SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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

February 9, 2009

Executive Summary

The purpose of this document is to summarize technical information contained in the Picayune Strand Restoration project implementation report (USACE and SFWMD 2004) and other sources to establish clear relationships among freshwater flows within and 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 that use the habitat in its healthy state. Two distinct water reservations will be made 1) water within the Picayune Strand Restoration Project boundary for the protection of its fish and wildlife and 2) water at the southern boundary of the project for the protection of estuarine fish and wildlife.

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), Florida Administrative Code (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, without-project and with-project conditions were calculated. The target for Picayune Strand is the pre-drainage condition.

The analysis of the information presented in this document identifies small quantities of water irregularly available that is not part of the water identified to be reserved for the protection of fish and wildlife for the Fakahatchee Estuary. The reservations will be reviewed and revised if needed in light of changed conditions no later than 2014 per the water reservation rules contained in proposed Chapter 40E-10, FAC.

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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) surface freshwater flows and the ecological response of inland 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. There are two distinct quantities of water to be reserved: water for the protection of fish and wildlife within the boundary of the Picayune Strand Restoration Project and water for the protection of estuarine fish and wildlife found in the Fakahatchee Estuary. The hydrologic restoration targets for both the inland and estuarine systems are the pre-drainage hydrologic conditions.

This document highlights key pieces of technical information 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, 2) the existing condition (2000) with the project features implemented (with-project), and 3) the existing condition (2000) without the project features implemented (without-project). Finally, it quantifies the water to be reserved under state law for both Picayune Strand and the Fakahatchee Estuary.

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 reviewed the information contained in this report and related documents and provided 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 panel's final report is provided in Appendix C of this document. The SFWMD incorporated the panel's recommendations into the technical document and summarized the SFWMD responses in Appendix D.

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; US Congress 2000) and in Sections 385.26-27 of the Programmatic Regulations for Implementation of the Comprehensive Everglades Restoration Plan (DOD 2003). This will ensure 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, Chuirazzi et al. 2009) 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
- 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 the web board accessed from https://my.sfwmd.gov/watersupplyruledevelopment, Water Reservations tab.
- Picayune Strand Restoration Project: Faka Union/Miller Pump Stations-Levees, Canals and Roads Technical Review Briefing presentation (NOVA Consulting, Inc. 2008). Available on the web board accessed from https://my.sfwmd.gov/watersupplyruledevelopment, Water Reservations tab.
- Assessment of Salinities and Bio-Abundances Resulting from Runoff into Faka Union Bay for CERP Scenarios (Wang and Browder 2004). Available on the web board accessed from https://my.sfwmd.gov/watersupplyruledevelopment, Water Reservations tab.

1.2 Document Structure

This document is organized into ten 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 inland system and its valued ecosystem components. Section 5 describes the estuarine system and its valued ecosystem components. 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), with-project, and without-project hydrologic conditions. Section 8 presents the modeling results. Section 9 summarizes the portion of existing and with-project water to be reserved for protection of fish and wildlife. Section 10 contains references cited within this report.

Four appendices are also provided. Appendix A contains a description of indicator regions and graphs that compare pre-drainage (target), with-project and without-project water stage for the 32 indicator regions, which allows us to see changes in water depths within specific areas of Picayune Strand and the surrounding area. Appendix B contains graphs of surface water inflows to the project from Miller, Faka Union and Merritt Canals near I-75 for the 13-year period of simulation. This represents the water expected to flow in these canals from Northern Golden Gates Estates and elsewhere to Picayune Strand and be distributed through the pump stations located at the north end of the project at these canals. Appendix C contains the Scientific Peer Review of the Draft Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream Estuaries, and Appendix D summarizes our responses to panel recommendations.

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 the Fakahatchee Estuary 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 (USACE and SFWMD 2004). 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 such uses 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 1** 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 was used for revising and refining this document.

A public rule development process for stakeholders and interested persons has been 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. The SFWMD Governing Board authorized the notice of rulemaking on December 2, 2008 , and is scheduled to hold a public hearing adopting the final rule.

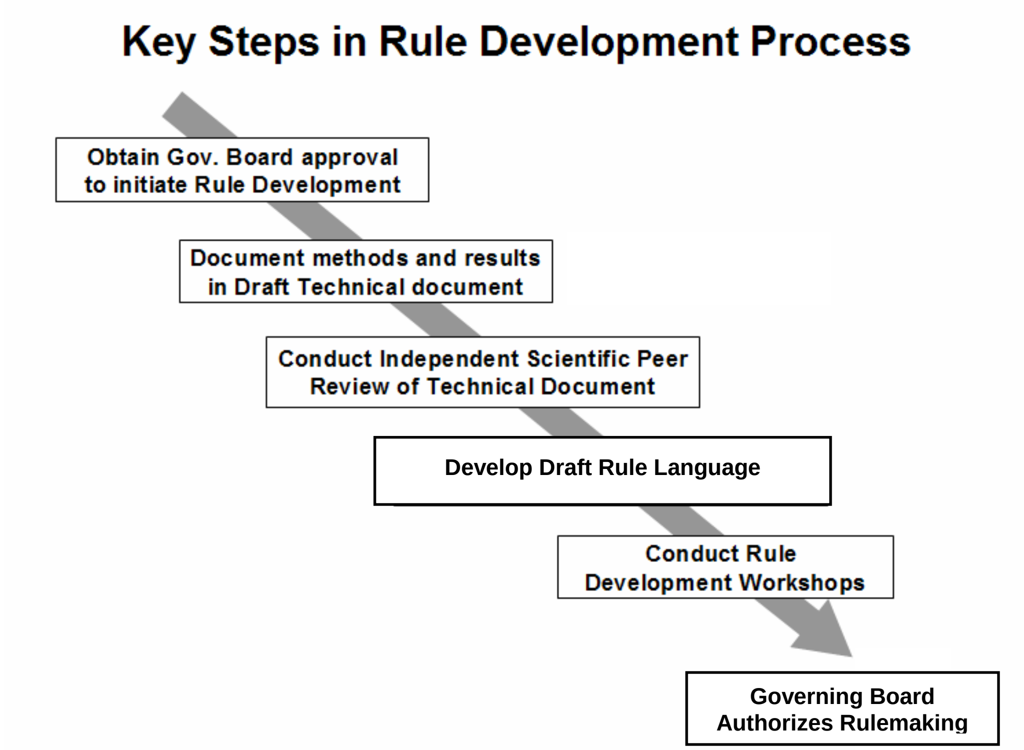

Figure 1. Process steps for developing technical information in support of a rule

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.
- Determine valued ecosystem components.
- 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. Roads and canals are impeding overland sheet flow. An extensive canal system was excavated to drain surface waters and provide fill for the road system. 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 Faka Union Bay, greatly decreased freshwater overland flow and seepage into the remaining receiving estuaries, 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.

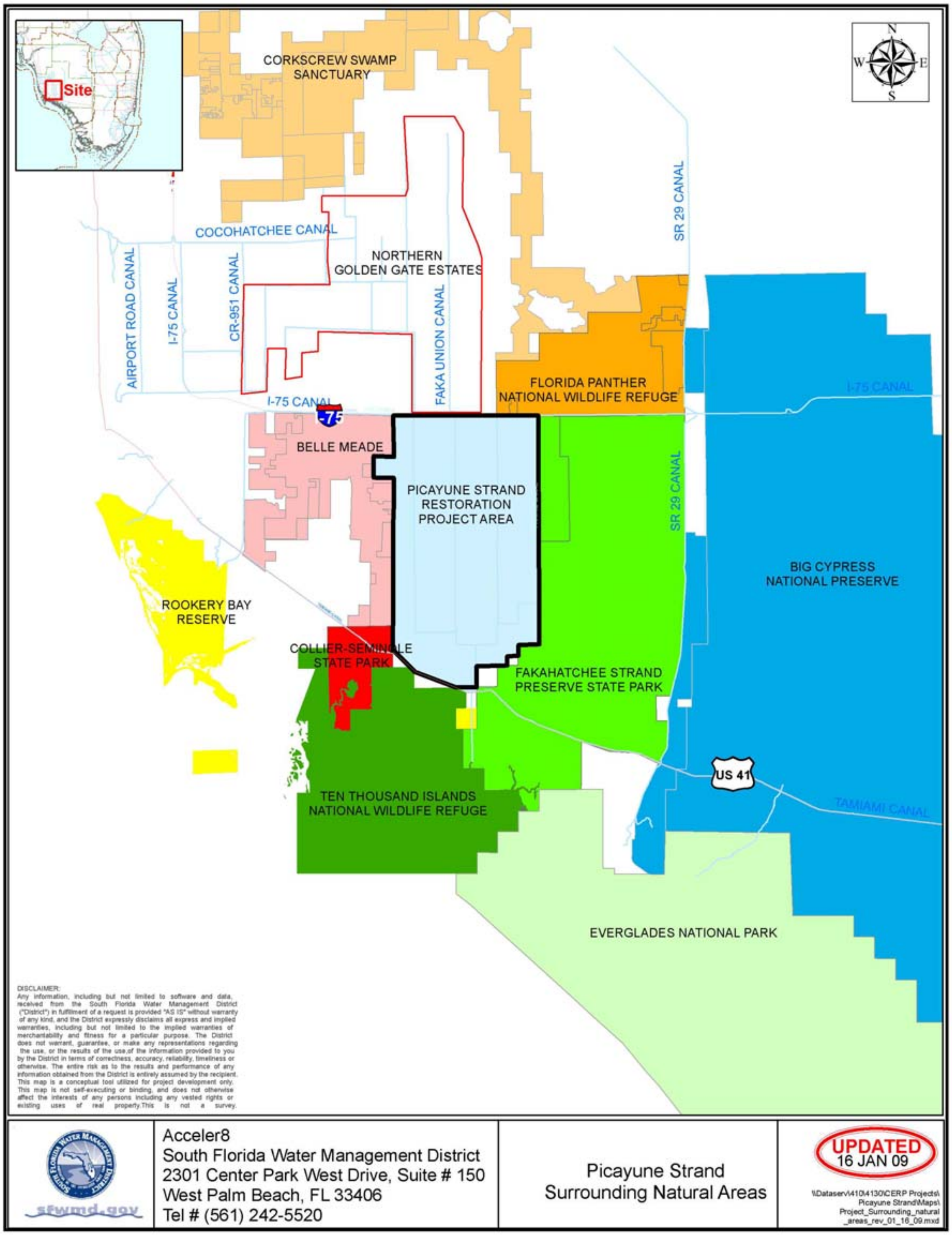

Figure 2. Picayune Strand Restoration project and surrounding area

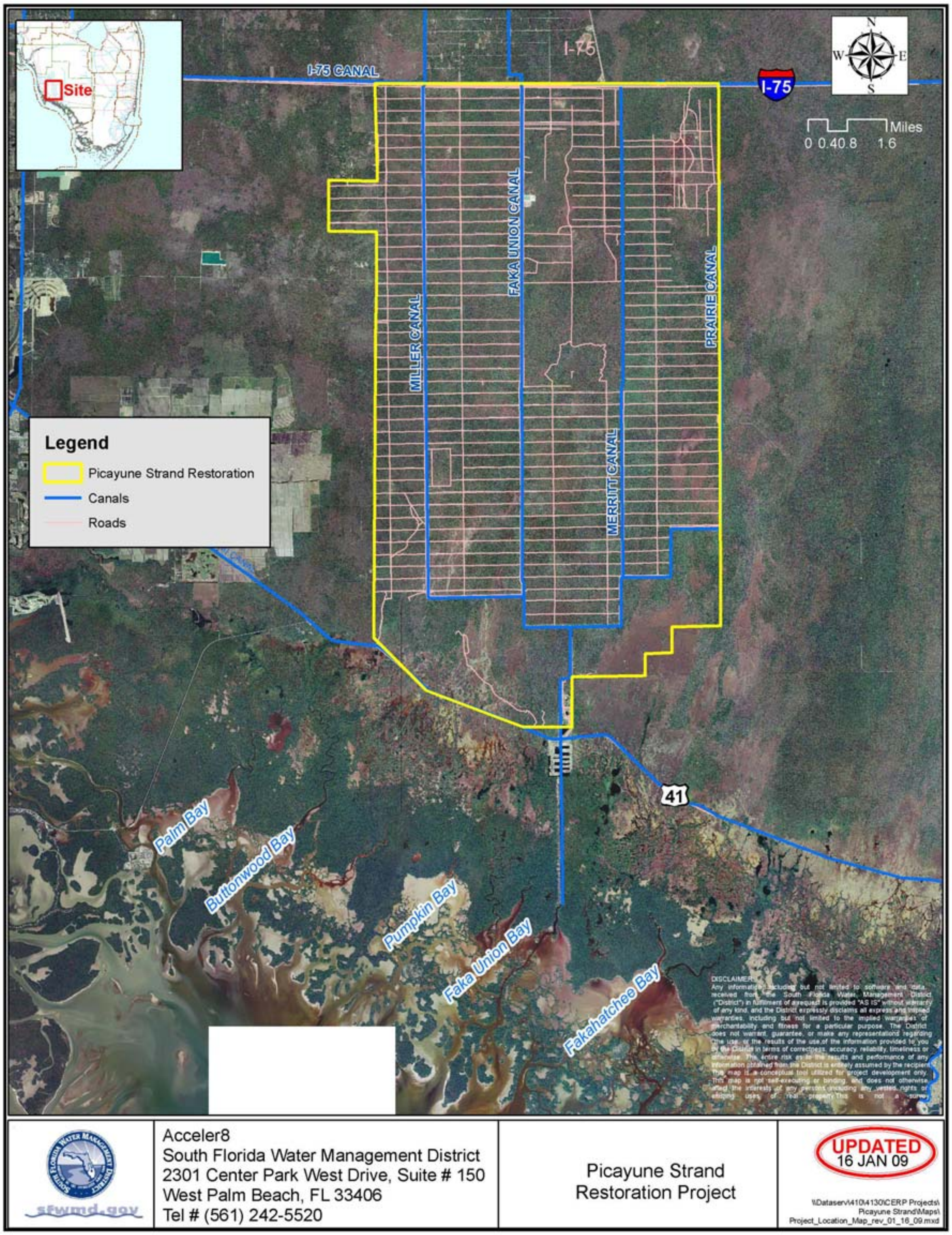

Figure 3. Southern Golden Gates Estates subdivision infrastructure and downstream estuaries

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 degradation 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, more than 8,000 acres will not receive flows so as to provide flood protection for upstream developed areas in Northern Golden Gates Estates by maintaining the same canal stages existing today. A levee will protect the Port of the Islands development. Additional conveyance will be placed under US 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, Buttonwood, Pumpkin, Faka Union and Fakahatchee Bays (**Figure 3**).

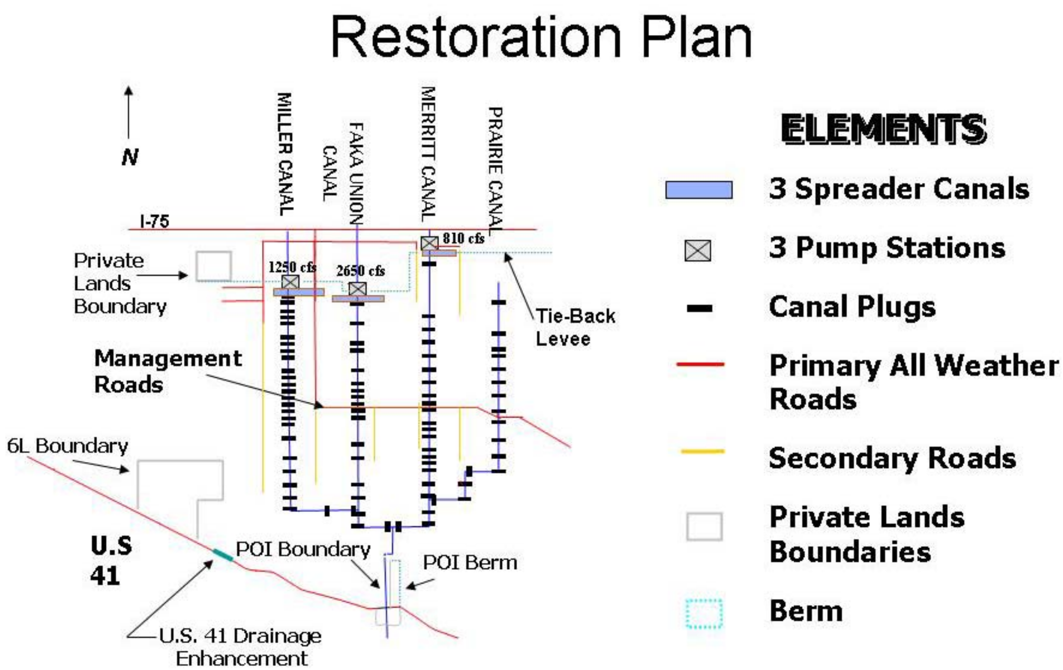

Figure 4. Construction features of the Picayune Strand Restoration Project

3.5 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, one pump station 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 cubic feet for second (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 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

Pump Station	Optimum Canal Stages (feet NAVD 88[1])	
	Wet Season	Dry Season
Miller	4.9	5.15
Faka Union	4.9	5.15
Merritt	5.2	8.0

[1] NAVD 88 = North American Vertical Datum of 1988

Section 4. Description of Picayune Strand Watershed and Valued Ecosystem Components

4.1 Watershed Description

4.1.1 Physiographic Setting

The Picayune Strand Restoration Project Area 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 Project 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 Fakahatchee Estuary, which is discussed in Section 5.

4.1.2 Climate

The Picayune Strand Restoration Project 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 (° F), with record extremes ranging from 105° F in late spring to 25° F 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. Pre-drainage surface runoff in the project area has been reported to be on the order of 0 to 10 inches annually (Kenner 1966).

4.1.3 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 Swamp. 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.

4.1.4 Hydrogeology

The geology of the area consists of a surficial aquifer system, the Lower Tamiami Aquifer and a 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).

4.1.5 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 sheet flow 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. Pre-drainage, natural surface runoff in the area has been reported to be up to 10 inches annually (USACE and SFWMD 2004). Seasonal flooding occurred over several to many 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 sheet flow receded below the ground surface. This natural sheet flow 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. Under pre-drainage conditions, fresh water reached the Ten Thousand Islands estuaries and associated acreages of salt marsh and mangrove swamp through a combination of overland sheet flow and groundwater seepage (USACE and SFWMD 2004). These estuaries are discussed in Section 5.

4.1.6 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.

4.1.7 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).

4.1.8 Fire

Fires were a common occurrence prior to drainage of the Picayune Strand area. They were an important ecological factor in the historic health and survival of many terrestrial and wetland communities. Natural fires were most common during the summer wet season because of the high frequency of lightening (Robertson 1953, Duever 2005). However, fires were often most extensive in late spring when lightning strikes from early wet season storms started fires at a time of year when water tables were at their lowest, and the overall landscape was at its driest. 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. Because this is when water supply demands are greatest, this is one of the most important reasons for protecting natural system hydrology at this time of year.

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 these unusually severe 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).

4.1.9 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).

4.2 Picayune Strand Valued Ecosystem Components

Hydrologic alterations within Picayune Strand have had major impacts on vegetation and wildlife, not only in the strand itself, but on surrounding lands in Fakahatchee Strand and Belle Meade as well. The lowered water levels and the associated increasingly severe fires are steadily converting natural plant communities to communities of exotic plant species and virtually mono-specific palm forests. The drained lands can no longer support the once abundant aquatic fauna that populated Picayune Strand during the summer wet season and was the base of the food chain for wading birds and other predators during the dry season. The clear linkages between hydrology and plant communities and between hydrology, aquatic fauna, wood storks and white ibis, and the relative ease with which they can be monitored make them particularly useful as valued ecosystem components.

4.2.1 Major Plant Communities

Hydrologic and fire regimes control the character and distribution of major types of plant communities in the Picayune Strand Restoration Project 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, resulting in dense stands of fire-tolerant cabbage palms and fast-growing woody exotics in some areas (Tabb et al. 1976, Gunderson and Loope 1982).

The reduced depth and duration of inundation have affected plant community composition within Picayune Strand, which has changed from that of primarily wetland vegetation to a more upland system, now dominated over large areas by invasive native and exotic vegetation (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). Much of the original cypress and cypress with palms communities have been replaced by cabbage palm hammocks or pine flatwoods (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 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, invasive native and exotic 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.

The native cabbage palm has become dominant throughout much of the project area during the past few decades (SFWMD and NRCS 2003). These palms form dense populations of similar-sized, young trees, beneath widely spaced individuals that appear to be much older. The younger palms are thought to be 20-30 years old, having originated after the hydrology of the area changed. 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).

Environmental Factors Controlling Composition and Characteristics of Major Southwest Florida Plant Communities

Our understanding of the hydrologic regimes for the major southwest Florida plant communities (**Table 2**) have evolved from work initially done in the mid-1970s at Corkscrew Swamp Sanctuary. This study was designed to document the effects on the sanctuary of drainage associated with the Golden Gate Estates developments. A number of approaches were used over a three-year period to document changes in the Corkscrew Swamp ecology that could be attributed to the large downstream development. However, all of the parameters, including weekly water level measurements at 31 sites located in all of the major plant communities, indicated there had been no significant changes in the Corkscrew Swamp hydrologic regime or other aspects of its ecology that could be attributed to the Golden Gate Estates drainage canals. Since the canals were the only major disturbance in the Corkscrew Swamp watershed, it appeared that the three years of hydrologic measurements that were collected in this study represented the best information available on an undisturbed natural ecosystem in southwest Florida and possibly all of south Florida. Over the years, it has become apparent that hydrologic regime is the most significant driver in determining distribution of upland (pineland, hardwood hammocks), wetland (wet prairie, marsh, cypress) and aquatic (ponds, lakes, streams) plant communities in south Florida.

Fire is another major natural driver in further shaping the character and distribution of plant communities. Fire determines the successional status of major community types, as well as providing a disturbance mechanism that can reset the successional sequence. Thus, pineland can succeed to hardwood forests in the absence of fire, and can be returned to pineland with the appropriate fire regime. Wet prairies, which occur on mineral soils, can succeed to wax myrtle (*Myrica cerifera*) thickets, which can then succeed to cypress at the wetter end of the gradient and to pine and eventually, hardwood forest on the drier end of the gradient. Marshes, which occur on organic soils, succeed to willow (*Salix caroliniana*) thickets and then cypress (*Taxodium distichum*), which can succeed to cypress forest on the drier end of the moisture gradient and to swamp forest on the wetter end of the gradient. Ponds can be created by fires burning into organic marsh or swamp forest soils and can gradually refill with organic sediments and become marshes and eventually swamp forests over long periods of time. With sufficiently frequent and severe fires, the later successional stages can be reset to earlier successional stages.

The next most important driver of the character of south Florida plant communities is a site's substrates, which can be described as sand, marl, rock and organic. Pinelands are on mineral soils. Hardwood hammocks can be described by the dominant canopy species, which are associated with certain types of substrates: oaks on sandy soils, swamp bay and red maple on loamy soils, and tropical hardwood hammocks on rocky soils. As was mentioned earlier, wet prairies are typically on mineral soils (sand, marl and rock), while marshes are on organic soils. The more mono-specific cypress forests are on mineral soils, while mixed cypress - hardwood swamp forests are on organic soils.

Table 2. Hydrologic regimes for major southwest Florida plant communities

Southwest Florida Plant Communities	Hydroperiod (months)	Seasonal Water Level (inches)		
		Wet Average Year	Dry Average Year	1-in-10 Year Drought
Xeric Flatwood Xeric Hammock	0	< -24	-60	-90
Mesic Flatwood Mesic Hammock	≤1	≤ 2	-46	-76
Hydric Flatwood Hydric Hammock	1 - 2	2 - 6	-30	-60
Wet Prairie Dwarf Cypress	2 - 6	6 - 12	-24	-54
Marsh	6 - 10	12 - 24	-6	-46
Cypress	6 - 8	12 - 18	-16	-46
Swamp Forest	8 - 10	18 - 24	-6	-36
Open Water	>10	≥ 24	< 24	-6
Tidal Marsh Mangrove Beach	Tidal	Tidal	Tidal	Tidal

The successional models assume that seed sources are always immediately available when conditions become appropriate for a species to be able to germinate and survive on a specific site. They also assume that these natural processes are operating over long time periods (centuries) in an ecosystem without human disturbances. The only place for which we have hydrologic and plant community data in south Florida where these conditions were approximated in the 1970s was Corkscrew Swamp Sanctuary, which lay in the upper part of a watershed with little development at that time.

The water levels and hydroperiods in the models and **Table 2** do not overlap because of the necessity of having unique hydrologic ranges for each major habitat when interpreting model output. Obviously, there is significant overlap in the actual hydrologic characteristics among the various major plant communities, but these could not be recognized if we were going to use the model as a predictive tool for identifying the location and acreages of plant communities.

The above concepts have been incorporated into a number of models over the years. The first model (**Figure 5**) was created for the Corkscrew Swamp Sanctuary (Duever et al. 1976). This was later modified to apply to natural plant communities in southwest Florida (Duever 1984) (**Figure 6**), the Kissimmee River floodplain in 1993, Disney Wilderness Preserve in central Florida in 1999, and finally to south Florida in 2006 (**Figure 7**). In addition, the hydrology of major plant communities had been studied at Lake Hatchineha in central Florida in 1985 (Duever et al. 1988) and the Okefenokee Swamp in 1977-1986 (Duever 1979). Each site contributed information on hydrology and plant community relationships, sometimes based on years of field water level measurements, and other times based on a consensus among knowledgeable people with many years of field experience in an area. These relationships varied from site-to-site, largely as a function of amounts of water flowing through the sites and the size of the wetlands and/or water bodies. Sites with more through-flow were flashier systems with a greater range and frequency of water level fluctuations. Larger isolated wetlands and/or water bodies had a lesser range of water level fluctuation and longer hydroperiods. However, the relative ranking of the plant communities still remained the same at all of the sites even if the specific ranges of the hydrologic parameters were different. The current version of the south Florida fire and hydroperiod succession model (**Figure 7**) and the supporting description of major plant community characteristics (**Table 3**) were developed between 2000 and 2006 by a subcommittee of the South Florida Interagency Fire Management Council. The final draft of this version was presented at the Council's annual meeting in December 2006.

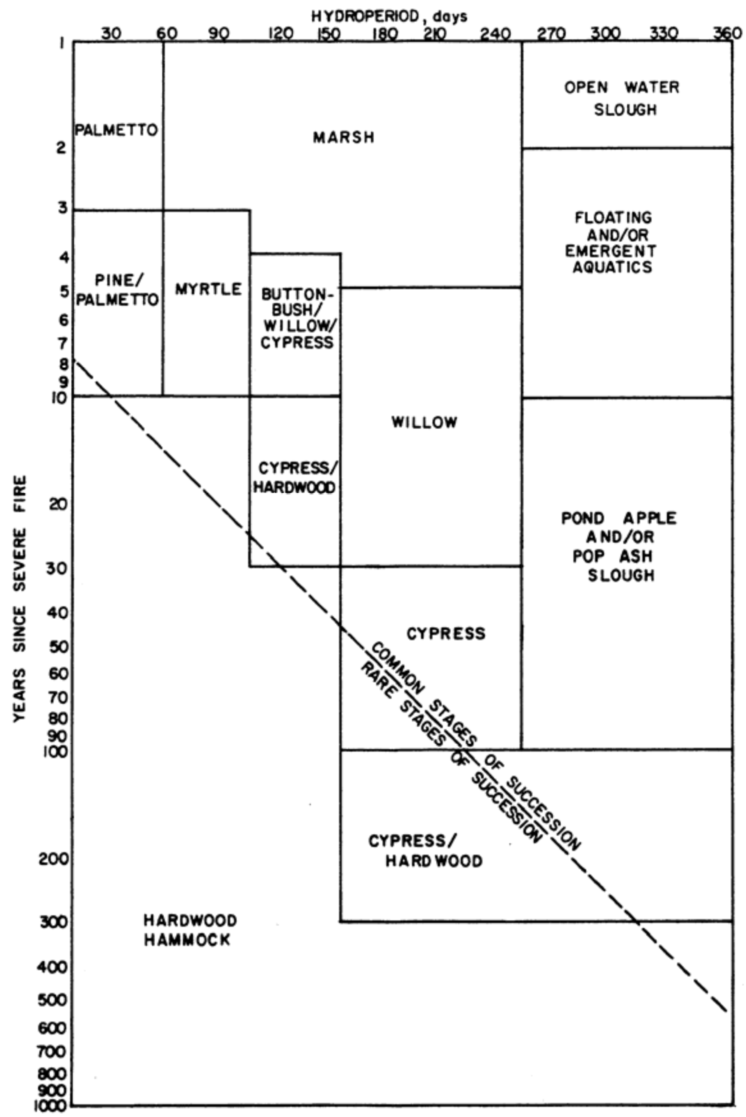

Figure 5. Successional patterns and rates in Corkscrew Swamp plant communities

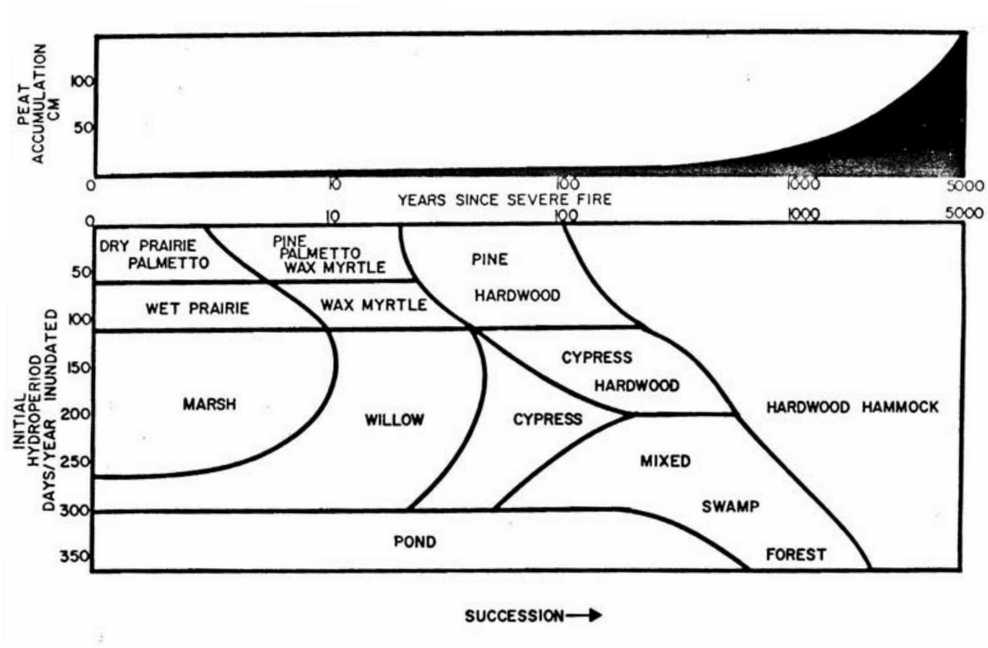

Figure 6. Big Cypress Swamp successional patterns as a function of hydroperiod and time since severe fire and peat accumulation as a function of time

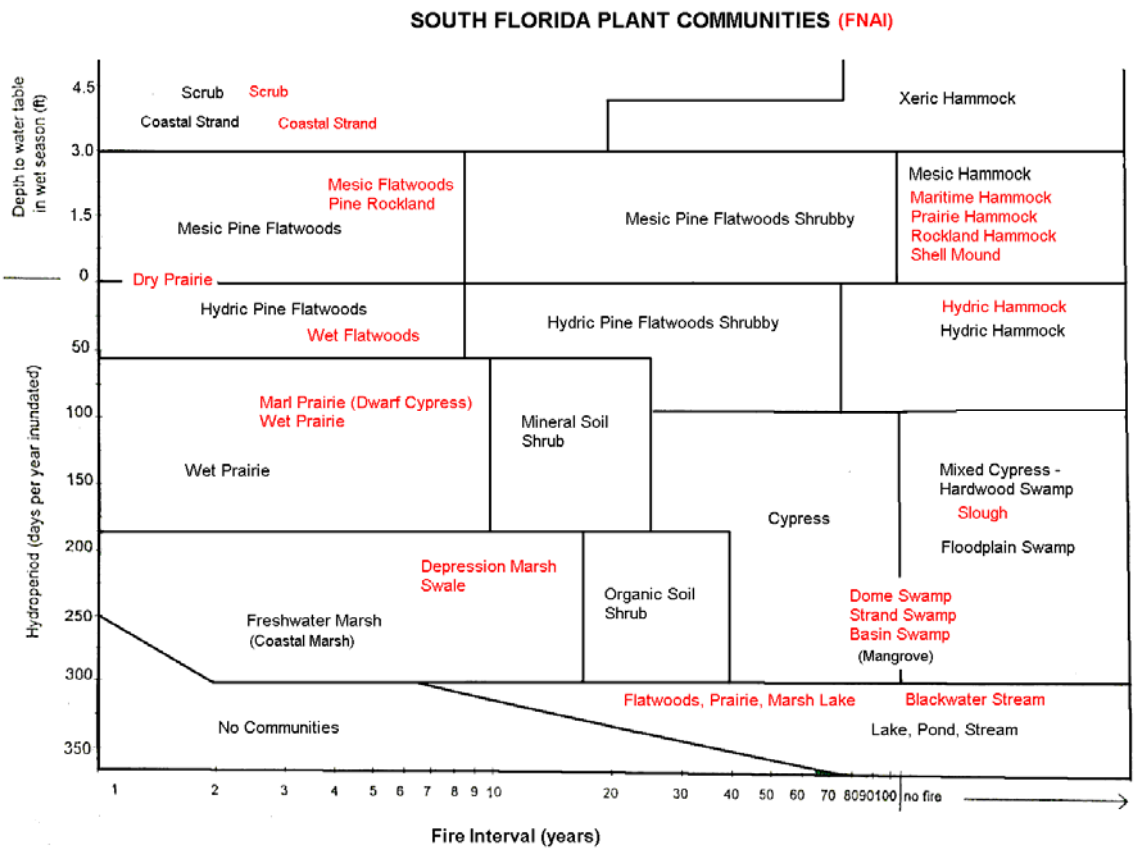

Figure 7. Current version of the south Florida fire and hydroperiod succession model

Table 3. Plant communities and their characteristics in south Florida

Plant Community	Topographic Setting and Soils	Dominant Vegetation	Hydrology	Fire
Lake, Pond	Basins of standing water that are too deep for emergent vegetation.	Floating or submerged aquatic plants.	Normally have water above ground. Edges or all (depending on size and depth) could dry down in extreme (>50 year) droughts.	During extreme droughts, exposed dry organics on bottom can burn. Can be created by organic soil fires.
Stream	Flowing water in a distinct channel that is too deep for emergent vegetation.	Floating or submerged aquatic plants.	Normally continuous flows, with amounts and rates of flow dependent on size of water pulses from rainstorms or water control structure releases. Groundwater base flow inputs.	During extreme droughts, exposed dry organics on bottom of old oxbows can burn.
Floodplain Swamp	Lands associated with streams that are regularly, but not continuously, inundated by flowing water.	Canopy of cypress and/or mixed hardwoods, including Carolina ash, red maple, pond apple, sabal palm, Florida elm.	Shallow-to-deep intermittent flooding depending on size of pulses of water from rainstorms or water control structure releases. Groundwater base flow inputs.	Fire about every 20 - 50 years promotes cypress along swamp edge. Less frequent fire (+100 years) promotes hardwoods in swamp interior.
Mixed Cypress - Hardwood Swamp	Wetlands with deep (>1 feet [ft]) organic soils.	Closed canopy of cypress and mixed hardwoods, including red maple, sweet bay, Carolina ash, Carolina willow, pond apple, and dahoon holly with occasional sabal palm.	Inundated 8 - 10 months per year. Normal wet season water depths of 1.5 - 2 ft. Annual water table fluctuation of 2 - 4 ft.	Found on sites infrequently (+100 years) reached by fire, due to extended inundation and high soil moisture.
Cypress	Wetlands with sandy or shallow (<1 ft) organic soils.	Canopy dominated by small-to-medium sized cypress.	Inundated 6 - 8 months per year. Normal wet season water depths of 1 - 1.5 ft. Annual water table fluctuation of 3 - 5 ft.	Maintained by light - moderate intensity surface fires every 20 - 60 years.
Mangrove Swamp	Tidal sites with sand, rock or organic substrates.	Canopy dominated by red, black or white mangroves or buttonwood.	Daily tidal inundation. Water fresh to hypersaline.	Developed and maintained by the absence of fire.
Organic Soil Shrub Wetland	Wetlands, sheet flow sloughs, and edges of lakes and streams with organic soils.	Single or mixed species, open to dense thickets of Carolina willow or buttonbush.	Inundated 4 - 10 months per year. Normal wet season water depths of 0.5 - 2 ft. Annual water table fluctuation of 1.5 - 3 ft.	Maintained by light intensity surface fires every 18 - 30 years.
Freshwater Marsh	Depression and flowway wetlands, and fringes of lakes and streams on organic soils.	Tall (5 - 10 ft), dense herbaceous community, often only a few species including pickerelweed, arrowhead, tall sawgrass, maidencane, fire flag.	Inundated 6 - 10 months per year. Normal wet season water depths of 1 - 2 ft. Annual water table fluctuation of 2 - 3 ft.	Maintained by moderately intense fires about every 1 - 10 years.
Mineral Soil Shrub Wetland	Depression and flowway wetlands, and fringes of lakes and streams on mineral soils.	Single or mixed species, open to dense thickets of wax myrtle, groundsel tree, gallberry.	Inundated 2 - 6 months per year. Normal wet season water depths of 0.5 - 1.3 ft. Annual water table fluctuation of 3 - 4 ft.	Maintained by low intensity fires about every 9 - 15 years.

