousand Islands estuaries (Figure 3) and associated acreages of salt marsh and mangrove swamp through a combination of overland sheet flow and groundwater seepage (USACE and SFWMD 2004). The quantity and timing of freshwater inflows determined many characteristics of estuarine habitat by establishing salinity, other aspects of water chemistry, and dynamics of currents and water exchange. This slow year-round influx of fresh water maintained salinity in the natural range that estuarine species require.

4.6 Land Uses

The ultimate source of all ecological stressors in the region is development for residential and agricultural use (Duever 2005). Land drainage activities began in southwest Florida with the diversion and channelization of the Caloosahatchee River (USACE and SFWMD 2004). Significant anthropogenic alterations of the hydrologic regime and vegetative communities have occurred within the project area beginning with cypress logging operations in the 1940s and 1950s. The greatest changes occurred with development of the Northern and Southern Golden Gate Estates subdivisions in the 1960s. An extensive canal system was excavated to drain surface waters and provide fill for development. These canals are part of the Faka Union Canal system.

4.7 Existing Inland Hydrology

Existing flows down the canals into Picayune Strand are designed to provide wet season drainage for Northern Golden Gate Estates. The canals continually drain Northern Golden Gates Estates into Picayune Strand until the water table in the subdivision is so low that the canals can no longer extract water from the land. The canal system increased drainage 16 times faster than historic conditions, lowered previously existing ground water levels from 2 to 4 feet (Addison et al. 2006), and reduced hydroperiods by 2 to 4 months (Gore 1988). Water table drawdowns associated with Southern Golden Gates Estates canals have extended over two miles into Fakahatchee Strand Preserve State Park (USACE and SFWMD 2004).

In addition to canal drainage, consumptive use of water surrounding the project extracts water from the area further lowering water levels on a local scale beyond the effects of the canals, particularly during the dry season. Currently, the homes in Northern Golden Gate Estates are on individual wells and septic tanks. The result of this combination is that the deeper freshwater aquifers are being lowered by pumping and the surficial aquifer is being raised as a result of landscape irrigation and septic tank seepage, particularly during the dry season. Regardless of the higher water levels in the surficial aquifer during the dry season, flows into Picayune Strand are virtually nonexistent because the water table is still relatively low compared to pre-drainage conditions. For more information on the affects of consumptive use on the hydrology of the area, refer to Appendix D of the project implementation report (USACE and SFWMD 2004).

4.8 Existing Estuarine Hydrology

The Faka Union Canal system degrades marine habitat in Faka Union Bay by sending it too much fresh water too fast. Runoff that once slowly drained as overland sheet flow is now channelized and released into Faka Union Bay as a point discharge, causing freshwater shock loads to the bay's estuary (SFWMD and NRCS 2003). High concentration of fresh water lowers salinity as it discharges into Faka Union Bay. The canal system also affects the area of optimum-salinity habitat in nearby bays of the Ten Thousand Islands region (Figure 3) by diverting to Faka Union Bay fresh water that would otherwise have entered these other systems as surface or groundwater flows. Browder et al. (1989) noted a reverse salinity gradient into Pumpkin Bay during part of the year, probably due to the large amount of fresh water exiting the Ten Thousand Islands region through Faka Union Bay. These alterations in the timing and quantity of fresh water flowing into the estuaries have an impact on natural biodiversity by affecting food availability, predation pressure and reproductive success (USACE and SFWMD 2004). At the extreme east and receiving drainage primarily from the Fakahatchee Strand Preserve State Forest is Fakahatchee Bay, which is considered relatively unchanged from its historic condition.

4.9 Fire

Fires were a common occurrence on the predrainage Picayune Strand area. They were an important ecological factor in the historic health and survival of many terrestrial communities. Natural fires were normally most common during the summer wet season because of the high frequency of lightening (Robertson 1953, Duever 2005). Cypress sloughs would have seldom experienced fires, except during dry years in the areas adjacent to prairies (Wade et al. 1980). In winter and early spring, dried wetlands became susceptible to fire.

Thirty years of alterations to the hydrological cycle caused by canals have resulted in more frequent and intense wildfires within the project area (USACE and SFWMD 2004). Fires commonly move from prairies or flatwoods farther into adjacent cypress sloughs or other hydric forest communities than was historically common (SFWMD and NRCS 2003). This alters species compositions in communities formerly more hydric, as most resident species are not well adapted to withstand fires (Wade et al. 1980). Fires may burn closer to or below surface soil, as surface water and moisture levels are lower than levels before drainage. Intense fires have burned out soil organic matter that is associated with many hydric plant communities. Due to rapid drainage by canals, the window for prescribed burning is greatly reduced. Fewer prescribed burns lead to fuel build up, more intense wildfires, and a reduced ability to control exotics (USACE and SFWMD 2004).

4.10 Water Quality

The physical and chemical conditions of surface waters in the Class III freshwater bodies of the project area generally meet state water quality standards (USACE and SFWMD 2004). The quality of groundwater is also within the Florida Department of Environmental Protection's (FDEP) drinking water standard for potable supply. According to the FDEP Impaired Waters Rule Assessment, the Faka Union Canal and the estuaries receiving flow from the Faka Union Basin meet standards for dissolved oxygen, fecal coliform, turbidity and chlorophyll. Receiving estuaries from the Faka Union basin are listed as impaired water bodies due to the concentrations of bacteria found in shellfish (USACE and SFWMD 2004).

Data from monitoring sites located at the inflows of the project area along the Faka Union and Merritt Canals indicate mean phosphorus concentrations of 15 parts per billion (ppb) (USACE and SFWMD 2004). The estuarine sampling site located at the outfall of the Faka Union Canal weir averaged 20 ppb. While there have been no indications that these concentrations have caused algal blooms within the project area, the downstream estuarine systems are classified as extremely oligotrophic and impairments from sustained levels of nutrients are a concern. Also, higher concentrations of nutrients can encourage the spread and potential dominance of the area by invasive and exotic vegetation (Duever et al. 1986, Duever 2005).

4.11 Conceptual Ecological Models

Based on the natural system and anthropogenic characteristics discussed above, conceptual ecological models were developed to depict the major human influences on a system and how they affect the natural processes. Two models pertain to the Picayune Strand area: the Big Cypress Regional Ecosystem Conceptual Ecological Model (Figure 5; Duever 2005) and the Everglades Mangrove Estuaries Conceptual Ecological Model (Figure 6; Davis et al. 2005). The models include all major external drivers, stressors, ecological effects and attributes that describe cause-and-effect linkages between these components. External drivers (rectangles), such as canal systems, create stressors (ovals), such as lowered water table and shortened hydroperiod. These stressors have various effects (diamonds) on the ecosystem, which are reflected in changes to ecosystem attributes (hexagons).

The Big Cypress Regional Ecosystem Conceptual Ecological Model (Figure 5; Duever 2005) presents the major human influences on freshwater wetlands within the Picayune Strand area. The conceptual model describes how these processes and their disruption affects the plant and animal communities of the area. An example of such an effect caused by lowered water table and shortened hydroperiod (stressors) is wetland community shift to more terrestrial plant communities (effect), which results in altered vegetation community gradients and mosaics (attribute).

The Everglades Mangrove Estuaries Conceptual Ecological Model (Figure 6; Davis et al. 2005) presents the major human influences within the coastal regions of South Florida into which Picayune Strand drains. The conceptual model describes how the estuarine processes and their disruption affects the plant and animal communities of the area. An example of a cause-and-effect relationship within these mangrove estuaries is the effect water management ultimately has on wood storks. Water management (driver) of the Golden Gates Estates causes changes in freshwater flow volume, duration and distribution (stressor). These changes in coastal salinity gradients (effect) alters the production and concentration of mangrove fish (another effect), which affects the ability of wood storks (attribute) to successfully reproduce.

The full document describing the Big Cypress Regional Ecosystem Conceptual Ecological Model document is available at the following web site: www.evergladesplan.org/pm/recover/recover_docs/cems/cem_big_cypress.pdf. The Everglades Mangrove Estuaries Conceptual Ecological Model document is available at www.evergladesplan.org/pm/recover/recover_docs/cems/cem_eg_mangrove.pdf. The use of these models is described in a separate document by Ogden et al. (2005a) available at www.evergladesplan.org/pm/recover/recover_docs/cems/cem_use_of_cems.pdf.

Using these conceptual ecological models and their attributes, we identified valued ecosystem components. The conceptual models also helped identify the stressors on these attributes and how they affect the valued ecosystem components. It is this cause-and-effect relationship that allows us to use hydrologic performance measures to predict ecological response to hydrologic changes to the natural system.

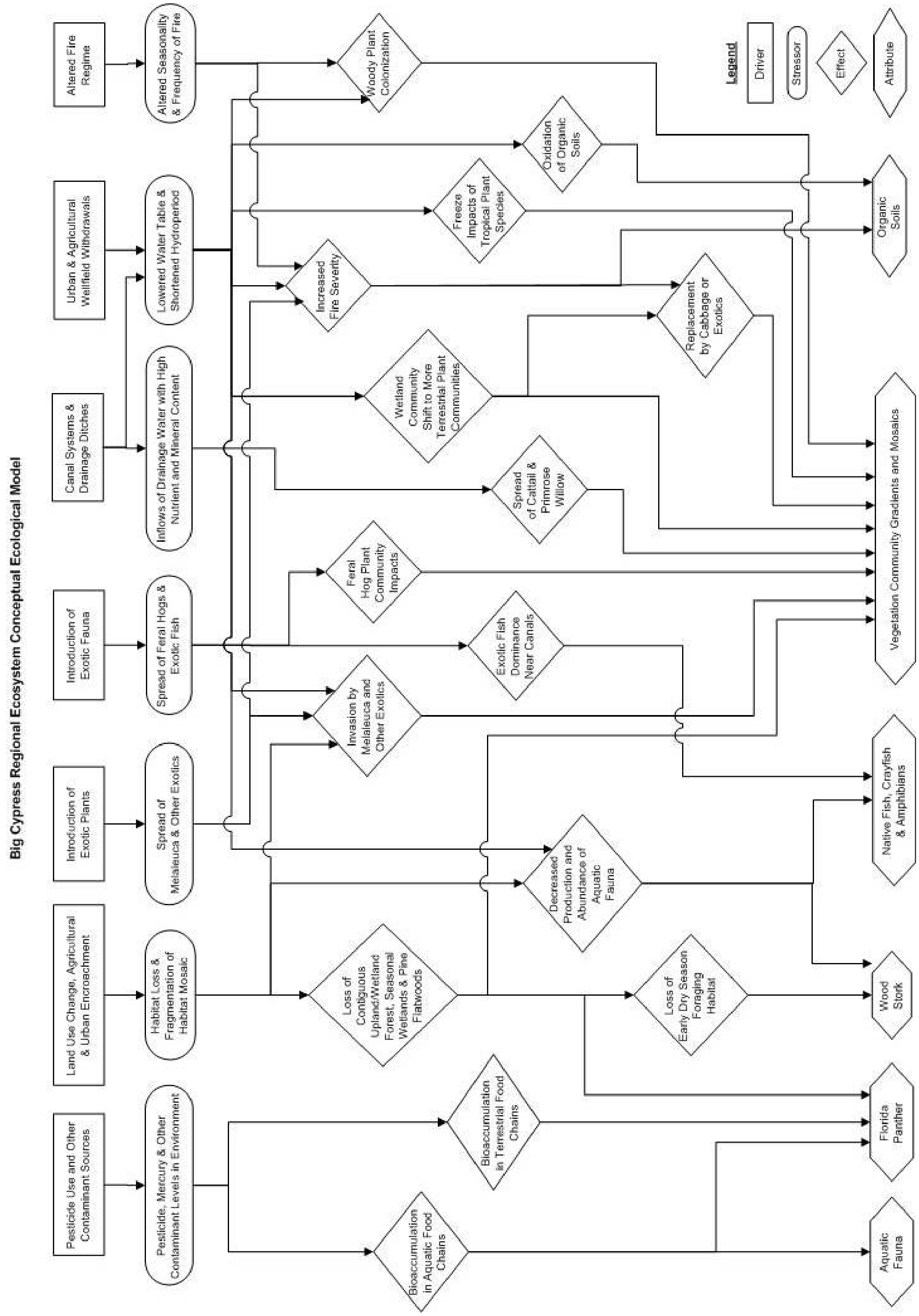


Figure 5. Big Cypress Regional Ecosystem Conceptual Ecological Model

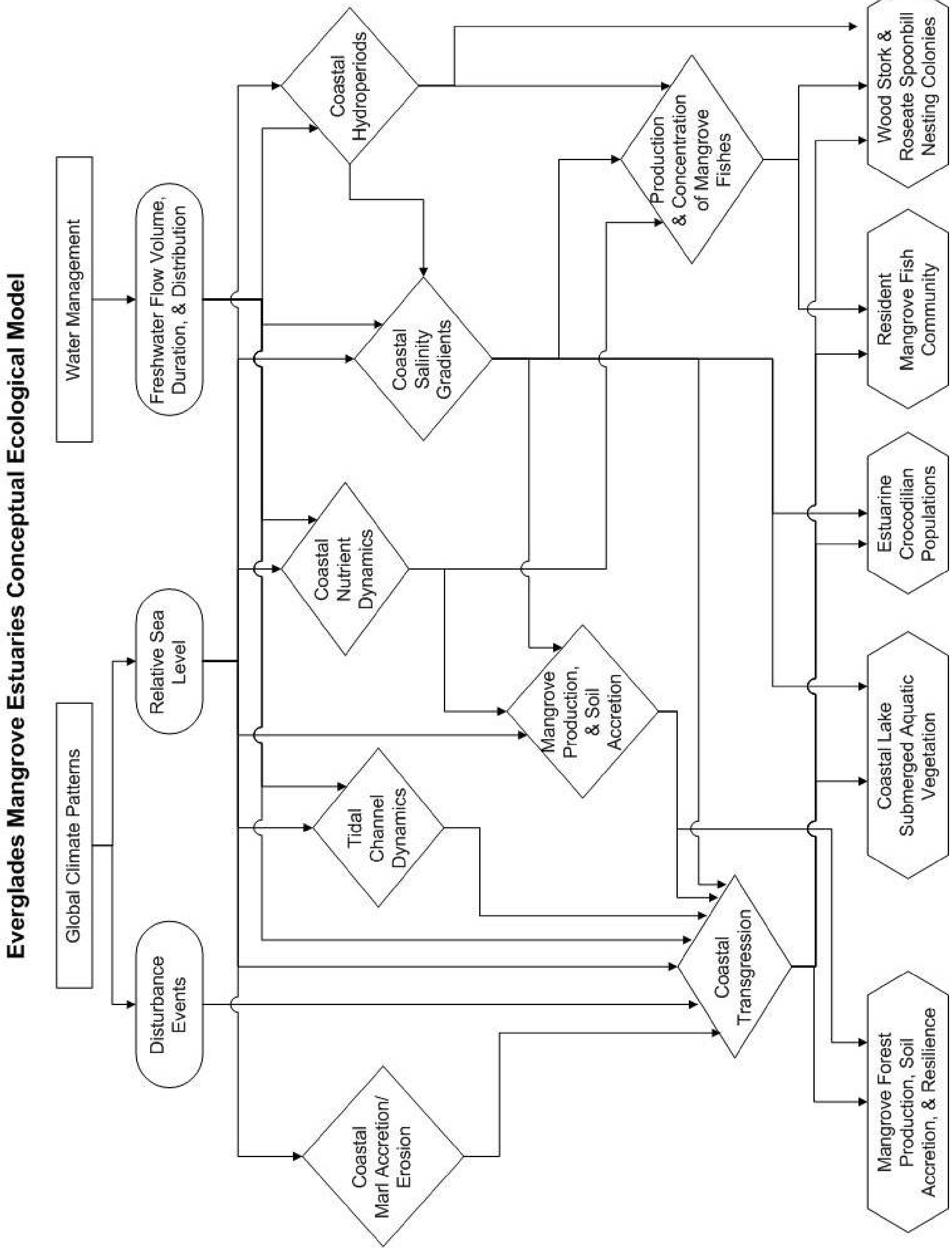


Figure 6. Everglades Mangrove Estuaries Conceptual Ecological Model

Section 5. Identification of Valued Ecosystem Components and Their Hydrologic Requirements

This chapter provides a brief description of valued ecosystem components and their hydrologic requirements that are characteristic of healthy and sustainable native plant and animal communities. These valued ecosystem components are attributes in the conceptual ecological models discussed in the previous section. More detailed information on biological resources can be found in the Picayune Strand Restoration Project Baseline Report (Chuirazzi and Duever 2008). This report can be viewed at the following web site: my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_SFER/PORTLET_SFER/TAB2236041/VOLUME1/appendices/v1_app_7a-2.pdf.

5.1 Inland Valued Ecosystem Components

Attributes of the Big Cypress Regional Ecosystem Conceptual Ecological Model (Figure 5; Duever 2005) include 1) pre-drainage vegetation community gradients and mosaics (plant communities), 2) native fish, crayfish and amphibians (aquatic fauna), and 3) wood storks. These attributes, along with the white ibis, are considered valued ecosystem components for the inland, freshwater portion of Picayune Strand.

5.1.1 Major Plant Communities

Hydrologic and fire regimes control the character and distribution of major types plant communities in this area (Davis 1943, Craighead 1971). The hydrologic alterations have reduced the depth and duration of inundation, which shifted wetland plant communities towards shallower wetland types or with sufficient drainage to upland types (Alexander and Crook 1973, Duever 1984). These shifts can include colonization by native woody species, such as slash pine (*Pinus elliottii*), cabbage palms (*Sabal palmetto*), and a variety of hardwoods, such as red maple (*Acer rubrum*) and laurel oak (*Quercus laurifolia*), or by exotic species, such as Brazilian pepper (*Schinus terebinthifolius*). Fires are more frequent and severe in these drier environments, in some areas resulting in dense stands of fire-tolerant cabbage palms and fast-growing woody exotics (Tabb et al. 1976, Gunderson and Loope 1982).

In July 2001, the Natural Resources Conservation Service (NRCS) provided a detailed map, based on 1940 aerial photographs, of pre-drainage distribution of major plant community types in the Picayune Strand Restoration area (Figure 7, left) (SFWMD and NRCS 2003). Comparison of 1940 and 1953 aerial photography with 1954 soil survey information verifies historic plant communities within this map. Using 1995 color infrared aerial photography, current soil survey information (1998), and extensive groundtruthing, the NRCS also developed a map of 1995 plant communities (Figure 7, right) analogous to that developed for 1940 (SFWMD and NRCS 2003). Acreages and percentages of each plant community in 1940 are compared to those in 1995 in Table 2. Hydrologic requirements of these communities as well as their relative abundance in 1940 and 1995 are provided in Table 3. Major native plant communities in the project area prior to drainage were cypress-dominated forest, wet prairie and pine flatwood. Almost 40,000 acres were cypress forest. Freshwater marsh and hammock communities were also present. Even those sites normally designated as uplands, particularly islands of pine flatwoods often had water at or above the ground surface for at least short periods during the wet season (USACE and SFWMD 2004).

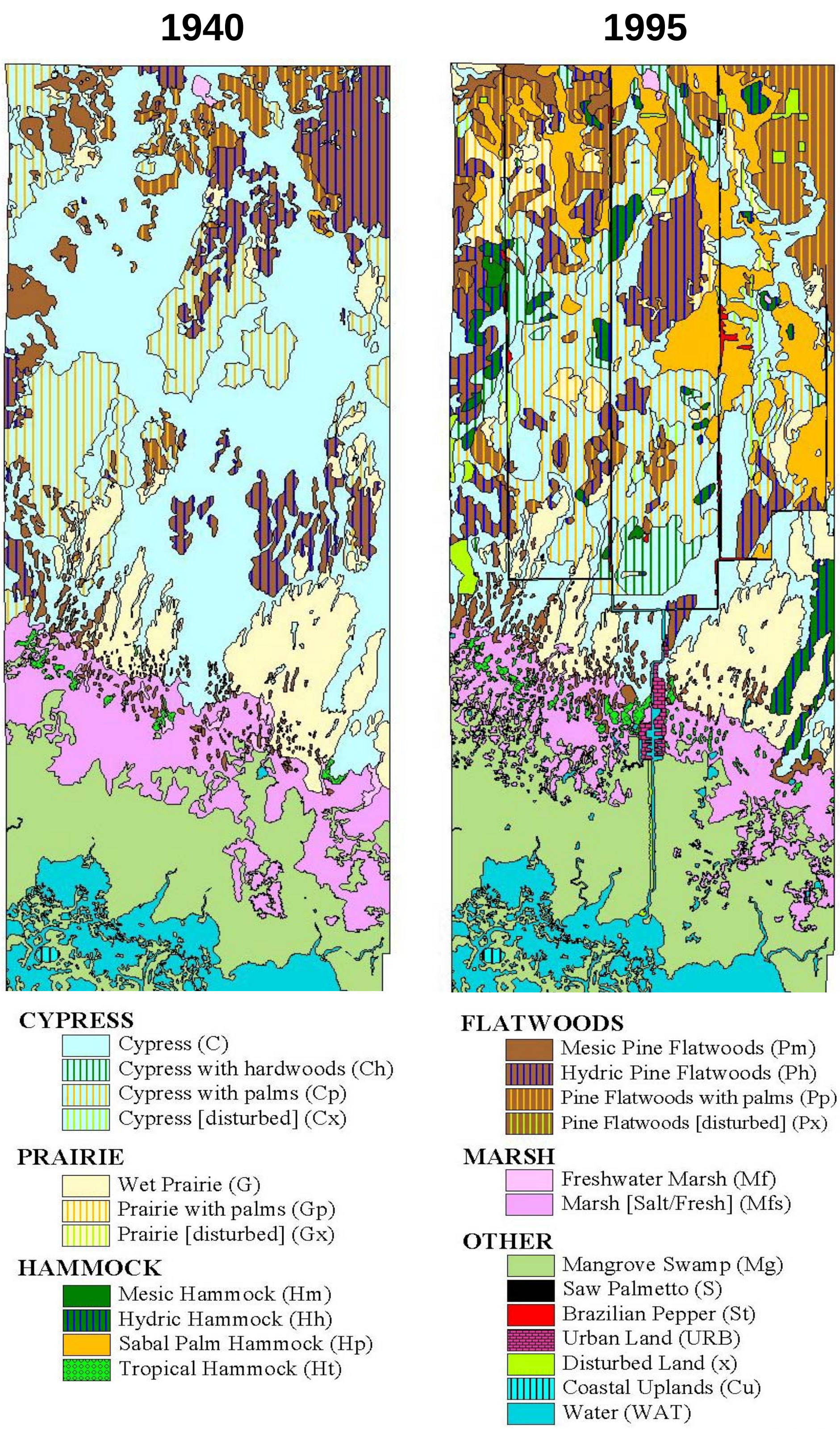


Figure 7. Pre-drainage (1940) and post-development (1995) vegetation maps of Picayune Strand

Table 2. Acreages and percentages of each plant community in 1940 and 1995

PLANT COMMUNITY	1940 Acres	1940 Percent Total Acreage	1995 Acres	1995 Percent Total Acreage	Difference (1995 – 1940) Acres	Difference (1995 – 1940) Percent Total Acreage Change
Cypress	30,583	30.5%	10,567	10.5%	-20,016	-19.9%
Cypress with hardwoods	0.0	0.0%	2,846	2.8%	2,846	2.8%
Cypress with palms	8,758	8.7%	9,026	9.0%	2678	0.3%
Coastal Uplands	303	0.3%	302	0.3%	0	0.0%
Cypress (disturbed)	0	0.0%	1,246	1.2%	1,246	1.2%
Wet Prairie	7,619	7.6%	7,031	7.0%	-588	-0.6%
Prairie with palms	0	0.0%	2,044	2.0%	2,044	2.0%
Prairie (disturbed)	0	0.0%	162	0.2%	162	0.2%
Hydric Hammock	0	0.0%	2,574	2.6%	2,574	2.6%
Mesic Hammock	0	0.0%	150	0.1%	150	0.1%
Cabbage Palm Hammock	56	0.1%	7,286	7.3%	7,230	7.2%
Tropical Hammock	265	0.3%	689	0.7%	424	0.4%
Freshwater Marsh	512	0.5%	95	0.1%	-417	-0.4%
Marsh (Salt/Fresh)	8,574	8.5%	6,480	6.5%	-2,094	-2.1%
Mangrove	16,565	16.5%	18,417	18.3%	1,852.8	1.8%
Hydric Pine Flatwoods	7,141	7.1%	5,853	5.8%	-1,288	-1.3%
Mesic Pine Flatwoods	2,908	2.9%	1,983	2.0%	-925	-0.9%
Pine Flatwoods with palms	2,408	2.4%	6,478	6.5%	4,070	4.1%
Pine Flatwoods (disturbed)	0	0.0%	48	0.0%	48	0.0%
Saw Palmetto	0	0.0%	6	0.0%	6	0.0%
Brazilian Pepper	0	0.0%	273	0.3%	273	0.3%
Urban Land	0	0.0%	299	0.3%	299	0.3%
Water	14,722	14.7%	15,844	15.8%	1,122	1.1%
Disturbed Land	0.0	0.0%	725	0.7%	725	0.7%
		100%		100%		

The reduced depth and duration of inundation have affected plant community composition, which has changed from that of wetland and transitional vegetation to more upland, invasive and exotic-dominated systems (Tables 2 and 3; Figures 8 and 9) (SFWMD and NRCS 2003, USACE and SFWMD 2004, Duever 2005). As historic cypress strands became drier due to the canal-induced drawdown, vegetative succession shifted toward a mixed cypress-hardwood-cabbage palm system (USACE and SFWMD 2004). Cypress forest has been reduced by almost half from 40,000 acres in 1940 to 20,000 acres in 1995 (Table 2) and location of cypress with palms communities have shifted (Figures 8 and 9). Much of the original cypress and cypress with palms community has been replaced by cabbage palm hammocks or pine flatwoods (SFWMD and NRCS 2003). Hammock communities now include mesic and hardwood hammocks in addition to cabbage palm and hydric hammocks present in 1940 (SFWMD and NRCS 2003). Fires are more frequent and severe, resulting in dense stands of fire-tolerant cabbage palms (Tabb et al. 1976, Gunderson and Loope 1992, Duever 2005). Invasive exotic species like Brazilian pepper (*Schinus terebinthifolius*) have become dominant in many of these formerly hydric communities (USACE and SFWMD 2004). Brazilian pepper often occurs as a result of soil disturbance associated with canals and adjacent spoil piles and forms a nearly complete shrub layer. To ensure restoration, it and other exotic and invasive plant species must be monitored and removed from leveled roadways and filled canals. Plant communities within Picayune Strand are still in transition following disturbance of natural conditions. These communities are not stable and will not maintain current characteristics over the long term. In absence of the project, communities will succeed towards more upland and exotic plant communities.

Table 3. Descriptions of major plant communities in 1940 and 1995

Community Type	Dominant Species	Other Species	Wet Season Water Depth (inches)	Hydro-periods (months)	Non-Hydrologic Influences	Pre-drainage (1940) Relative Abundance	1995 Relative Abundance
Cypress Forests	dense stands of bald cypress (*Taxodium distichum*)	hardwoods (< 30% cover)	12 - 24	6 – 10	< fire	++++	++++
Freshwater Marsh	low-diversity herbaceous with tall, dense strands of grass and forbs	bald cypress (< 30% cover)	12 - 24	6 – 10	fire organic soils	++	++
Wet Prairie	high-diversity herbaceous with short open stands of grasses sedges and forbs	slash pine or bald cypress (< 30% cover)	6 - 12	2 – 6	fire mineral soils (sand, marl, rock)	+++	+++
Hydric Pine Flatwoods	open canopy of slash pines with dense and diverse herbaceous ground cover of grasses, sedges and forbs		2 - 6	1 – 2	fire sand or rock substrate	+++	+++
Flatwoods with Cabbage Palm	slash pines with cabbage palm (*Sabal palmetto*)		< 2 - 6	< 1 – 2	fire	+++	+++
Cabbage Palm Hammocks	cabbage palms		< 2 - 6	<1 – 2	> fires sand or rock substrate	+	+++
Hydric Hammock			6 - 12	2-6	fire		+++
Mesic Pine Flatwoods	open canopy of slash pines (*Pinus eliottii*) pines with dense saw palmetto (*Serenoa repens*)		< 2	< 1	fire sand or rock substrate	+++	+++
Mesic Hammock			< 2	<1	no fire	-	++
Brazilian Pepper			< 2	<1	exotic	-	++
Hardwood Hammocks	hardwood species	cabbage palms, live oaks (*Quercus virginiana*)	+/- 6	0 – 2	no fire sand or rock substrate	++	++

Relative abundance scale: "-" = absent; "+" = rage; "++" = common; "+++" = abundant"; "++++" = very abundant

The native cabbage palm (*Sabal palmetto*) has become dominant throughout much of the project area during the past few decades, increasing from approximately 60 acres in 1940 to approximately 7,300 acres in 1995 (Table 2) (SFWMD and NRCS 2003). These palms form dense populations of similar-sized, apparently young trees, beneath widely spaced individuals that appear to be very old. The younger palms are thought to be 20-30 years old, having originated after the hydrology of the area changed. Only old growth palms were found in the control sites. Cabbage palm forest has now become almost a pure biotype within many areas. The Florida Division of Forestry now considers the cabbage palm in the project area as an invasive species that needs to be controlled in order to maintain ecosystem diversity (USACE and SFWMD 2004).