Table 3 continued.

Plant Community	Topographic Setting and Soils	Dominant Vegetation	Hydrology	Fire
Dwarf Cypress	Depression and flowway wetlands, and fringes of lakes and streams on limestone bedrock.	Single species, open stands of stunted cypress with sparse ground cover	Inundated 2 - 6 months per year. Normal wet season water depths of 0.5 - 1.3 ft. Annual water table fluctuation of 3 - 4 ft.	Maintained by low intensity fires about every 10 - 20 years.
Wet Prairie	Depression and flowway wetlands, and fringes of lakes and streams on mineral soils.	Short (1.5 - 4.5 ft), open, diverse herbaceous community with many species of grasses, sedges, and forbs, including sand cordgrass, beak sedges, milkworts, St. Johns-wort, muhly, short sawgrass.	Inundated 2 - 6 months per year. Normal wet season water depths of 0.5 - 1.3 ft. Annual water table fluctuation of 3 - 4 ft.	Maintained by moderate-high intensity fires about every 1 - 5 years.
Coastal Marsh	Coastal saline sites with sand, shell, rock or organic substrates.	Short (<4.5 ft), open, diverse herbaceous community with many species of grasses, sedges, and forbs, including smooth cordgrass, black needle rush, spike rush.	Daily tidal inundation. Water fresh to hypersaline. Freshwater sheet flow during wet season.	Maintained by moderate-high intensity fires about every 1 - 5 years.
Hydric Pine Flatwoods	Light to dark brown, sandy soils on sites with little topographic relief.	Canopy trees primarily slash pine. Diverse, primarily herbaceous ground cover with about 500 species, including wiregrass, bluestems, saw palmetto.	Inundated 1- 2 months per year. Normal wet season water depths from 0 - 0.5 ft above ground. Annual water table fluctuation of 3 - 4 ft.	Maintained by moderately intense fires about every 1 - 6 years.
Hydric Pine Flatwoods Shrubby	Light to dark brown, sandy soils on sites with little topographic relief.	Canopy trees primarily slash pine. Understory dominated by open to dense thickets of shrubs, particularly wax myrtle.	Inundated 1 - 2 months per year. Normal wet season water depths from 0 - 0.5 ft above ground. Annual water table fluctuation of 3 - 4 ft.	Maintained by low-moderate intensity fires about every 8 - 15 years.
Mesic Pine Flatwoods	Light to dark brown, sandy soils or limerock on sites with little topographic relief.	Canopy trees primarily slash pine. Understory dominated by dense saw palmetto.	Inundated 0 - 1 month per year. Normal wet season water depths from 0 - 3 ft below ground. Annual water table fluctuation of 3 - 4 ft.	Maintained by moderately intense fires about every 1 - 6 years.
Mesic Pine Flatwoods Shrubby	Light to dark brown, sandy soils on sites with little topographic relief.	Canopy trees primarily slash pine. Understory dominated by open to dense thickets of shrubs, particularly gallberry, staggerbush, wax myrtle, blueberry, saw palmetto.	Inundated 0 - 1 month per year. Normal wet season water depths from 0 - 3 ft below ground. Annual water table fluctuation of 3 - 4 ft.	Maintained by low-moderate intensity fires about every 8 - 15 years.

Table 3 continued.

Plant Community	Topographic Setting and Soils	Dominant Vegetation	Hydrology	Fire
Hydric Hammock	Loamy or sandy soils on elevated sites often within or adjacent to larger wetlands.	Forest with a closed canopy that includes a variety of tree species, including laurel oak, sabal palm, red maple, swamp bay. Sparse ground cover.	Inundated 1 - 2 months per year. Normal wet season water depths from 0 - 0.5 ft above ground. Annual water table fluctuation of 3 - 4 ft.	Found on sites that have not experienced fire for more than 100 years.
Mesic Hammock	Sand, shell or rock substrates on elevated sites often within or adjacent to larger inland or coastal wetlands.	Closed canopy of live oak and/or tropical hardwoods. Sparse ground cover.	Inundated 0 - 1 month per year. Normal wet season water depths from 0 - 3 ft below ground. Annual water table fluctuation of 3 - 4 ft.	Found on sites that have not experienced fire for more than 100 years.
Coastal Strand	Well drained sands on beach ridges adjacent to high energy beaches.	Dense thickets of salt tolerant shrubs and small trees, including saw palmetto, sea grape, scrub oaks, lantana, greenbrier and cabbage palm.	Wet season water table usually more than 3 ft below ground.	Maintained by low-moderate intensity fires about every 2 - 15 years.
Scrub	White well drained sands on locally higher elevations or at the top of steep slopes.	Dense thickets of low (<10-ft high) shrubs and xeric oaks, including myrtle oak, live oak, sand live oak, with scattered patches of mostly bare white sand and a very scattered overstory of slash pine.	Wet season water table usually more than 3 ft below ground.	Maintained by high intensity fires every 6 - 55 years.
Xeric Hammock	White well drained sands on locally higher elevations or at the top of steep slopes.	Dense, tall (10 - 20 ft) closed canopy forest of xeric oaks, including myrtle oak, live oak, sand live oak, with a very scattered overstory of slash or sand pine and little ground cover.	Wet season water table usually more than 3 ft below ground.	Develops in the absence of fire for 50 years.

In addition to the hydrology-fire successional model, as part of the Disney Wilderness Preserve and south Florida efforts, we also developed mineral soil and organic soil transition models that allowed us to estimate the kinds and frequencies of fires that would maintain existing communities, that would allow succession to proceed, and that would return communities to earlier successional stages (**Figures 8** and **9**). These models were based on the knowledge and experience of a number of individuals with many years of experience with fire in these ecosystems. These successional and transition models represent our current hypotheses of the relationships between fire and hydrology in determining the characteristics and distribution of major plant communities in naturally functioning south Florida environments.

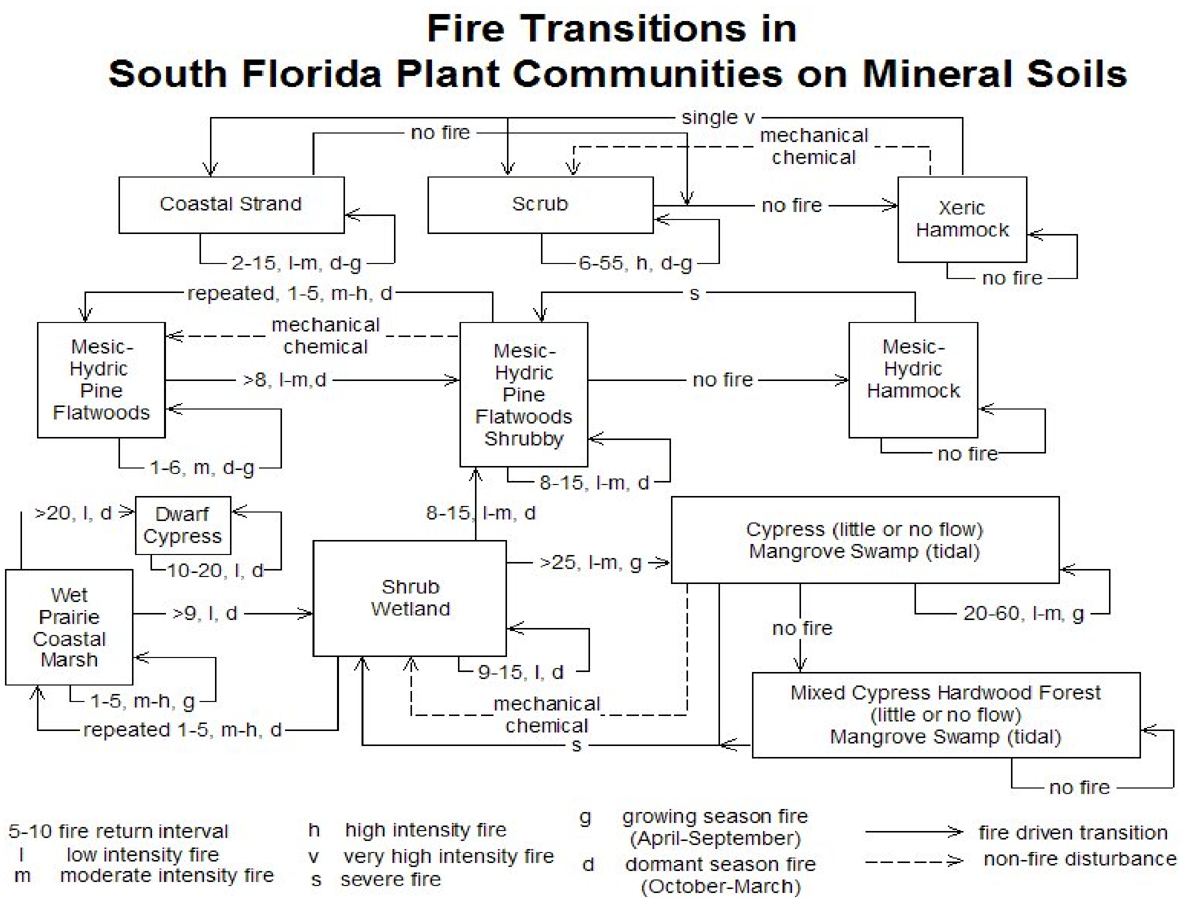

Figure 8. Fire transitions in south Florida plant communities on mineral soils

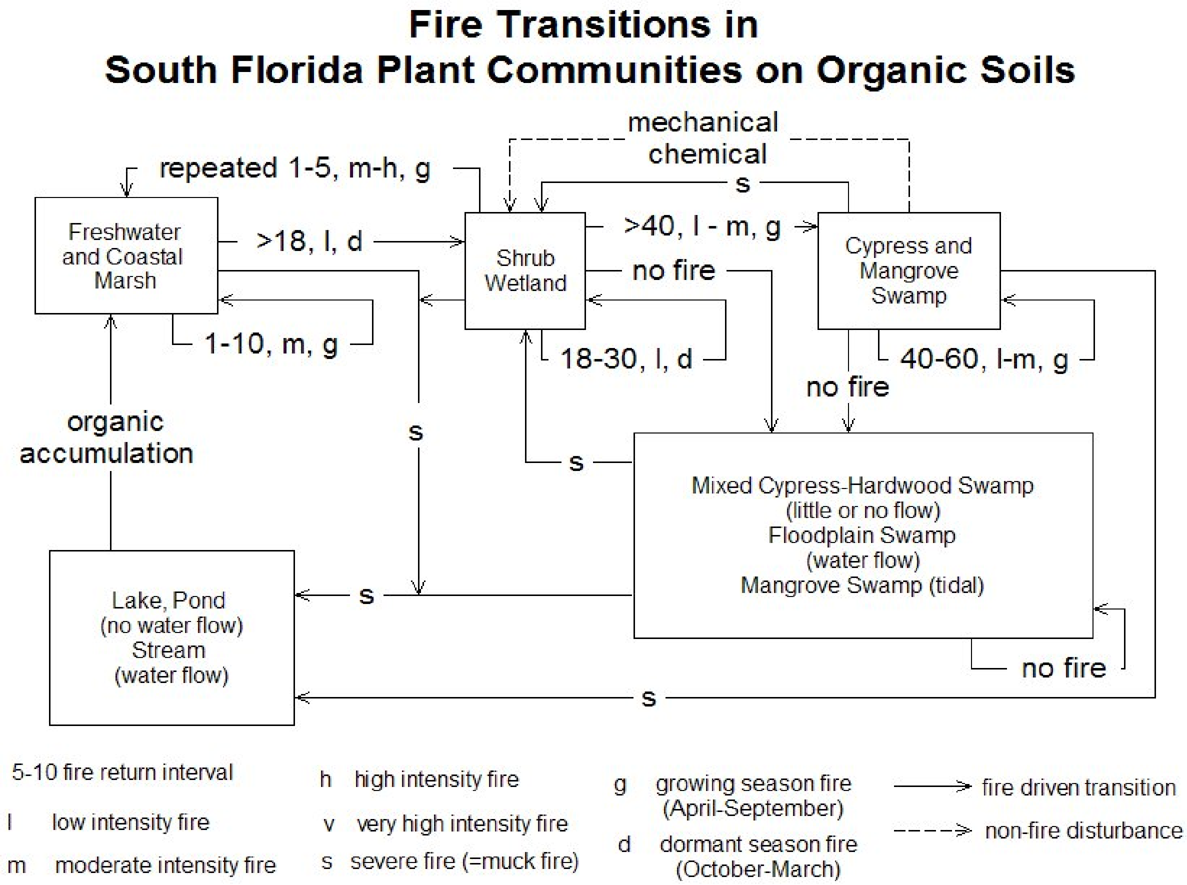

Figure 9. Fire transitions in south Florida plant communities on organic soils

Plant Community Analyses for Picayune Strand Restoration

Hydrology parameters were calculated by the MIKE SHE model for pre-drainage, existing (2000), 2050 without-project base conditions, and 2050 with-project (restoration) within Picayune Strand and surrounding areas (**Table 4** and **Figures 10** to **13**).[1] Plant community distributions were predicted based on the relationship between the hydrologic characteristics of each major community type and on average wet season water depths (July 1 through October 1) as predicted by the model. Restoration of more natural hydrology is expected to result in a return to more natural distribution and acreage (**Figure 14**) of plant communities.

[1] Note that the conditions used to determine water reservations were the pre-drainage, 2000 with-project, and 2000 without-project conditions, which use land and water use condition from 2000. Table 4 and Figures 10 to 13 use the 2050 without-project and 2050 with-project conditions, which use projected land and water use condition expected in 2050.

Table 4. Acreages of plant communities as calculated by the MIKE SHE model

Plant Communities	Average Wet Season Water Level	Plant Community Acreages			
		Pre-Drainage	2000 Existing	2050 without-project	2050 with-project
Picayune Strand Restoration Project Area					
Mesic Pine Flatwoods / Mesic Hammock	< 0.2 ft	9,194	55,058	54,078	18,388
Hydric Pine Flatwoods / Hydric Hammock	0.2 - 0.5 ft	11,260	2,273	3,254	10,433
Wet Prairie	0.5 - 1 ft	19,420	878	1,033	14,720
Cypress Forest / Freshwater Marsh	1 - 2 ft	16,166	930	826	13,739
Open Water	> 2 ft	3,254	155	103	2,014
Totals		59,294	59,294	59,294	59,294
Florida Panther National Wildlife Refuge					
Mesic Pine Flatwoods / Mesic Hammock	< 0.2 ft	10,743	5,527	5,475	5,372
Hydric Pine Flatwoods / Hydric Hammock	0.2 - 0.5 ft	5,940	11,673	11,776	12,395
Wet Prairie	0.5 - 1 ft	6,146	6,456	6,405	6,095
Cypress Forest / Freswater Marsh	1 - 2 ft	2,118	1,291	1,291	1,085
Open Water	> 2 ft	0	0	0	0
Totals		24,947	24,947	24,947	24,947
Fakahatchee Strand Preserve State Park					
Mesic Pine Flatwoods / Mesic Hammock	< 0.2 ft	25,102	29,544	29,027	23,036
Hydric Pine Flatwoods / Hydric Hammock	0.2 - 0.5 ft	22,313	28,666	28,511	30,990
Wet Prairie	0.5 - 1 ft	22,106	15,340	15,908	18,078
Cypress Forest / Freshwater Marsh	1 - 2 ft	10,640	6,611	6,715	7,954
Open Water	> 2 ft	0	0	0	103
Totals		80,161	80,161	80,161	80,161
Belle Meade					
Mesic Pine Flatwoods / Mesic Hammock	< 0.2 ft	6,146	11,209	10,898	12,552
Hydric Pine Flatwoods / Hydric Hammock	0.2 - 0.5 ft	7,231	7,851	7,748	5,630
Wet Prairie	0.5 - 1 ft	8,729	7,644	7,799	6,198
Cypress Forest / Freshwater Marsh	1 - 2 ft	7,490	3,202	3,461	5,423
Open Water	> 2 ft	465	155	155	258
Totals		30,061	30,061	30,061	30,061
Collier-Seminole State Park					
Mesic Pine Flatwoods / Mesic Hammock	< 0.2 ft	52	826	1,136	465
Hydric Pine Flatwoods / Hydric Hammock	0.2 - 0.5 ft	620	1,240	1,240	465
Wet Prairie	0.5 - 1 ft	1,395	723	878	1,085
Cypress Forest / Freshwater Marsh	1 - 2 ft	2,117	1,188	878	1,343
Open Water	> 2 ft	155	362	207	981
Totals		4,339	4,339	4,339	4,339

Pre-drainage Condition Average Wet Season (July 1 – October 1) Surface Water Depth for an Average Year (1994)

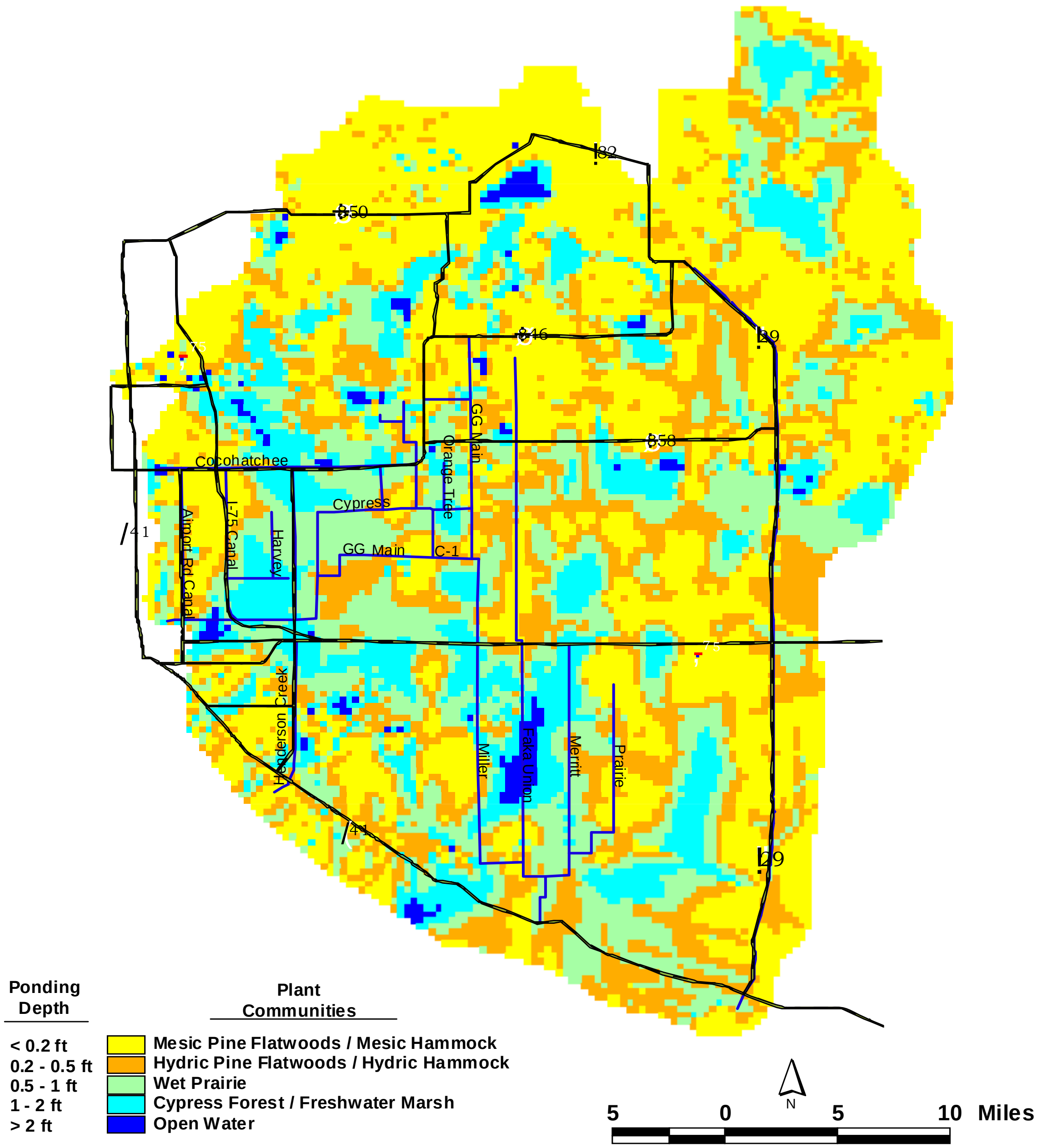

Figure 10. MIKE SHE average wet season and associated major plant communities in Big Cypress basin under pre-drainage conditions

Existing Condition Average Wet Season (July 1 – October 1) Surface Water Depth for an Average Year (1994)

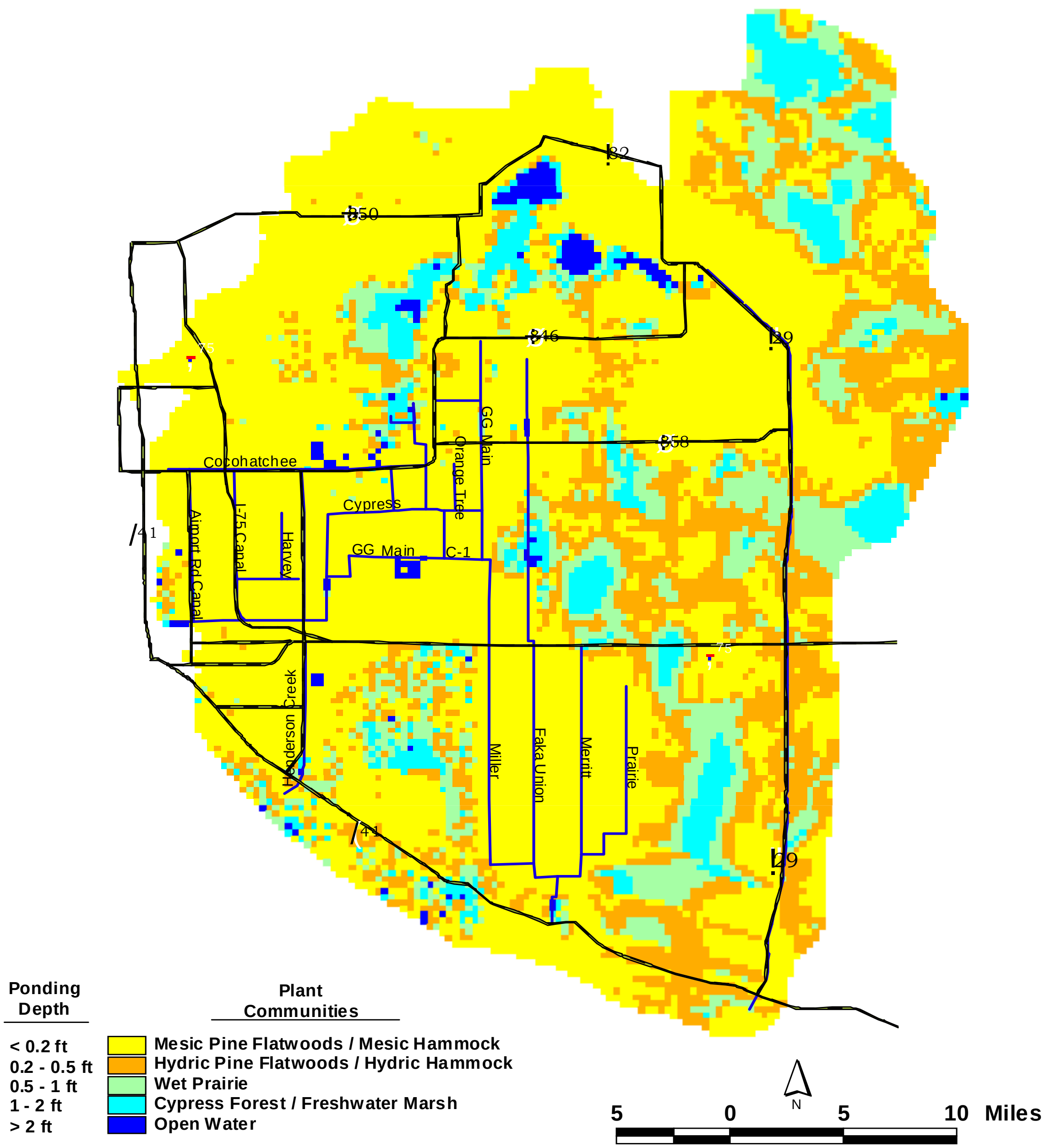

Figure 11. MIKE SHE average wet season and associated major plant communities in Big Cypress basin under existing conditions

Future Without-Project Condition Average Wet Season (July 1 – October 1) Surface Water Depth for an Average Year (1994)

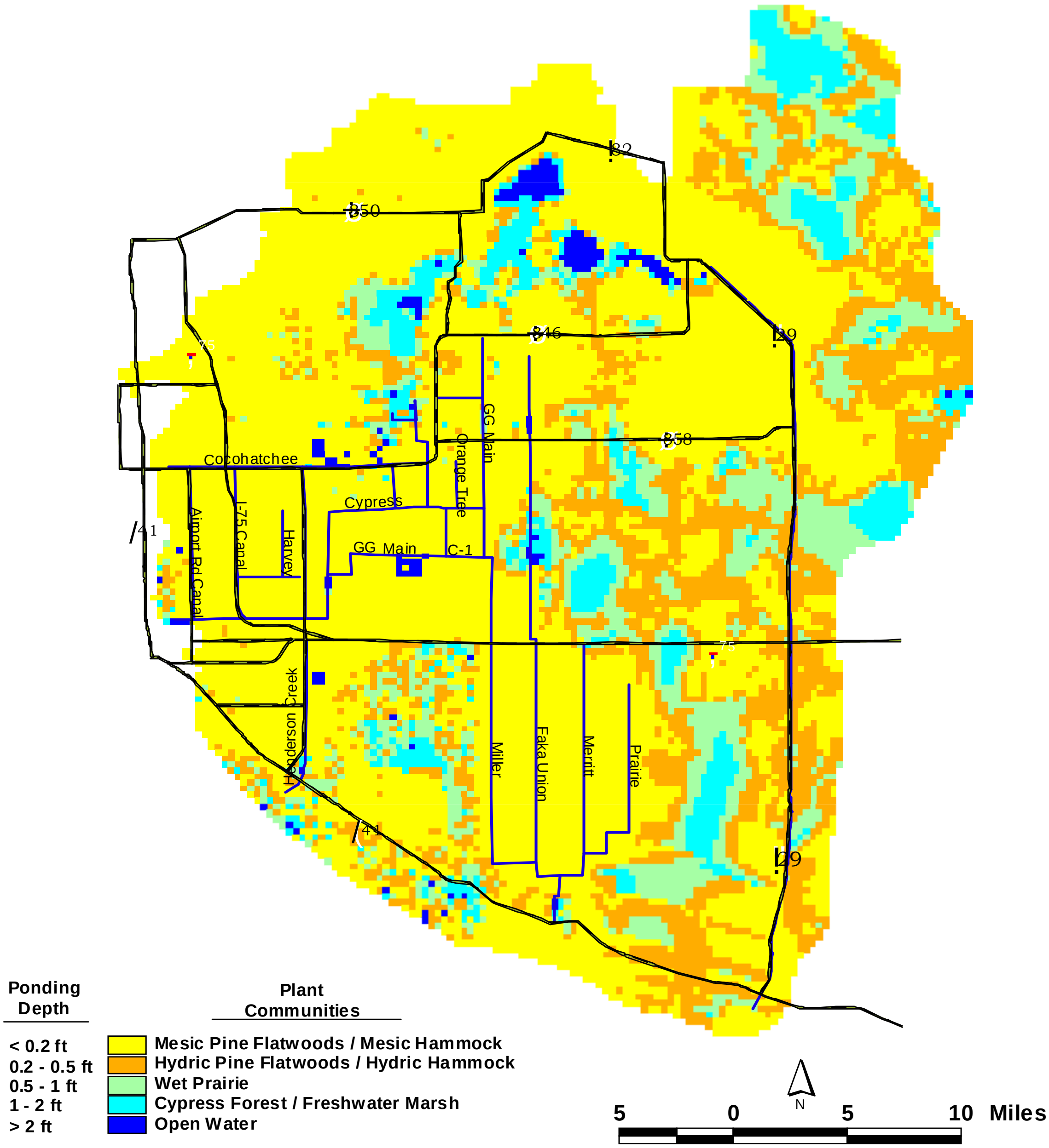

Figure 12. MIKE SHE average wet season and associated major plant communities in Big Cypress basin under future (2050) without-project conditions

Future With-Project (Restoration) Condition Average Wet Season (July 1 – October 1) Surface Water Depth for an Average Year (1994)

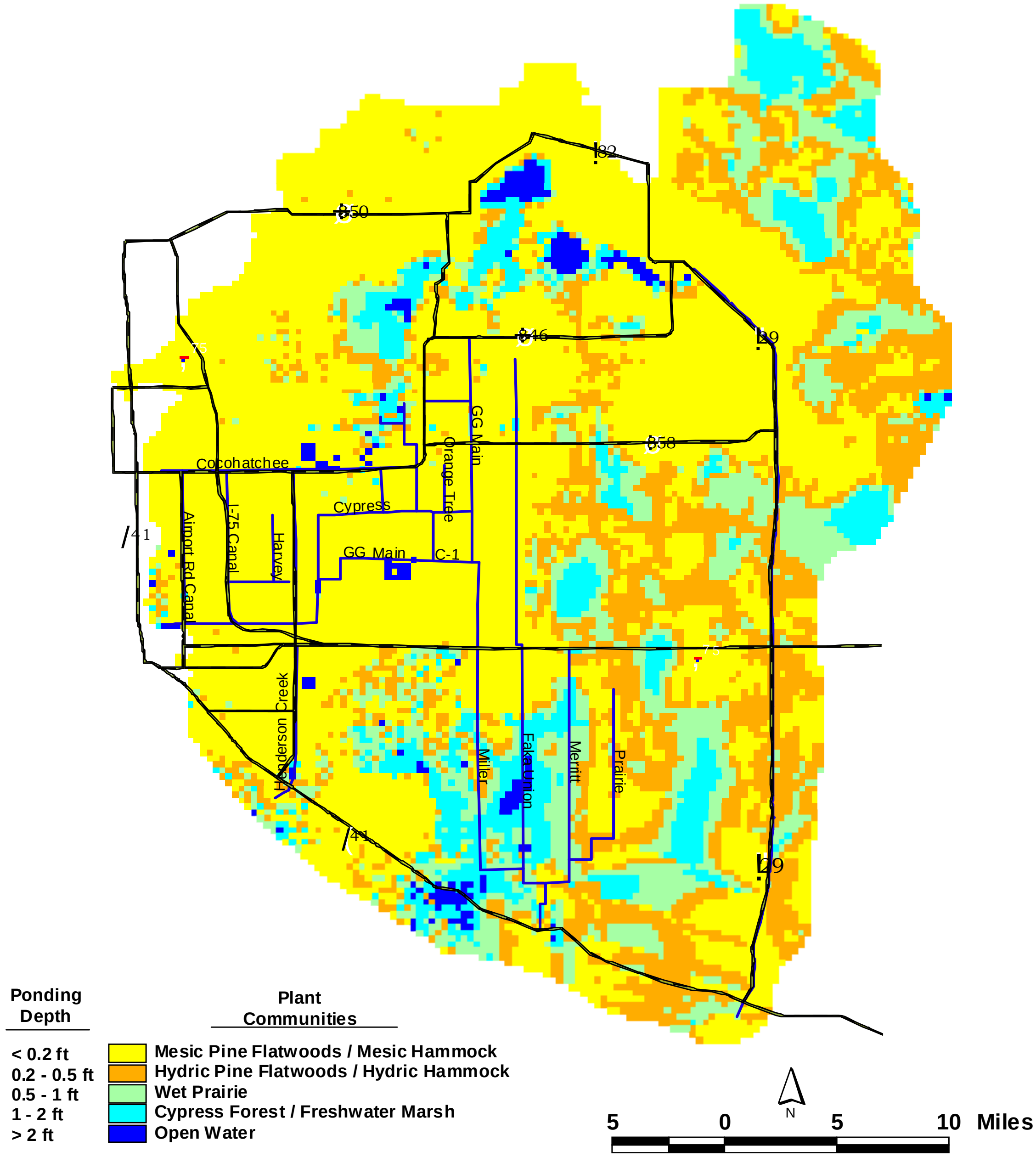

Figure 13. MIKE SHE average wet season and associated major plant communities in Big Cypress basin under future (2050) with-project conditions

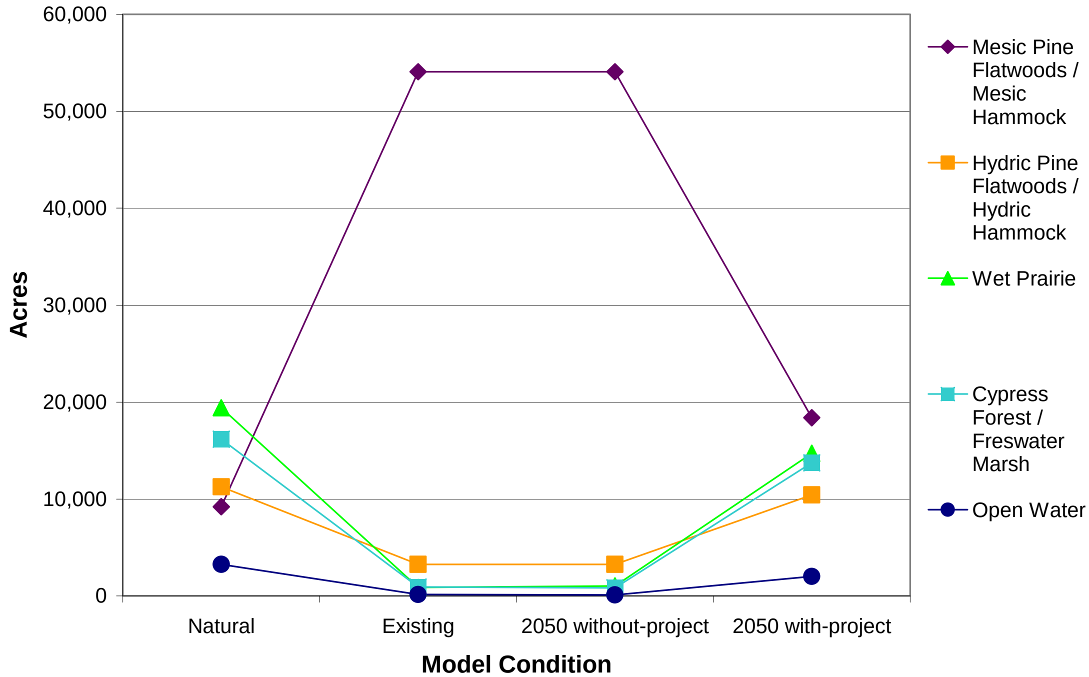

Figure 14. Plant community acreages within Picayune Strand for the pre-drainage (natural), existing without-project, 2050 without-project and 2050 with-project conditions of the MIKE SHE Model

4.2.2 Aquatic Fauna, White Ibis and Wood Stork

The changes in hydrology and plant community structure, along with habitat loss and fragmentation, have affected other valued ecosystem components. These include aquatic fauna, white ibis 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. They are affected by hydrologic changes.

Prior to drainage, Picayune Strand was primarily a wetland ecosystem, with a variety of short to long hydroperiod plant communities that were ideal for the production of large numbers of small fish, amphibians and aquatic macroinvertebrates. This forage base was in turn able to support a variety of predators, including white ibis and wood stork. With the exception of a few small areas where organic soil loss has lowered the ground surface to a new equilibrium with the current water table, the drainage canals have eliminated the presence of standing water over most of Picayune Strand for more than short periods after heavy rainfall events. Without extended periods of inundation, aquatic fauna populations cannot survive and build up over the summer wet season to form the abundant prey base for wading birds as occurred prior to drainage. It is expected that following restoration, aquatic fauna will reestablish something approximating their pre-drainage populations within a year or two and wading birds will quickly begin to take advantage of this restored forage base.