5.1.2 Aquatic Fauna, White Ibis and Wood Storks

The changes in hydrology and plant community structure, along with habitat loss and fragmentation, have affected other valued ecosystem components. These include aquatic fauna, wading birds and wood storks. The current condition of these components and how they are affected by hydrology are discussed here, though these valued ecosystem components were not directly used to determine water to be reserved.

Prior to drainage, wetland systems in Picayune Strand contained water during summer and fall and, depending on local topographic gradients, most dried out completely sometime during winter through late spring (USACE and SFWMD 2004). Drainage of Picayune Strand has degraded resources for vertebrates. These wetlands can no longer function effectively as refugia for alligators, turtles, amphibians and fish during droughts. Shortened hydroperiods have resulted in impacts such as inhibited growth of periphytic algae, which are an important part of the food web that sustains small forage fish, amphibians and macroinvertebrates. These small fauna are an important food source for larger animals, such as wading birds, reptiles and mammals. The extent of this loss of function in the project area was demonstrated during the 2001 drought when no natural wetlands in the project area retained any water whatsoever. In adjacent Fakahatchee Strand Preserve State Park, an area that has not been as seriously impacted by drainage, some of the deeper wetlands retained water and were refuges for wildlife (Nelson et al. 2001). The white ibis (*Eudocimus albus*) and wood stork (*Mycteria americana*) require large areas for foraging so they can take advantage of different wetlands in a large area that are flooding and drying down at different times of the year to extend the period over which they can find food. Reestablishment of sheetflow-dominated hydrology within Picayune Strand will create connections between wetlands; allow aquatic fauna dispersal; establish dry season or drought resistant refugia; and reduce predation on forage fish species, and reduce unwanted exotic fish species that compete with forage fish (Duever 2005).

5.2 Estuarine Valued Ecosystem Components

Although the Everglades Mangrove Estuaries Conceptual Model (Davis et al., Figure 6) does not specify oysters and nekton as attributes, they were chosen as valued ecosystem components because of their strong relationship to salinity and ecological response. Oysters are sessile, therefore, they respond to salinity changes before most other organisms. Nekton feed on oysters so are indirectly affected by salinity in a manner similar to oysters. The hydrologic performance measures are developed based on the salinity regime needed for these organisms. Because the hydrologic models yield freshwater flows delivered to the estuaries, it is necessary to relate flow to estuarine salinity.

Shorelines within the Ten Thousand Islands region were generally lined with mangroves (USACE and SFWMD 2004). Mangroves supported productivity of creeks, bays and islands by producing leaf litter and dissolved organic matter that was exported by outgoing tides to bays and channels. Red mangrove roots provided substrate for settling of crustaceans and mollusks, and particularly for oysters, algae, tunicates and annelids, as well as shelter for juvenile fish. Sand and mud bottoms sheltered mollusks, crustaceans and other invertebrates, as well as fish. Plankton and nekton provided food for the filter-feeding fish, oysters and other invertebrates. Submerged aquatic vegetation may have covered significant parts of bay bottoms under natural conditions. Both oyster reefs and submerged aquatic vegetation are important habitat for juvenile fish and their prey.

Alterations in the timing and quantity of fresh water flowing into an estuary can have an impact on natural biodiversity by effecting food availability, predation pressure, and reproductive success and can directly cause chronic and acute stress (Serafy et al. 1997, Sklar and Browder 1998). The alteration in natural salinity conditions, caused by alterations in surface and groundwater flow, has caused a reduction in oyster reef and submerged aquatic vegetation and displacement of mangrove zones (Davis et al. 2005). Faka Union Bay has been damaged by the flashy high and low flows that lead to salinity extremes. The other bays receive much less flow than they did prior to drainage. These conditions have caused prolonged salinity stresses and have eliminated or displaced a high proportion of the animal communities from the bay. Suppressed plankton development has resulted in very low relative abundance of fish and a considerable drop in shellfish harvest levels. The impact on commercial and recreational fisheries has been significant.

5.2.1 Oysters

In the Faka Union estuary, a system that receives excessive pulses of fresh water during the rainy season, the distribution of reefs, the regions of maximum living density, and the foci of maximum oyster productivity are displaced seaward relative to undisturbed estuaries. Fresh water inundates the estuary for 5-6 months of the year. Higher salinity and temperature increases *P. marinus* prevalence in adult oysters. While upstream locations in the Faka Union estuary have lower disease prevalence among adult American oysters (*Crassostrea virginica*), juveniles experience heavy mortality due to freshwater releases and runoff. Mortality was particularly severe in the furthest upstream sections of the Faka Union Canal/River. Growth rates and condition index of oysters are higher at downstream locations. Spat recruitment occurred during September and October, a period late for southwest Florida (Volety and Saverese 2001).

Salinity is critical to the reproduction, development and growth of the American oyster. Oysters require a narrow range of salinities for successful spawning (between 15-25 parts per thousand [ppt]) during the months of May through July. Food availability is greatest between 15 and 35 ppt, so growth is maximized under these conditions. Predation and disease (caused by the parasite *Perkinsus*) can cause high mortality within oyster populations during periods of prolonged high salinity (> 25 ppt). Infrequent pulses of fresh water effectively reduce predation pressures and significantly reduce the number of infectious parasites. Consequently, periods of lower salinity (< 15 ppt) are also needed.

Improved estuarine health will occur in Faka Union with the restoration of sheetflow from Picayune Strand to the estuaries. The reestablishment of more normal salinity regimens will maximize reef development, living density, and oyster growth, recruitment and productivity in middle reaches. This will restore the best conditions for reef development to these areas with the greatest accommodation space for reef formation.

5.2.2 Nekton

Nekton species are those living organisms living suspended in the water. Many of the nekton species, composed principally of fish and crustaceans, utilizing the estuaries are dependent upon oyster reefs for food. Consequently, the same conditions favorable for oyster health and reef development favor nekton. Timing of reproduction of fish and crustacean species dependent upon reefs may differ from those months critical to the biology of oysters themselves. By examining the impacts of salinity, this approach generated specific salinity targets for different times of the year for these organisms. In addition, many fish and crustacean species critical to estuarine structure and function have specific salinity tolerances for other physiological functions. These species were used to target particular salinities.

Saverese et al. (2004) determined that the best indicator fin-fish species were mullet, sea trout and redfish (*Mugil* spp., *Cynoscion* spp., *Sciaenops ocellatus*). For these species, the critical months of reproductive activity are, respectively, October, March-May and November. Shrimp and blue crabs (*Penaeus duorarum*, *Callinectes sapidus*) were also used as the crustacean estuarine indicators; their reproductive months span from May-June and September-October, respectively. Two year-round reef-resident crabs, the stenohaline *Petrolisthes armatus* and the euryhaline *Eurypanopeus depressus*, were also included in the evaluation as they are highly dependent upon variable salinity conditions found in the oligohaline (1-10 ppt) and mesohaline (15-25 ppt) zones of unaltered estuaries (Shirley 2002).

The Ten Thousand Islands area contains nursery grounds for pink shrimp and other shrimp recruited to fishing grounds near Sanibel Island (Costello and Allen 1966). Laboratory experiments with juvenile pink shrimp from Florida Bay indicate a low tolerance to salinity extremes, especially low salinity (Browder et al. 2002).

The blue crab was one of the more abundant macroinvertebrate species in Faka Union and Fakahatchee Bays in the early 1970s (Carter et al. 1973, Evink 1975) and Faka Union, Fakahatchee and Pumpkin Bays in the early 1980s (Browder et al. 1986). In addition to its commercial importance, this species is a major prey item for large fish, wading birds and sea turtles (Van Heukelem 1991). Blue crabs have different salinity requirements or preferences at different life stages. Juveniles prefer seagrass habitat but also use salt marsh habitat and have been found in greatest numbers in the low to intermediate salinities (2-21 ppt) characteristic of upper and middle estuaries. Adult males spend most of their time in low salinity water (< 10 ppt). Females move from higher to lower salinities as they approach their terminal molt in order to mate. Females with eggs are usually found at 23-33 ppt. Spawning usually occurs from 2 to 9 months following mating. Two spawning peaks typically occur in the Gulf of Mexico, one in late spring and the other in late summer or early fall. The optimum salinity for hatching is 23-28 ppt. Larvae are usually found at > 20 ppt. Optima of 16-43 ppt were reported for survival and 11.5-35.5 ppt for development. The best strategy to promote high blue crab density may be to maintain a broad salinity gradient and provide the natural timing of flow in relation to rainfall.

Shirley et al. (1997) studied the recruitment dynamics of crabs on oyster reef habitats in Henderson Creek and Blackwater River (May 1996 to April 1997) relative to salinity fluctuations. Saverese et al. (2004) found recruitment of juvenile porcellanid (stenohaline) and xanthid (euryhaline) crabs to both estuaries were similar, peaking in the early wet season. In contrast, significantly fewer adult stenohaline crabs were found in Henderson Creek than in Blackwater River. Site-specific differences in salinity fluctuations were also observed. This study concluded that the altered freshwater inflow into Henderson Creek adversely affected stenohaline crab populations. The Rookery Bay Reserve staff has monitored crab populations on oyster reefs within Henderson Creek and Blackwater River and expanded this study to include Fakahatchee Bay and Faka Union Bay. The data generated by this study indicates that altered freshwater inflow is reflected in the relative abundance of stenohaline and euryhaline oyster reef crab populations (Shirley et al. 2002). Once they recruit to a reef, these species must remain on the reef and tolerate conditions at that location in order to survive. The extreme salinity fluctuations that occur in Faka Union Bay as a result of the canal system may limit the abundance of both of these species. The relative abundance of the two species at a site can provide an index of recent prevailing conditions (i.e., low and fluctuating or high and relatively stable) (Shirley et al. 2002).

Section 6. Hydrologic Performance Measures and Targets

To measure the effectiveness of various alternatives on valued ecosystem components, performance measures were developed for Picayune Strand Restoration. These performance measures relate to how the main stressor on the system, hydrology, affects three valued ecosystem components: inland vegetation communities, oysters and nekton.

6.1 Hydrologic Performance Measures and Targets for Inland Plant Communities

There is a relationship between wetland hydrology and the types of plant communities that can exist on a site (Duever et al. 1975, Duever 1984). The MIKE SHE model can be applied to quantify the surface and sub-surface flow conditions over a period of time and, therefore, can be used to estimate plant community acreage. The use of this model is discussed in more detail in Section 7. This section presents the hydrologic performance measures and their targets used to simulate improvements to the natural system with the project implemented. These performance measures are average water levels for the dry season (April 1-June 1), average water levels for the wet season (July1-October 1), annual maximum water levels, and annual minimum water levels. These performance measures were evaluated at 32 locations (indicator regions/well sites) (Figure 9). In this section, we provide an example of how performance measures were used to evaluate plan performance and then a summary of the evaluation results. The target for the protection of fish and wildlife in Picayune Strand south of the pump stations is the pre-drainage condition. North of the pump stations the target for the protection of fish and wildlife is the existing condition.

6.1.1 An Example of Application of a Hydrologic Performance Measure and Target

An example of this connection between wetland hydrology and types of plant communities is provided by a set of output from the MIKE SHE model. Average wet season water levels from July 1 through October 1, which is often closely related to hydroperiod, were used. These two hydrologic parameters are important determinants of the long-term distribution of the major types of plant communities in Picayune Strand (USACE and SFWMD 2004). Based on this correspondence between water depths and major plant community types, acreage of each community was estimated (Table 4) by determining the number of cells (each cell equals 51.65 acres) within each range of water depths present under pre-drainage conditions and with-project conditions (Figure 8). The target for hydrology in Picayune Strand south of the pump stations is the pre-drainage condition. North of the pump stations the target is the existing condition.

Table 4. Wet season water depths and major plant community types using MIKE SHE output[1]

Plant Community	Water Depth (feet)	Acres of Major Plant Communities		Percent of Each Plant Community	
		Pre-drainage	With- Project	Pre-drainage	With- Project
Mesic Flatwoods	<0.2	9,194	18,388	16%	31%
Hydric Flatwoods	0.2 - 0.5	11,260	10,433	19%	18%
Wet Prairie	0.5 - 1.0	19,420	14,720	33%	25%
Cypress / Marsh	1.0 - 2.0	16,166	13,739	27%	23%
Open Water	>2.0	3,254	2,014	5%	3%
Total		59,294	59,294	100%	100%

[1] The percentages in this table, which represent model output, do not exactly match the percentages in Table 2, which recommend measured values, because of topographical issues discussed in Section 7.2.3.

Results of the MIKE SHE model run for pre-drainage conditions indicated that water depths appropriate for cypress and marsh communities made up about 27 percent of Picayune Strand, wet prairie made up 33 percent, and flatwoods made up 35 percent (Table 4; Figure 8). Large areas were primarily shallow-to-deep water environments and would be occupied by cypress forest with smaller areas of wet prairie grading into pine flatwoods. North and south of U.S. 41 and the western side of the area were deeper areas. While some of the more inland portions of this deeper area were cypress communities, it was predominantly herbaceous plant communities including wet prairies and saltwater marshes. The relatively drier upland communities existed as small islands in the vicinity of I-75.

When comparing simulated water depths, there were only small differences in water depth between pre-drainage and with-project (Table 4; Figure 8), except for generally drier conditions upstream of the pumps. Most of this difference in upland communities over pre-drainage conditions was intentional, resulting from locating the pumps and spreader canals some distance south of I-75 to maintain upland habitat for wildlife in this area. The target north of the pump stations is to maintain existing conditions in Miller, Faka Union and Merritt Canals. This includes maintaining flood protection for Northern Golden Gate Estates and other adjacent lands.