Aquatic Fauna

Small forage fish, amphibians and aquatic macroinvertebrates are very mobile organisms, at least over distances on the order of a few miles. This is evidenced by their ability to rapidly recolonize newly inundated sites at the beginning of the wet season; sites that have been dry for at least several months and sometimes much longer (Carlson and Duever 1979).

Different species have a variety of strategies for recolonizing a newly inundated site. Some species, such as copepods and snails, have life history stages that allow them to withstand dry periods in situ and emerge when the water returns. Others, such as crayfish, merely follow the water table down into the ground, and up to the ground surface again with the arrival of wet season rains. However, populations of many species, particularly fish, are restricted to localized and often very scattered areas that retain surface water. Once water levels begin to rise and expand across the landscape during the wet season, they quickly disperse into newly available habitat. While those populations that survive in these refugia during dry periods may represent relatively few individuals initially, they typically have relatively short life cycles that permit them to increase in numbers and biomass rapidly through the summer wet season (Haake and Dean 1983, Loftus and Eklund 1994). In addition, many of the aquatic macroinvertebrates, including dragonflies, mayflies, beetles and true bugs, have flying adult stages that facilitate their dispersal over significant distances. Others, such as frogs, have terrestrial life history stages that allow them to travel overland to distant breeding sites during wet periods.

Picayune Strand is fortunate in that it is surrounded by large areas that have not been as severely drained, which will be sources of fish, amphibians and aquatic macroinvertebrates that have been mostly absent from the failed Southern Golden Gate Estates development for many decades. There is nowhere in Picayune Strand that is more than five miles from existing populations of these organisms, which are capable of moving into all parts of Picayune Strand within one or two years once its normal hydrologic regime is restored.

Wading Birds

While it is likely that some wading bird rookeries will become established in Picayune Strand following restoration, their occurrence is notoriously erratic in space and from year-to-year. This is largely due to the tempo-spatial variability of climatic conditions in south Florida that creates variable hydrologic conditions that in turn affects the productivity of wading bird food resources, and thus wading bird reproductive condition and success (Duever et al. 1994). However, regardless of whether they ever nest in Picayune Strand, they can be expected to regularly use the area for both breeding and nonbreeding season foraging following restoration. It will be a large area dominated by the full range of short to long hydroperiod wetland communities that will produce large amounts of the types of food to which wading birds are attracted (Ogden 1994, Robertson and Kushlan 1984).

The restored Picayune Strand's diverse mix of herbaceous, shrub and forested wetlands, with scattered open water ponds will be ideal for supporting diverse bird populations, including wading birds. Even if Picayune Strand does not provide breeding sites for wading birds, it is not far from existing wading bird rookeries, particularly Corkscrew Swamp Sanctuary and its wood stork colony, which is within 15 to 25 miles of all parts of Picayune Strand. Wood storks are known to fly up to 80 miles from their rookeries late in the dry season when foraging sites are getting scarce, and thus, Picayune Strand is well within their normal foraging range (Browder 1978). Bancroft et al. (1994) found that the average nesting season foraging range for five species of wading birds in an Everglades rookery varied from about 2 to 19 miles, with an average distance for all species of about 7 miles. Foraging range increased through the dry season as suitable sites became scarce. Based on these distances, any rookeries in surrounding natural areas such as Belle Meade, Collier Seminole and Fakahatchee Strand Preserve State Parks, Rookery Bay National Estuarine Research Reserve, Florida Panther and Ten Thousand Islands National

Wildlife Refuges, and even Big Cypress National Preserve and Everglades National Park would benefit from the large area of restored foraging opportunities in Picayune Strand.

Section 5. Description of Ten Thousand Islands Estuaries and Valued Ecosystem Components

The Big Cypress and Everglades watersheds are the exclusive drainage basins entering the Ten Thousand Islands. The Big Cypress watershed drains the majority of Collier County, supplying fresh water to the estuaries of the Ten Thousand Islands through a series of tributaries. Estuaries within the Ten Thousand Islands region include the following river/bay systems, from west to east: Royal Palm Creek/Palm Bay, Blackwater River/Blackwater Bay, Whitney River/Buttonwood Bay, Pumpkin River/Pumpkin Bay, Wood River, Little Wood River, Faka Union Canal/Faka Union Bay and Fakahatchee Bay (**Figure 15**; Saverese et al, 2004a). These estuarine areas are also referred to collectively as Fakahatchee Estuary.

5.1 Formation of Ten Thousand Islands Estuaries

The extensive network of estuarine environments in south Florida is the direct result of late Holocene coastal sedimentation rates exceeding that of sea level rise producing offshore barriers to fresh water entering the Gulf of Mexico. This entrapment of fresh water produces expansive brackish environments unique to these coastal settings. The orientation of the coast in the Ten Thousand Island region is different from the rest of Florida's gulf coast resulting in limited long shore drift and, as a result, an absence of barrier islands to produce protected lagoons (Tanner 1960). Instead, reef-building organisms have produced offshore barriers to form the regional estuarine system. The main organisms responsible for this phenomenon in Southwest Florida were the eastern oyster (*Crassostrea virginica*) and vermetiform gastropods as well as the subsequent establishment of red mangrove (*Rhizophora mangle*) upon these reef substrates. Parkinson (1987) described the historic succession of these communities within the Ten Thousand Islands, beginning with the onset of vermetiform gastropods after the rate of sea level rise dropped to approximately 4 centimeters (cm) per 100 years. The vermetiform reefs produced offshore structures, which retained fresh water in bays along the south Florida coast creating environmental conditions favorable for the development of eastern oyster reef communities. Once established, these oysters increased sedimentation around them producing intertidal reef structures that provided substrate for both further oyster development and the establishment of mangrove propagules. The recruitment of mangroves upon these communities marks the completion of this organismal succession producing a myriad of mangrove islands separating the interior bays from the Gulf of Mexico (Hoye 2008). These organisms grow vertically into the water column decreasing the flow velocity and forcing sediment out of suspension (Furukawa et al. 1997, Pietros and Rice 2003). Wholpart (2007) suggests these organisms have been present in the Ten Thousand Islands for at least 1,640 years.

5.2 Pre-Drainage Hydrologic Conditions

Prior to anthropogenic impacts, flat topography, marly soils and seasonal rainfall cycle were principal influences on hydrology of the Picayune Strand area. This natural sheet flow system absorbed floodwater, promoted groundwater recharge, sustained wetland vegetation, rejuvenated freshwater aquifers, assimilated nutrients and removed suspended materials. Fresh water reached the Ten Thousand Islands estuaries 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.

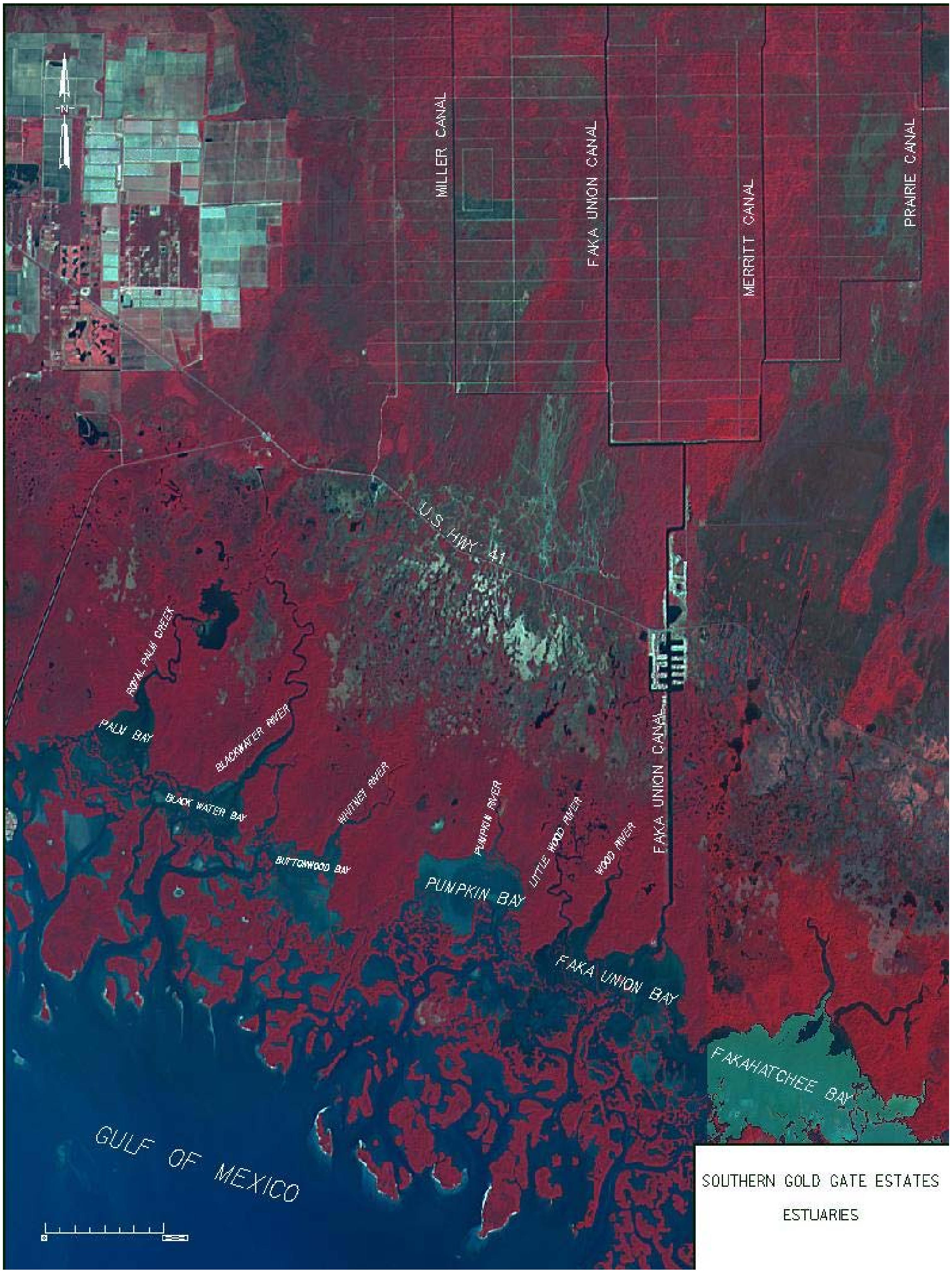

Figure 15. Locations of estuaries and bays in relation to the Southern Golden Gate Estates development and canal system

Shorelines were generally lined with mangroves (USACE and SFWMD 2004). Mangroves supported productivity of creeks, bays and islands by producing large masses of 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, mollusks, particularly 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, organisms living suspended in the water, 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.

5.3 Current Conditions

Unlike most of south Florida, Collier County's estuarine areas remained virtually unaltered until the 1960s when severe pressure for residential and agricultural development occurred. Canals within the project area are part of the Faka Union Canal system. This system degrades marine habitat in Faka Union Bay by sending it too much fresh water too fast during wet season discharges. 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 by diverting to Faka Union Bay fresh water that would otherwise have entered these other systems as surface or groundwater flows. These alterations in the timing and quantity of fresh water flowing into the estuaries has an impact on natural biodiversity by affecting food availability, predation pressure, reproductive success, and most likely has caused chronic and acute stress to these fishes and turtles (USACE and SFWMD 2004). At the extreme east, and receiving drainage primarily from the Fakahatchee Strand Preserve State Park, is Fakahatchee Bay, which is considered relatively unchanged from its historic condition.

5.4 Relationship between Flow and Salinity

The objectives for the estuarine system are to reduce the amplitude, rate and frequency of salinity change and increase habitat heterogeneity in terms of salinity. A suitable salinity regime is critical to the success of the benthic communities of the Ten Thousand Islands and the mangrove islands that define this unique estuarine system. With respect to Faka Union Bay and adjacent estuaries, the general hydrologic restoration objectives for management of the Faka Union Canal should be to 1) decrease the volume of wet season flows, 2) increase the duration of dry season flows, 3) increase the lag time between rainfall events and associated peak flows, 4) delay and shorten the period of little or no flows in the dry season. The salinity patterns in Faka Union Bay should approximate those that would be expected to result from freshwater flow from an unchannelized upstream basin given the same rainfall pattern.

Freshwater flows into Faka Union Bay have been monitored for many years from a stage gage at Port of the Islands just upstream of the fixed weir on the Faka Union Canal. In 1986, Wang and Browder developed regression relationships between Faka Union Canal discharges and observed salinities at five locations in Faka Union Bay and four locations in the channel leading from the west Florida Shelf to the mouth of the bay (**Figure 16**). The established regressions assumed a hyperbolic relationship between discharge and salinity at each station and were crucial to the prediction of salinity in the bay.

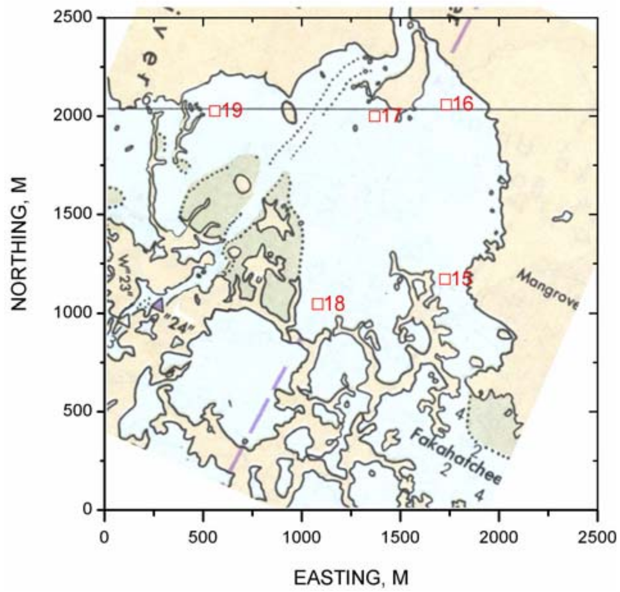

Figure 16. Chart of Faka Union Bay with station locations

Browder and Wang believed that a redistribution of flows between the canal and the culverts under Tamiami Trail (US 41) had taken place. This belief was based on a personal communication with A. Nath, SFWMD, in which he stated that the canals had accumulated substantial living and dead vegetation that had been cleaned out starting in 1992. In 2004, an effort was made to determine whether the shift in the discharge salinity relationship was due to a change in the proportion of total runoff discharged through the canal (as opposed to through the culverts beneath the Tamiami Trail) between the two observation periods (Wang and Browder 2004). A change in slope was noted in the plot of cumulative rainfall from 1985 to 2002 against cumulative discharge. Browder and Wang attributed this change in slope to a change in the discharge per unit of rainfall, which took place some time around 1995. This change led to a significant increase of discharge for similar rainfall events (**Figure 17**). To establish precise regression lines of discharge versus rainfall before and after cleaning was difficult because of the apparent effect of partial canal blocking that developed in the early 1990s. Browder and Wang were unable to use data collected prior to 1985 as it was deemed of poor quality or incomplete; a regression of data collected prior to 1990 would have too few points to be significant. Because of these data problems, it was not possible to precisely determine how much the recorded canal discharge per unit of rainfall increased after 1995 compared to pre-1995. However, based on regressions from 1985 to 1992 and from 1993 to 2002, the increase was estimated to be approximately 50% of the post-1995 discharge (100% of the pre-1995 discharge).

Observations and model simulations demonstrated that flows in the canal in the later years very nearly represented 100% of flows to the bay. Browder and Wang (2004) concluded that when they previously developed the hyperbolic relationships between Faka Canal discharge and bay salinity, the canal only carried approximately half of the total flow to the bay, and a similar flow reached the bay through local streams fed by the culverts. By reducing discharges in 2000-2002 by 50%, the resulting data points fell very closely to the hyperbolic relationships (**Figure 18**) established in the 1986 study. This was further verified by dividing the total flows to the bay in half and using the hyperbolic relationships of the 1982-1984 work, which provided salinity predictions for five stations in the bay, in contrast to the single station of the 2000-2002 study, allowing for the prediction of the boundary salinities in the 2004 simulations.

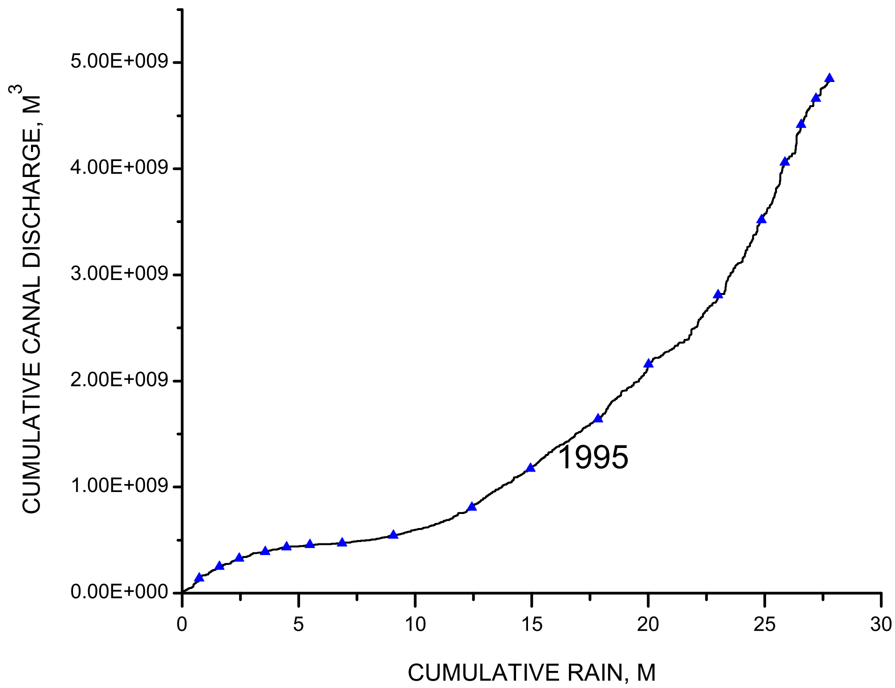

Figure 17. Mass balance of cumulative rain versus cumulative Faka Union Canal discharge 1985 to 2002

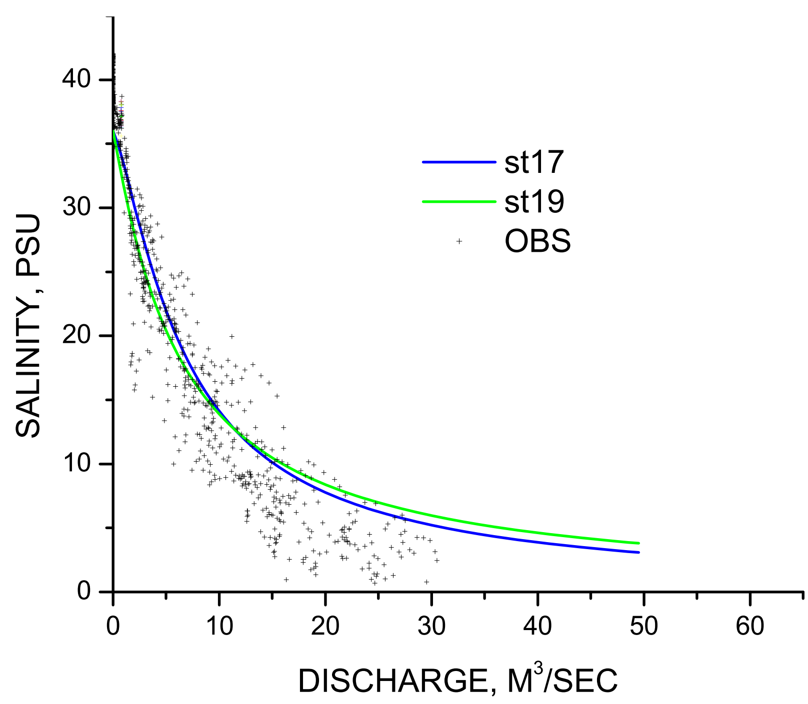

Figure 18. Discharge and rainfall data with revised regression relationships

Browder and Wang (2004) provided another test to determine whether the canal discharge had been altered during the selected period of 1985 to 2002 by examining cumulative discharge versus cumulative rainfall. In the 1985 to 1995 period, approximately 125,000,000 cubic meters (m^3) of fresh water discharged into the Faka Union Bay per 100 cm of precipitation. In contrast, from 1995 through 2002, approximately 220,000,000 m^3 of fresh water was observed discharging into the bay per 100 cm of precipitation. This represents a 43% increase in discharge when normalized by the amount of rainfall (Wang and Browder 2004) as seen in **Figure 19**. This difference in discharge volumes and discharge location drastically changed the salinity regime of Faka Union Bay, as well as adversely impacting other adjacent embayments.

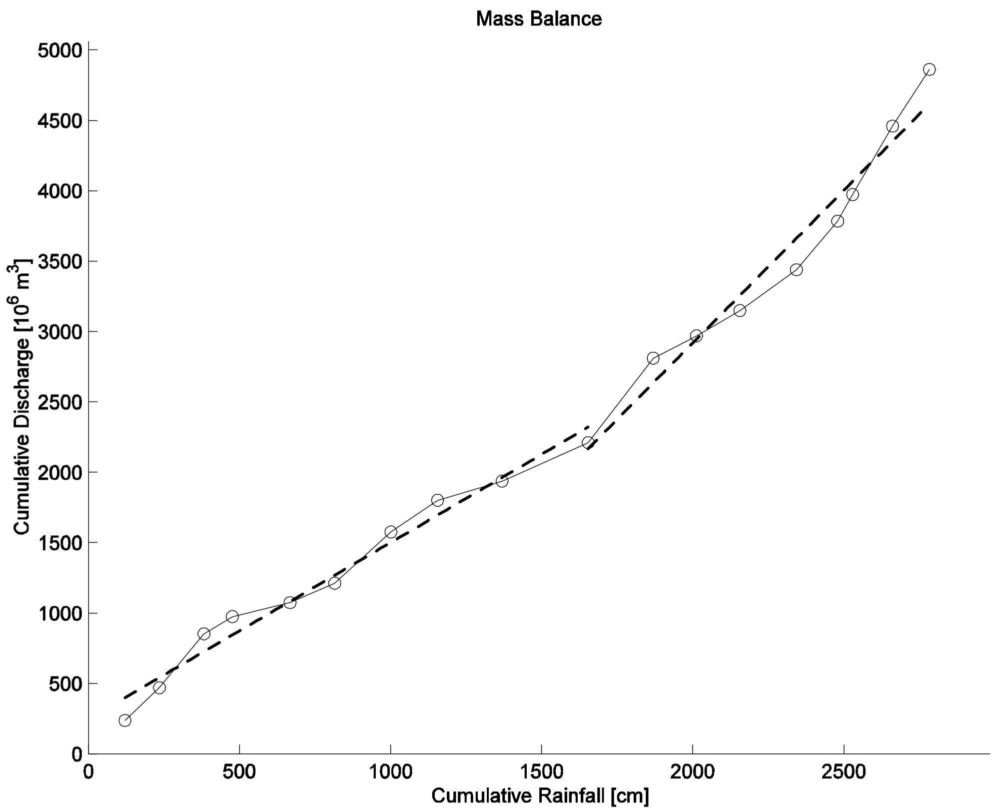

Figure 19. Mass balance curve with the tendency of the data, after fitting a straight line, y = ax + b, indicated by the dashed line in the figure

These calculations made it possible for Wang and Browder (2004) to develop model-generated salinity fields as in **Figures 20** and **21**. This salinity model has only been validated for Faka Union Bay. Flow is represented by Q.

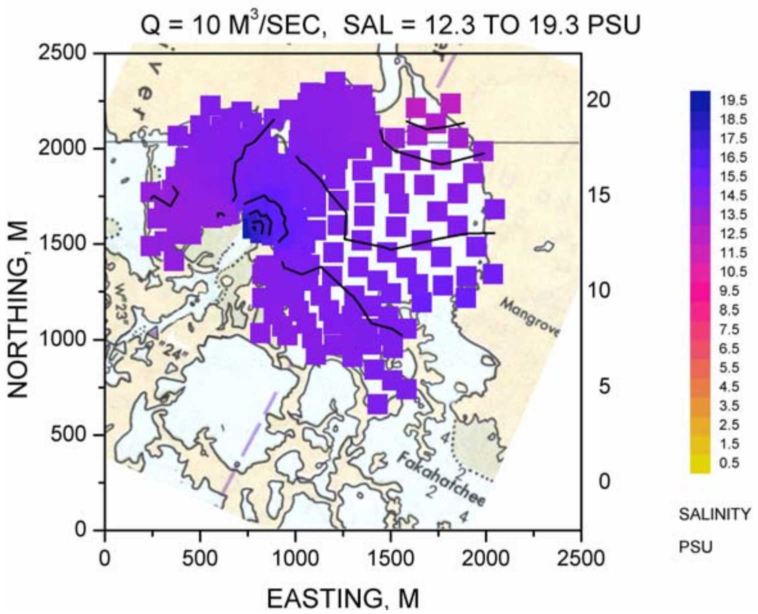

Figure 20. Model-computed salinity field for freshwater inflow of 10 cubic meters per second (m^3/s)

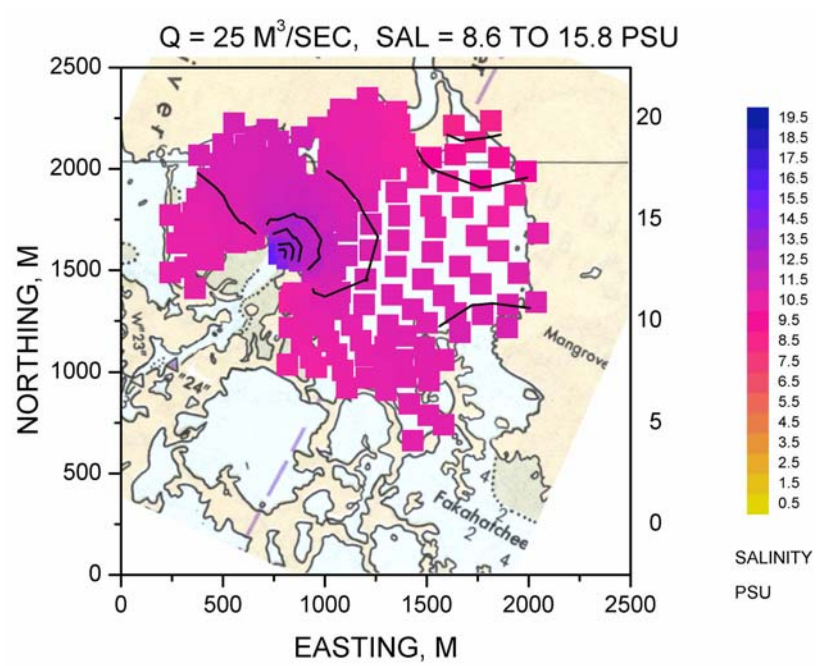

Figure 21. Model-computed salinity field for freshwater inflow of 25 m^3/s

Since 2000, Rookery Bay National Estuarine Research Preserve has been monitoring salinity at the mouth of the trunk canal. Savarese et al. (2004a) calculated the relationship between flow and salinity for Faka Union by regression analysis (**Figure 22**). The exponential function relating salinity to flow was used to evaluate the effectiveness of the flows generated by the various restoration alternatives proposed for the Picayune Strand Restoration Project.

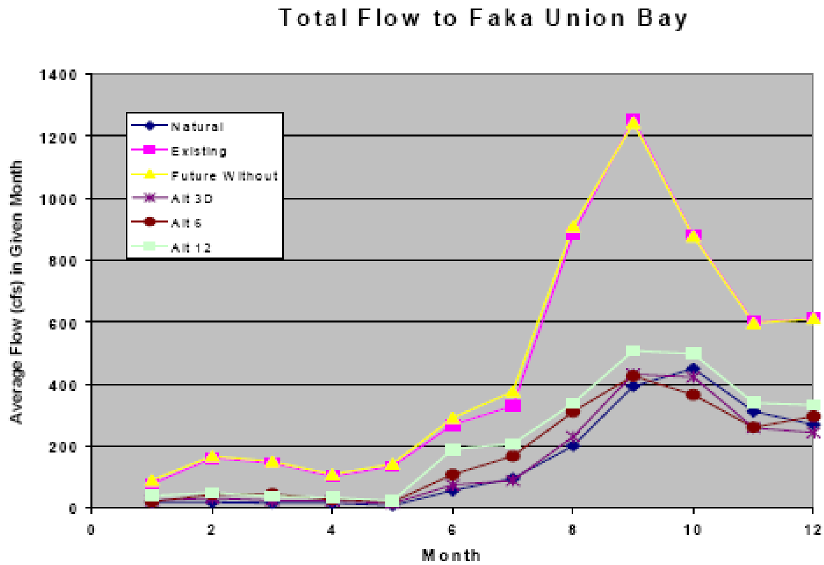

Figure 22. Total monthly water flows into Faka Union Bay predicted by the various modeled alternatives

This evaluation was also completed for other bays within the Ten Thousand Islands area, such as Pumpkin Bay (**Figure 23**), which is also expected to be impacted by the Picayune Strand Restoration Project. Saverese et al. (2004a) also used this regression analysis to evaluate alternatives based on similarity to natural conditions in Faka Union Bay (**Figure 24**). This evaluation demonstrated the vast changes in hydrology that would occur with the possible implementation of the alternatives. In all cases, the wet season freshwater inflows in the months of July through November were drastically reduced in contrast to the existing or future without-project scenarios.

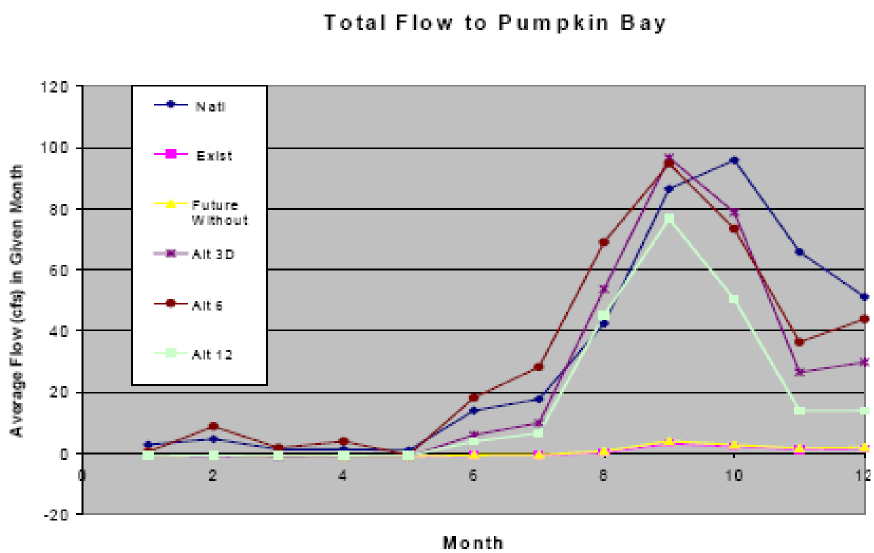

Figure 23. Total monthly water flows into Pumpkin Bay predicted by the various modeled alternatives

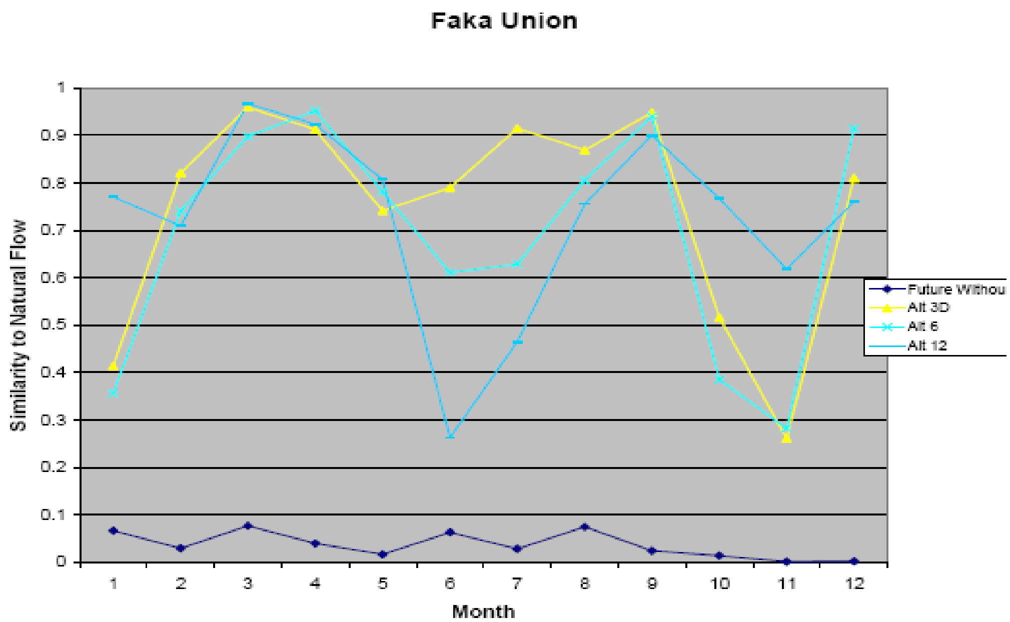

Figure 24. Evaluation of alternatives based on similarity to pre-drainage conditions in Faka Union Bay. On the y-axis, a value of 1.0 indicates a perfect restoration to pre-drainage conditions, 0.0 indicates no improvement towards pre-drainage conditions

The effect of canal discharges (200, 500, 1000, and 1500 cfs) on salinity patterns (isohaline contours) over the entire Faka Union Bay, was simulated with a finite element hydrodynamic model). The salinity range extends from 19-24 parts per thousand (ppt) at 200 cfs, 10-17 ppt at 500 cfs, 5-10 ppt at 1000 cfs, and 4-8 cfs at 1500 cfs. The effect of discharge rates of 50 to 371 cfs on bay salinity habitat shows at 50 cfs, about 95% of the bay is covered by salinities in the range 33-36 ppt and the lowest salinities are 24-27 ppt. The 24-27 ppt range covers a substantial part of the bay ~8-30% at cfs of 59 through 300. The 24-27 ppt and 33-36 ppt ranges occur somewhere in the bay at flows from 50 to 371 cfs. A major change in pattern occurs at 371 cfs, when the salinity ranges of 9-12 through 18-21 ppt become dominant.

More recent monitoring data collected by Rookery Bay National Estuarine Research Preserve at the mouth of the Faka Union Canal shows a comparable hyperbolic function (Savarese et al. 2004a). Mean daily salinities at the canal mouth for years 2000-2002 demonstrate that a 500 cfs flow issuing from the Faka Union Canal produces a salinity of approximately 18 ppt (based on best fit negative exponential function). The Savarese relationship concurred with the previous one in that a rapid change in salinity occurred from 0 to 500 cfs and a more gradual change from 500 cfs to 2500 cfs (Savarese et al. 2004a).

Using the Rookery Bay National Estuarine Research Preserve data, Savarese et al. also compared salinities at homologous locations in Faka Union and Fakahatchee Bays. Normal overland flows in Picayune Strand Restoration Area are typically from north-northeast to south southwest, curving slightly to the west as they approach the coast. Thus, Fakahatchee Bay is relatively unaffected by the canals. Faka Union Bay currently receives extremely high and flashy flows from the canal network's point discharge at Port of the Islands. Savarese et al. (2004a) found a strong linear relationship (r^2 = 0.97) with an intercept at 8.5 ppt and a slope of 0.78. The relationship indicated that, when salinities are low, Faka Union salinities are about 10 ppt less than Fakahatchee salinities; at high salinities (i.e., 40 ppt), Faka Union salinities are about the same as Fakahatchee salinities. The linear relationship between Fakahatchee and Faka Union

Bays suggests that present variability in freshwater inputs to both bays is similar (Savarese et al, 2004a); however, a salinity frequency histogram of the same data indicates there are more days with low and high salinities in Faka Union Bay and more days with moderate salinities in Fakahatchee Bay.

5.5 Estuarine Valued Ecosystem Components

Alterations in the salinity regime places stress on the sensitive life history stages of many estuarine species (Odum 1970, Chamberlain and Doering 1998). The alteration in natural salinity conditions has caused a reduction in oyster reef and submerged aquatic vegetation; displacement of mangrove zones; elimination or displacement of a high proportion of the benthic, midwater and fish plankton communities. The valued ecosystem components chosen to determine water reservations for the Ten Thousand Islands estuaries are oyster reefs, submerged aquatic vegetation, and nekton, which are organisms living suspended in the water. The effects of altered salinity on these organisms are well documented.