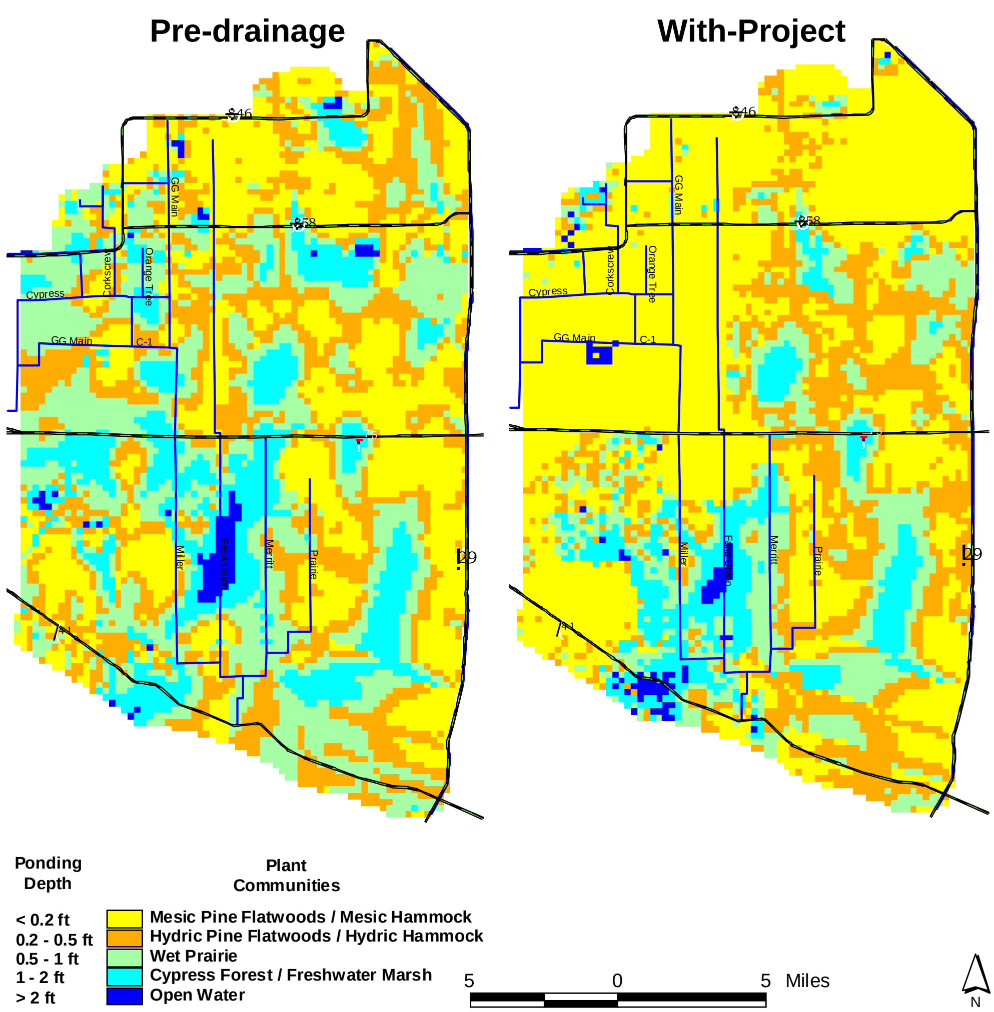


Figure 8. Pre-drainage and with-project average wet season water depth and corresponding plant community types

6.1.2 Summary of Evaluation Results

The four hydrologic performance measures indicate the degree of restoration as shown in Table 5 which presents the average percent of pre-drainage conditions water levels predicted for existing and with-project conditions. The entries are the average of 32 indicator regions, 23 in Picayune Strand and 9 in adjacent Belle Meade and Fakahatchee Strand (green dots in Figure 9). The average dry season water level and the minimum water level are farther from the pre-drainage conditions predictions than are the average wet season and maximum water levels. For the with-project condition, the four performance measures would average from 95 to 97 percent of pre-drainage conditions. This is a very high degree of restoration. The performance measures are used to evaluate hydrologic changes that affect the valued ecosystem components.

Table 5. Average percent of pre-drainage conditions for four hydrologic performance measures

Performance Measure	Percent of Pre-drainage Conditions	
	Existing	With-Project
Average dry season water level	61%	95%
Average wet Season water level	74%	96%
Average maximum water level	81%	97%
Average minimum water level	59%	96%

6.1.3 Water Depth at Indicator Regions

Comparing pre-drainage (target) and with-project water stage for the 32 indicator regions (green dots in Figure 9) allows identification of the changes in water depths within specific areas of Picayune Strand and the surrounding area. Weekly stage hydrographs represent the time series of average weekly stages over each of the 32 cells. They are used to compare several pre-drainage hydrologic characteristics to the with-project condition. The characteristics are seasonal water level fluctuations, minimum and maximum levels, and the occurrence and frequency of the cell dry out. Weekly stage duration curves provide an indication of the cumulative probability that a particular stage is exceeded or not exceeded. The probability of exceeding a given stage was quantified from a duration curve. The weekly stage hydrographs and stage duration curves generated for the indicator regions are presented in Appendix A.

6.2 Hydrologic Performance Measures for Oysters and Nekton in Estuaries

Alterations in the timing and quantity of fresh water flowing into an estuary can have an impact on natural biodiversity by affecting food availability, predation pressure and reproductive success and can directly cause chronic and acute stress (Serafy et al. 1997, Sklar and Browder 1998). The amount and timing of freshwater flow determines the salinity regime of an estuary. Altered salinity is the main stressor to estuarine fauna. Because the hydrologic models yield freshwater flows delivered to the estuaries, it is necessary to relate flow to estuarine salinity when developing targets and measuring modeled performance. The relationship between flow and salinity is shown in Figure 10.

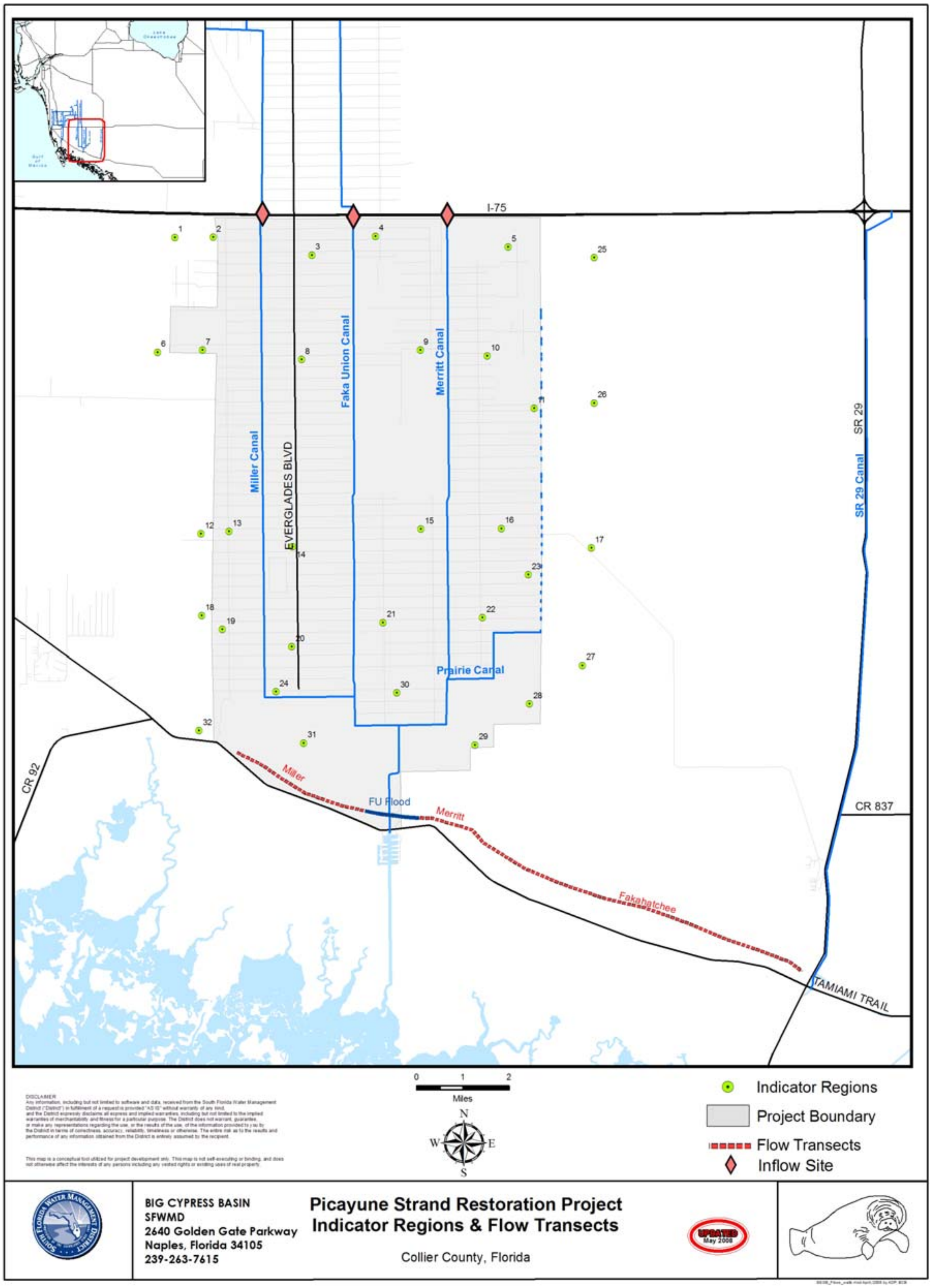


Figure 9. Indicator regions and inflow points for Picayune Strand Restoration

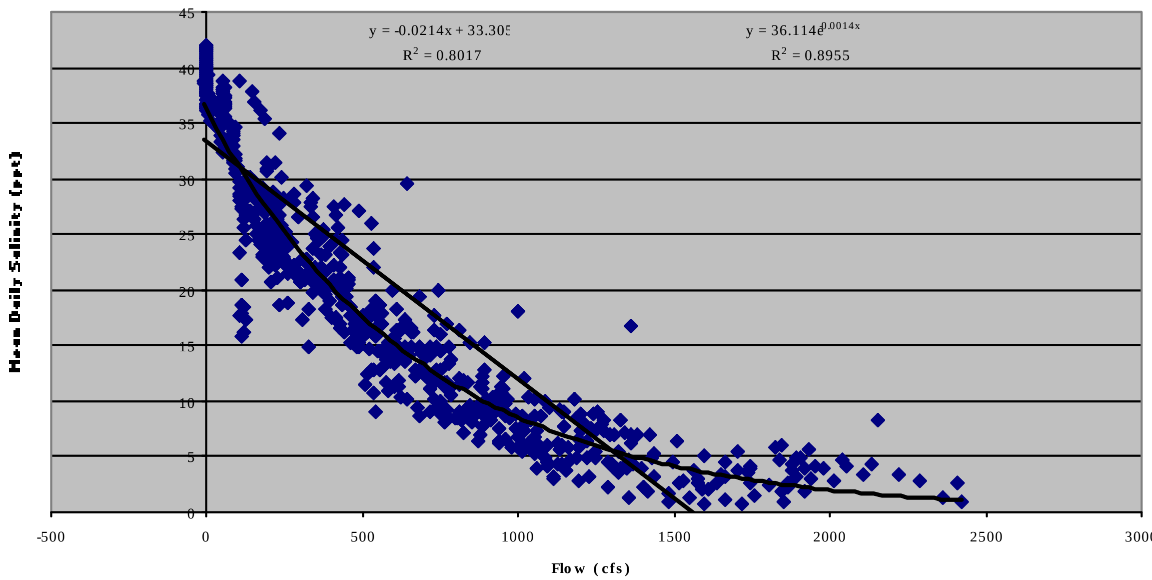


Figure 10. Relationship between flow and salinity above the fixed weir at Port of the Islands on the Faka Union Canal for 2000 to 2002.

The relationship between measured salinity and flow entering estuarine bays, and the relatively well studied relationships between salinity and estuarine biology, were used to develop performance measures for Faka Union Bay. Faka Union Bay is the only estuary within the Ten Thousand Islands affected by restoration of Picayune Strand that has been monitored thoroughly enough to permit the use of this relationship. Based on the salinity to flow calibration for Faka Union (Figure 10) and the required salinity for oysters and nekton populations, the following hydrologic targets are derived:

- The number of days (or percent of year) of average canal discharge > 500 cfs should be minimized to reduce the frequency and duration of pulses of fresh water.
- The number of days (or percent of year) of average canal discharge < 50 cfs should be minimized to extend flow into the dry season.
- The number of days (or percent of year) of average canal discharge between 300 and 500 cfs should be maximized to improve reproductive conditions for nekton.

The target for the protection of fish and wildlife in the downstream estuaries of Picayune Strand is the pre-drainage condition The with-project condition had four months out of the 36 months simulated when flows were above 500 cfs or below 50 cfs. The total number of days when critical levels were violated was 91 days compared to the 1,095 days in the period of simulation.

Section 7. Modeling Tools

The complex interaction of surface water and groundwater within the Picayune Strand watershed require that the effectiveness of the performance measures be evaluated by integrated modeling of surface and groundwater flows. An integrated Picayune Strand Restoration Project model was formulated by the application of the mathematical modeling system MIKE SHE developed by the Danish Hydraulic Institute (DHI). The objectives of this modeling effort are to evaluate the performance of the restoration plans in reestablishing the historic sheet flow patterns, reducing the amount of point source freshwater discharge to the downstream estuaries and thereby establishing a desirable wetland hydrologic regime for restoration of all fish and wildlife habitat of the region.

The MIKE SHE modeling system is an integrated and distributed, physically-based mathematical model with finite difference computational solution. The system comprises a number of flow modules that may be combined to describe flow within the entire land-based part of the hydrological cycle. The main components of the MIKE SHE modeling system that have been applied in the Picayune Strand Restoration modeling studies are the one-dimensional hydraulic (MIKE 11) model and the following modules: overland flow and channel (MIKE SHE OC), unsaturated flow (MIKE SHE UZ), saturated flow (MIKE SHE SZ), evapotranspiration (MIKE SHE ET), irrigation demand (MIKE SHE IR), and pre- and post-processing (MIKE SHE PP). The simulation methods of these components are described below, and presented in Table 6.