5.5.1 Oyster Reefs

The eastern oyster is the principal suspension feeder within these estuarine waters. Oyster reef development is critical to estuarine ecology and to the geomorphologic structure of the region (Parkinson 1989, Savarese et al. 2002). Oysters remove the carbon fixed in the water column by phytoplankton and transfer that carbon to the benthos. This filter feeding action improves water quality and clarity to support benthic primary production. Oyster reefs are essential fish habitat and provide substrate for many species, including prized game fish such as red drum (*Sciaenops ocellatus*). The mangrove islands that differentiate the inner and outer bays and passages are built upon oyster reefs (Parkinson 1989, Savarese et al. 2002).

Oyster reefs make excellent sentinels for estuarine condition particularly those systems located within the Ten Thousand Islands. Depending on the physical attributes of these estuaries, such as the amount of fresh water entering the estuary, the retention of fresh water, and the tidal mixing within the estuary, the location along the estuarine axis that supports oyster reef production will change.

Recent studies examined the impact of water management practices on oyster physiology and ecology (Savarese and Volety 2001, Savarese et al. 2003). A number of measures were quantified, including oyster growth and recruitment; oyster living density and productivity; geographic distribution and aerial density of oyster reefs; and incidence of the oyster disease dermo (caused by the protozoan parasite *Perkinsus marinus*). Comparisons were made between Faka Union and Blackwater Bays and among spatially homologous locations along the downstream, to upstream estuarine axis (Savarese and Volety 2001). Comparisons of oyster physiology and ecology among the three systems demonstrated that the impacts of freshwater inundation from channelization and drainage of the wetlands within the Picayune Strand Restoration Project Area have adversely affected oysters and the development of oyster reefs.

To quantify the distribution of oyster reefs along an estuarine axis, Savarese and Volety (2001) established the homologue approach. Using this approach, five homologues, delineated by green polygons in **Figures 25** and **28**, were established within each estuary - Blackwater (**Figure 25**), Pumpkin (**Figure 26**), Faka Union (**Figure 27**) and Fakahatchee (**Figure 28**) Bays (Hoye 2008) - at locations along the estuarine axis that exhibit comparable geomorphology, which suggests similar physical properties and water quality (Savarese et al. 2003). Savarese et al. (2004b) documented the distribution of oyster reefs, indicated by yellow patches, utilizing this approach allowing direct comparison of the distribution of oysters within each of these estuaries and the reefs are all approximately one meter in thickness suggesting a similar timing of initiation.

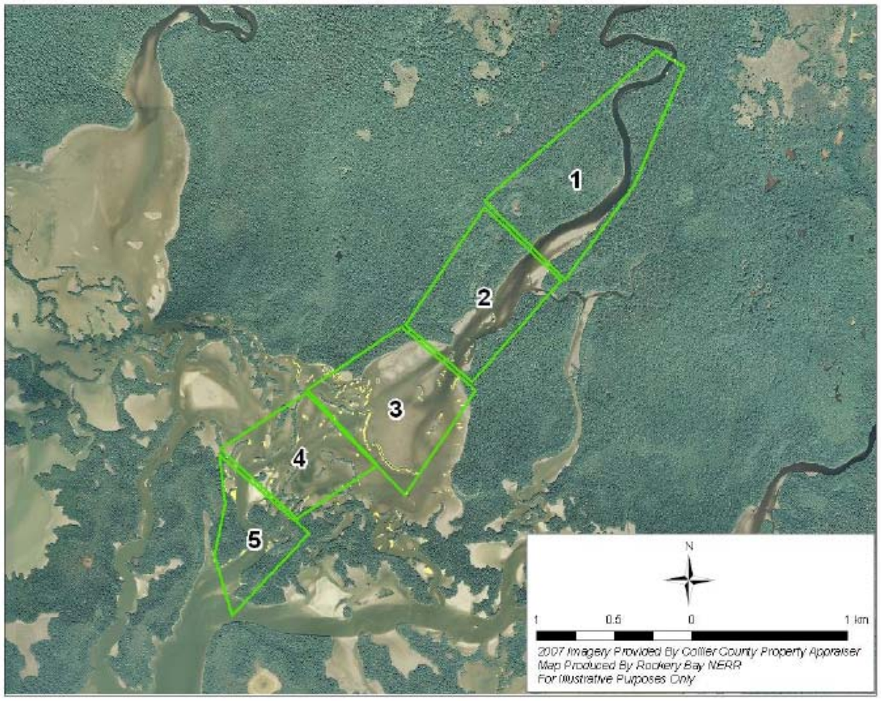

Figure 25. Oyster reef distribution in Blackwater Bay

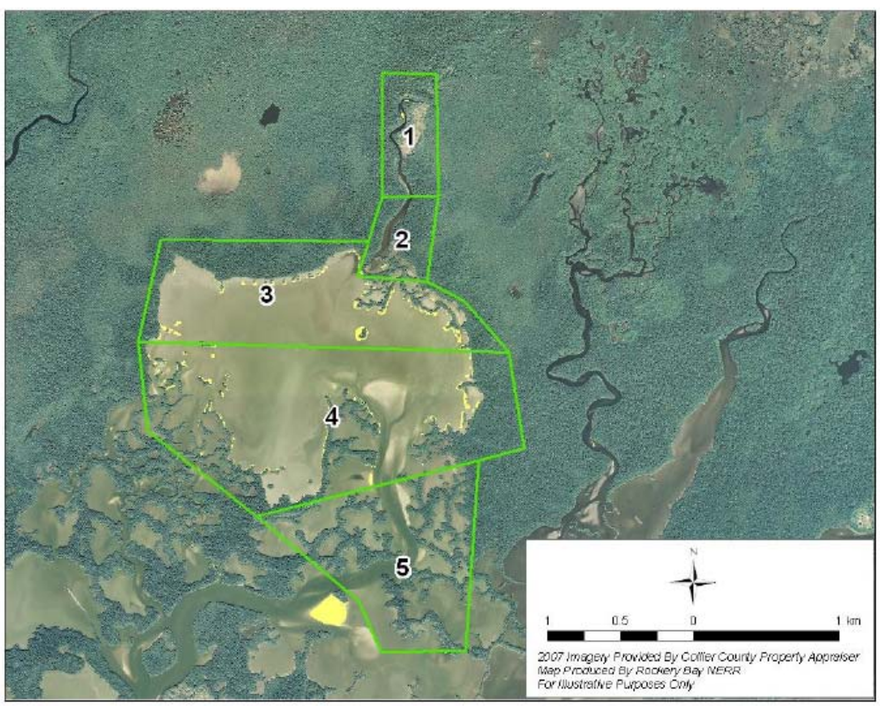

Figure 26. Oyster reef distribution in Pumpkin Bay

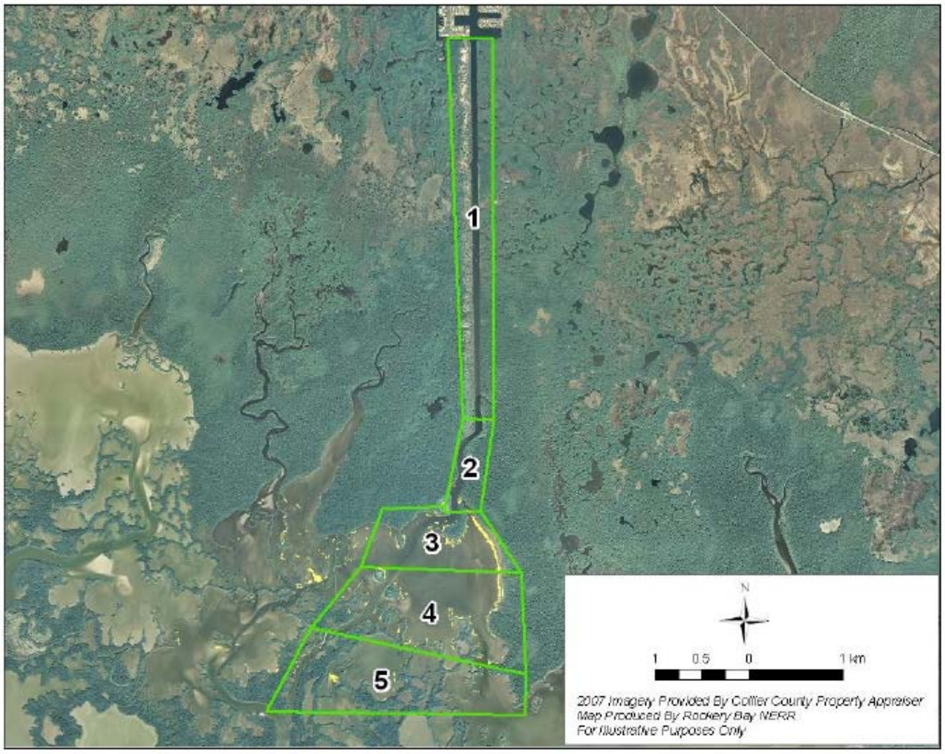

Figure 27. Oyster reef distribution in Faka Union Bay

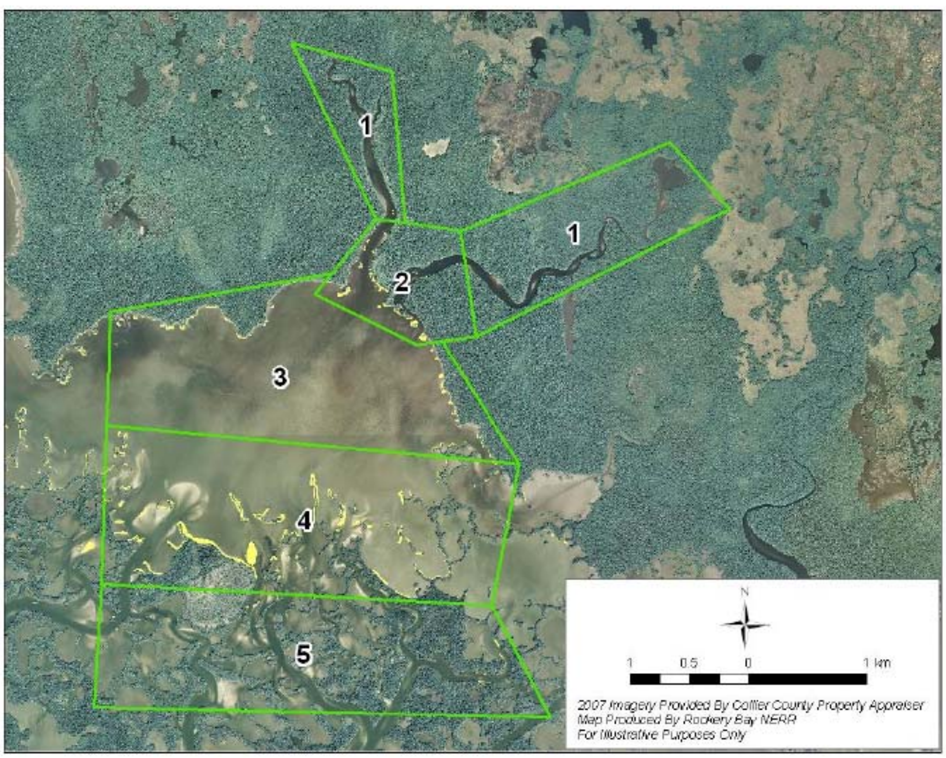

Figure 28. Oyster reef distribution in Fakahatchee Bay

Salinity is critical to the reproduction, development and growth of the eastern oyster. The optimum salinities for oyster reef production are those that range from 10 to 20 parts per thousand (ppt). Salinities in this range ensure successful reproduction of oysters and lower levels of predation than are typical of more marine environments. Both conditions allow for the successful recruitment of oyster spat (Butler 1956). Furthermore, Winstead et al. (2004) suggests that oysters present in these salinities are less susceptible to dermo, which are disease causing parasites, while conditions of either high salinity or temperature will allow for the presence of these parasites. Oysters require a narrow range of salinities for successful spawning, between 15-25 ppt, during the months of May through July. Food availability is greatest between 15 and 35 ppt, so growth is maximized under these conditions.

In the Faka Union Bay, which receives excessive 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 pristine estuaries. While upstream locations in the Faka Union estuarine system have lower disease prevalence among adult oysters, juveniles experience heavy mortality due to freshwater releases or runoff. Mortality is particularly severe in the furthest upstream sections of the Faka Union Canal. Growth rates and condition index of oysters are higher at downstream locations. Spat recruitment occurs during September and October, a period late for southwest Florida (Volety and Savarese 2001).

The Ten Thousand Island bays deprived of sheet flow and seepage show inland-trending displacement of the mangrove and tidal zone, as well as some vegetation and oyster reef die-off. In these estuaries, reduction of the slow pulse of the sheet flow and groundwater seepage during the early dry season is believed to have led to hypersaline conditions in late spring. Higher salinity and temperature increases dermo disease prevalence in adult oysters.

Flows between 300-500 cfs generate the ideal salinities for oyster reproduction during the peak spawning period of May through July. To maximize growth, flows between 100-500 cfs are needed throughout the year. Lastly, flows ranging between 500-1000 cfs are required occasionally to minimize the ill effects of disease and predation (Savarese et al. 2004b).

The reestablishment of more normal salinity regimens will maximize oyster reef development, living density, growth, recruitment and productivity of oysters in middle reaches of the Ten Thousand Islands estuaries. This will restore the best conditions for reef development to these areas with the greatest accommodation space for reef formation.

5.5.2 Submerged Aquatic Vegetation

Submerged aquatic vegetation is an integral part of many shallow-water estuarine and coastal systems worldwide. Such vegetation, generally composed of seagrasses when in near-marine salinities, provides many benefits to society including sediment stabilization, habitat for estuarine animals, and direct and indirect support of commercial and recreational fisheries (USFWS 2002, FDEP 2000).

Species composition and standing stocks of submerged aquatic vegetation and macroalgae appear to be quite sensitive to salinity variation such as that caused by seasonal and anthropogenic changes to freshwater inflow (Chamberlain and Doering 1998). Increases or decreases in salinity may give one species a competitive advantage over another (Livingston 1987, Zieman 1982).

Submerged aquatic vegetation also needs suitable substrate for successful recruitment and establishment. Deposits of silt and muck can displace or modify normal substrate in the estuary and contribute to the decrease in extent of submerged aquatic vegetation beds.

Little is known of submerged aquatic vegetation of the southwest coast of Florida, especially in the Ten Thousand Islands where freshwater flows are projected to change as a result of Picayune Strand restoration. A comparison of data collected in several studies (Carter et al. 1973, Yokel 1975, Browder et al. 1986) suggests that the seagrass cover in Faka Union Bay and other nearby bays has declined substantially since at least about 1970.

Seagrasses are not extensive in the open water areas of the Ten Thousand Islands (Locker and Jarrett 2005, 2006), but are considered locally abundant in the shallow waters off the outermost islands along the gulf edge of the Ten Thousand Islands. Seagrass beds are extensive in the shallow Gulf waters south of Cape Romano. In these shallow waters, seagrass beds were more abundant and widely distributed in the past and have declined in the region due to environmental and/or human factors (Carter et al. 1973, Yokel 1975, Browder et al. 1986).

Marine seagrasses that occur in the Ten Thousand Islands area include turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), Cuban shoal grass (*Halodule wrightii*), and two *Halophila* species, star grass (*H. engelmannii*) and paddle grass (*H. decipiens*). Widgeon grass (*Ruppia maritima*), occurs in some of the inner bays and creeks. Widgeon grass is generally found in waters of 25 ppt or less; however, it can tolerate a wide range of salinities from fresh to 32 ppt. As a result, the distribution and abundance of widgeon grass can vary seasonally.

5.5.3 Nekton

Many of the nektonic 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. Many fish and crustacean species critical to estuarine structure and function have specific salinity tolerances so these species were used to target particular salinities.

Fish

Ten Thousand Islands estuaries not receiving direct discharge appear to have a greater abundance, biomass and diversity of fish and macroinvertebrates than Faka Union Bay (Carter et al. 1973, Colby et al. 1985, and Browder et al. 1986). Browder and Wang (1988) suggested that reduction in optimal-salinity habitat was one possible cause for lower abundance. 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 entering the Ten Thousand Islands through Faka Union Bay. Alterations in the natural salinity regime and timing of freshwater discharges have resulted in a decline in juvenile fish abundance, distribution and species richness (Odum 1970, Myers and Ewel 1990, Chamberlain and Doering 1998). Browder et al. (1986) documented lower fish populations in Faka Union Bay relative to neighboring Fakahatchee and Pumpkin Bays. Colby et al. (1985) suggested that variation in the availability of benthic prey might also have influenced the observed pattern of fish distribution, as direct effects of altered salinity or reduced availability of suitable bottom habitat were not enough to explain the lower fish abundance in Faka Union Bay. Loss of seagrass habitat may have contributed to the decline in fish abundance in Faka Union, Fakahatchee, and Pumpkin Bays.

Ichthyoplankton

Normally, ichthyoplankton concentrations in Faka Union Pass are lower than those in the other passes throughout the year, not just during periods of high discharges. Browder (1988) found that the concentration of fish larvae in bayward transport was nearly twice as great in Fakahatchee Bay as in Faka Union Bay, but was low overall in Pumpkin Bay relative to Fakahatchee Bay. Eight dominant taxa were examined in the Browder et al. 1986 study and 19 dominant taxa were examined in the Browder 1988 study. Collins and Finucane (1984) also collected fewer zooplankton, fish eggs and fish larvae from Faka Union Bay than from Fakahatchee Bay. Browder et al. (1986) found higher concentrations of clingfishes and blennies in Fakahatchee Bay than in Pumpkin Bay, but no significant differences between Fakahatchee and Faka Union Bays.

Four of the 19 dominant ichthyoplankton taxa studied reach peak concentrations in the season of peak discharges, September and October. These studies demonstrated the negative effects of excessive canal discharges associated with the Faka Union Canal on larval fish recruitment. In addition, the ichthyoplankton studies provide information on the time of the year when there is the greatest need for appropriate nursery conditions in Faka Union and nearby bays.

Euryhaline and Stenohaline Crabs

Species inhabiting estuaries have evolved to respond to seasonal changes in freshwater input and its affect on salinity; however, few species are adapted to abrupt, high amplitude fluctuations in salinity (Serafy et al. 1997). Euryhaline species are better adapted than stenohaline species at tolerating salinity fluctuations. Therefore, the ratio of stenohaline to euryhaline species is a sensitive biological indicator of the amplitude and frequency of salinity variation. Green porcelain crabs (*Petrolisthes armatus*), a stenohaline species, and flatback mud crabs (*Eurypanopeus depressus*), a euryhaline species, occur on oyster reefs within the Ten Thousand Island region. Once recruited to a reef, they cannot move to another area to escape unfavorable conditions. 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 2002).

From May 1996 to April 1997, Shirley et al. (1997) studied the recruitment dynamics of crabs on oyster reef habitats in Henderson Creek and Blackwater River relative to salinity fluctuations. Savarese et al. (2004a) found recruitment of juvenile stenohaline and 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 National Estuarine Research Preserve staff has monitored crab populations on oyster reefs within Henderson Creek and Blackwater River and expanded this study to include Fakahatchee and Faka Union Bays. 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 2002).

Shrimp and Blue Crabs

Shrimp (*Penaeus duorarum*) and blue crabs (*Callinectes sapidus*) were also used as the crustacean estuarine indicators. The Ten Thousand Island area contains nursery grounds for pink 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). Browder et al. (1986) found significantly higher blue crab abundances in Pumpkin Bay than in Faka Union Bay. Blue crab abundance varied seasonally, being highest in winter and spring and lowest in summer and fall. Abundance was significantly higher in Pumpkin Bay in summer and fall and Fakahatchee Bay in winter (Savarese et al. 2004b).

This species is dependent on estuaries during several life stages. Blue crabs have different salinity requirements or preferences at different life stages (Pattillo et al. 1997). 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 greater than 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.

Section 6. Hydrologic Performance Measures and Targets

To measure the effectiveness of various alternatives on valued ecosystem components, performance measures were developed for the Picayune Strand Restoration Project. These performance measures relate to how the main stressor on the system, hydrologic alteration, affects three of the valued ecosystem components for Picayune Strand and Fakahatchee Estuary: 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 subsurface 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 evaluate improvements to the natural system with the project implemented. These performance measures are as follows:

1. Average water levels for the dry season (April 1 - June 1)
2. Average water levels for the wet season (July 1 - October 1)
3. Annual maximum water levels
4. Annual minimum water levels

These performance measures were evaluated at 32 locations (indicator regions/well sites) (see Figure 33 in Section 6.1.5) located within and outside of the project are that provide a project-scale evaluation of the hydrologic effects of the proposed project. In this section, an example of how performance measures were used to evaluate plan performance is provided followed by a summary of the evaluation results. Also discussed are uncertainties associated with using performance measures.

6.1.1 Hydrologic Performance Measure and Target Application Example

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 5**) by determining the number of cells (each cell equals 51.65 acres) within each range of water depths present under pre-drainage conditions and 2000 with-project conditions (**Figure 29**). 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.

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 5**; **Figure 29**). 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

US 41 along 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 were located primarily along the eastern edge of the project.

Table 5. 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	2000 With-Project	Pre-drainage	2000 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%

When comparing simulated water depths, there were only small differences in water depth between pre-drainage and 2000 with-project (**Table 5**; **Figure 29**), 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. The target north of the pump stations is to maintain existing conditions in Miller, Faka Union and Merritt Canals to maintain flood protection for Northern Golden Gate Estates and other adjacent lands.

6.1.2 Uncertainty Associated with Defining Pre-development Biotic Targets and Predicting With-Project Restoration Success

The primary natural processes and management activities that will result in the restoration and long-term maintenance of natural south Florida ecosystems and the biota they support are hydrologic and fire regimes and control of exotics. Since we expect the pre-development hydrology to be substantially reestablished below the pump stations and spreader canals, we expect that the hydrologic stage will be set for restoration of the biota in this area. However, there are some significant uncertainties as to the success of ecosystem restoration over the long term. Two of these are the implementation and perpetual maintenance of an appropriate prescribed fire regime and an exotic control program. Accomplishment of both should be simplified over the long term by hydrologic restoration, although a major initial effort will likely be required to reset these to approximate pre-drainage conditions, followed by a long-term low level maintenance effort.

If the hydrologic and fire regimes are reestablished and exotics are controlled, it is reasonable to expect that the biota will return, since the seed populations for these organisms are currently present on the surrounding undrained lands. The main uncertainty is when. Most mobile aquatic animals should respond within one or two normal wet seasons to the hydrologic restoration. Plants and more sedentary animals will take longer to arrive and become established on site, particularly the longer lived species such as trees, which could take a century or more to achieve their pre-drainage character.

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

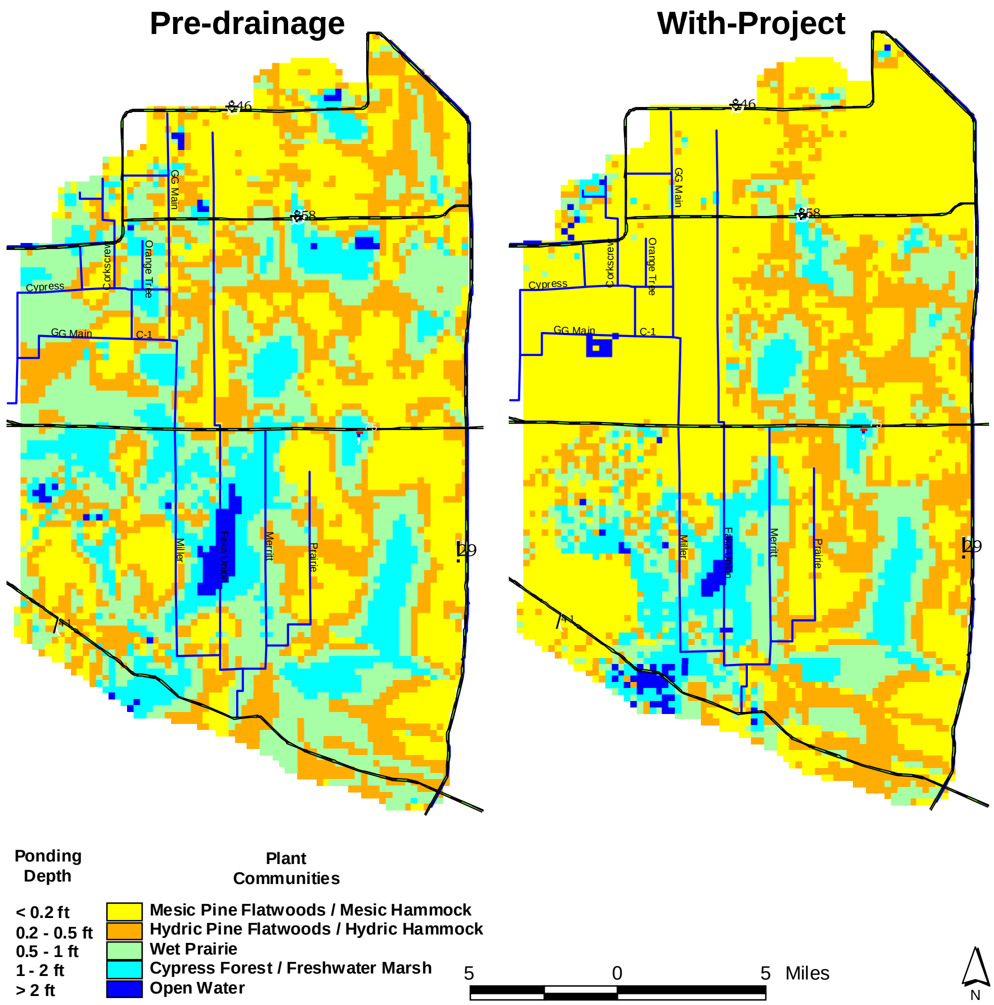

Figure 29. Pre-drainage and 2000 with-project average wet season water depths and corresponding plant community types

The composition of these restored communities will likely change over time, with certain species moving in and building up their populations rapidly throughout the site and others entering and spreading over the site more slowly. Also, as normally happens during ecological succession, certain species will inevitably dominate a seral stage. The exact composition of the biotic community will vary in a much less predictable manner depending on variability in climatic conditions and the sequencing of natural successional processes and disturbance events.

Thus, the biggest uncertainty as to the eventual outcome of biotic restoration is associated with whether the government agencies responsible for the restoration and maintenance of Picayune Strand have the necessary resources and direction to properly manage the site's hydrologic and fire regimes, and to maintain adequate control of exotics. Another less significant uncertainty is how long restoration will take, which will be variable in time depending upon climatic conditions, and in space depending on the degree different portions of Picayune Strand have been altered as a result of drainage and associated fires and invasive exotics.

Part of the restoration construction has been completed in Picayune Strand including filling in seven miles of Prairie Canal, the easternmost canal along the border shared with Fakahatchee Strand Preserve State Park and all roads east of Merritt Canal (**Figure 3**) have been removed. We are already seeing beginnings of hydrologic restoration from these efforts. Water levels are higher beginning in fall 2006 near the filled Prairie Canal than near the unfilled Merritt Canal along both Transect 2 (**Figure 30**) and Transect 3 (**Figure 31**). Sites along these transects are indicated by SGT2W# and SGT3W#, respectively, in **Figure 32**. These plots show reduced water level drawdowns in the Prairie Canal vicinity since it was filled compared to those near the Merritt Canal, which has not been filled, and halfway between the two canals.

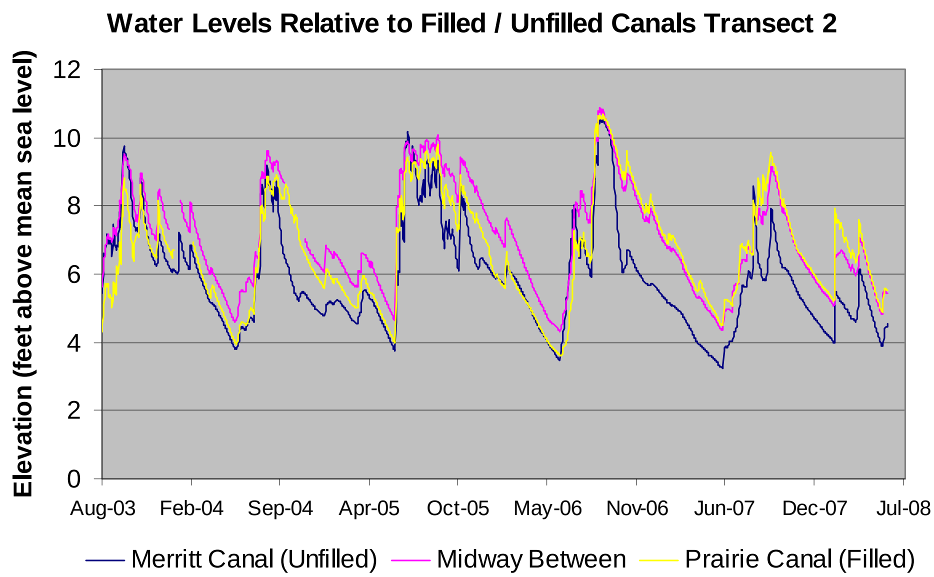

Figure 30. Transect 2 water levels near filled (SWT2W4) and unfilled (SWT2W6) canals

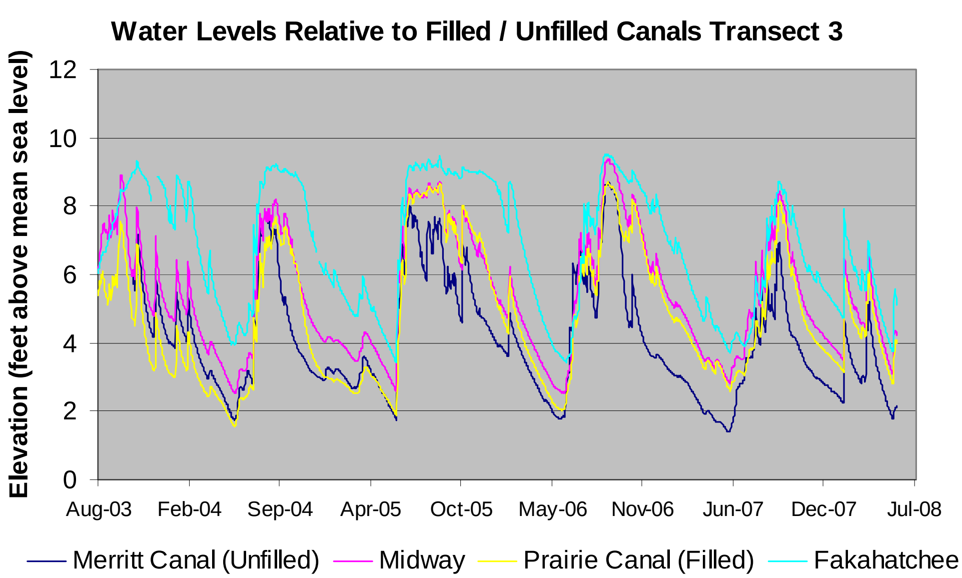

Figure 31. Transect 3 water levels near filled (SWT3W4) and unfilled (SWT3W6) canals

Picayune Strand Restoration Project
Hydrologic and Meteorologic Monitoring Sites

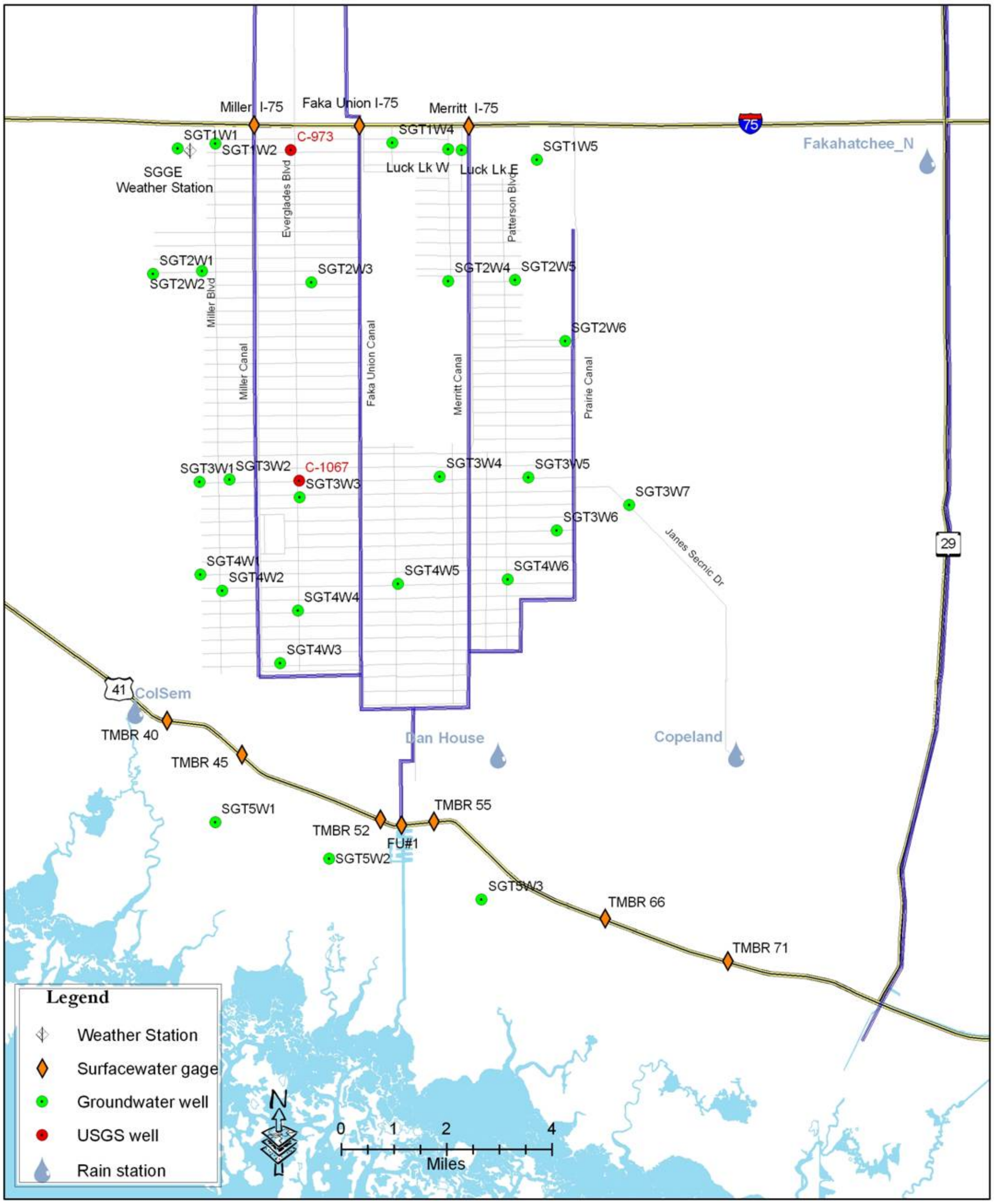

Figure 32. Picayune Strand Restoration Project hydrologic monitoring sites

6.1.3 Documentation of Plant Community Restoration

The hydrologic and ecological models used in the Picayune Strand Restoration Project are invaluable in rapidly predicting the general patterns of response to a variety of restoration scenarios. However, their 50+-acre cell size and the limited accuracy of the incorporated data layers at the fine scales that determine plant community distribution do not allow the prediction of the detailed spatial pattern of the restored plant communities. A monitoring program has been established that will document the long-term recovery of these communities.

Restoration of the Picayune Strand plant communities is being evaluated using two 50-meter transects located near each of the 27 monitoring wells within Picayune Strand, in the brackish marshes south of Tamiami Trail, and at nine reference sites in Fakahatchee Strand Preserve State Park and Florida Panther National Wildlife Refuge. The reference sites include three each of the major plant communities (pine flatwoods, cypress forest, wet prairie) found in Picayune Strand. The monitoring metrics include species composition and/or cover in four strata (canopy trees, subcanopy trees, shrubs, ground cover).

The 27 wells have been located in a more or less regular north-south and east-west grid to provide spatial representation of all parts of the restoration site (**Figure 32**). However, the specific location of each well was selected on the basis of providing good representation, where feasible, of most of the major Picayune Strand plant communities within each east-west line of the grid. We attempted to base this judgment not only on existing plant communities, but also on our assessment of the likely pre-drainage and post-restoration plant communities. The estimate of the pre-drainage plant community was based primarily on the existing living vegetation and the nonliving remains of earlier vegetation that was still present. The depth of organic soil loss that was estimated to have occurred post drainage at a site provided insights into the likelihood of the return of the original plant community versus the development of a deeper water community. To assist in these determinations, fourteen points along each of the transects at the 27 wells in and below Picayune Strand were surveyed to determine their average and range of elevations so we could relate water levels in the nearby wells to water levels in the plant communities in which each transect is located. These data in combination with the previously described information on how plant communities are related to a site's long-term hydrologic regime formed the basis for predicting the restored plant community that will exist along each transect. Particularly in the forested cypress and pine communities, the predicted plant community at many sites will be different from what currently is present because of drainage and the resulting severe fire impacts that have destroyed many of these forests over the last 40 years. In some cases, the restored community will be different from the original plant community because of significant organic soil loss, which has lowered the local topography and will result in deeper water depths and a wetter community. Achieving the predicted plant communities would constitute restoration success, and documenting water levels and their seasonal, annual and multi-year variation will provide an early measure of the likelihood that over the long term the predicted plant community will become established. This of course assumes that an appropriate fire regime exists and exotic vegetation is kept under control.

Since the sites discussed above include multiple representations of all of the major community types and they are distributed throughout Picayune Strand, they will document whether we are restoring the mosaic of these communities over all or part of Picayune Strand. Also, since these communities exist along a hydrologic gradient, if we are successfully restoring all of the major community types at our monitoring sites throughout Picayune Strand, it is reasonable to expect that we will be restoring both wetter and drier adjacent communities, and thus we are reestablishing their distribution along the restored hydrologic gradients.

6.1.4 Summary of Evaluation Results

The four hydrologic performance measures indicate the degree of restoration as shown in **Table 6**, which presents the average percent of pre-drainage conditions water levels predicted for without-project (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 33**). 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 measure would results in matching 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 6. Average percent of pre-drainage conditions for hydrologic performance measures

Performance Measure	Percent of Pre-drainage Conditions	
	2000 Existing Without-Project	2000 Existing With-Project
1. Average dry season water level	61%	95%
2. Average wet season water level	74%	96%
3. Average maximum water level	81%	97%
4. Average minimum water level	59%	96%

6.1.5 Water Depth at Indicator Regions

Comparing pre-drainage (target) and 2000 with-project water stage for the 32 indicator regions (green dots in **Figure 33**) 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 2000 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.

There are a number of patterns that can be seen in the normalized duration curves and groundwater stage hydrographs for the 32 indicator regions. No change from 2000 with-project conditions was found in the northwest corner of Picayune Strand and the adjacent Belle Meade (Indicator Regions 1, 2, 6, 7). These regions are north of the pump stations and spreader canals and therefore will not see any increased water levels. Several other wells in the north-central portion of Picayune Strand (3, 4) will have slightly wetter dry season conditions that probably result from higher stages below the pumps. A number of the indicator regions will have been returned to pre-drainage or close to pre-drainage conditions (Indicator Regions 5, 8, 9, 10, 11, 15, 16, 17, 20, 22, 23, 24, 25, 26, 27, 28, 29, and 30). They are located primarily in the eastern portion of Picayune Strand and adjacent Fakahatchee Strand. However, two of the sites that have returned to pre-drainage system conditions are located in southwestern Picayune Strand (Indicator Regions 20, 24). The last group of sites is located in southwestern Picayune Strand and adjacent Belle Meade. These sites show more water than under pre-drainage conditions. At the westernmost sites this occurs throughout the year (Indicator Regions 12, 18, 19, 32), while in others, it only occurs during the wet season (Indicator Regions 1, 31) or dry season (Indicator

Regions 13, 14). This peculiar pattern could be a result of wet season dumping of water from the adjacent agricultural lands to the west and dry season irrigation and seepage from these lands during the dry season. Based on these results, the only water not needed for Picayune Strand restoration would be that being removed from the agricultural lands to the southwest of Picayune Strand or irrigation seepage from those same irrigated lands during the dry season.

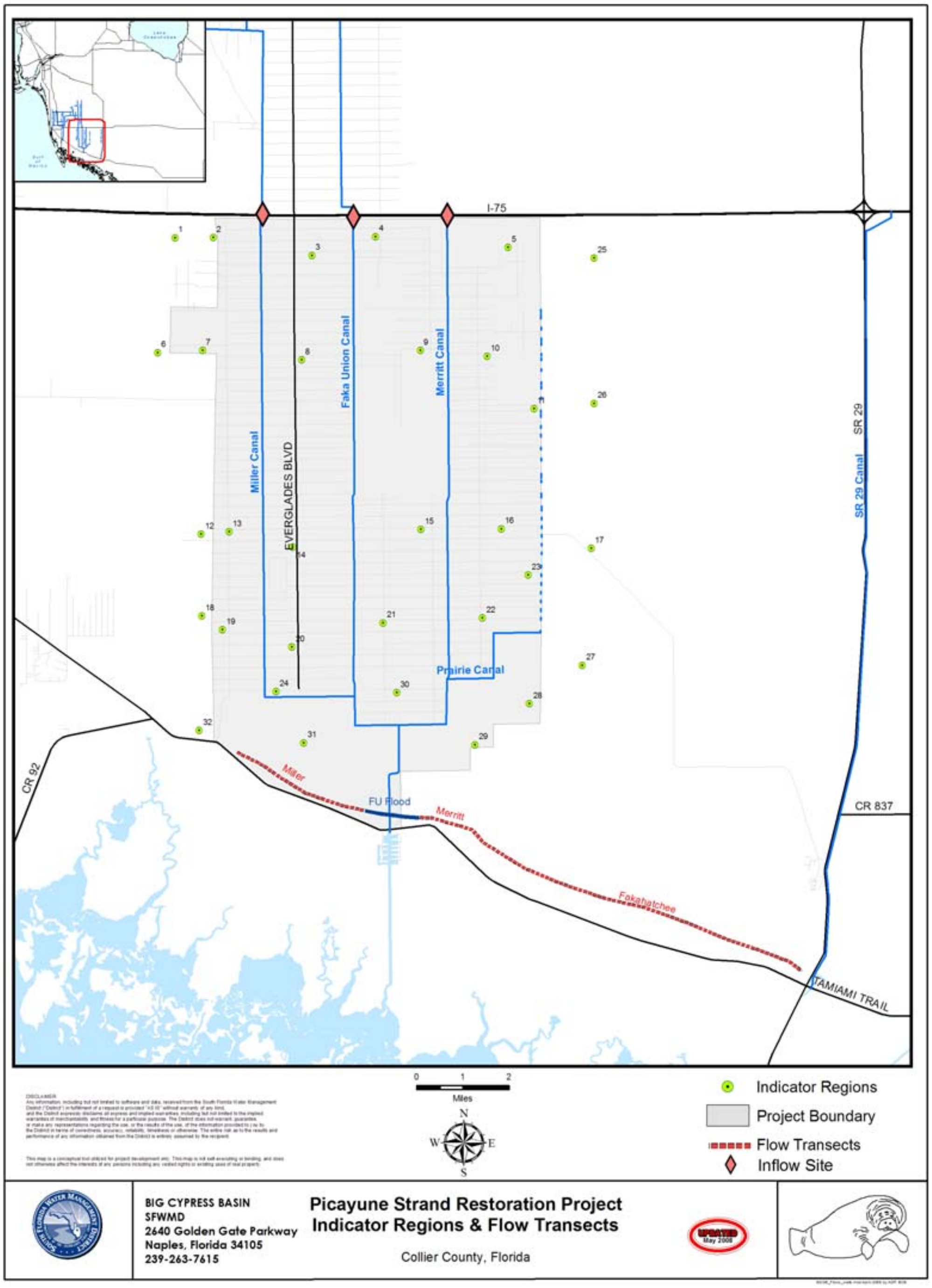

Figure 33. Indicator regions and inflow points for Picayune Strand

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 34**.

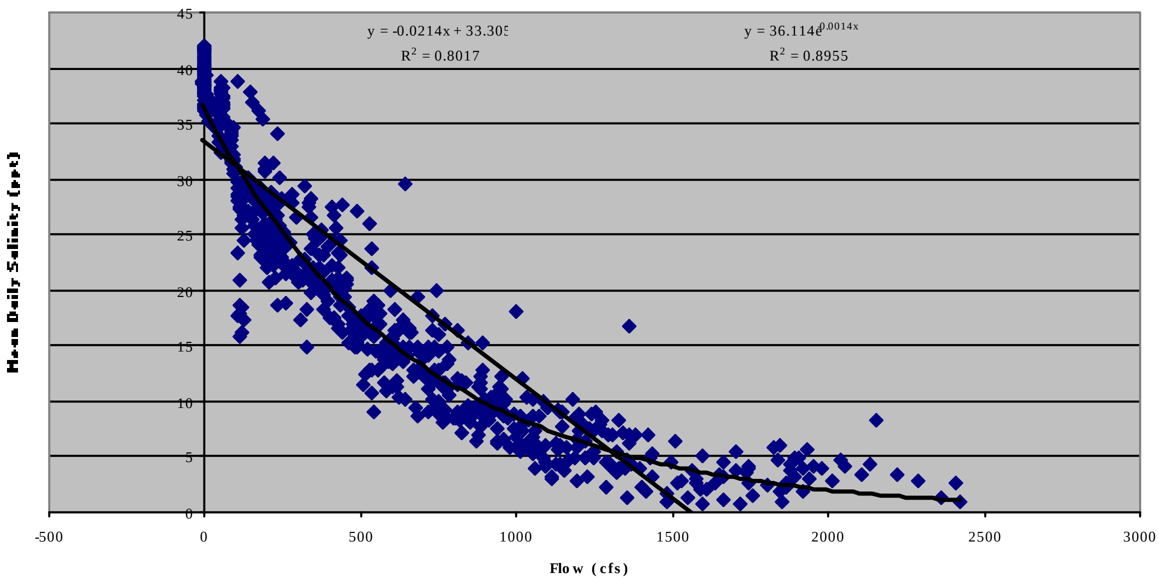

Figure 34. Relationship between flow and salinity above the fixed weir at Port of the Islands on the Faka Union Canal 2000 to 2002

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 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 34**) and the required salinity for oysters and nekton, 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 2000 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 flows within the Picayune Strand watershed require that the effectiveness of different scenarios on the performance measures be evaluated by integrated modeling of surface and groundwater flows. An integrated hydrologic-hydraulic model of the Picayune Strand Restoration Project 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 historic sheet flow patterns and 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 Project 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 7**.

Table 7. Model components applied for the Picayune Strand Restoration Project

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 35**) and covers an approximately 1200-square mile area of western Collier County. This domain is set up on a 1500-feet by 1500-feet grid that has 6171 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. For more information on the model and simulations see the Big Cypress Basin Integrated Hydrologic-Hydraulic Model (DHI 2002) and the project implementation report (USACE and SFWMD 2004).

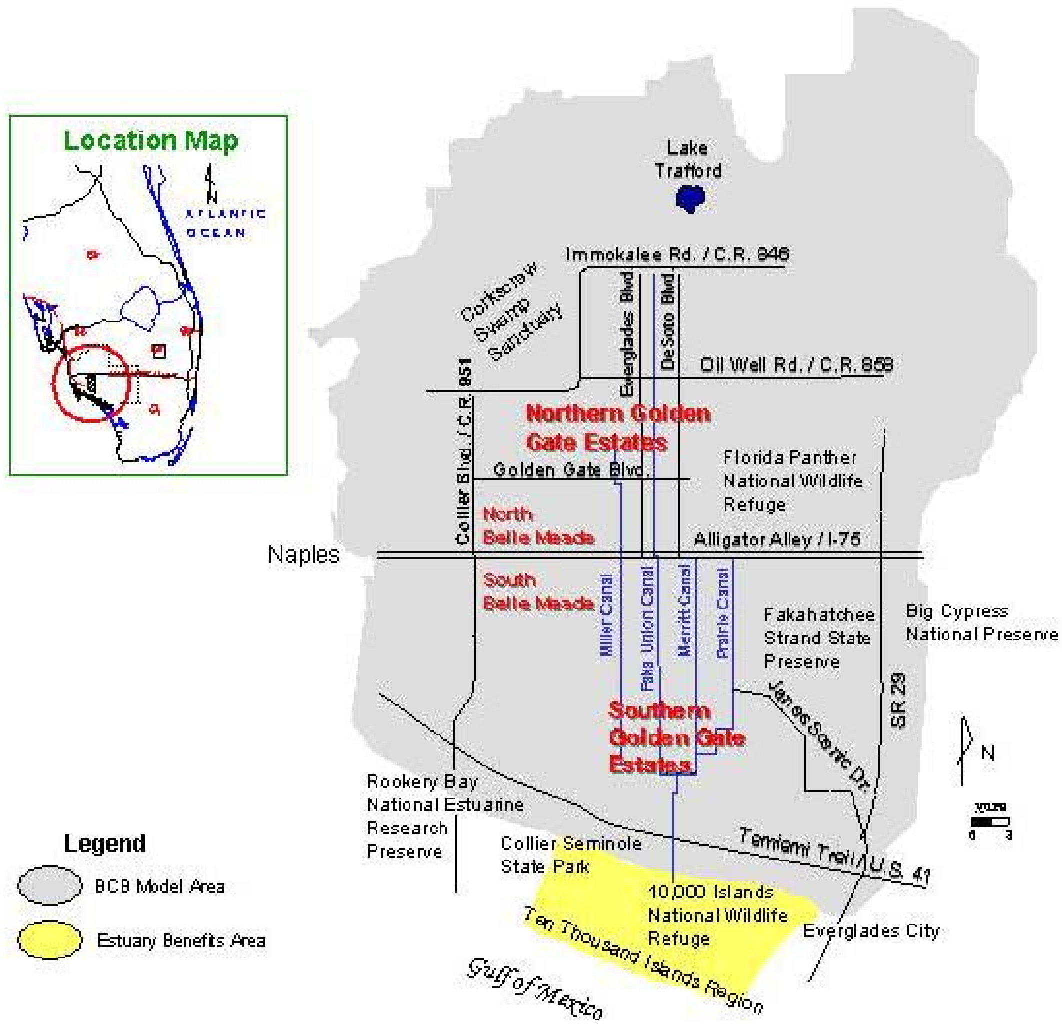

Figure 35. Big Cypress Basin Regional Model boundary

7.1 Period of Record

In developing the long-term hydrologic simulation for the Picayune Strand Restoration Project, a series of comprehensive analyses were performed based on the available length of continuous records of rainfall, surface and groundwater levels, and stream flow data. In the greater Faka Union Canal watershed and its immediate vicinity, long-term records of rainfall are available at the following stations:

- Corkscrew Swamp Sanctuary 1959 – present
- The Conservancy of Naples 1941 – present
- Everglades City 1924 – present
- Immokalee IFAS 1965 – present
- Miles City Forestry Tower 1965 – present

Although each of the stations has some periods of missing records, generalized continuous process modeling of rainfall-runoff can be performed for a 35-year period. However, continuous records of stream flow data are available for only one station (Faka Union Canal at US 41) beginning in 1969. In order to develop a reliable model of the watershed, a more intense network of monitoring stations of prominent calibration parameters such as surface and groundwater stages and stream flow is desired. Reliable continuous records of surface water stages on the tributary canals and groundwater levels of the three primary aquifers are available since the 1980s. Hence, development of a calibrated and verified surface and groundwater integrated model for the watershed for a period longer than 13 years was not deemed feasible.

A 13-year period of continuous simulation between January 1, 1988 and December 31, 2000 was chosen as the long-term simulation period based on the representation of a complete cycle of drought, wet and average hydro-meteorological conditions typical of southwest Florida and western Collier County in particular. As illustrated in **Figure 36** (Corkscrew rainfall vs. Faka Union Canal stream flow), the years of 1994, 1995 and 2000 were respectively representative of average, wet and dry conditions for the Faka Union Canal watershed. Annual rainfall of the other four stations in **Figures 37** to **41** attest to the reasoning behind selecting the 13-year period as the representative period of long-term simulated operation of the Picayune Strand Restoration Project.

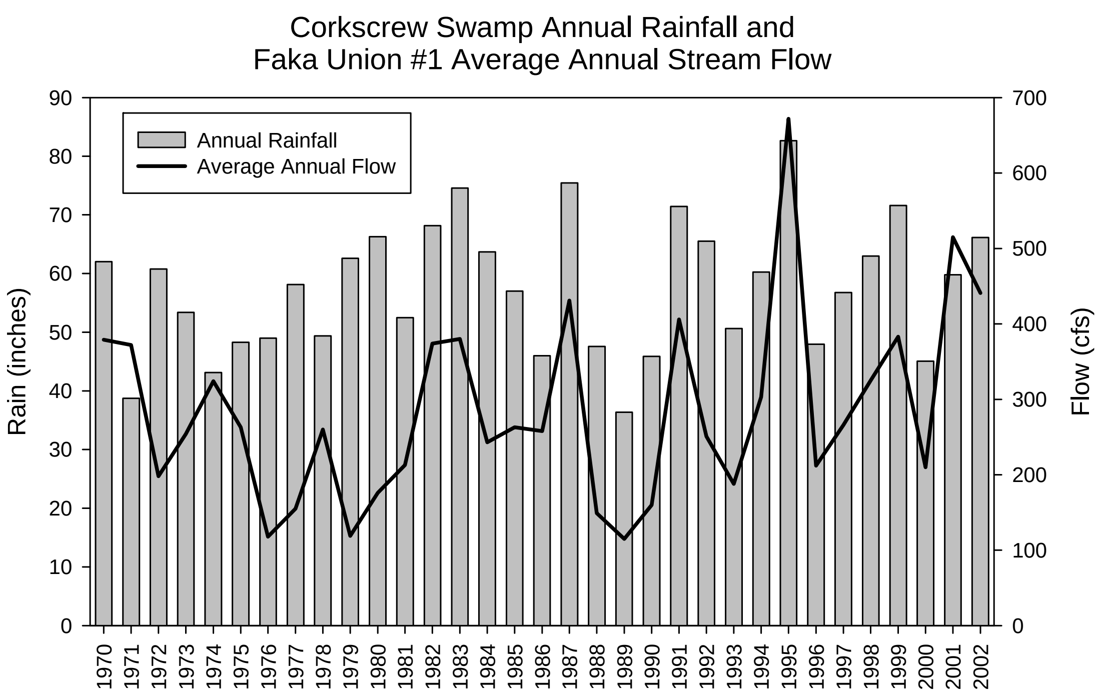

Figure 36. Annual variability of rainfall versus stream flow in the Faka Union Canal watershed

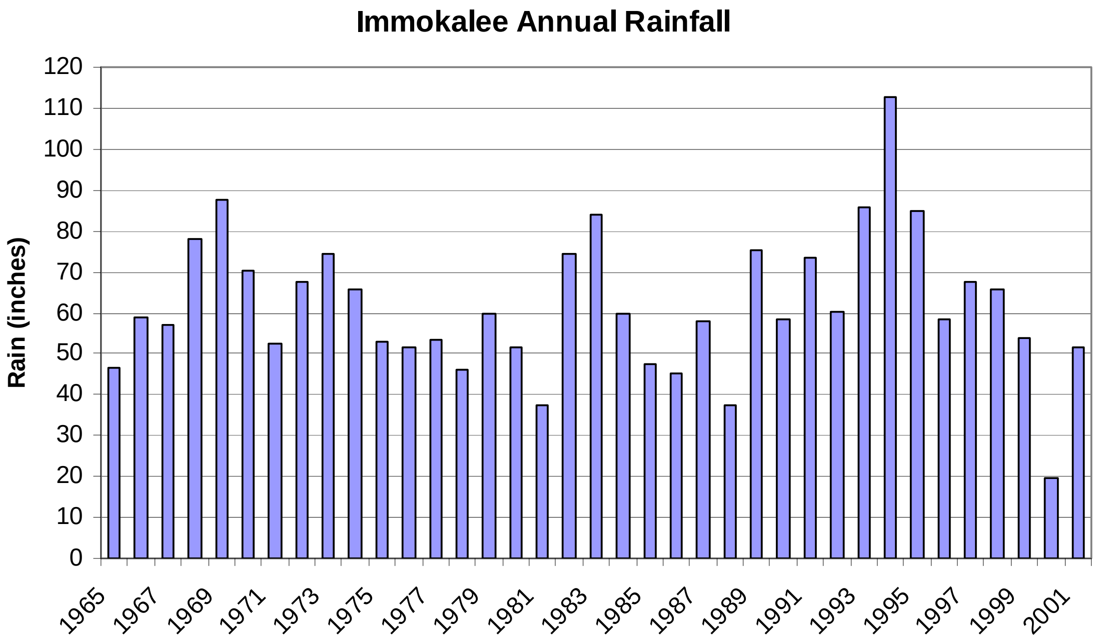

Figure 37. Annual rainfall in Immokalee

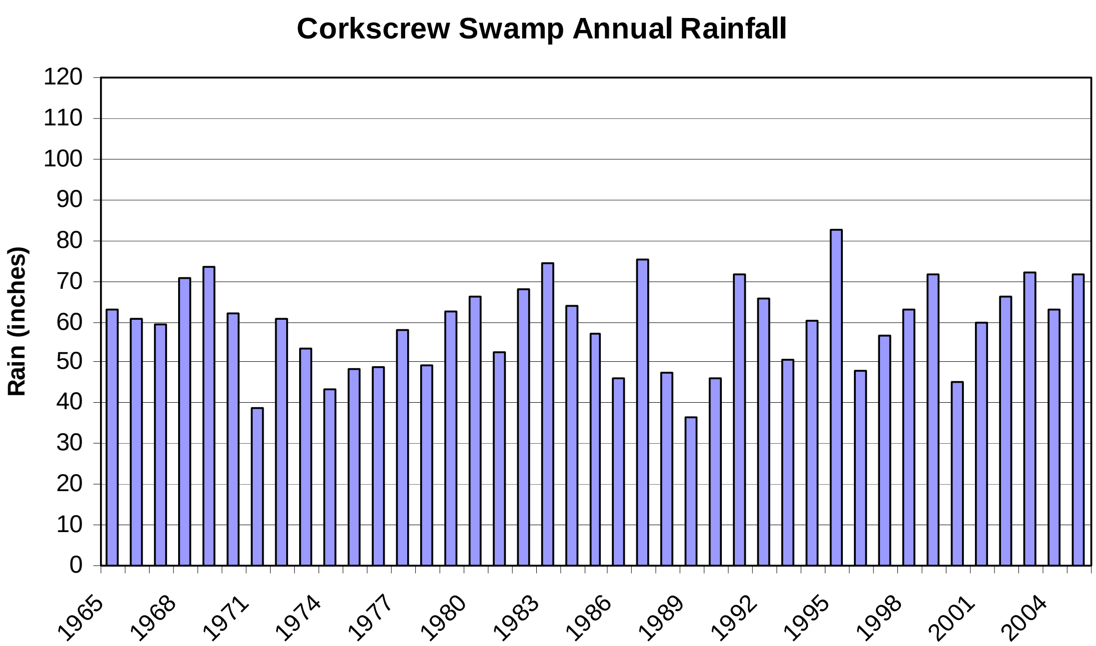

Figure 38. Annual rainfall in Corkscrew Swamp

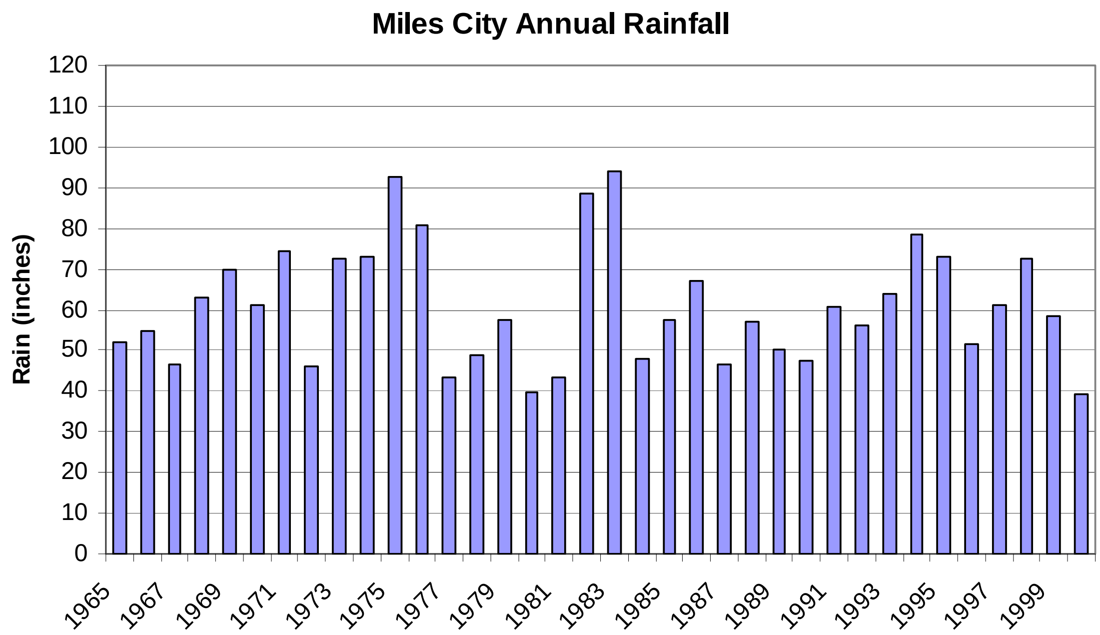

Figure 39. Annual rainfall in Miles City

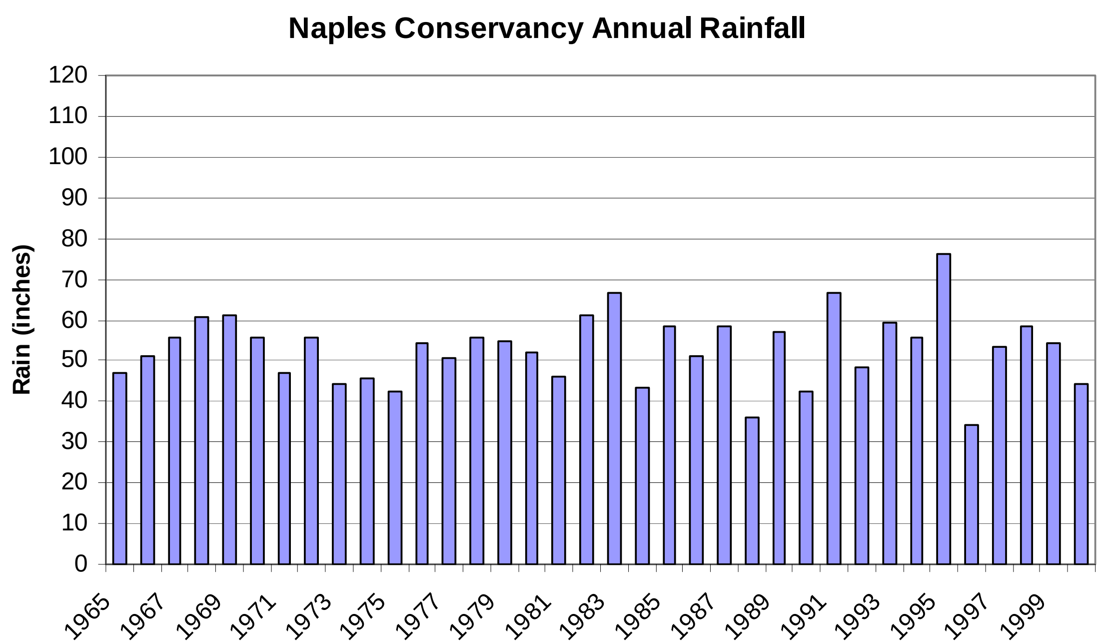

Figure 40. Annual rainfall in Naples Conservancy

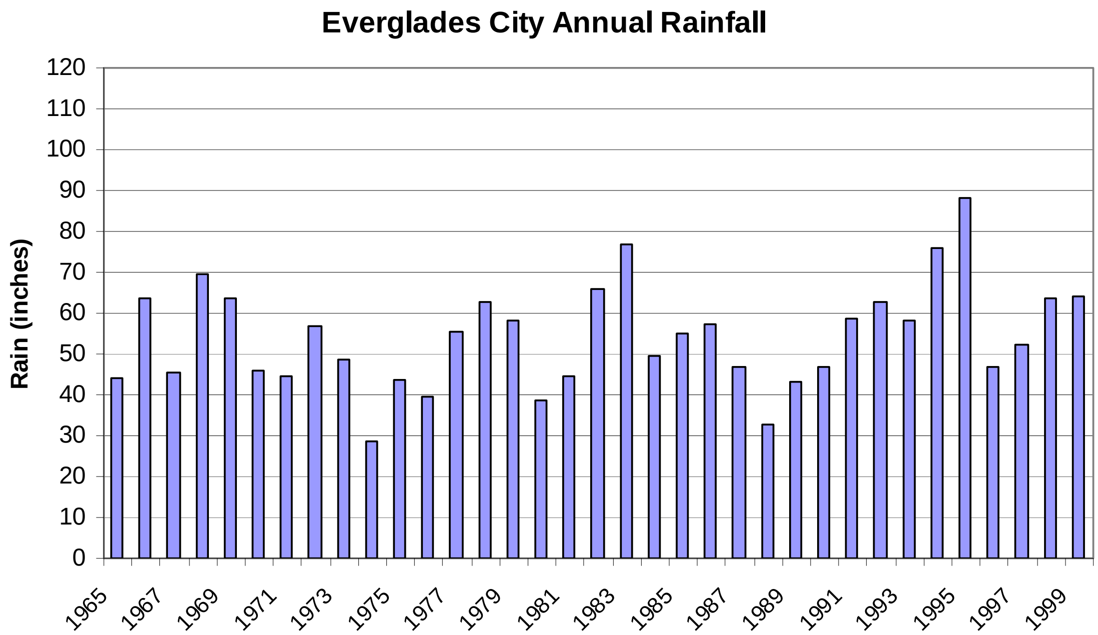

Figure 41. Annual rainfall in Everglades City

7.2 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.

7.2.1 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 ET. Daily potential ET 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 data set 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.

7.2.2 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 condition map was developed into a digital vegetation coverage from the 2001 SFWMD Soil Classification Database.

7.2.3 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, and several other land surveys performed by the SFWMD and the Natural Resources Conservation Service.

7.2.4 Canal Network – Hydraulic Data

Channel flows used in the Picayune Strand Restoration Project modeling are described by the one-dimension 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 Big Cypress Basin 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.

7.2.5 Unsaturated Zone Soil Properties

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.

7.2.6 Saturated Zone Groundwater Flow Properties

MIKE SHE computes groundwater flow and potential head using a three-dimension 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 impermeable. 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 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.

7.3 Simulated Project Conditions

The modeling efforts for development of the project implementation report for the project utilized five conditions: 1) pre-drainage, 2) existing with 2000 land use, 4) restored with 2000 land use, 3) future (2050) no action and 5) restored with future (2050) 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 the first three simulations: 1) pre-drainage condition, 2) with-project condition, and 3) without-project condition. The with- and without-project conditions use 2000 land use.

The results from the pre-drainage conditions simulation were used as a baseline for determining how well restoration plans performed. Comparison between the with-project and without-project provides a measure of how well the proposed plan has improved the indices for establishing a desirable wetland hydrologic regime for restoration of the fish and wildlife habitats of the region.

7.3.1 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 (see **Figure 29** in Section 6.1.1) was incorporated into the NSM to represent the natural condition. Topography data and geologic formation parameters are the same as those for the 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.

7.3.2 2000 With-Project Condition

The 2000 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** in Section 3.4 has the following common features:

- The existing weir structures south of I-75 except for Faka Union #1 were removed.
- Build and operate 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 1500 x 1500 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 were 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. 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 4488 feet in Miller Canal, 7040 feet in Faka Union Canal, and 1425 feet in Merritt Canal. Minor road widths are generally much smaller than the 1500-feet by 1500-feet model cell, and because of this resolution, the simulation of road removal was ignored.

Due to the one-dimensional hydraulic routing approach by MIKE 11, 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 between canal overbanks to allow for east-west flow, thereby artificially creating one large wetland system.

7.3.3 2000 Without-Project Condition

The 2000 without-project condition represents 2000 land use and water withdrawal data of the watershed. The canal and water control structure network was operated under the present wet and dry season operating schedules. The capital improvement projects such as modifications to the Big Cypress Basin canal and structure network constructed after 2000 were not represented. No features of the Picayune Strand Restoration Project such as pumps, canal blocks, spreader canals, levees and road removal were incorporated.

7.4 Topography

Under pre-drainage conditions, the topographically lower flowway defines where the main wetland flowway is located. It begins north of the Merritt Canal above I-75 (see **Figure 3** in Section 3.2). 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** in Section 3.1). 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 (see **Figure 29** in Section 6.1.1) 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 2000 with-project condition, hydrologic pattern is the same as under pre-drainage conditions, with some modifications that are appropriate to the restoration components (see **Figure 4** in Section 3.4). 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 pre-drainage 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 pre-drainage 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 (see **Figure 29** in Section 6.1.1) 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 ecosystem 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. If altered topography (i.e. canals and roads) is eliminated and overland flows restored, average wet season water depths should approximate pre-drainage 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.

7.5 Uncertainty in Hydrologic Modeling

Uncertainties and associated risks of failures in achieving desired objectives can not be avoided when modeling water and environmental resource enhancement projects. Models are the theoretical formulation of a landscape and the mathematical representation of hydrologic events on this landscape. As such, they have inherent uncertainty.

The uncertainties in the hydrologic-hydraulic modeling of Picayune Strand Restoration Project scenarios result from model structure and parameters, levels of confidence on data and operational features, and random spatial and temporal variations of natural processes simplistically represented in the model. The model structure of the integrated MIKESHE/MIKE 11 modeling system may not have been able to perfectly simulate the true physical behavior or process of the unique surface and groundwater flow characteristics of south Florida, which has low relief and a highly fluctuating water table. Model parameters can fail to reflect spatial and temporal variability when represented by a lumped approach of many surface and groundwater parameters. Since most of the land-based parameters in the Picayune Strand Restoration Project model represent the homogeneous characteristic of a 1500-feet by 1500-feet grid, or a tract of 51 acres, uncertainty is introduced by lumping parameters within each of these tracts. Data uncertainty may include inaccuracy or error of measurement, an inadequate monitoring network, and missing or non-continuous data. Representation of hydrologic recurrences developed through stochastic analysis can involve uncertainty due to the statistical variables chosen, their skewness, and bias, based on the length of measured records. The confidence levels of stochastic modeling increase with the length of measured records.

The hydrologic-hydraulic model used in plan formulation for the Picayune Strand Restoration Project evolved over a decade from its initial formulation as the Big Cypress Basin Watershed Plan Model through continual testing; recalibration with newly procured data on topography, land use, soils, vegetation, canal-floodplain survey and pumpage and related hydrogeological property data; and boundary condition configurations. The measure of model verification indices, such as correlation coefficients, mean error, absolute error, root mean square error, standard deviation of errors, etc. continually improved while developing the project implementation report for this restoration project and beyond. Although the models have uncertainties, the SFWMD considers them to be the best available information on which to base water reservations for Picayune Strand and Fakahatchee Estuary. The models are based on data and scientific principles that have been peer reviewed and accepted by experts in the relevant fields.

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

For purposes of identifying the water made available for the protection of fish and wildlife, volume probability curves were produced for inflows into Picayune Strand as well as for inflows into the estuarine system south of Picayune Strand, referred to collectively as Fakahatchee Estuary. 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 inflows entering Picayune Strand via the Miller, Faka Union and Merritt Canals near I-75 (arrows in **Figure 42**), and inflows into the estuarine system (arrows in **Figure 43**).