Table 6. Model components applied for Picayune Strand Restoration

Model Component	Simulates	Fully Dynamic Coupling with:	Dimension	Governing Equation
MIKE SHE OC	Overland sheet flow and water depth, depression storage	MIKE SHE SZ, UZ and MIKE 11	2-D	Saint-Venants equation (kinematic wave approximation)
MIKE 11	Fully dynamic river and canal hydraulics (flow and water level)	MIKE SHE SZ, OL	1-D	Saint-Venants equation (dynamic wave approximation)
MIKE SHE UZ	Flow and water content of the unsaturated zone, infiltration and groundwater recharge	MIKE SHE SZ, OL	1-D	Richard's equation / gravitational flow (no effects of capillary potential)
MIKE SHE ET	Soil and free water surface evaporation, plant transpiration	MIKE SHE UZ, OL	-	Kristensen & Jensen / Penman-Monteith
MIKE SHE SZ	Saturated zone (groundwater) flows and water levels	MIKE SHE UZ, OL, and MIKE 11	3-D	Boussinesqs' equation
MIKE SHE IR	Irrigation demands (soil water deficit) and allocation (surface water/ groundwater)	MIKE SHE SZ, MIKE 11	-	-
MIKE SHE PP	Pre- and post-processing	-	-	-

The domain of the Picayune Strand Restoration integrated model has been adapted from the Big Cypress Basin Regional Model (Figure 11) and covers an approximately 1,200-square mile area of western Collier County. This domain is set up on a 1,500 feet by 1,500 feet grid that has 6,171 computational cells per layer. The model is set up on the State Plan North American Datum (NAD) 1983 Florida East coordinates and North American Vertical Datum (NAVD) 1988.

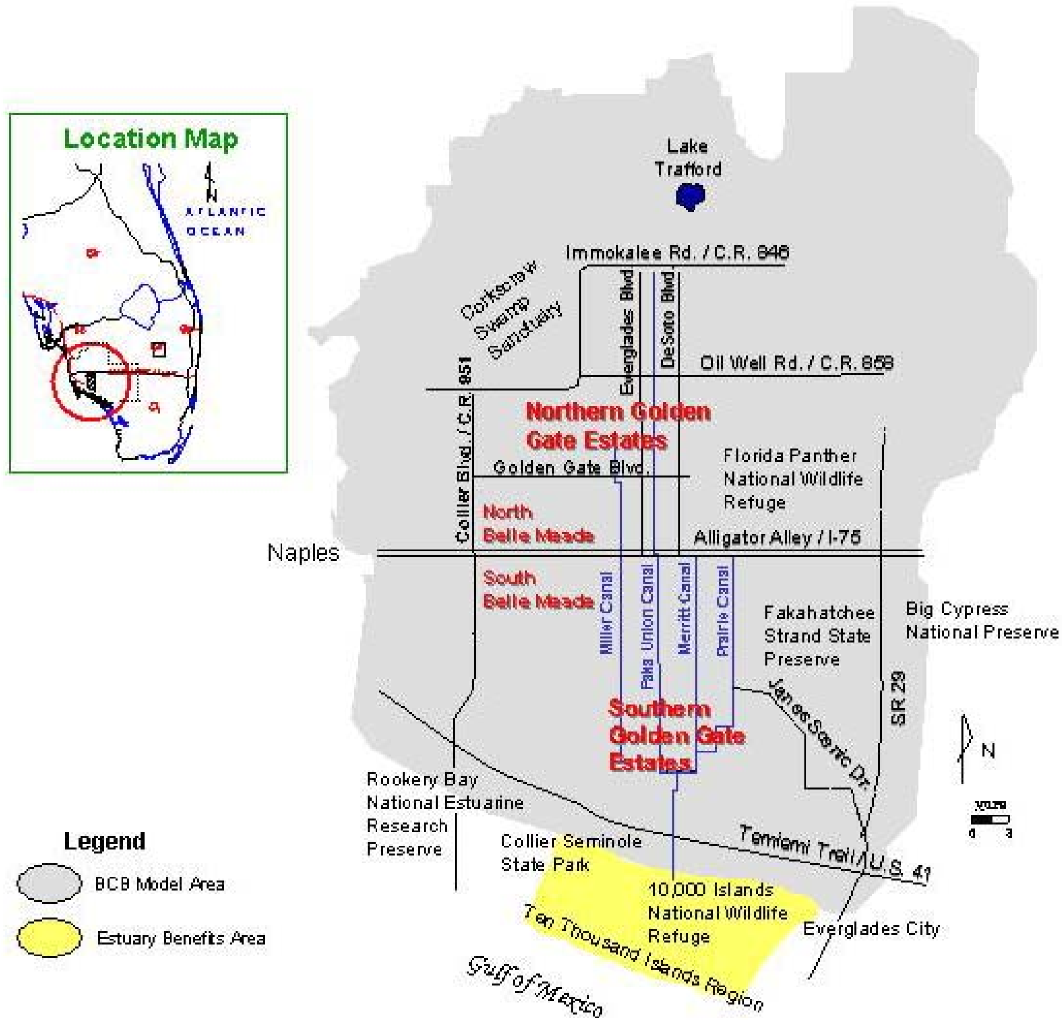


Figure 11. Big Cypress Basin Regional Model boundary

7.1 Input Data and Model Setup

An extensive database of meteorological and land-based hydrologic-hydraulic data was utilized for the development of the Big Cypress Basin Regional Model. Major input parameters of the model are meteorological data, land use, topographic data, canal network – hydraulic data, soil properties in the unsaturated zone, and properties of groundwater flow in the saturated zone.

7.1.1 Meteorological Data

The driving forces for the integrated model are rainfall and evapotranspiration. Continuous records of rainfall for the study area were chosen from 20 rainfall stations for a

13-year period of record (1988-2000). The conditions modeled represent the hydrologic conditions for a meteorological cycle covering average, wet and dry years in southwest Florida, which were observed to be 1994, 1995 and 2000, respectively. The measured rainfall from the 20 stations was spatially distributed by the application of triangulation method, (Triangular Irregular Network 10 or TIN-10) to generate daily rainfall records for the entire model period.

Evapotranspiration (ET) accounts for the bulk of water loss from the modeling area. Two vegetation parameters, leaf area index and the rooting depth, are used by MIKE SHE to calculate actual evapotranspiration. Daily potential evapotranspiration was calculated from an estimation of the wet marsh potential ET for the model domain. This was performed by the SFWMD Simple Method, which computes the long-term historical (1965-2000) wet marsh potential ET from the evaporation stations. Due to difference in the roughness characteristics between marsh and grass surfaces, the crop coefficients developed were modified for use with wet marsh potential ET. Additionally, five National Oceanic and Atmospheric Administration (NOAA) stations with long-term daily temperature data (1965-2000) were thoroughly checked and patched to correct systematic errors, trends and missing values with the purpose of producing the best possible temperature dataset for ET parameters and ET estimates. The spatial distribution of the wet marsh potential ET values for the model domain was also performed by the TIN-10 method across the five evaporation stations.

7.1.2 Land Use

A MIKE SHE land use distribution map was developed from the SFWMD 2000 land use geographic information system (GIS) database in the Florida Land Use, Cover and Forms Classification System (FLUCCS). The 2000 land use coverage contains 300 different land use types, which have been simplified into 23 vegetation cover classes that are hydrologically different. Additionally, a pre-drainage (natural) condition map was developed into a digital vegetation coverage from the 2001 SFWMD Soil Classification Database.

7.1.3 Topographic Data

The ground surface elevation was first interpolated to a 1,500-feet grid based on topographic data generated from the US Geological Service quadrangle data and enhanced by Light Detection and Ranging (LIDAR) survey data (2000) from Collier County, US Army Corps of Engineers cross-sectional surveys gathered in the Golden Gate Estates canal system (2003), and several other land surveys performed by the SFWMD and the Natural Resources Conservation Service.

7.1.4 Canal Network – Hydraulic Data

Channel flows used in the Picayune Strand Restoration modeling are described by the 1-D hydrodynamic river/flood model MIKE 11, which is coupled dynamically to the integrated hydrologic MIKE SHE model. Input for the model consists of the canal and water control structure represented by surveyed cross-sections, appropriate boundary consistent with actual surface boundaries, and bed resistance.

Cross-sections in the MIKE 11 model were converted from existing BCB UNET model with additional 150+ canal cross-sections, and weir, bridge and culvert structure details. The operational features of the control structures were specified according to the Big Cypress Basin Water Control Operation Manual (SFWMD 2007). Boundary conditions are specified at free upstream and downstream ends of the canal network. Upstream is a zero flow boundary. A tidal stage boundary condition has been applied to the downstream end of the channels.

The Manning's M (inverse of the traditional Manning's 'N') is the roughness parameter of the MIKE SHE/MIKE 11 model. Typical Manning's M values for natural stream channels and floodplains were adapted in a range between 5 meters and 35 meters depending on the density of the vegetation in the flow ways. However, many areas of the model, such as Corkscrew Swamp, will have values that exceed those values because of their very dense vegetated floodplain. Those values were based on aerial photographs, site inspections and engineering judgment.

7.1.5 Soil Properties in the Unsaturated Zone

Unsaturated flow in MIKE SHE is computed based on infiltration indices with simplified Richard's equation, and depends on a number of soil properties such as hydraulic conductivity, soil retention, residual soil moisture, and water content at field capacity. Although there are over 50 different soil types in Collier County, soils in the model domain were classified into six different hydrologic response groups. The predominant soil group in each grid cell was assigned to the model grid and soil water flow was calculated for each grid cell accordingly.

7.1.6 Properties of Groundwater Flow in the Saturated Zone

MIKE SHE computes groundwater flow and potential head using a 3-D finite-difference groundwater simulation module. The hydrogeology of the area was represented by three aquifer layers:

- Layer 1 - water table aquifer (the water table aquifer is well connected with the canal systems and responds rapidly to rainfall)
- Layer 2 - lower Tamiami aquifer
- Layer 3 - sandstone aquifer

The hydrogeological parameters specified for each layer in the model include horizontal and vertical hydraulic conductivities, and confined and unconfined storage coefficients. The boundary conditions for the confining layer are an impermeable boundary. The boundary conditions for the three aquifer layers are specified as combinations of constant head and variable head no-flow boundaries.

The Big Cypress Basin Regional Model has been calibrated with a daily observed data on surface water and groundwater stages and stream flows at numerous stations for a period from 1995-1999 and verified with hourly observations from the same period. In order to simplify the calibration procedure and obtain a well calibrated model within a reasonable time frame, some restrictions were imposed on the parameters. The number of primary calibration parameters was limited to available field observations and existing calibrated values used in other MIKE SHE models for watersheds located close to Picayune Strand.

7.2 Model Formulations Utilized for Water Reservation Analysis

The modeling efforts for development of the project implementation report for the project utilized five conditions: 1) natural system (pre-drainage), 2) existing with 2000 land use, 3) future no action, 4) restored (with-project) with 2000 land use, and 5) restored (with-project) with future land use. These conditions were used to evaluate the impact of restoration on surface and groundwater flow patterns and to determine project benefits as required by federal law and policy. The analysis for identification of water necessary for the protection of fish and wildlife requires comparison of two simulations: 1) pre-drainage (natural system) condition and 2) with-project condition.

The models for the two formulations simulated the meteorological conditions of a continuous 13-year period (1988-2000) and also for a representative average year condition. This 13-year period covered a representative cycle of dry, average and wet hydrologic conditions for southwest Florida in recent memory and also has adequate monitored data on rainfall, runoff and water levels for calibration and verification of an integrated model. The year 1994 was represented as a year of average hydrologic conditions during that cycle. The results from the natural systems conditions simulation were used as a baseline for determining how well the restoration performed. Comparison between the existing conditions and the restored system provides a measure of how well the proposed plan has improved the indices for establishing a desirable wetland hydrologic regime for restoration of the all fish and wildlife habitats of the region. For more information on the model and the simulations see the Big Cypress Basin Integrated Hydrologic-Hydraulic Model (DHI 2002) and the project implementation report (USACE and SFWMD 2004).

7.2.1 Pre-drainage Condition

Pre-drainage condition, which is used as the target for this project, is determined using the Natural System Model (NSM). This model attempts to simulate the hydrologic response of pre-drainage Picayune Strand using existing records of rainfall and other climatic inputs. The present landscape of south Florida has been greatly affected by land development, flood control and water management activities that have occurred since the early 1990s. The NSM, in its current form, attempts to simulate the hydrologic system as it would function today without the existence of human influence.

A southwest Florida pre-drainage vegetation map (Figure 8) was incorporated into the NSM to represent the natural condition. Topography data and geologic formation parameters are the same as existing regional model except all of the dominant anthropogenic features like roads, canals and water control structures were removed to represent the historic landscape. The land cover simulated by the NSM is static, i.e., the model does not attempt to simulate vegetation succession.

7.2.2 With-Project Condition

The with-project condition represents the simulation of the proposed elements of the project under the 2000 land and water use conditions using the MIKE SHE Model to observe the performance of the plan in achieving the desired objectives of the project. The configuration of the recommended plan, as illustrated earlier in Figure 4 has the following common features represented in the restored condition model:

- Removed the existing weir structures south of I-75 except for Faka Union #1
- Pump stations on Miller, Faka Union and Merritt Canals
- Existing channel cross-sections downstream of the pumps were replaced by spreader canal cross-sections and floodplain cross-sections extracted from the topography

- Floodplain codes were established between canal overbanks to allow for east-west flow
- Each cell size for the model is 1,500 X 1,500 feet

In the proposed plan, there are 83 canal plugs in the project area. In order to model conditions when the floodplain is fully established, the blocked portion and its cross-sections were modeled as the actual floodplain cross-sections extracted from topography. Flood plain cross-sections were delineated, based on the topography, and was basically added at the location of the existing branches, including Merritt, Miller, Faka Union and Prairie Canals from downstream of the spreader channels to the junction where the channels become one single main channel, Faka Union Canal. The downstream part of Faka Union Canal was maintained downstream of this point and so was the fixed crest weir. As for the spreader channels, the lengths were set to 4,488 feet in Miller Canal, 7,040 feet in Faka Union Canal, and 1,425 feet in Merritt Canal. Minor road widths are generally much smaller than the 1,500-feet by 1,500-feet model cell, and because of this resolution, the simulation road removal was ignored.

Due to the one-dimensional MIKE 11 approach, another modification to the setup was made. The main flow direction in the system is from north to south, but flow between the floodplains may also occur. Consequently, floodplain codes were established at the between canal overbanks to allow for east-west flow, thereby artificially creating one large wetland system.

7.2.3 Topography Issues

Under natural conditions, the topographically lower flowway defines where the main wetland flowway is located. It begins north of the Merritt Canal above I-75 (Figure 3). It turns southwest in northern Picayune Strand, and occupies most of the central portion of Picayune Strand along the Faka Union Canal. It then again turns southwest, crosses the southern end of the Miller Canal and passes into Collier Seminole State Park (Figure 2). There is a relatively deep open water area along the central portion of the Faka Union Canal. Most of the length of the flowway is moderately deep cypress bordered by shallower wet prairies. One distinctly drier portion of Picayune Strand is located along the Prairie Canal, which is where the "ridge line" between the main flowways in Picayune Strand and Fakahatchee Strand is located. This hydrologic "ridge" or "upland" is again created by the upright "U"s in the topographic contours through this area. Thus, the average wet season water depth patterns depicted on the maps from the current version of the MIKE SHE model (Figure 8) are quite reasonable given the current model design, even though they are quite different from what is believed to be the actual pattern.

In the with-project condition, hydrologic pattern is the same as under natural conditions, with some modifications that are appropriate to the restoration components (Figure 4). The northern and particularly the northwestern portion of Picayune Strand are dry because the canals are still present in this area, and the pumps and spreader canals are located below it. Average wet season water depths are generally lower in the central portion of Picayune Strand than under natural conditions. This is possibly due to rapid movement through this area of high flows produced when the pumps move high canal flows out of Northern Golden Gate Estates. This could result in lower average water depths for the majority of the wet season in this area. The associated more rapid movement of these higher flows towards the coast could then produce the generally wetter than natural water depths in the southwestern portion of Picayune Strand. Again, the average wet season water depth patterns depicted on the maps from the current version of the MIKE SHE model (Figure 8) are quite reasonable given the current model design, even though they are quite different from what is believed will be the actual pattern.

Discrepancies with the simulated topography would be significant if the project objective was to establish a new and different type of ecosystem in Picayune Strand from what was there originally. However, since the project's primary restoration objective is to approximate the original ecosystem that was present prior to drainage, it is not necessary to know beforehand the exact pattern of water depths that will be present following restoration. It seems reasonable to assume that the original topography is still present over most of Picayune Strand, and if elimination of what topography has been altered, i.e. the canals and roads, and restore overland flows, should result in average wet season water depths that approximate natural conditions. There will undoubtedly be improvements, including greater water depths in portions of Picayune Strand since there will be more water coming into the area during the wet season to maintain drainage in the Northern Golden Gate Estates. In addition, the resulting lack of wet season storage in Northern Golden Gate Estates also is expected to somewhat reduce dry season water depths. But these differences will be minor compared to the differences between the pre-drainage and currently drained conditions.

Section 8. Quantification of Water for Protection of Fish and Wildlife

A summary of spatial and temporal distributions of the simulated hydrologic responses on surface flow characteristics at selected locations within and around Picayune Strand are illustrated in the following series of figures and tables. These results represent the pre-drainage (target) and with-project hydrologic conditions that are being used to determine the water reservation for the protection of fish and wildlife and the amount of water, if any, in excess of the reservation that can be allocated for consumptive use. All model results are simulated using rainfall for the 1988 through 2000 period under the 2000 land and water use condition for the two scenarios, target (pre-drainage) and with-project. The target for the protection of fish and wildlife in Picayune Strand south of the pump stations is the pre-drainage condition. North of the pump stations the target for the protection of fish and wildlife is the existing condition. At some point in the future, the reservation will be reviewed and revised if needed in light of changed conditions.

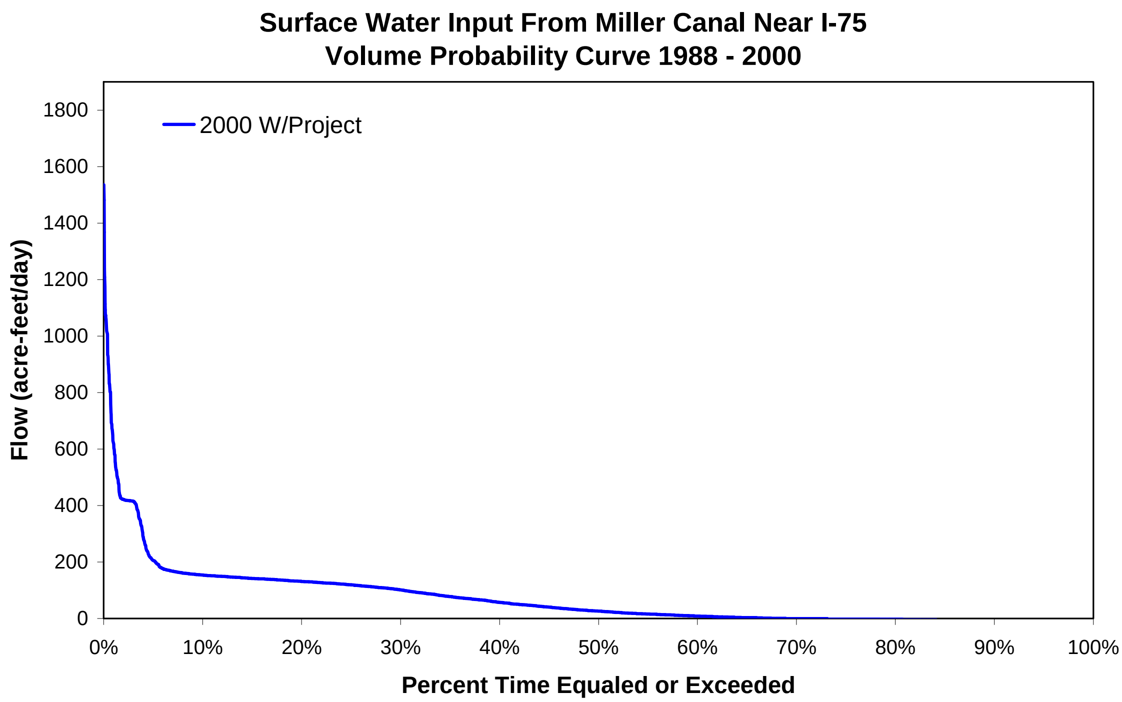
A volume probability curve ranks the daily surface inflows into a basin from the lowest to the highest possible value. Volume probability curves were created for the Miller, Faka Union and Merritt canals near I-75 (pink diamonds in Figure 9), along the Southern Transect (red line in Figure 9), and for Faka Union Canal where it crosses US 41 (blue line in Figure 9) (Figures 12 – 26). For each location, separate volume probability curves were generated for the entire 13-period of simulation, as wells as for the wet (June – October) and the dry (November – May) seasons over the 13-year period of simulation. The curves for the 3 sites near I-75 along the canal represent inflows into Picayune Strand. The Southern Transect represents sheet flow to the estuaries. The inflows from Faka Union Canal at US 41 represent the flows entering Faka Union Bay over the weir. All of the volume probability curves show the water flowing during the with-project condition.

Based on an analysis of the information presented in this document, while the project will improve the hydrology within the terrestrial portions of the Picayune Strand, the water needed for the protection of fish and wildlife will not be fully realized. As a result, all the water entering the project from the three canals located at the northern boundary of the project (Merritt, Miller and Faka Union) are considered necessary for protection of fish and wildlife. The project is effective in redistributing the flows across the southern estuary while reducing the existing harmful excessive flows into Faka Union Bay. The analysis shows that during wet conditions the project will discharge water above what is considered to be necessary for the protection of estuary fish and wildlife. However, during average and dry conditions, all of the discharges are less than or equal to the natural system targets for protection of fish and wildlife

To better understand the timing and distribution on flows, flow hydrographs for the 13-year period of record are for these stations comparing with-project flows to the targets are provided in Appendix B.

In Figure 21, the probability curve for flows throughout the entire period of simulation (1988 through 2000) indicates that 100% of the time, the target for the estuaries is met, with exceedances (water quantities exceeding target amounts) occurring less than 35% of the time. Figure 23, which represents wet season conditions, indicates the target is slightly exceeded approximately 60% of the time with-project. Dry season conditions depicted in Figure 25 indicate the flows for with-project simulation closely match the target. Similar results are shown for surface water deliveries at Faka Union Canal outlet near US 41 (Figures 22, 24 and 26). As indicated in the volume probability curve figures, the hydrologic conditions with-project closely approach the target levels for the estuaries.

Figure 12. Volume probability curve for surface water inflow from



Miller Canal near I-75 for 1988 through 2000

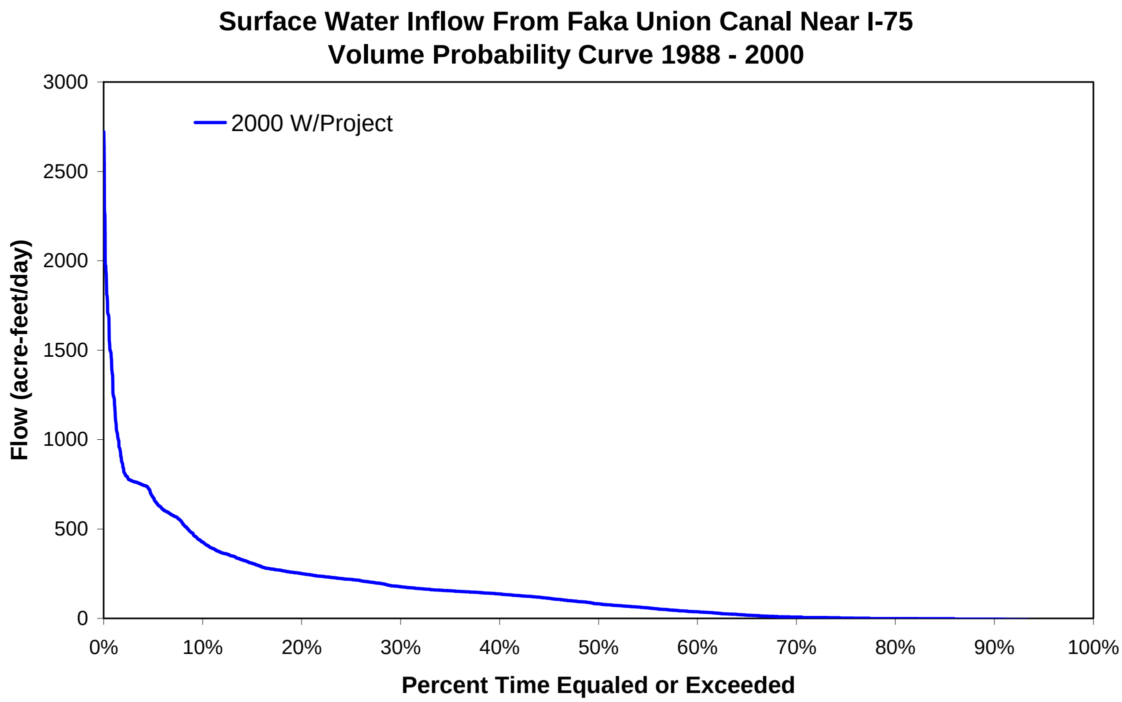


Figure 13. Volume probability curve for surface water inflow from Faka Union Canal near I-75 for 1988 through 2000

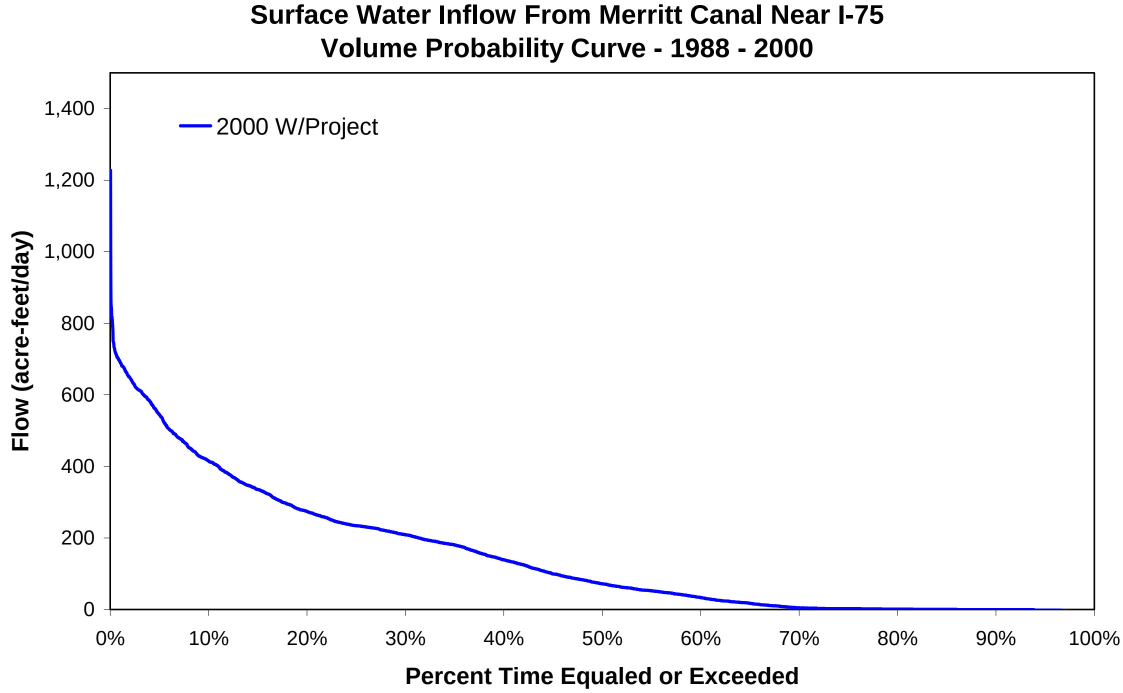


Figure 14. Volume probability curve for surface water inflow from Merritt Canal near I-75 for 1988 through 2000

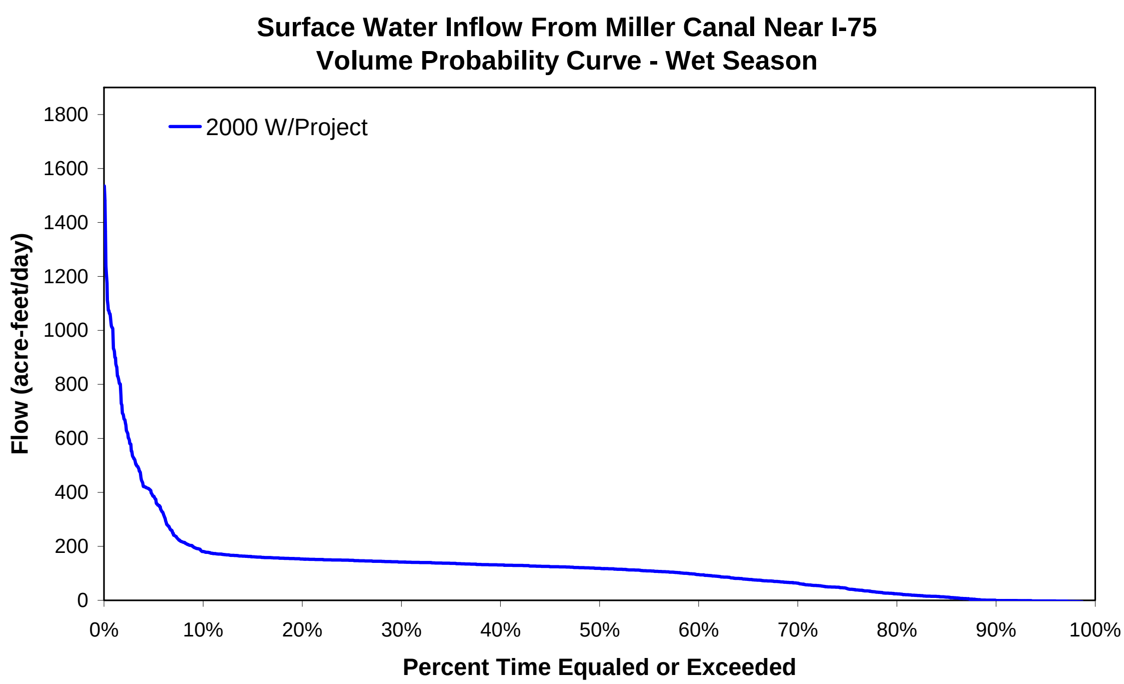


Figure 15. Volume probability curve for surface water inflow from Miller Canal near I-75 for the wet season