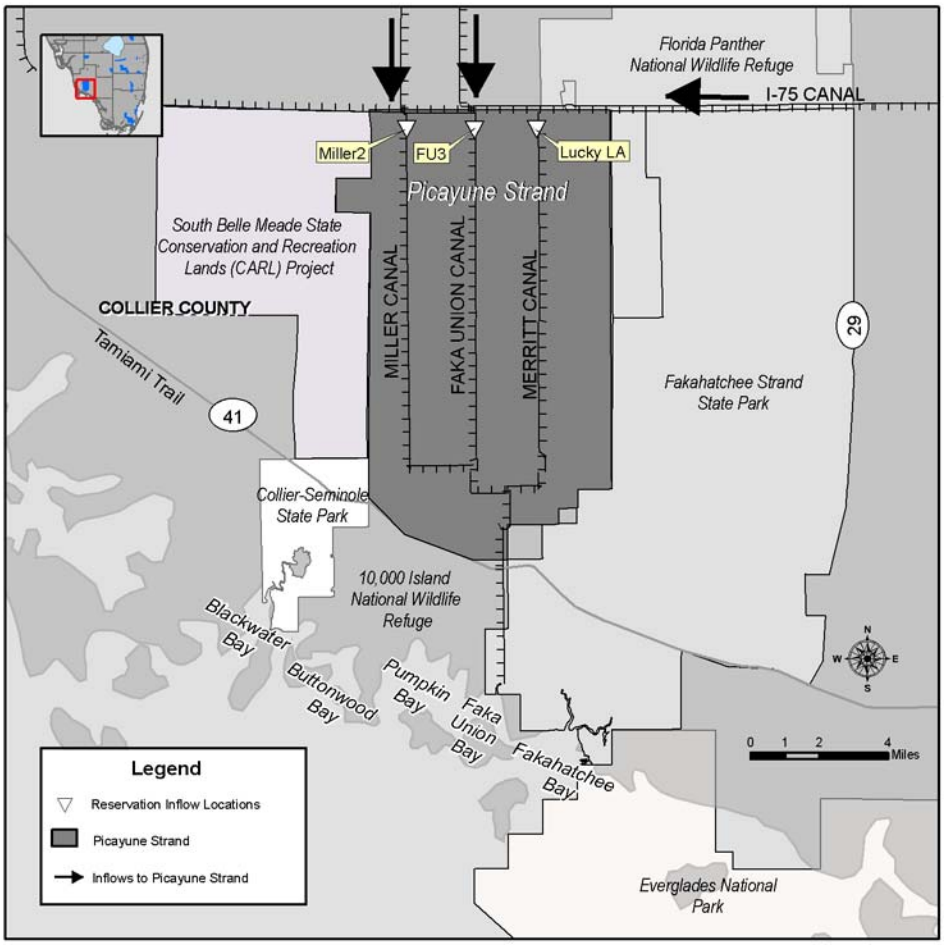

Figure 42. Inflow locations into Picayune Strand from Miller, Fake Union and Merritt Canals

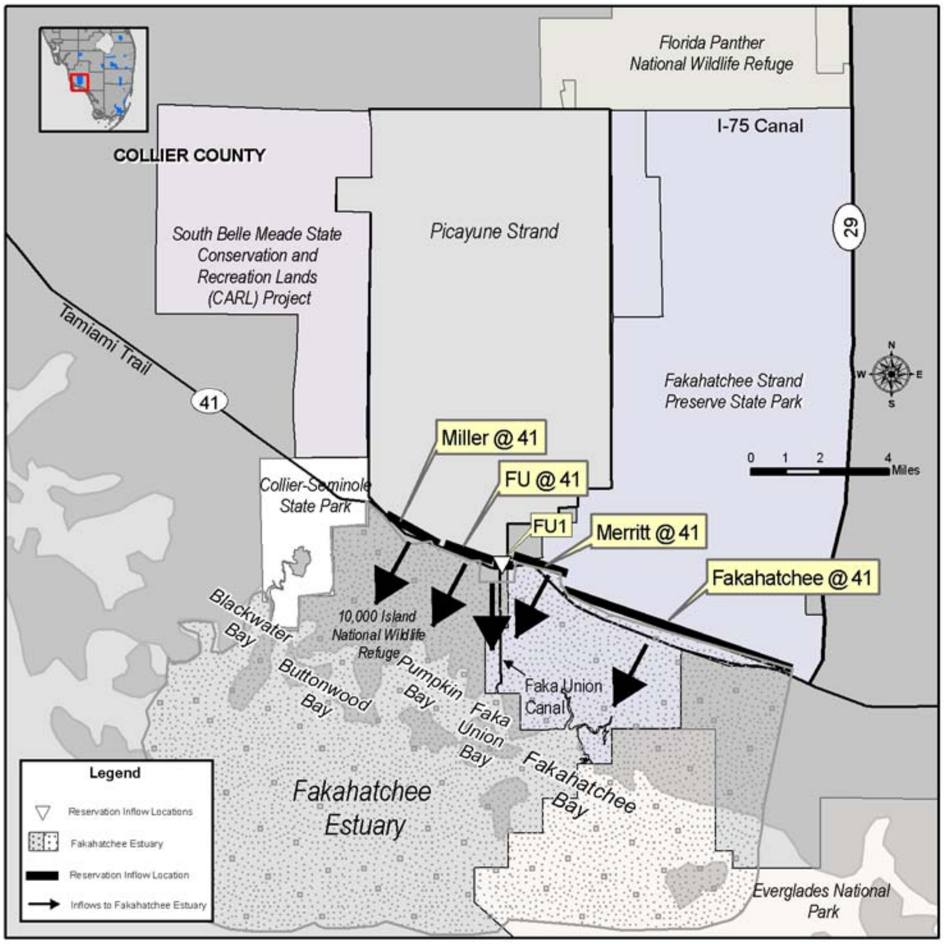

Figure 43. Inflow Locations into Fakahatchee Estuary

Volume probability curves for different simulated conditions can be compared. For the inflow locations shown in **Figures 42** and **43**, volume probability curves were produced for up to three simulated hydrologic conditions: pre-drainage, without-project and with-project. With- and without-project model results are simulated under 2000 land and water use conditions. Conditions simulated by the Natural Systems Model (NSM) are used for the pre-drainage condition.

The target for the protection of fish and wildlife in Picayune Strand north of the pump stations, which distribute the existing inflows across the wetlands, is the without-project condition. The target for the protection of fish and wildlife south of the pump stations in Picayune Strand is the pre-drainage condition hydropattern. For the estuaries, the targets are the pre-drainage condition inflows. The SFWMD has determined that the pre-drainage condition will result in the protection of fish and wildlife.

Volume probability curves depict the range of the quantities of water delivered to the basins under all climatic conditions through the period of record (1988 – 2000) and for the wet (June – October) and dry (November – May) seasons during this same period of record. This period includes sufficient variability in climate, including natural fluctuations of water, to be representative of long-term hydrologic conditions in the region.

When water is distributed across Picayune Strand in the 2000 with-project condition, the volume of water stored in the ground will increase as depicted in **Figure 44**.

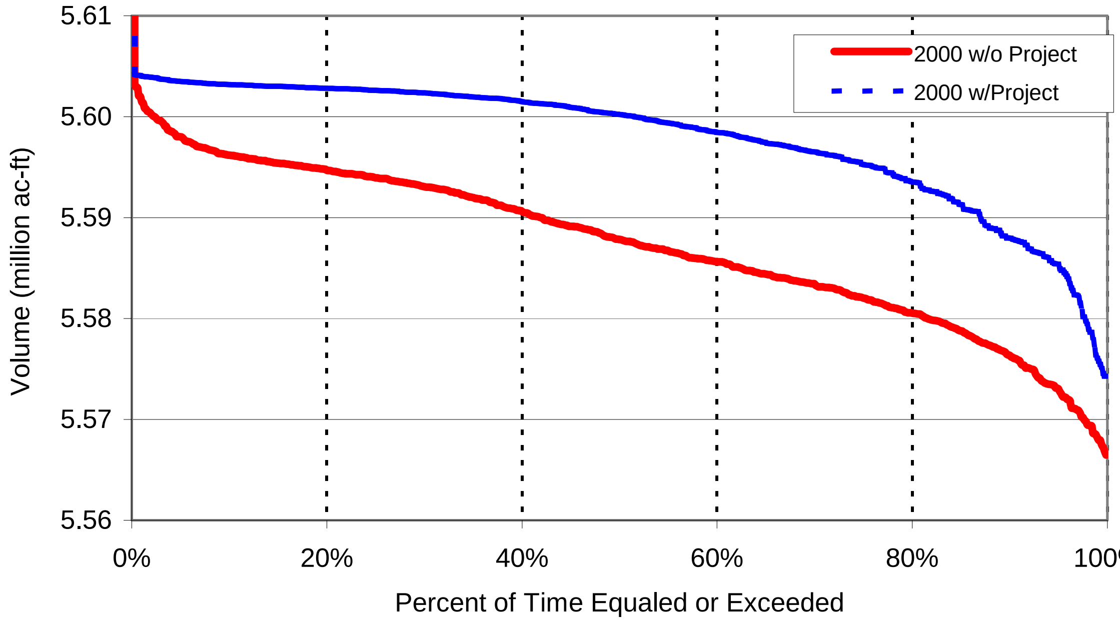

Figure 44. Groundwater storage volume probability 1988-2000

The volume under the restoration target curve is the water to be reserved under state law to protect fish and wildlife. If the water made available by the project (with-project) does not meet the target, then the volume of water to be reserved is the amount of water under the with-project volume probability curve.

Figures 45 through **53** compare the volumes of surface inflow into the Picayune Strand Restoration Project Area. For surface water flows into Picayune Strand via the three inflow canals the without-project and with-project conditions are shown. The target is the with-project condition; the NSM targets for canals do not exist given canals were not present in the pre-drainage landscape. The without-project condition is only shown for comparative purposes.

Figures 53 through **64** compare the surface water volumes flowing under Tamiami Trail (US 41) and into the estuarine system along the four transects shown in **Figure 43**. Transects capture sheet flow volumes for the pre-drainage, without-project and with-project conditions. The flow across these transects represents sheet flow to the estuarine system.

Simulated surface water flow through the weir along the Faka Union Canal (FU1) is presented in **Figures 66** through **68** and displays the without-project condition and with-project condition. The with-project condition is the target on these figures since no NSM target exists for canals. The inflows over the FU1 weir for the with-project condition represent the point source flows entering Faka Union Bay necessary for the protection of fish and wildlife.

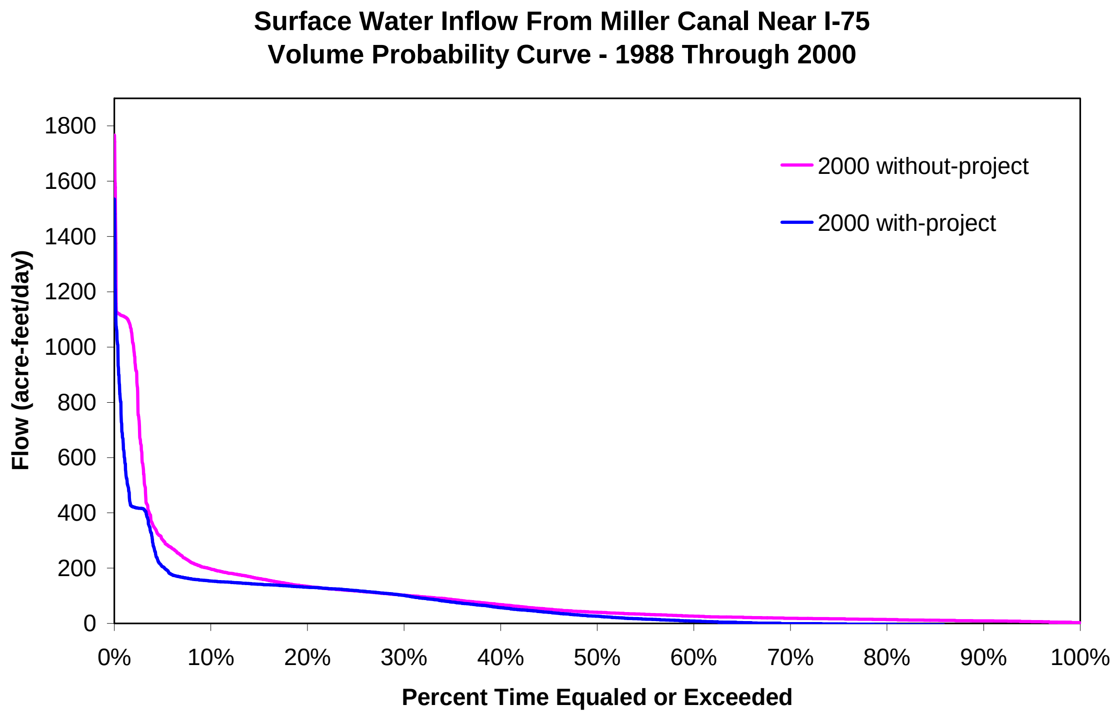

Figure 45. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Miller Canal for the entire period of record (1988 - 2000)

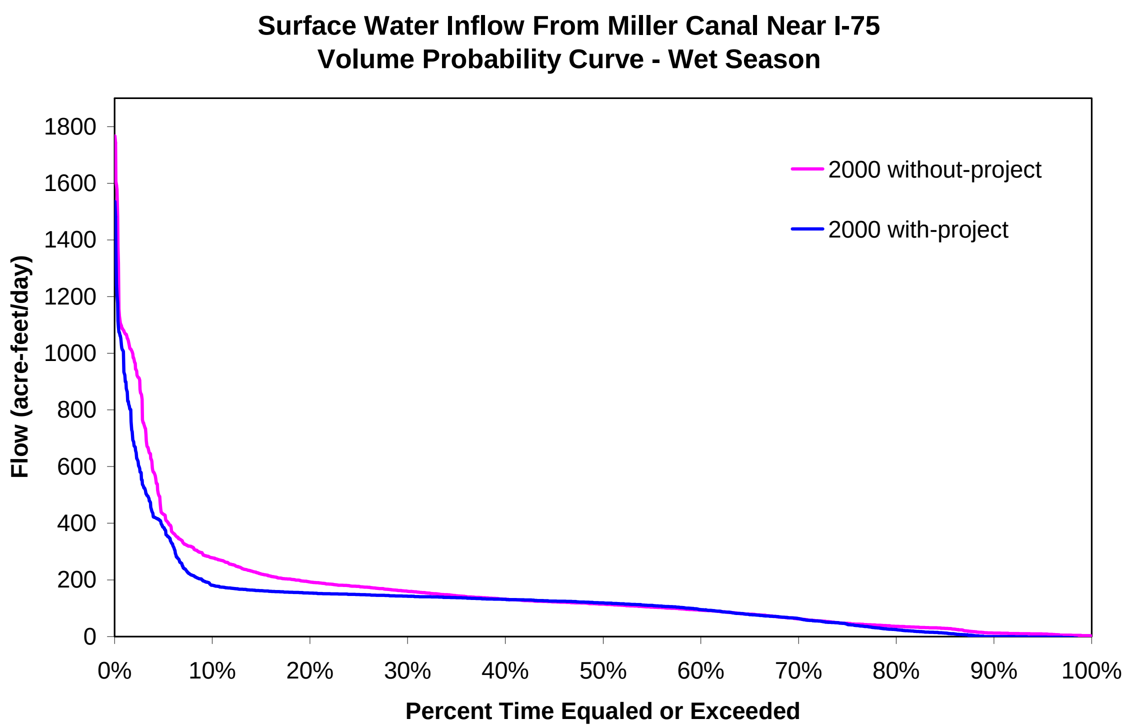

Figure 46. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Miller Canal for the wet seasons during the period of record (1988 - 2000)

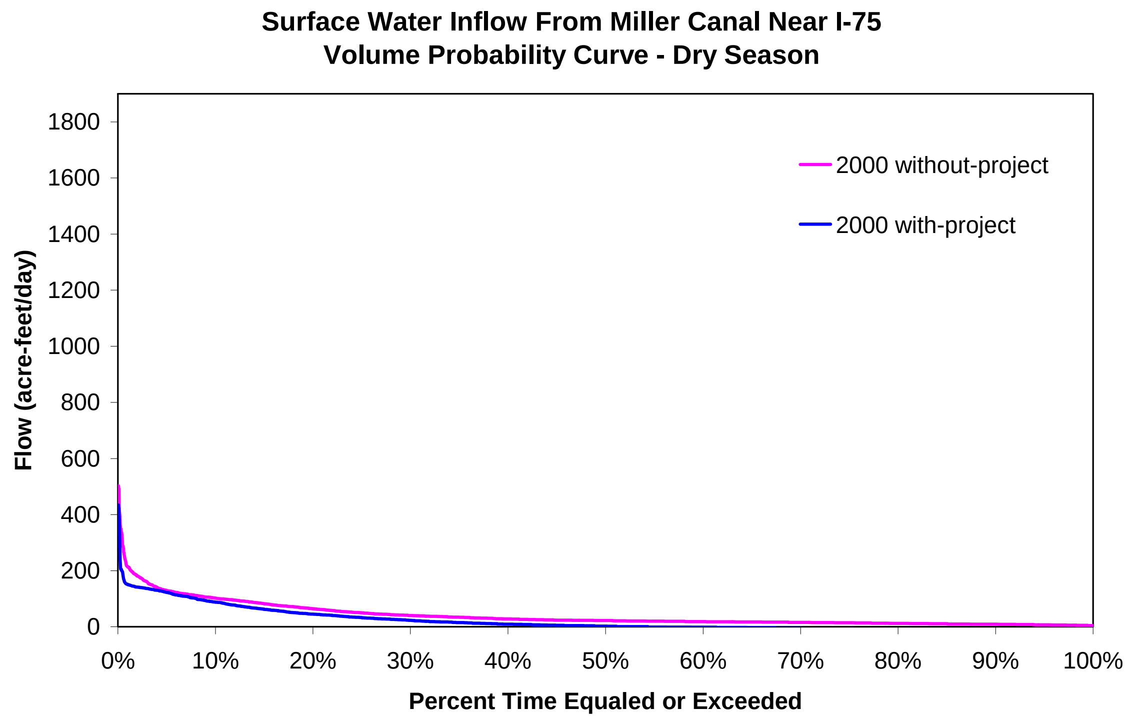

Figure 47. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Miller Canal for the dry seasons during the period of record (1988 - 2000)

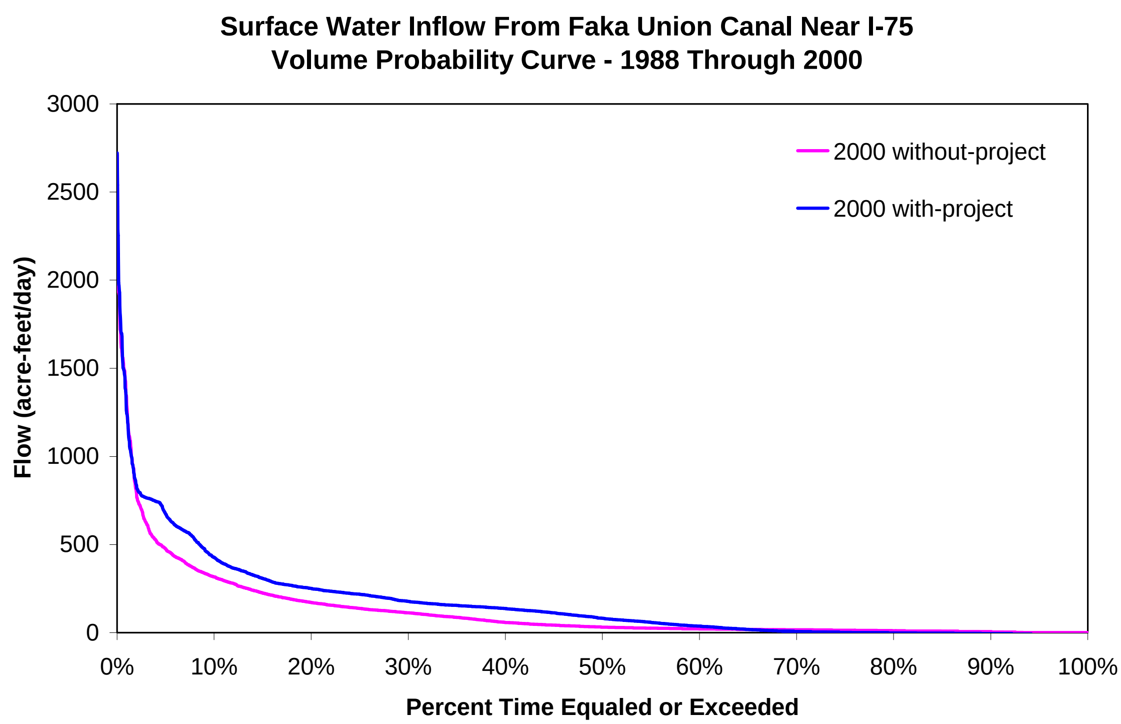

Figure 48. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal for the entire period of record (1988 - 2000)

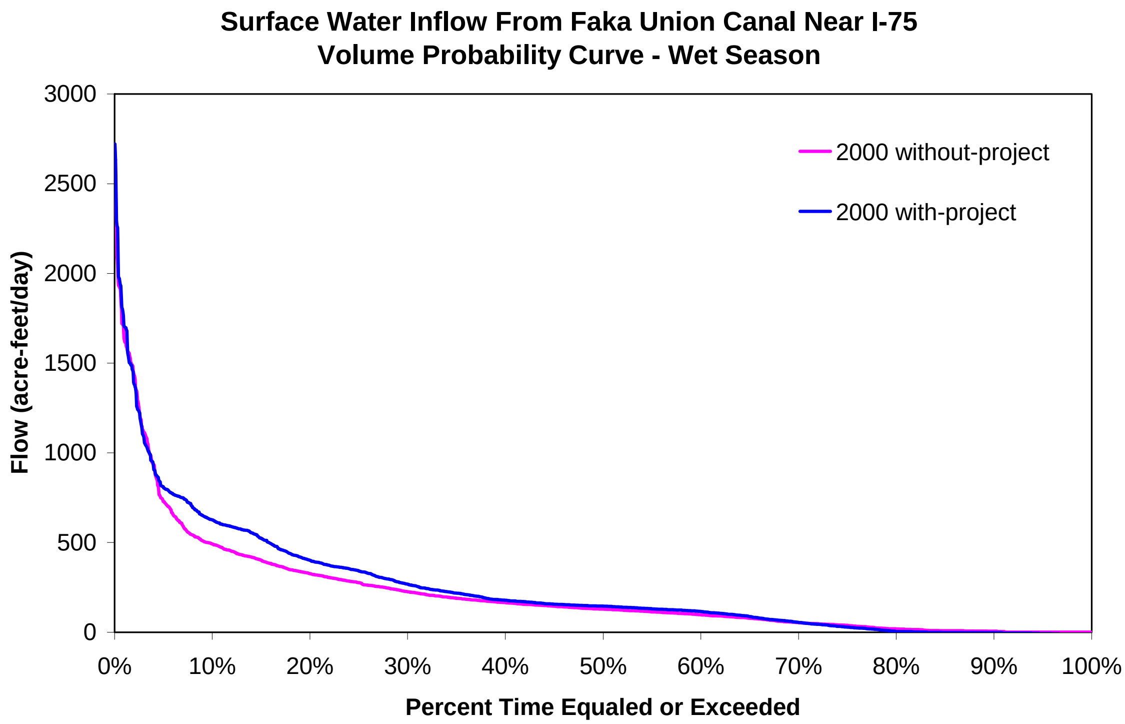

Figure 49. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal for the wet seasons during the period of record (1988 - 2000)

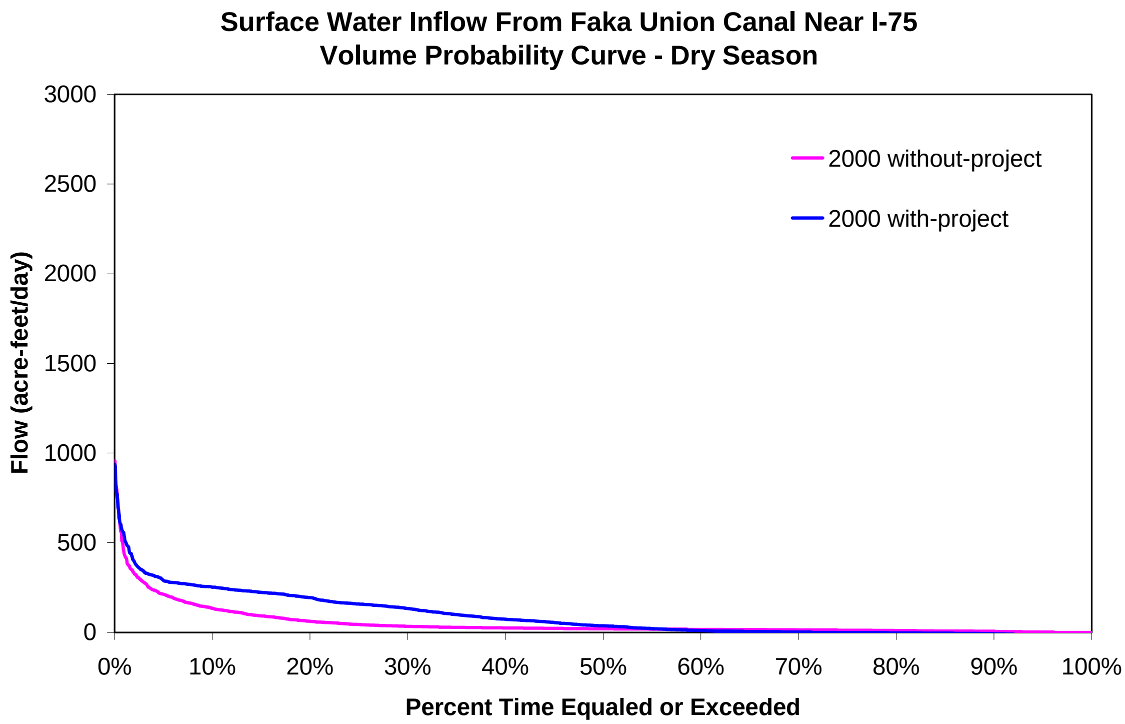

Figure 50. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal for the dry seasons during the period of record (1988 - 2000)

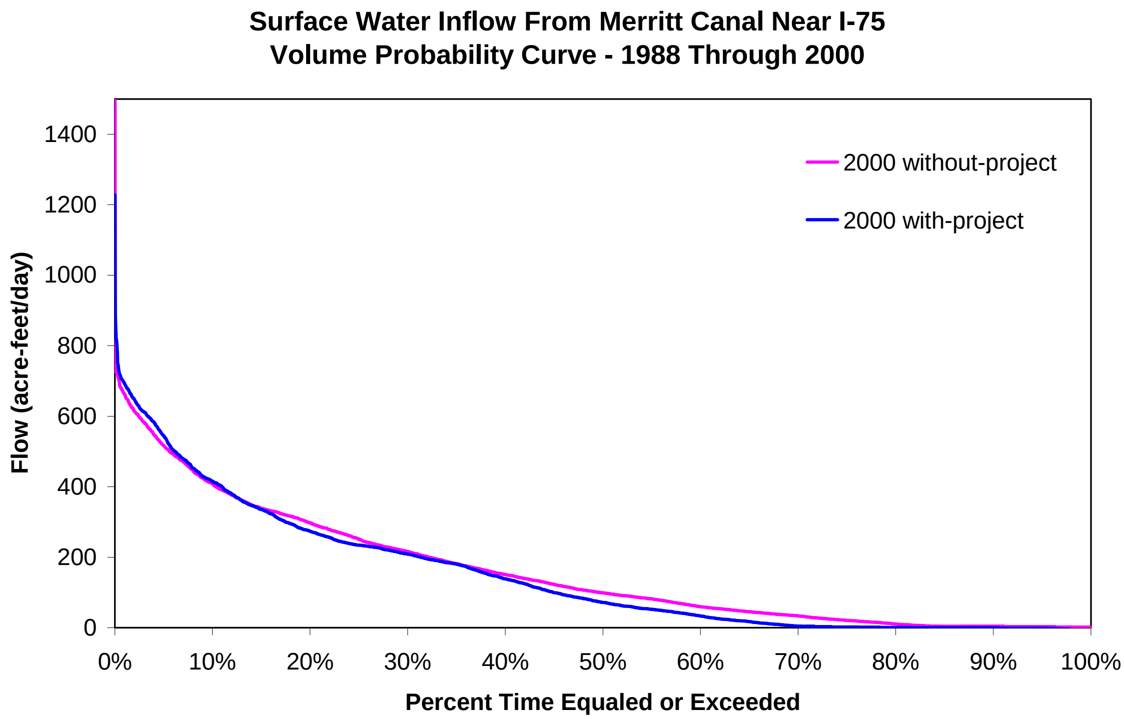

Figure 51. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Merritt Canal for the entire period of record (1988 - 2000)

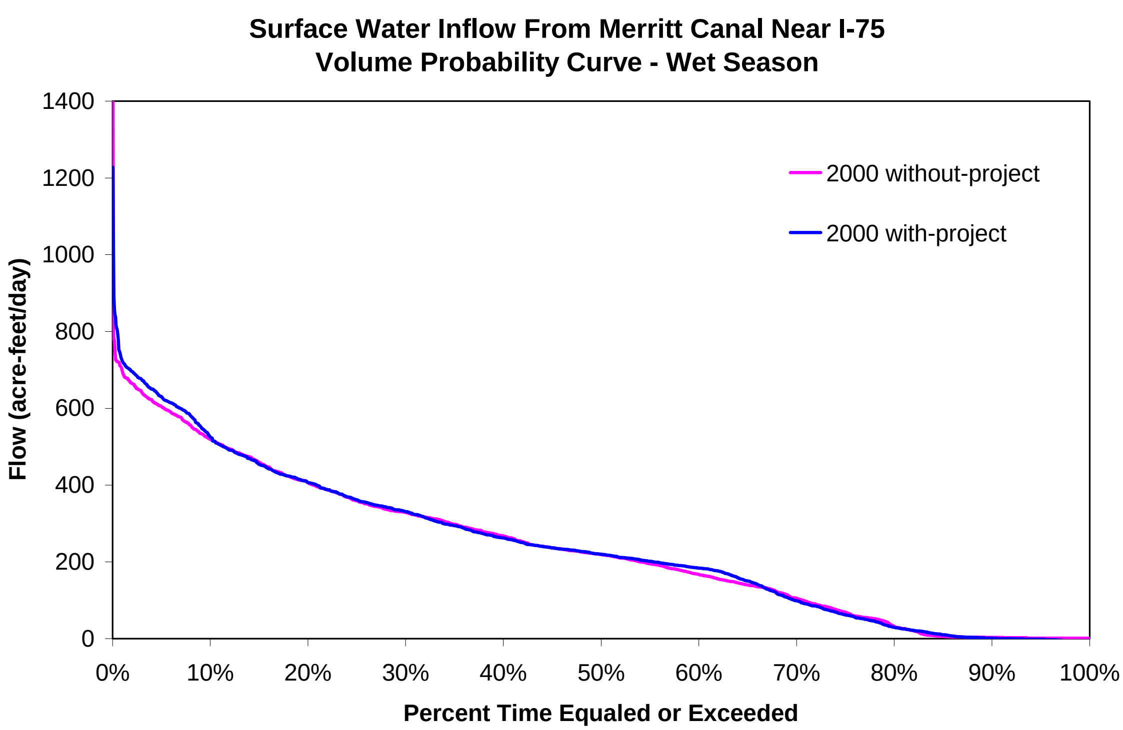

Figure 52. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Merritt Canal for the wet seasons during the period of record (1988 - 2000)

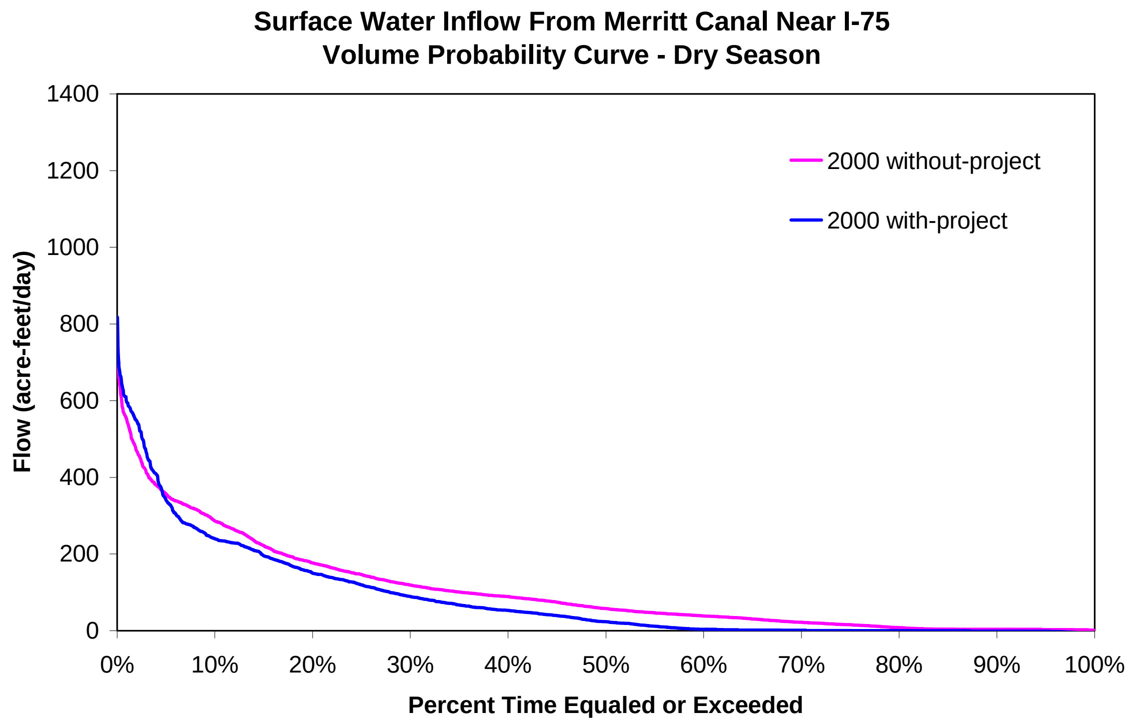

Figure 53. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Merritt Canal for the dry seasons during the period of record (1988 -2000)

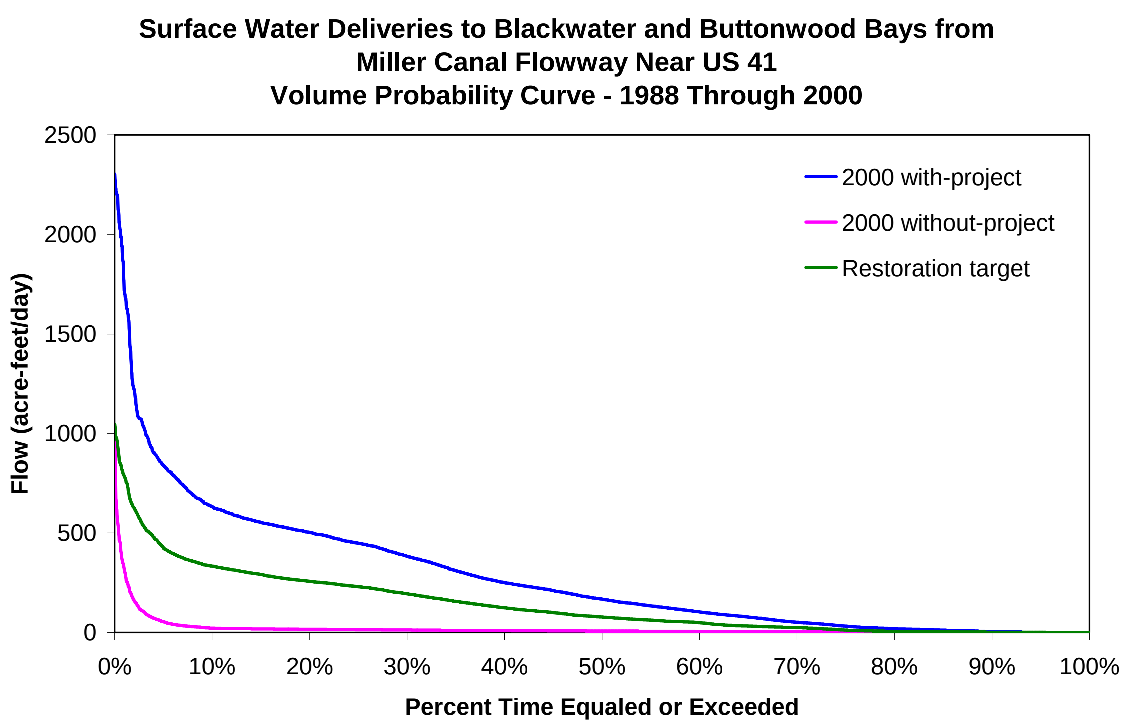

Figure 54. Volume probability curve for surface water inflow along the Miller Canal flowway near US 41 for the entire period of record (1988 - 2000)

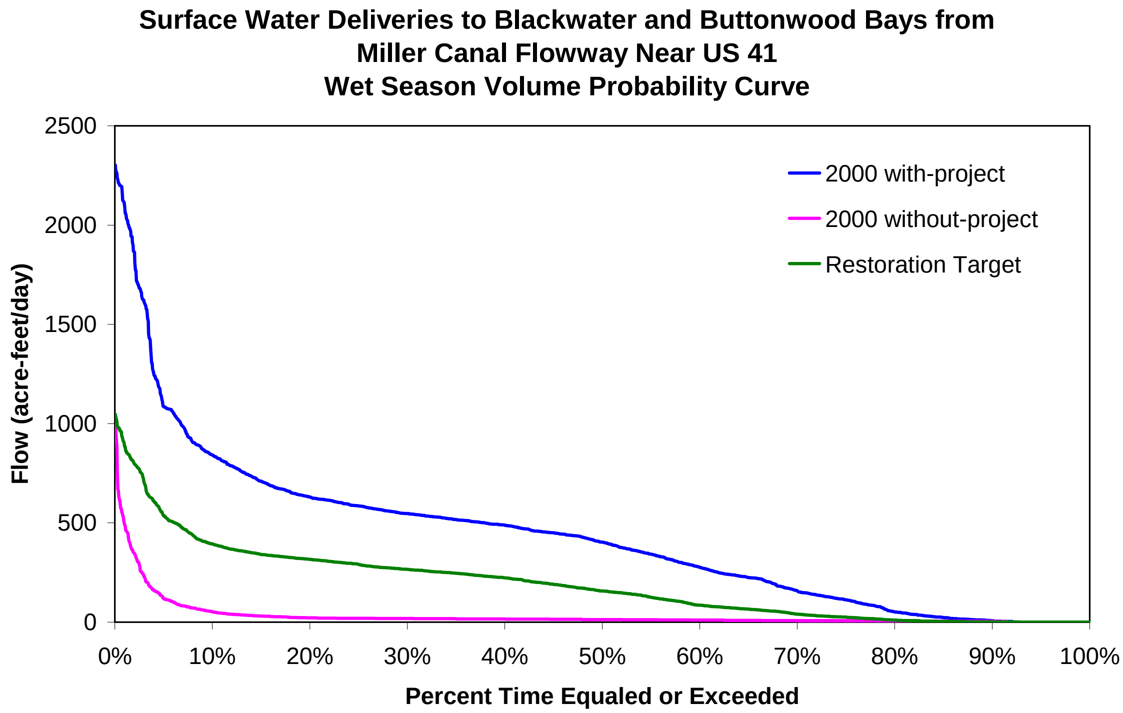

Figure 55. Volume probability curve for surface water inflow along the Miller Canal flowway near US 41 for the wet season for the period of record (1988 - 2000)

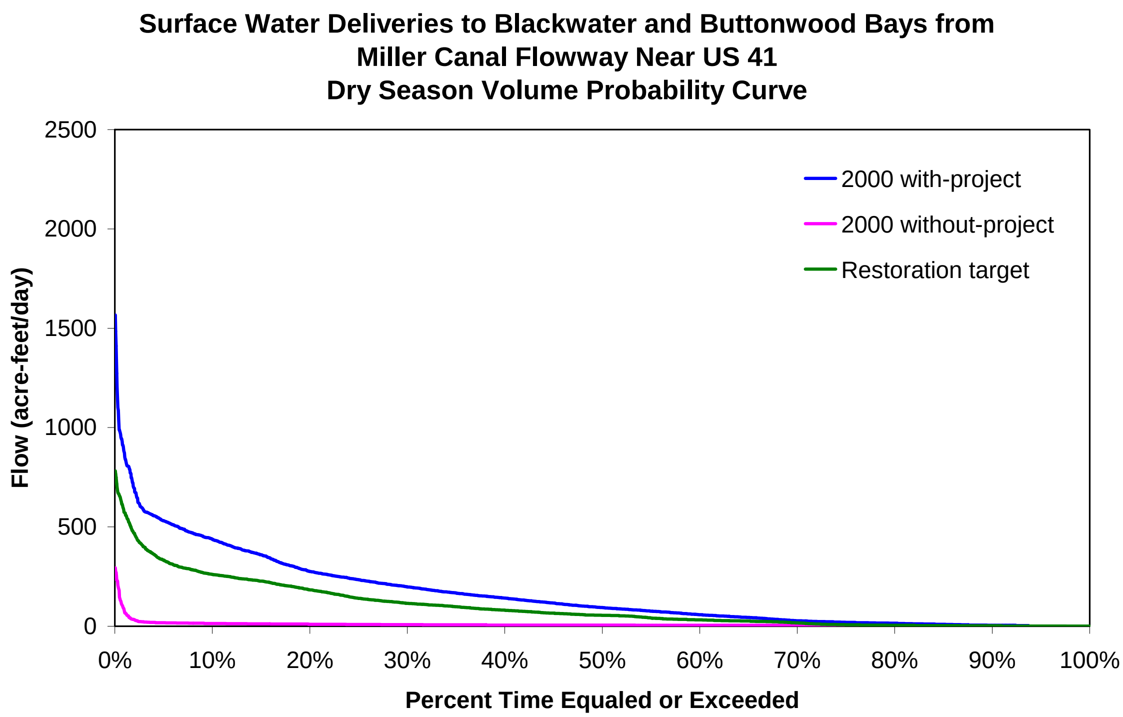

Figure 56. Volume probability curve for surface water inflow along the Miller Canal flowway near US 41 for the dry season during the period of record (1988 - 2000)

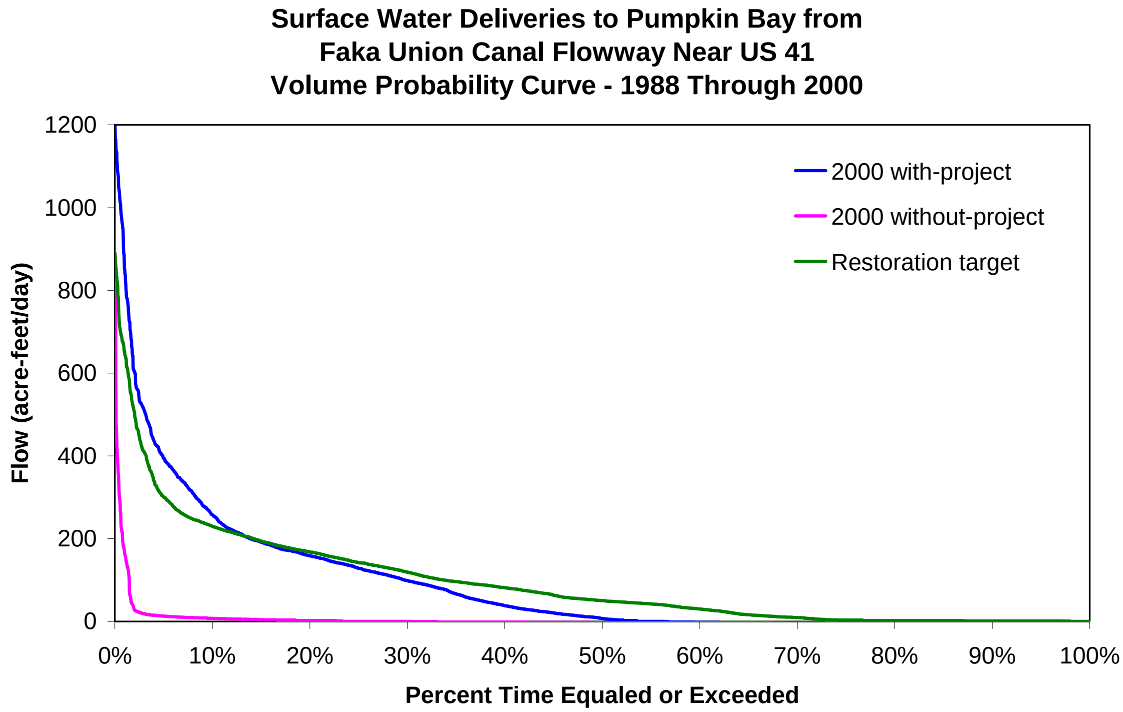

Figure 57. Volume probability curve for surface water inflow along the Faka Union Canal flowway near US 41 for the entire period of record (1988 - 2000)

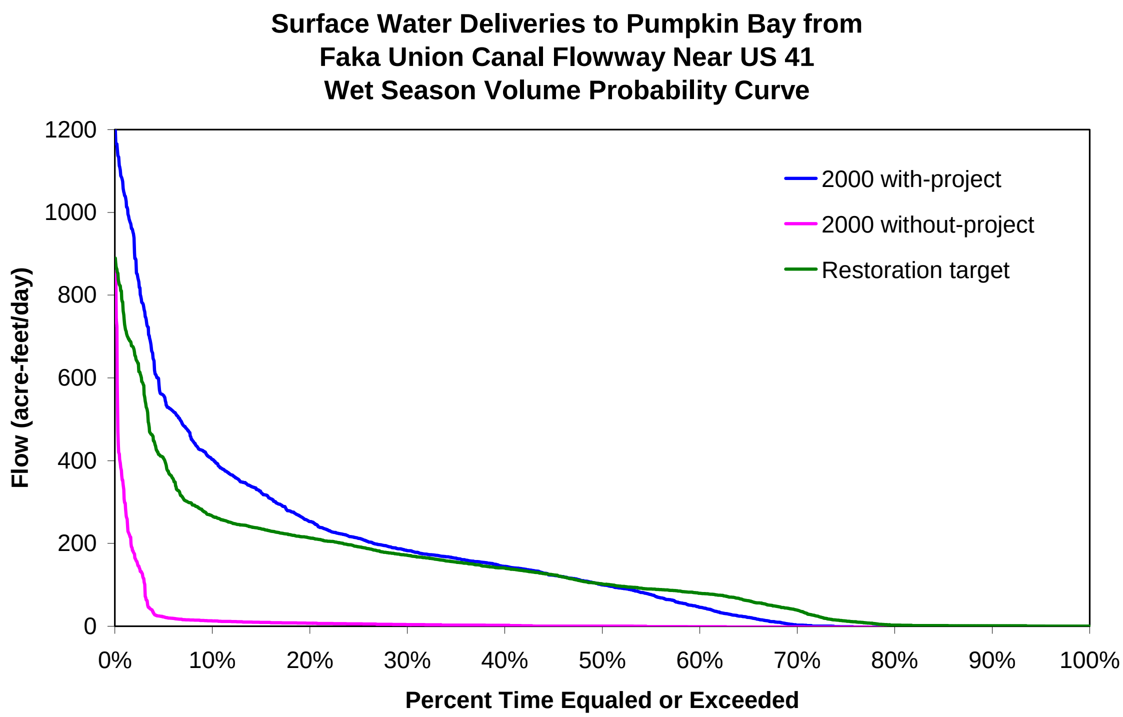

Figure 58. Volume probability curve for surface water inflow along the Faka Union Canal flowway near US 41 for the wet season for the period of record (1988 - 2000)

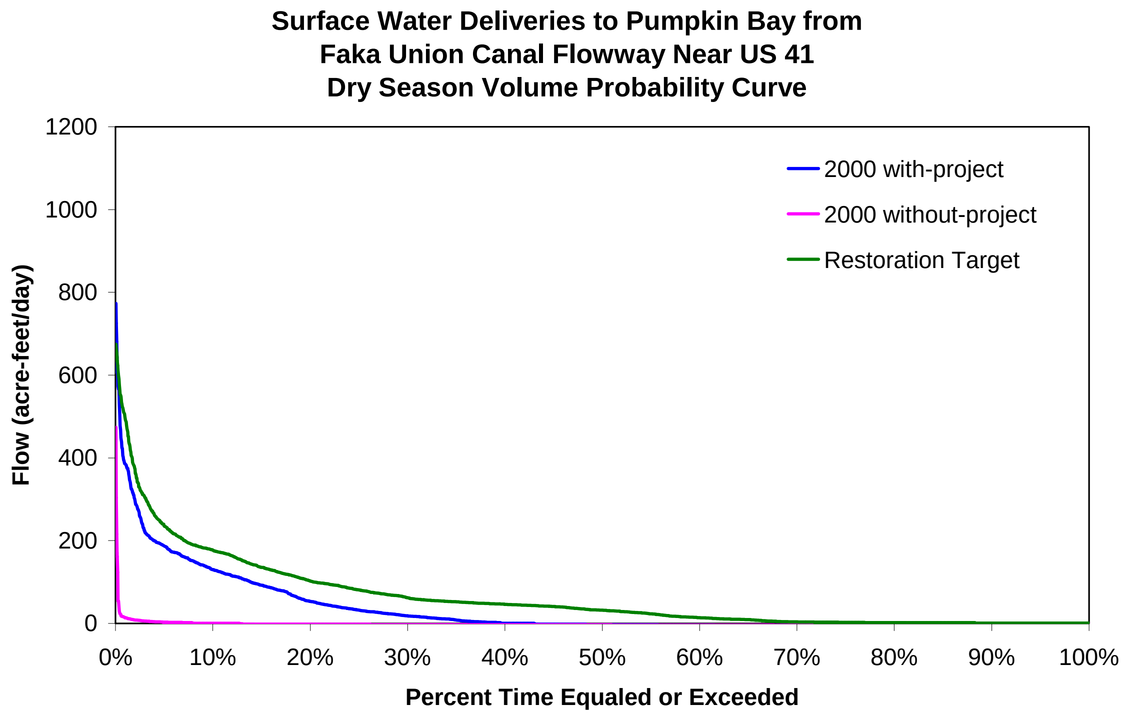

Figure 59. Volume probability curve for surface water inflow along the Faka Union Canal flowway near US 41 for the dry season during the period of record (1988 - 2000)

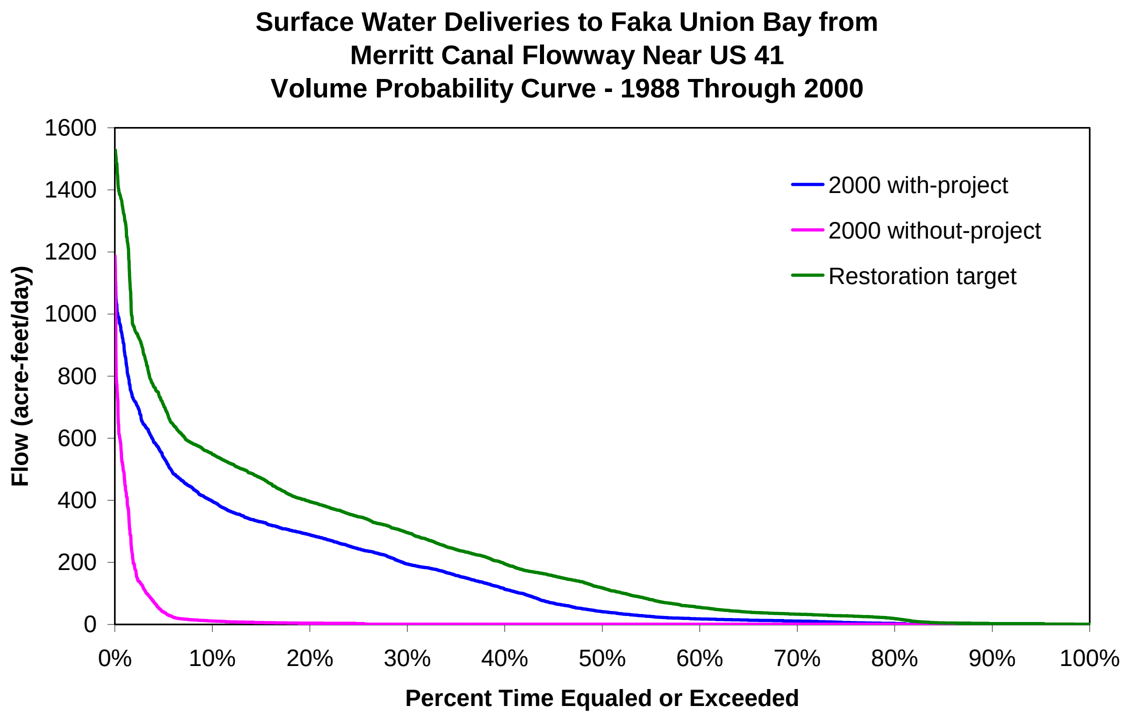

Figure 60. Volume probability curve for surface water inflow along the Merritt Canal flowway near US 41 for the entire period of record (1988 – 2000)

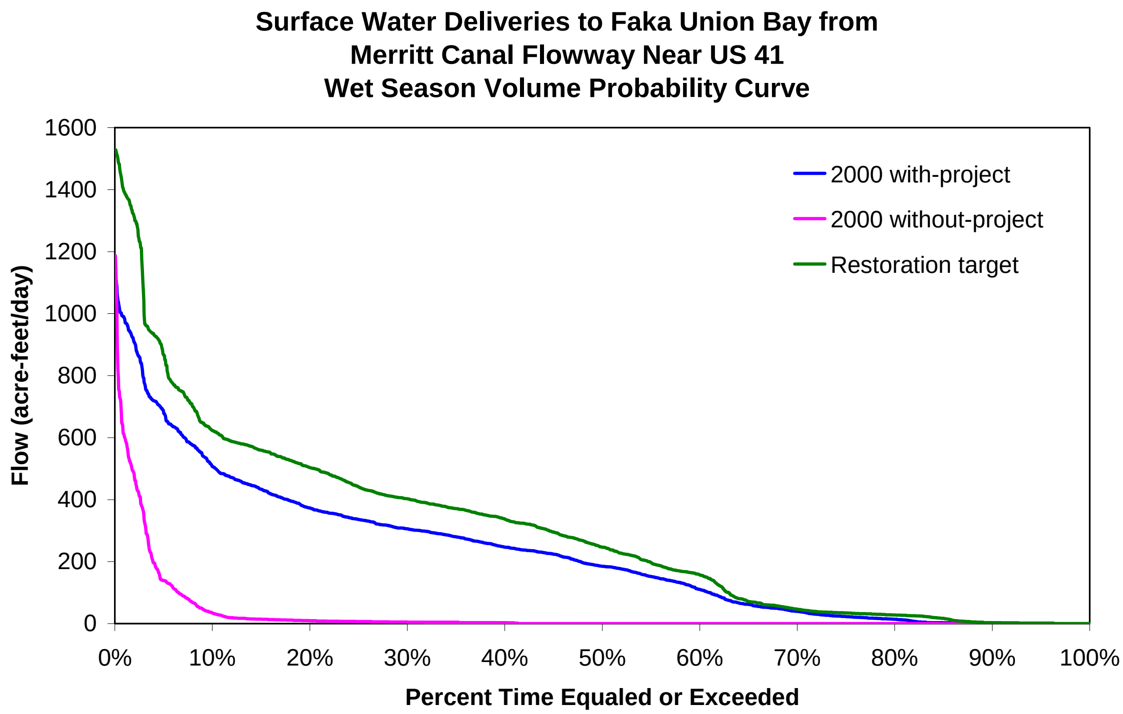

Figure 61. Volume probability curve for surface water inflow along the Merritt Canal flowway near US 41 for the wet season for the period of record (1988 -2000)

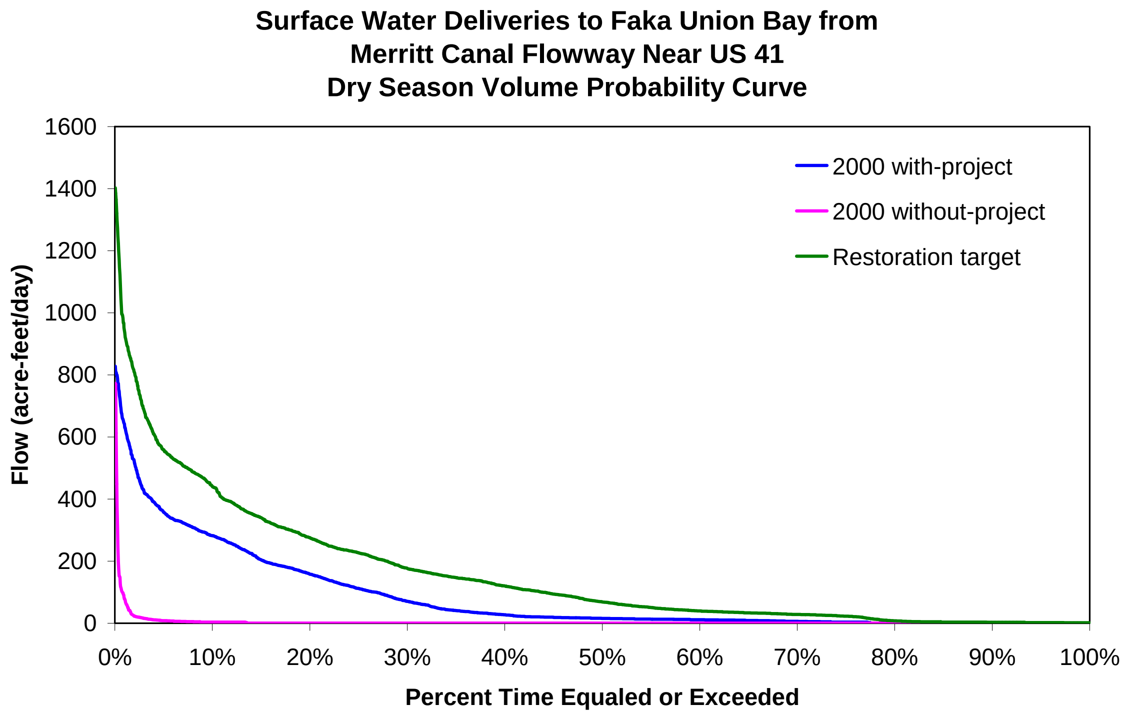

Figure 62. Volume probability curve for surface water inflow along the Merritt Canal flowway near US 41 for the dry season during the period of record (1988 - 2000)

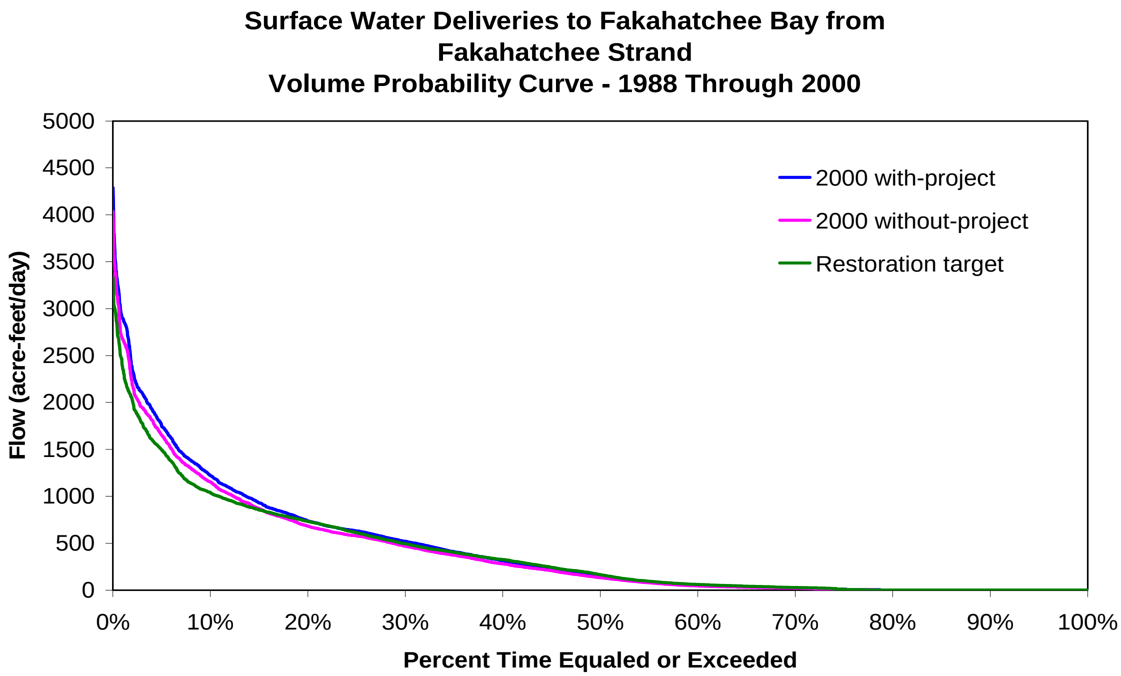

Figure 63. Volume probability curve for surface water inflow from Fakahatchee Strand for the entire period of record (1988 - 2000)

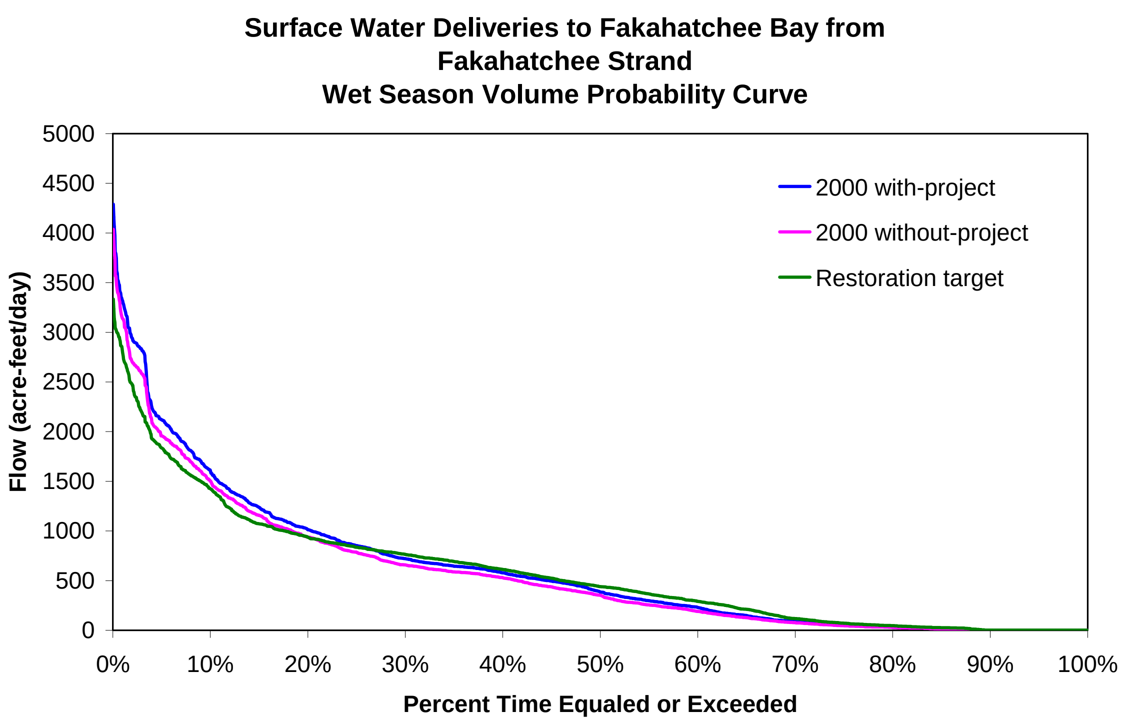

Figure 64. Volume probability curve for surface water inflow from Fakahatchee Strand for the wet season for the period of record (1988 - 2000)

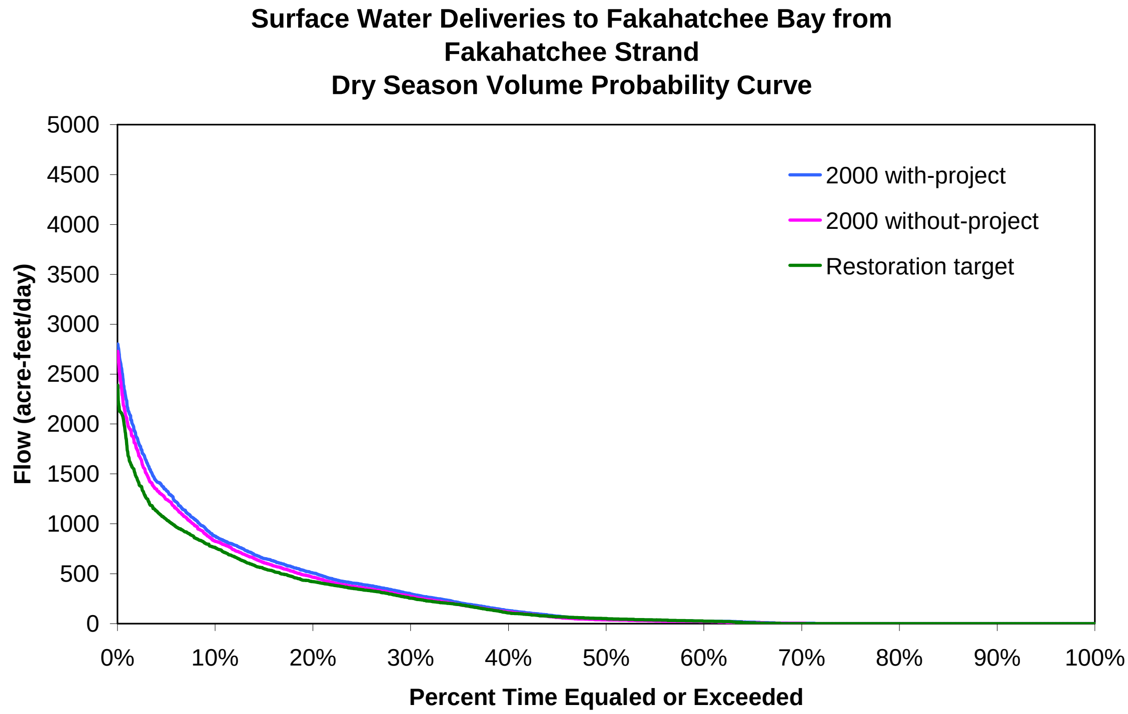

Figure 65. Volume probability curve for surface water inflow from Fakahatchee Strand for the dry season during the period of record (1988 - 2000)

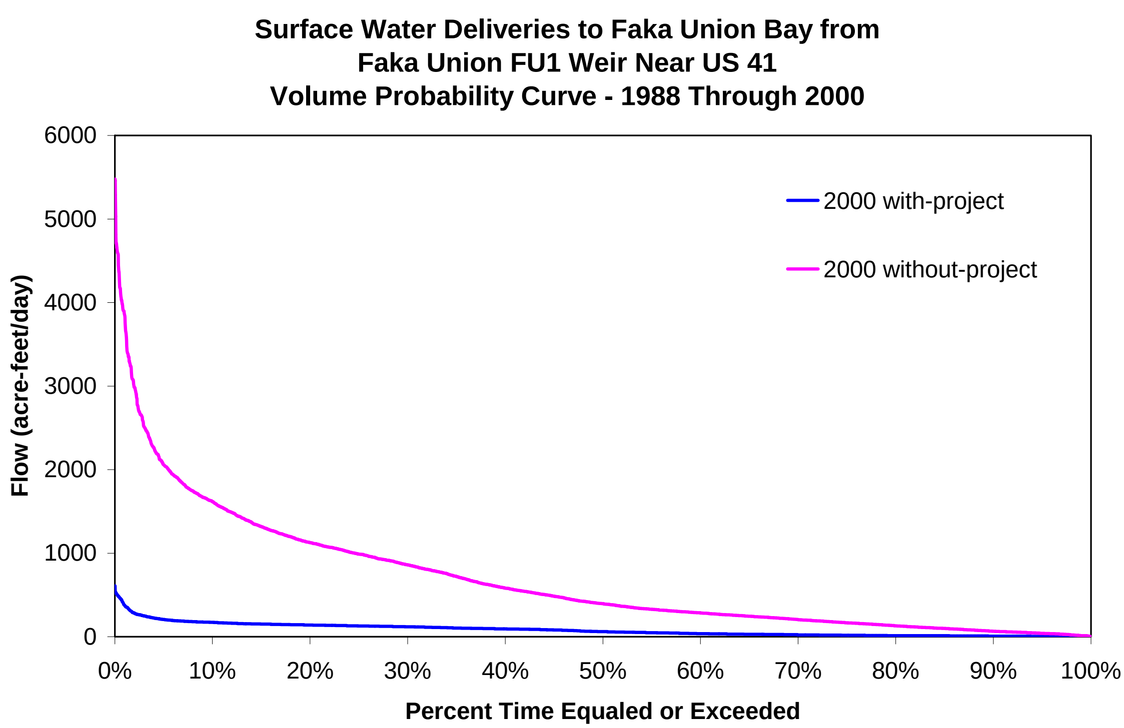

Figure 66. Volume probability curve for surface water inflow from the FU1 weir on Faka Union Canal for the entire period of record (1988 - 2000)

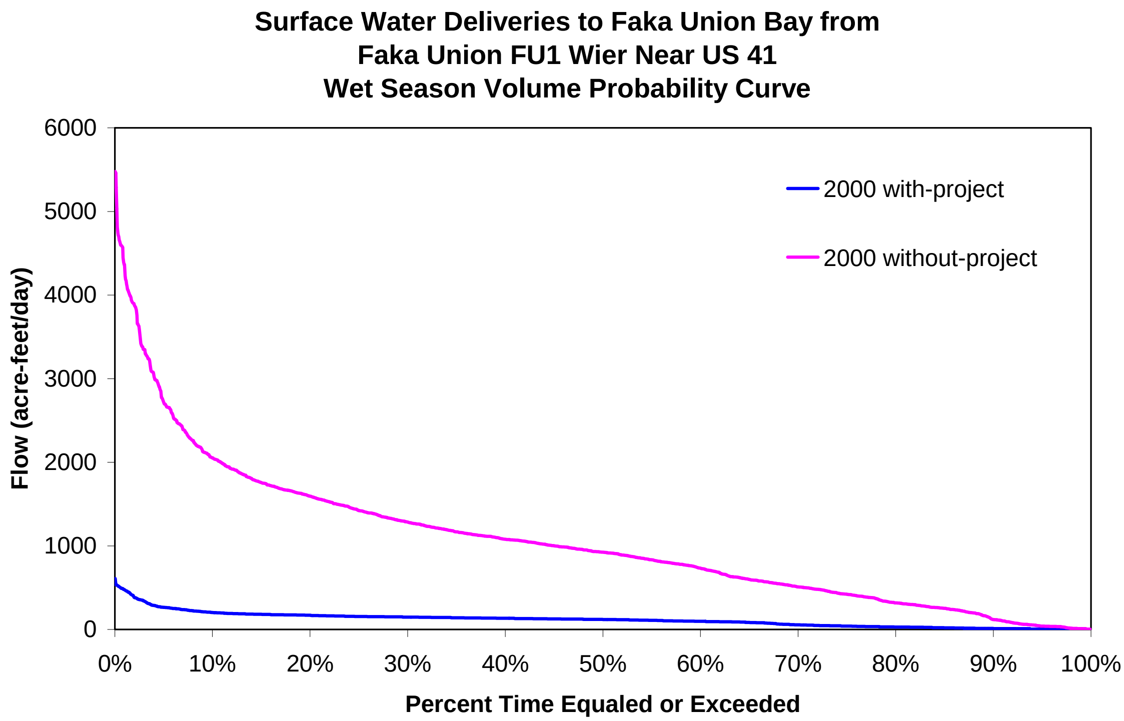

Figure 67. Volume probability curve for surface water inflow from the FU1 weir on Faka Union Canal for the wet season during the period of record (1988 - 2000)

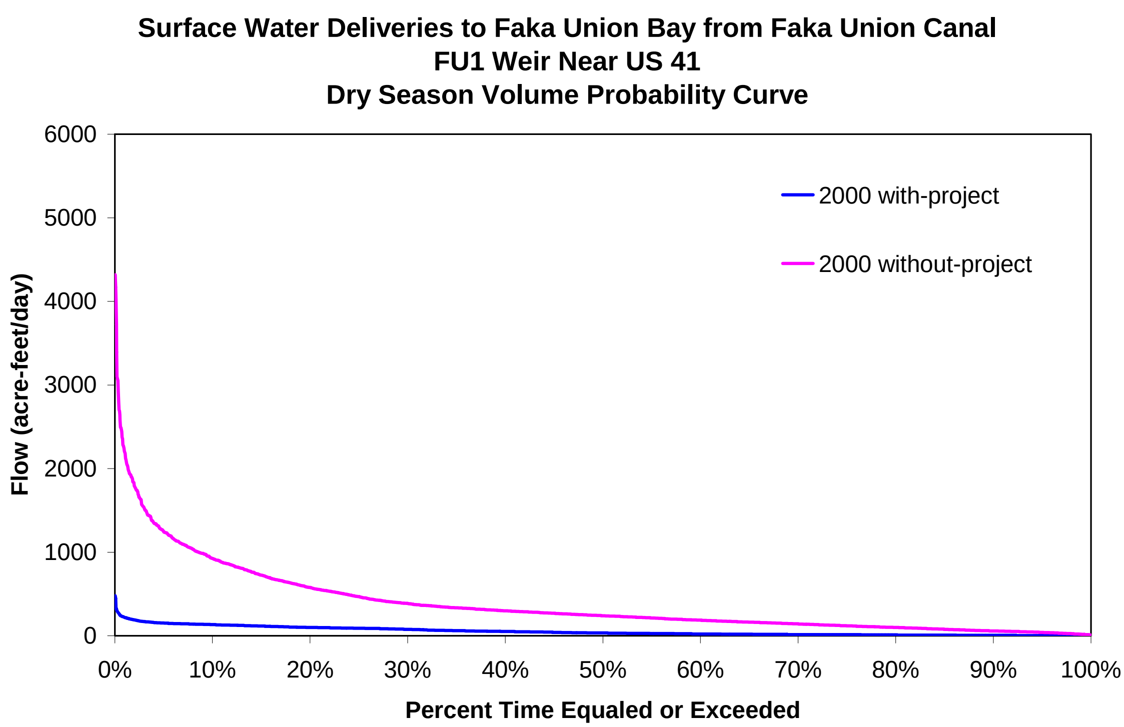

Figure 68. Volume probability curve for surface water inflow from the FU1 weir on Faka Union Canal for the dry season during the period of record (1988- 2000)

Section 9. Water to Be Reserved for Protection of Fish and Wildlife

9.1 Picayune Strand Inland System

Based on an analysis of the information presented in this document, while the project will improve the hydrology within the inland portions of the Picayune Strand, the water needed for the protection of fish and wildlife will not be fully realized. To better understand the timing and distribution of flows, stage hydrographs for the 13-year period of record for the inland wetlands comparing with-project flows to the targets are provided in Appendix A. 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 volume of water in the with-project simulations shown on **Figures 69** through **77** is necessary for the protection of fish and wildlife and will be protected under state rule.