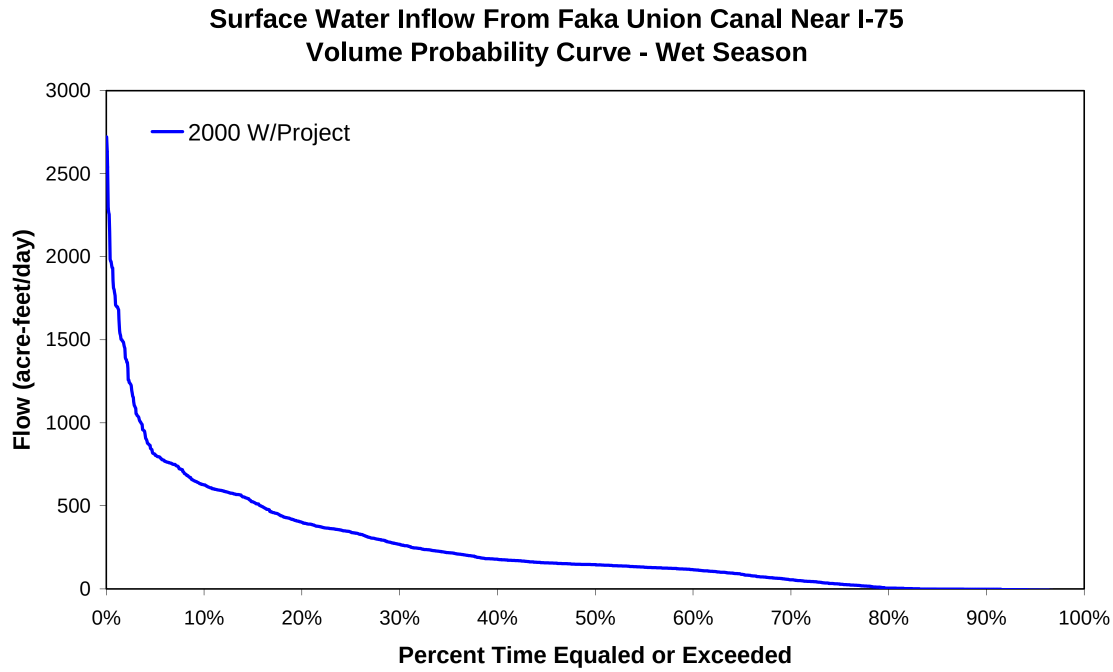


Figure 16. Volume probability curve for surface water inflow from Faka Union Canal near I-75 for the wet season

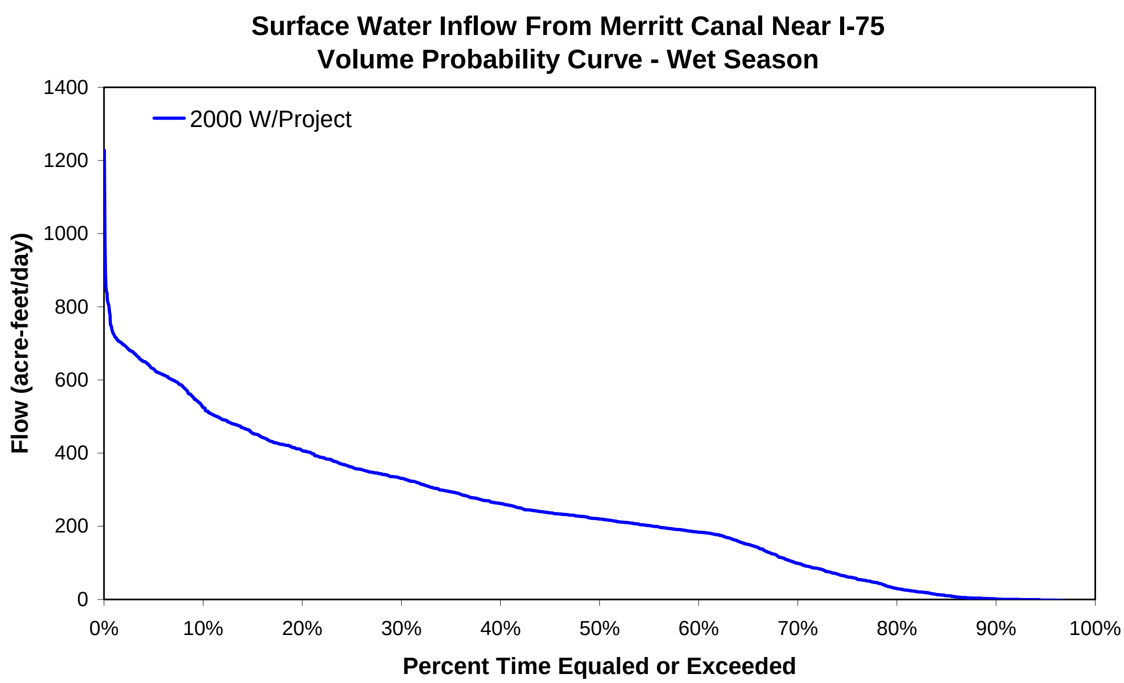


Figure 17. Volume probability curve for surface water inflow from Merritt Canal near I-75 for the wet season

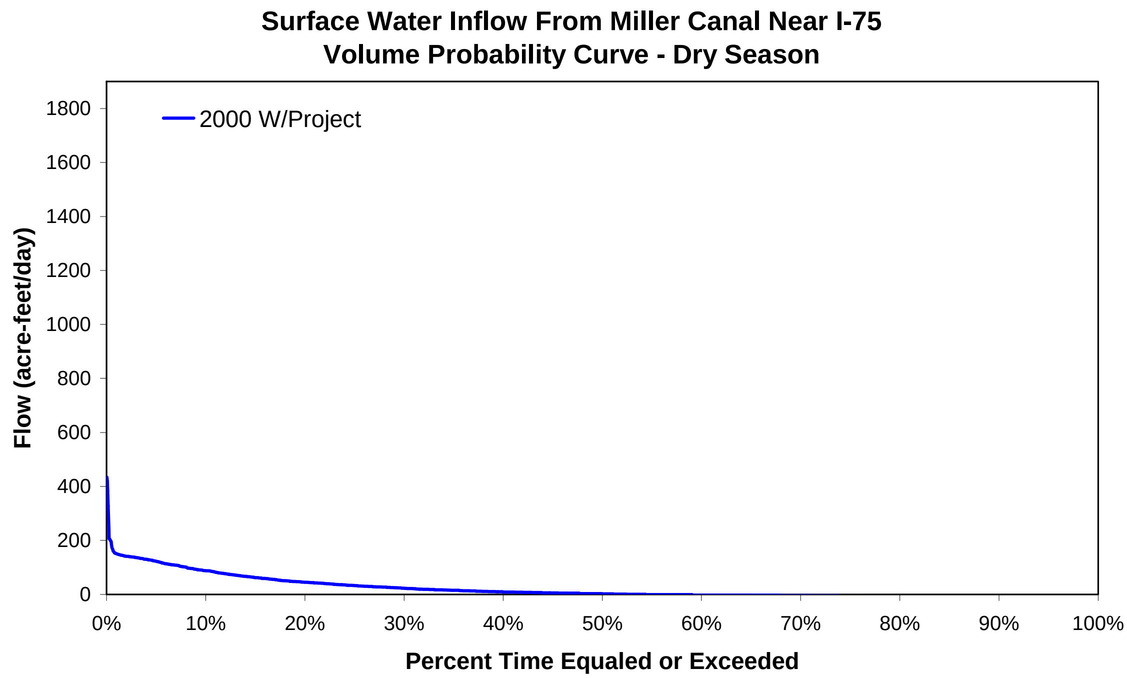


Figure 18. Volume probability curve for surface water inflow from Miller Canal near I-75 for the dry season

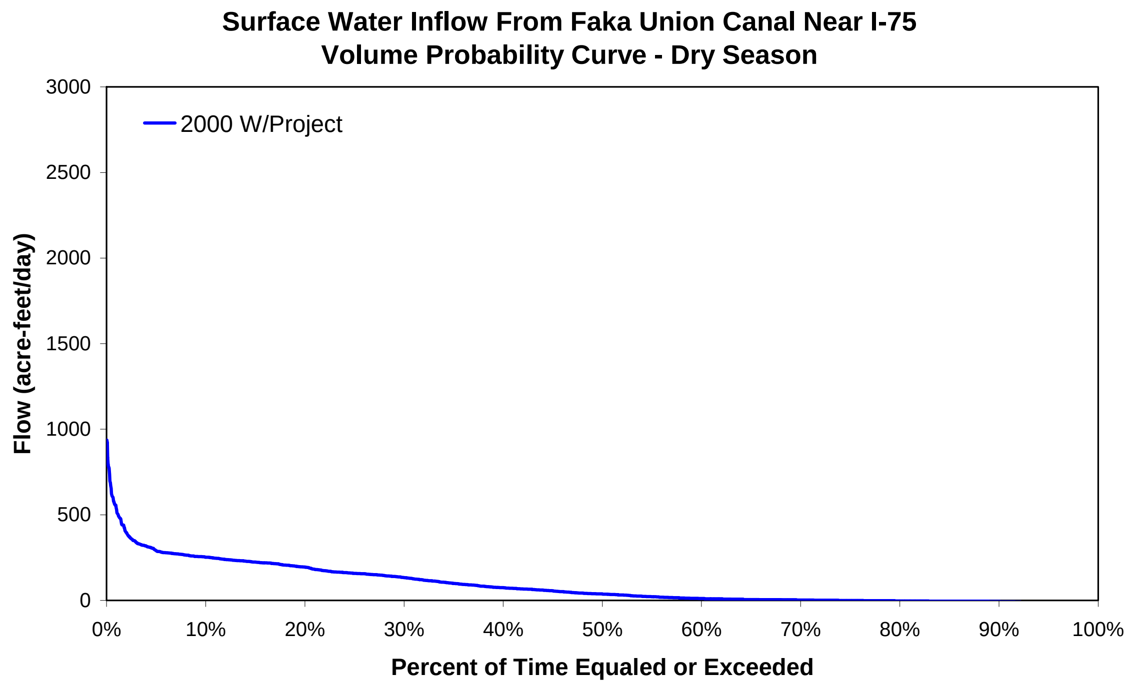


Figure 19. Volume probability curve for surface water inflow from Faka Union Canal near I-75 for the dry season

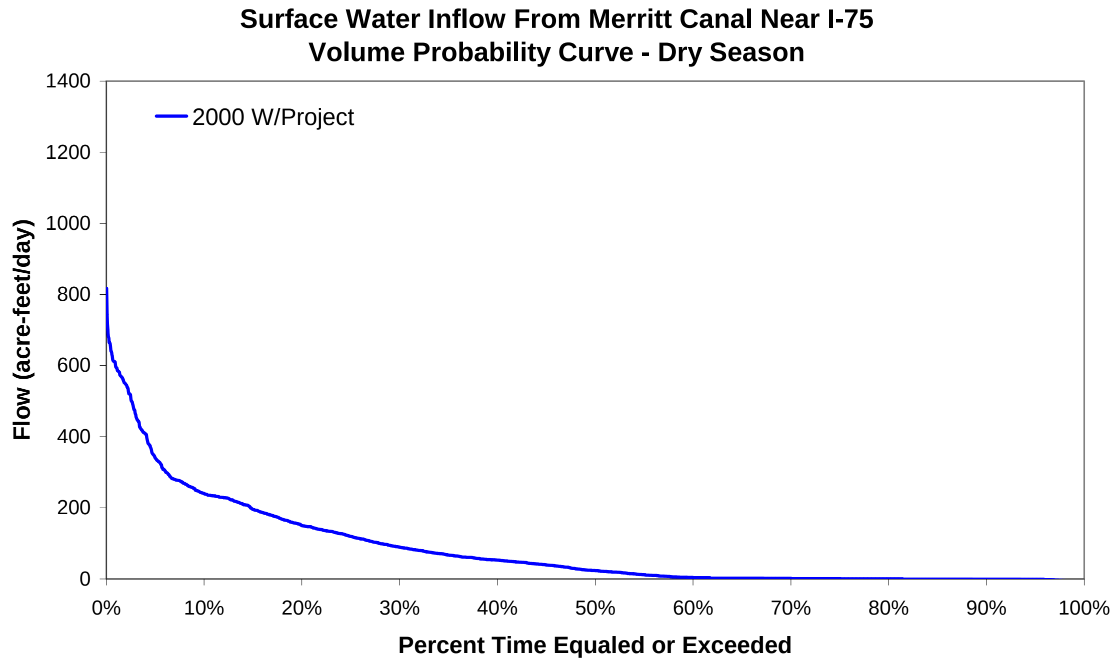


Figure 20. Volume probability curve for surface water inflow from Merritt Canal near I-75 for the dry season

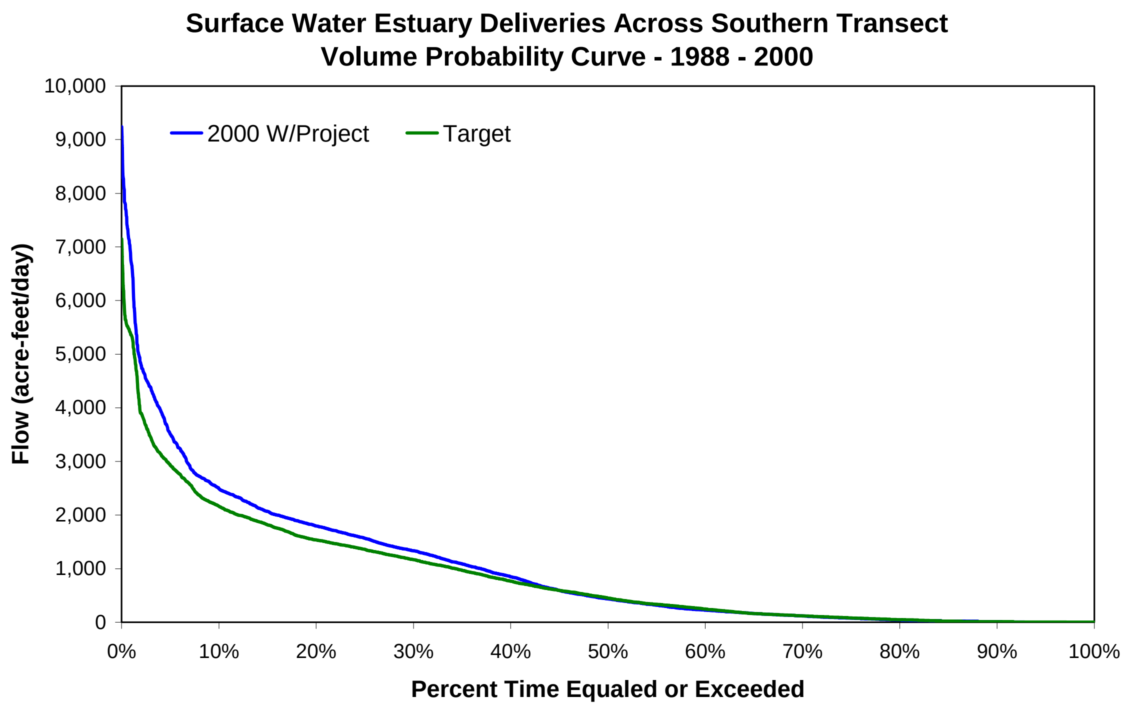


Figure 21. Volume probability curve for surface water deliveries across the Southern Transect for 1988 through 2000

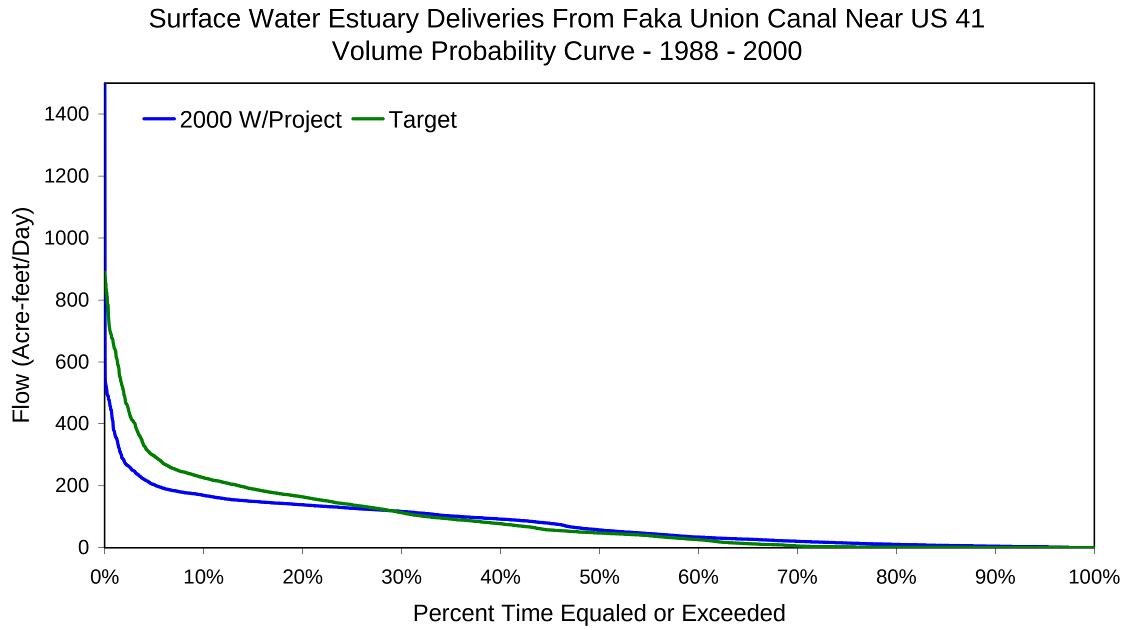


Figure 22. Volume probability curve for surface water inflow from Faka Union near US 41 weir into Faka Union Bay for 1988 through 2000

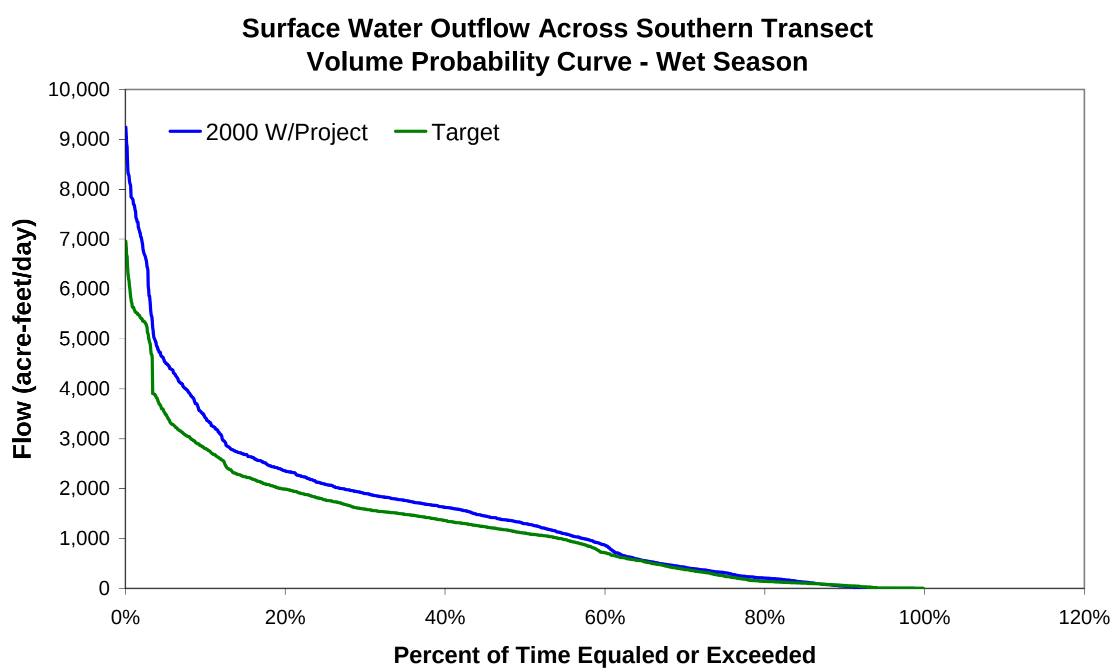


Figure 23. Volume probability curve for surface water deliveries across the Southern Transect for the wet season

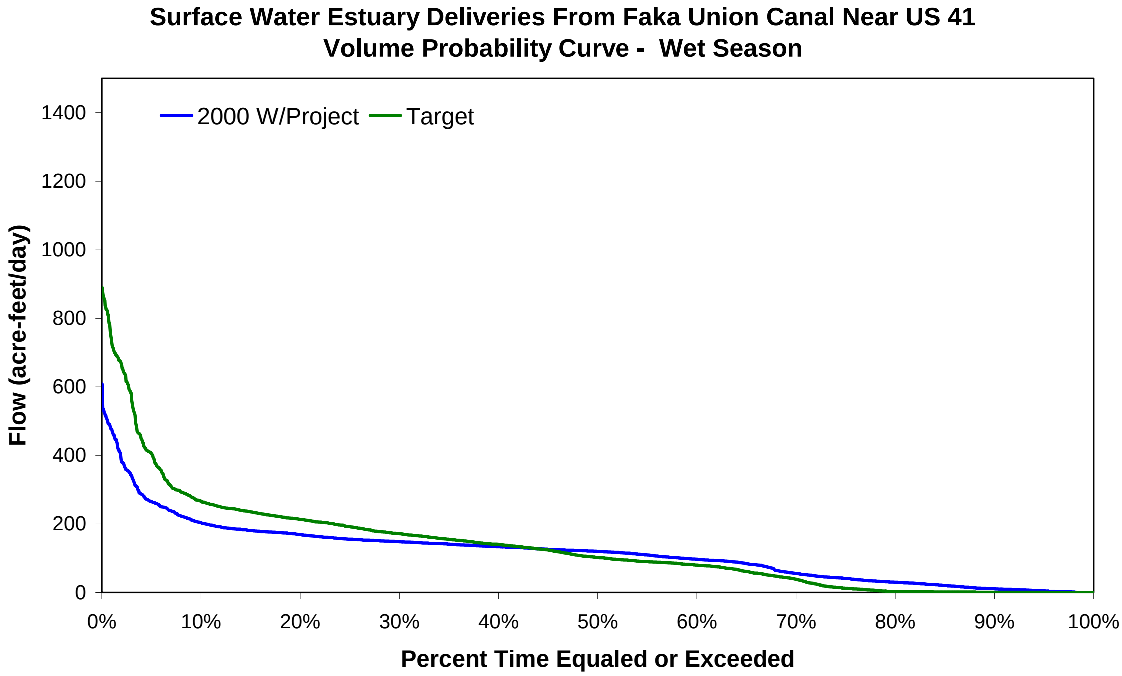


Figure 24. Volume probability curve for surface water inflow from Faka Union near US 41 weir into Faka Union Bay for the wet season

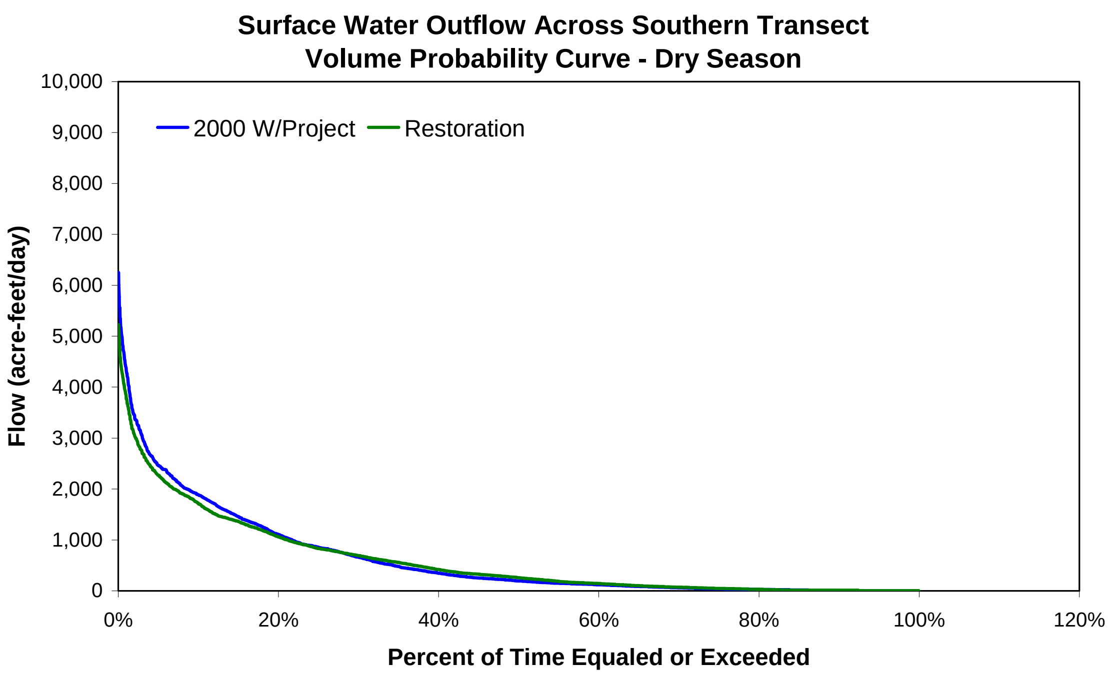


Figure 25. Volume probability curve for surface water deliveries across the Southern Transect for the dry season

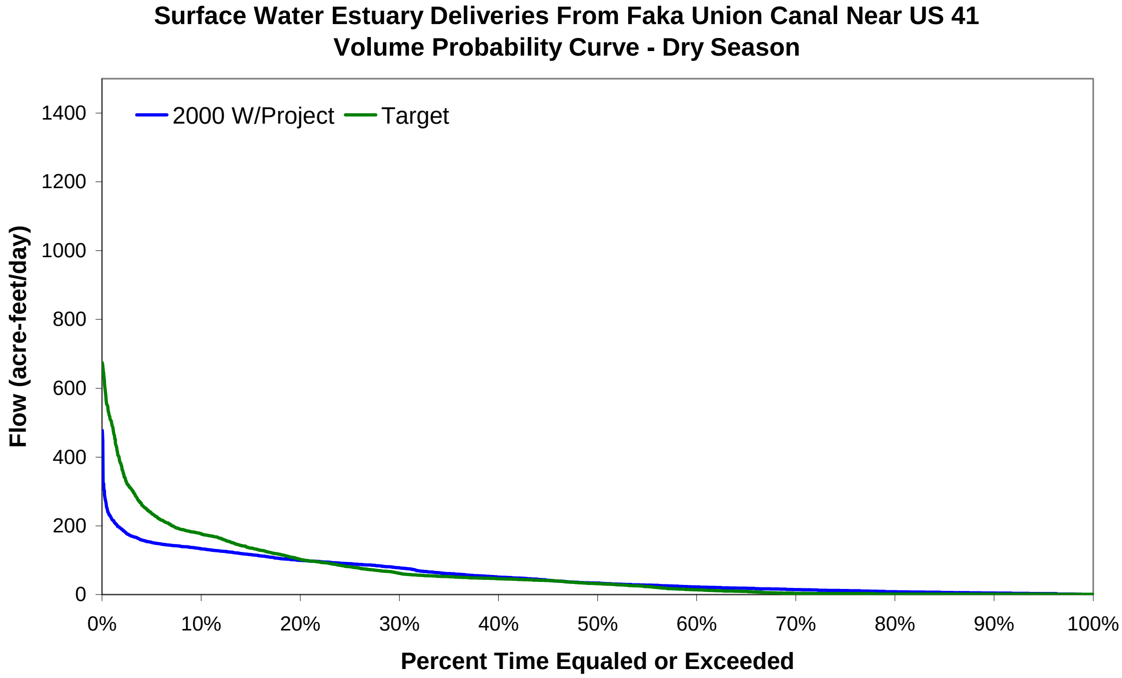


Figure 26. Volume probability curve for surface water inflow from Faka Union near US 41 weir into Faka Union Bay for the dry season

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