Inflow volume probability curves depict the range of the quantities of water delivered to the basins under all climatic conditions through the period of record (1988 – 2000) and for the wet (June – October) and dry (November – May) seasons during this same period of record. This period includes sufficient variability in climate, including natural fluctuations of water, to be representative of long-term hydrologic conditions in the region. A volume probability curve ranks the daily surface inflows into a basin from the lowest to the highest possible value.

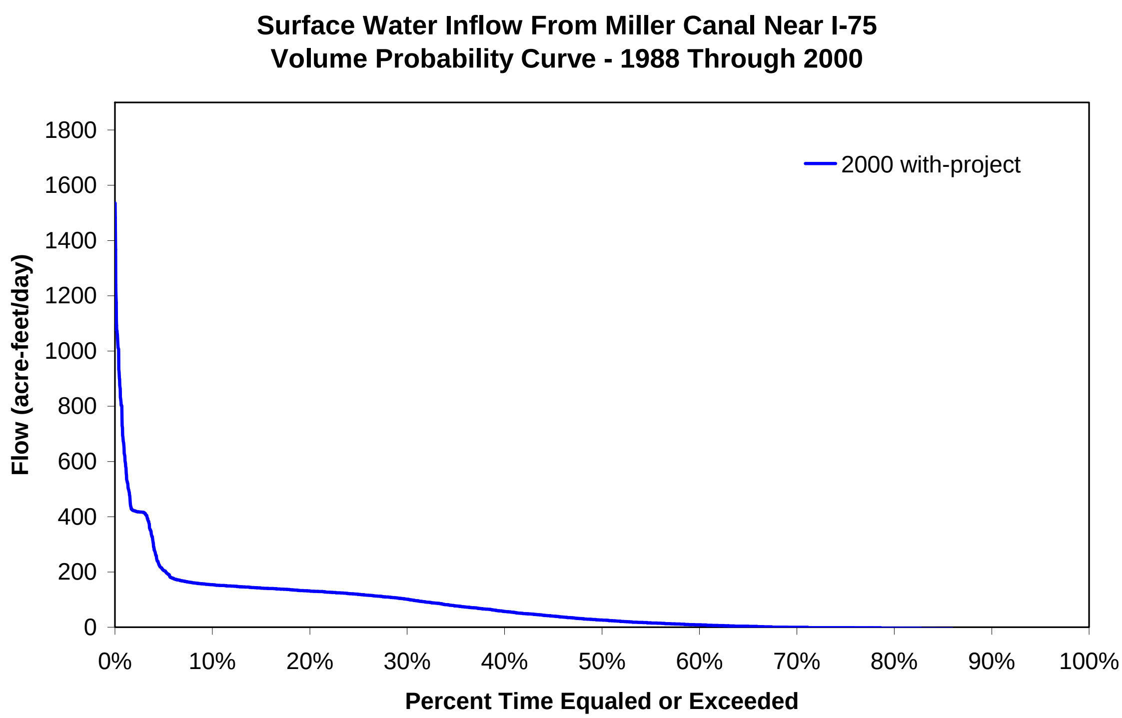

Figure 69. Volume probability curve of surface water deliveries into Picayune Strand Restoration Area from the Miller Canal to be reserved

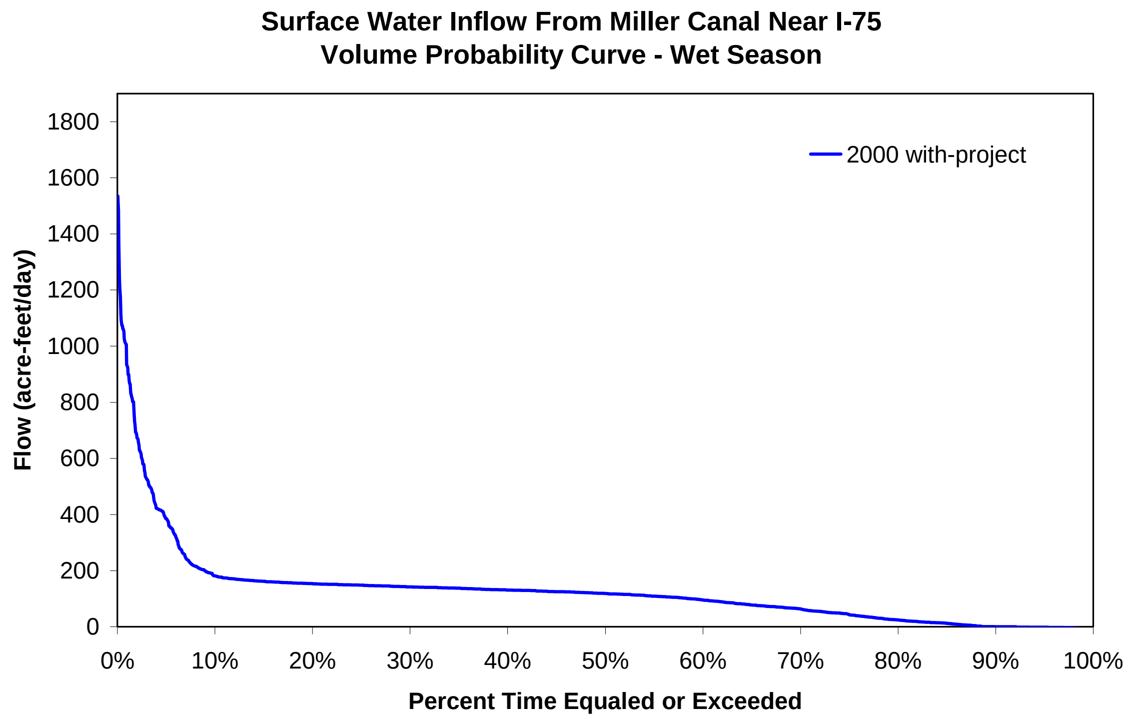

Figure 70. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Miller Canal to be reserved for the wet seasons

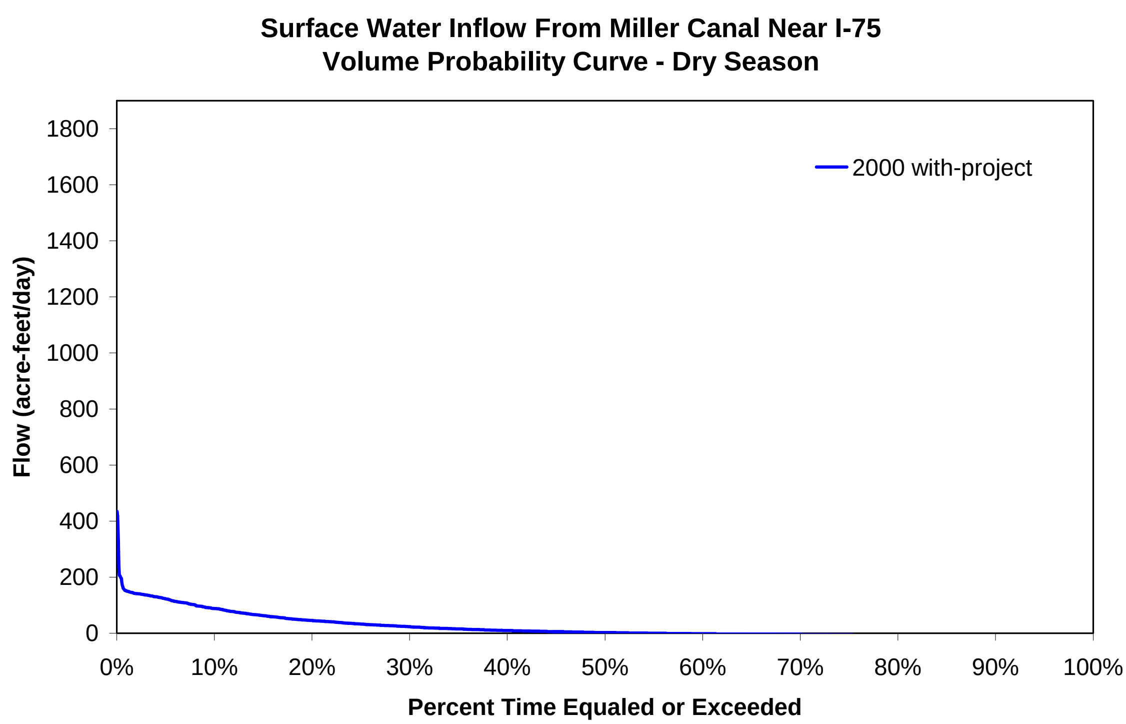

Figure 71. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Miller Canal to be reserved for the dry seasons

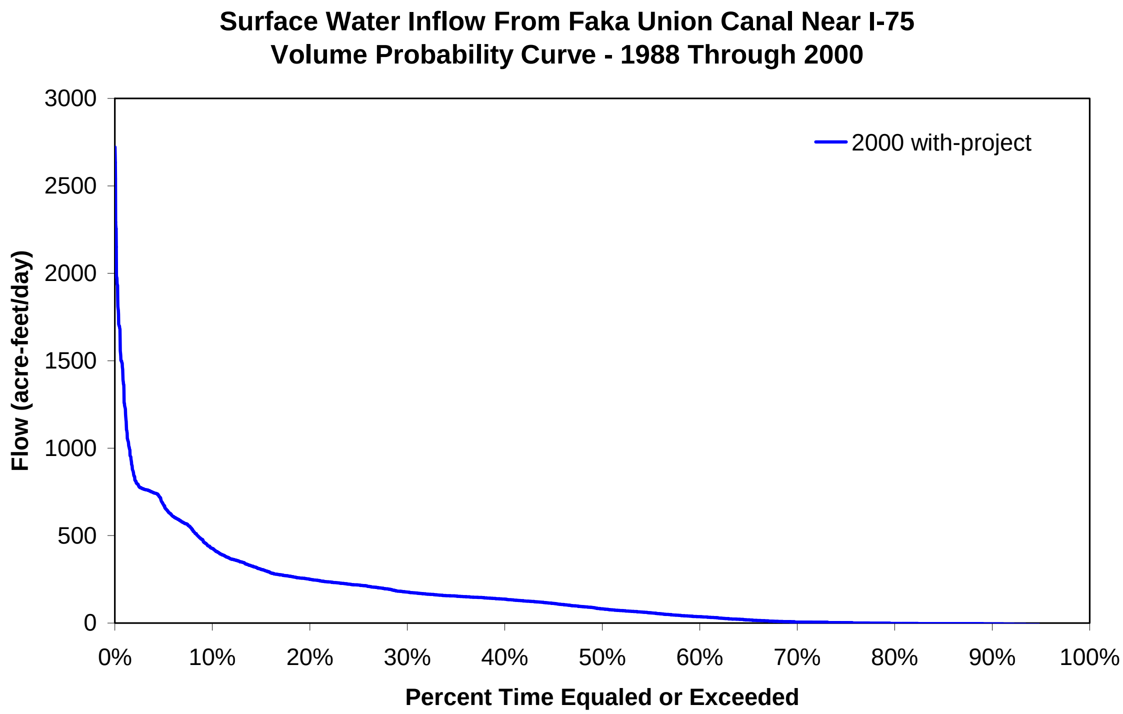

Figure 72. Volume probability curve of surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal to be reserved

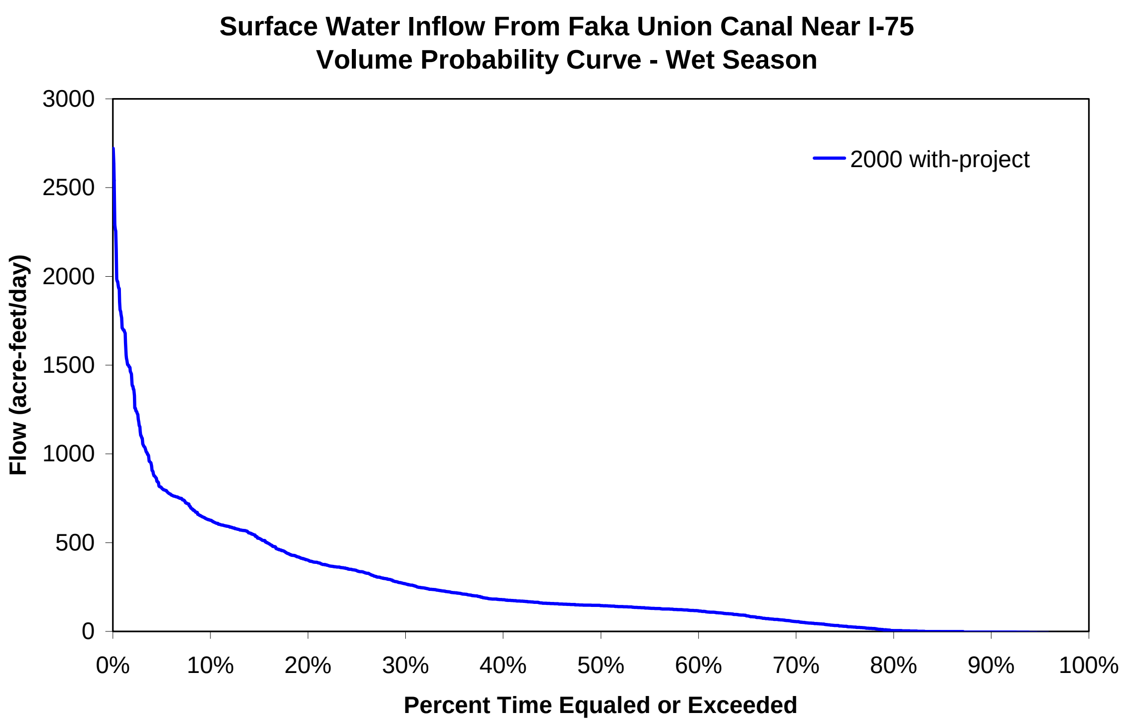

Figure 73. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal to be reserved for the wet seasons

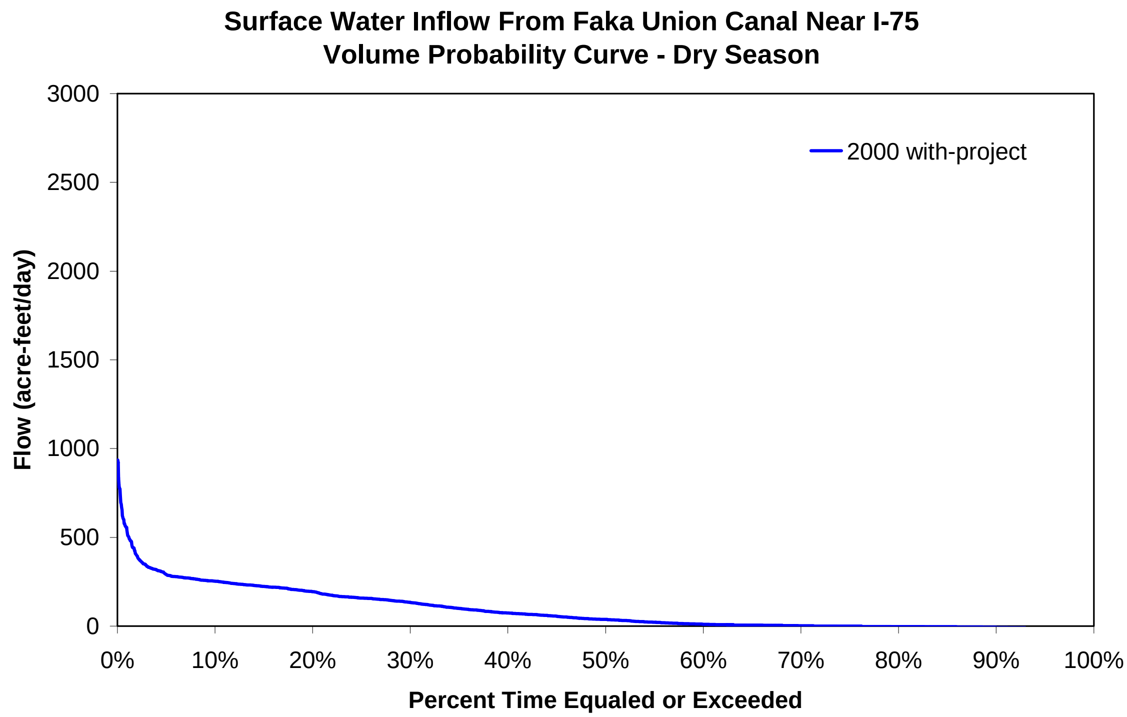

Figure 74. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal to be reserved for the dry seasons

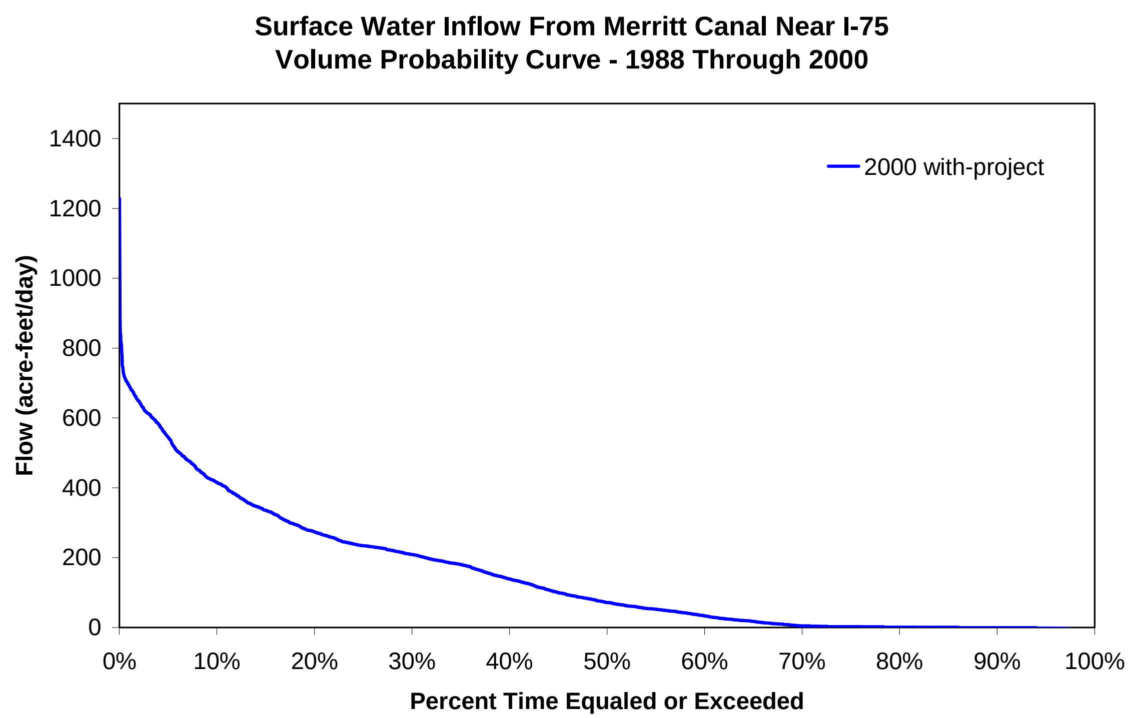

Figure 75. Volume probability curve of surface water deliveries into Picayune Strand Restoration Area from the Merritt Canal to be reserved

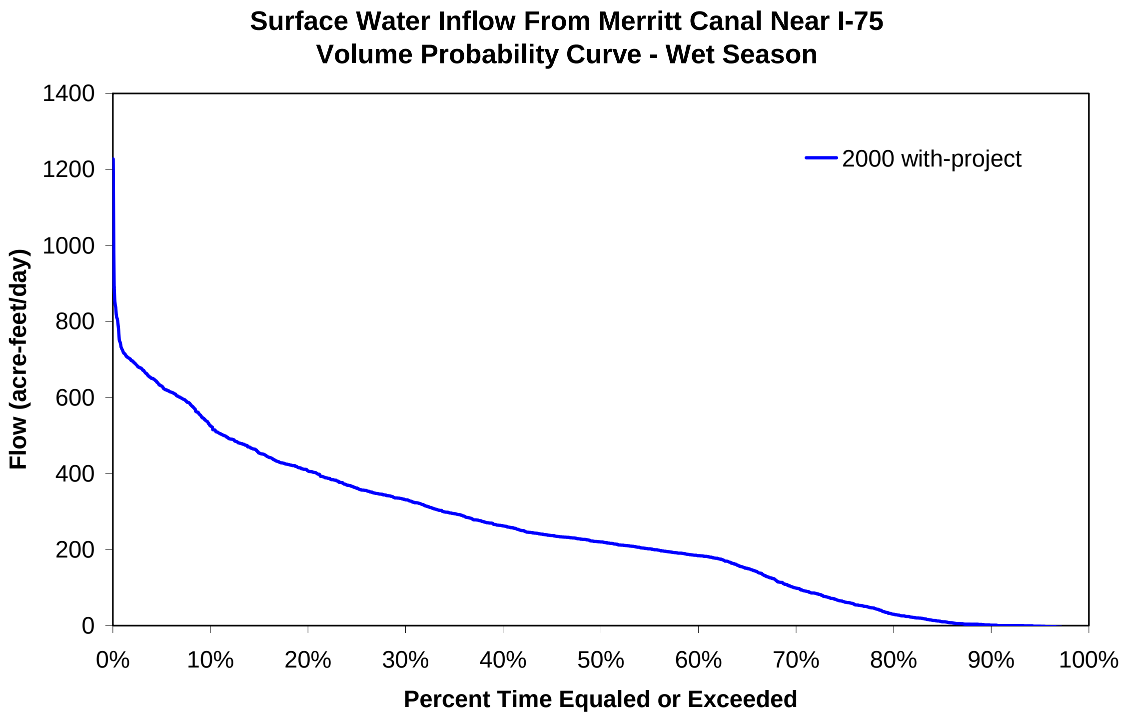

Figure 76. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal to be reserved for the wet seasons

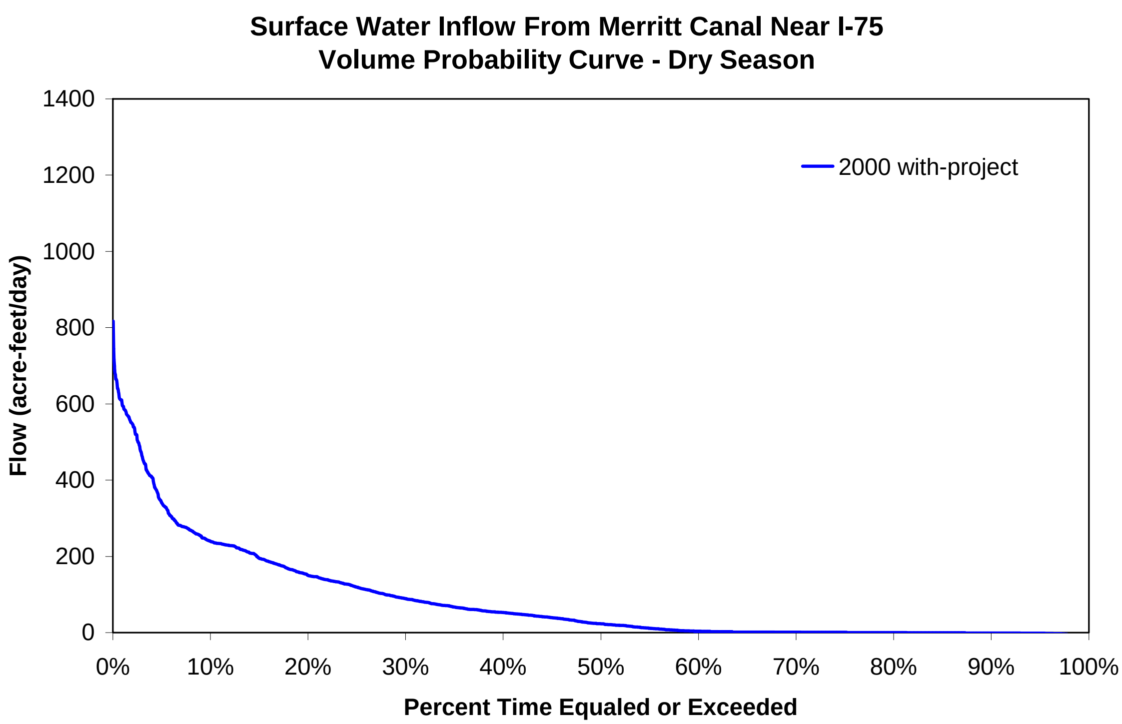

Figure 77. Volume probability curve for surface water deliveries into Picayune Strand Restoration Area from the Faka Union Canal to be reserved for the dry seasons

9.2 Fakahatchee Estuary

To achieve the objectives of the Picayune Strand Restoration Project, the area needs the water that it received naturally prior to the development of Golden Gate Estates in order to recreate or more closely resemble the normal timing and distribution of fresh water deliveries to the Fakahatchee Estuary. Annual and seasonal variations in this hydrologic regime should be closely tied to annual and seasonal rainfall patterns. The annual and seasonal variations from this average hydrologic regime are critical to structure and taxonomic composition of estuarine communities.

Based on an analysis of the information presented in this document, the project will improve the hydrology within the estuarine portions of the Fakahatchee Estuary. As a result, the water entering the project across the four transects and one canal located at the southern boundary of the project (see **Figure 43** in Section 8) are considered necessary for protection of fish and wildlife as depicted on the volume probability curves. The volume under curve is the water to be reserved under state law to protect fish and wildlife. If the water made available by the project does not meet the restoration target (pre-drainage condition), then the volume of water to be reserved is the amount of water under the with-project volume probability curve. The volume of water shown on **Figures 78** through **92** is the water necessary for the protection of fish and wildlife and will be protected under state rule.

Inflow volume probability curves depict the range of the quantities of water delivered to the basins under all climatic conditions through the period of record (1988 – 2000) and for the wet (June – October) and dry (November – May) seasons during this same period of record. This period includes sufficient variability in climate, including natural fluctuations of water, to be representative of long-term hydrologic conditions in the region. A volume probability curve ranks the daily surface inflows into a basin from the lowest to the highest possible value.

The project is effective in redistributing the flows across the southern boundary of the Picayune Strand Restoration Area 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 pre-drainage targets for protection of estuarine fish and wildlife. To better understand the timing and distribution on flows, flow hydrographs for the 13-year period of record for these stations comparing with-project flows to the targets are provided in Appendix B.

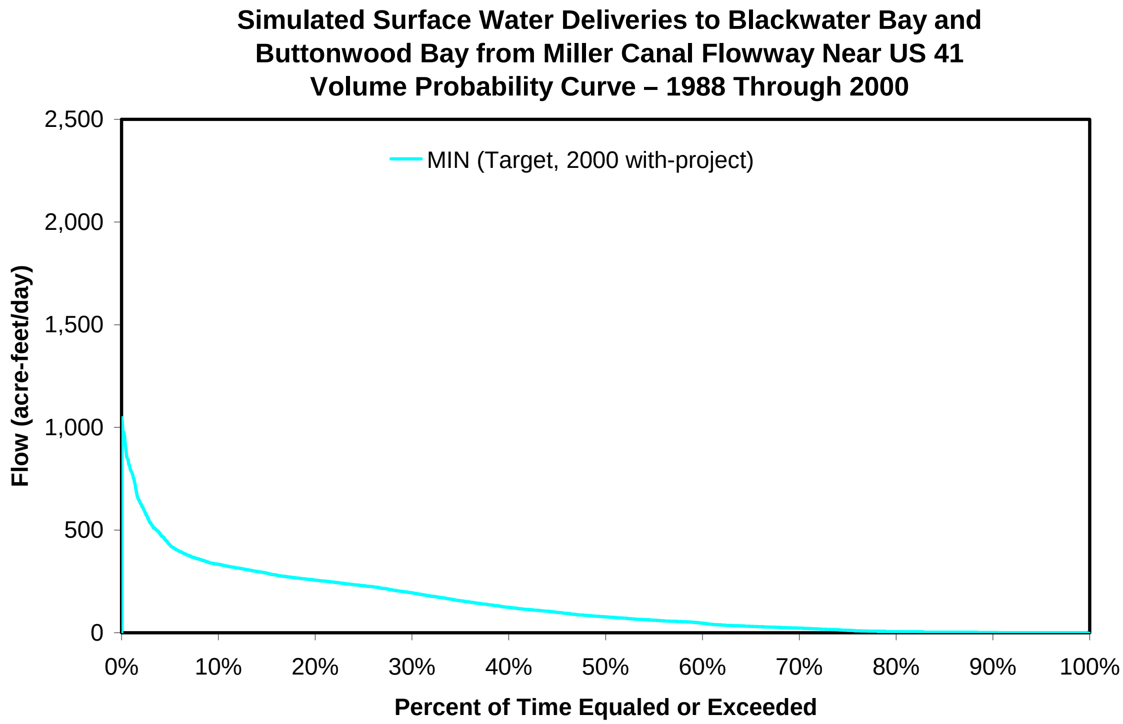

Figure 78. Volume probability curve for surface water inflow along the Miller Canal flowway to be reserved for the period of record (1988 - 2000)

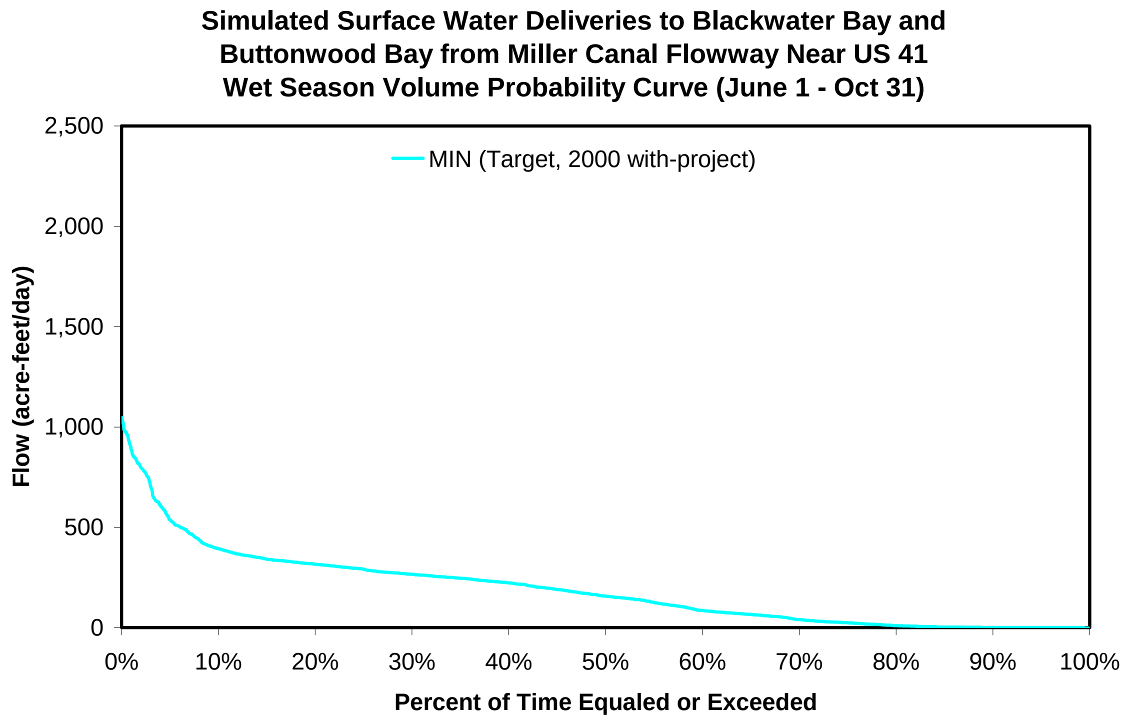

Figure 79. Volume probability curve for surface water inflow along the Miller Canal flowway to be reserved for the wet seasons during the period of record (1988 - 2000)

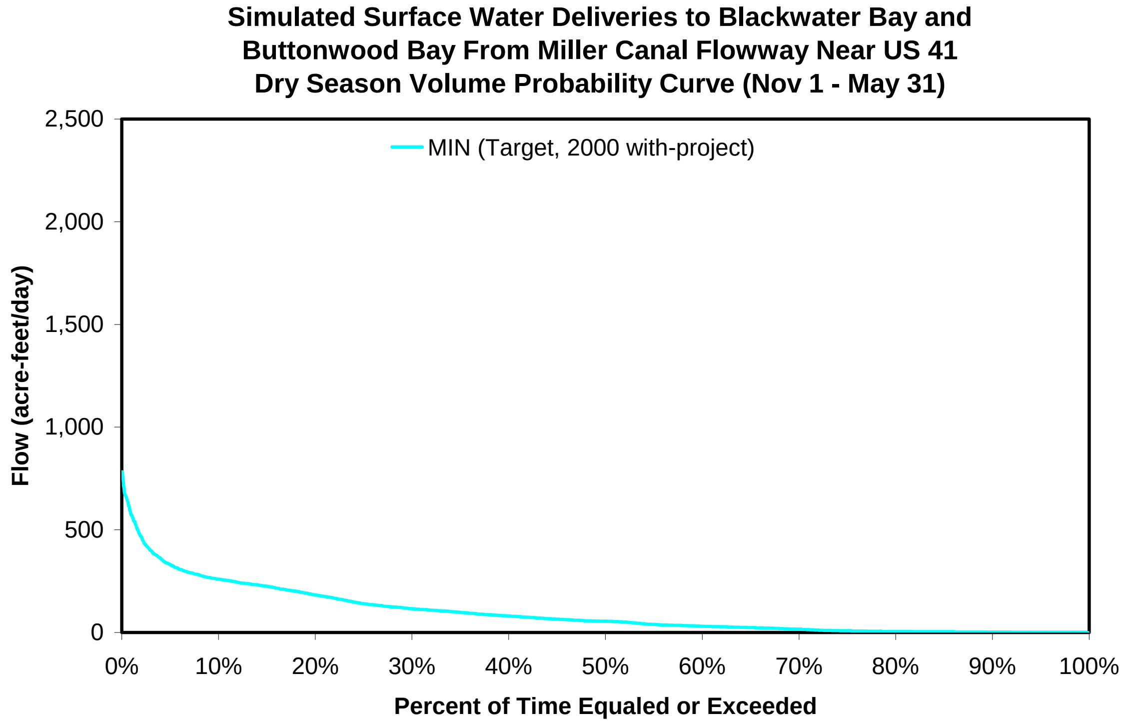

Figure 80. Volume probability curve for surface water inflow along the Miller Canal flowway to be reserved for the dry seasons during the period of record (1988 - 2000)

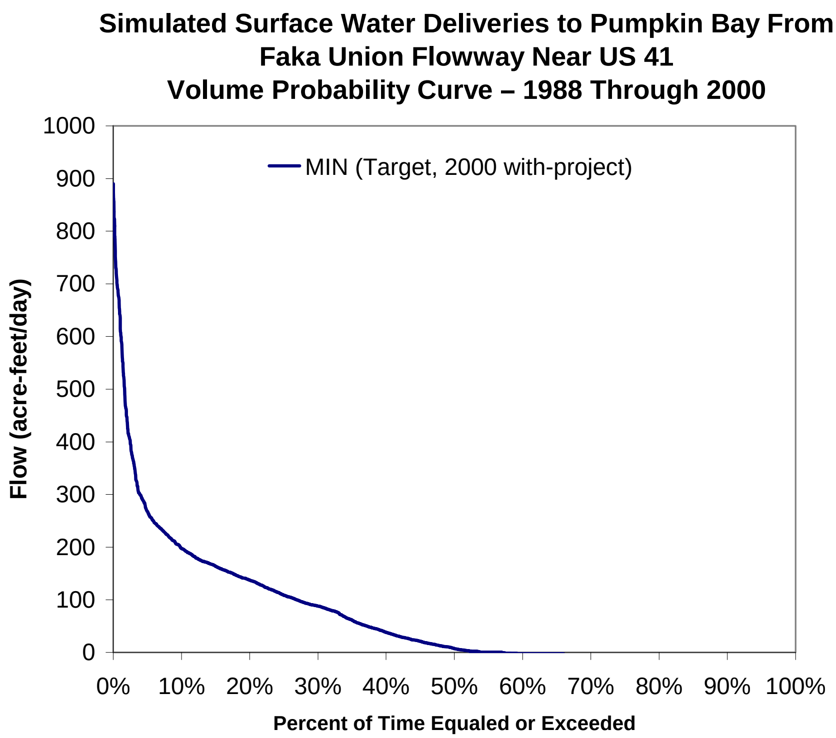

Figure 81. Volume probability curve for surface water inflow along the Faka Union Canal flowway to be reserved for the period of record (1988 - 2000)

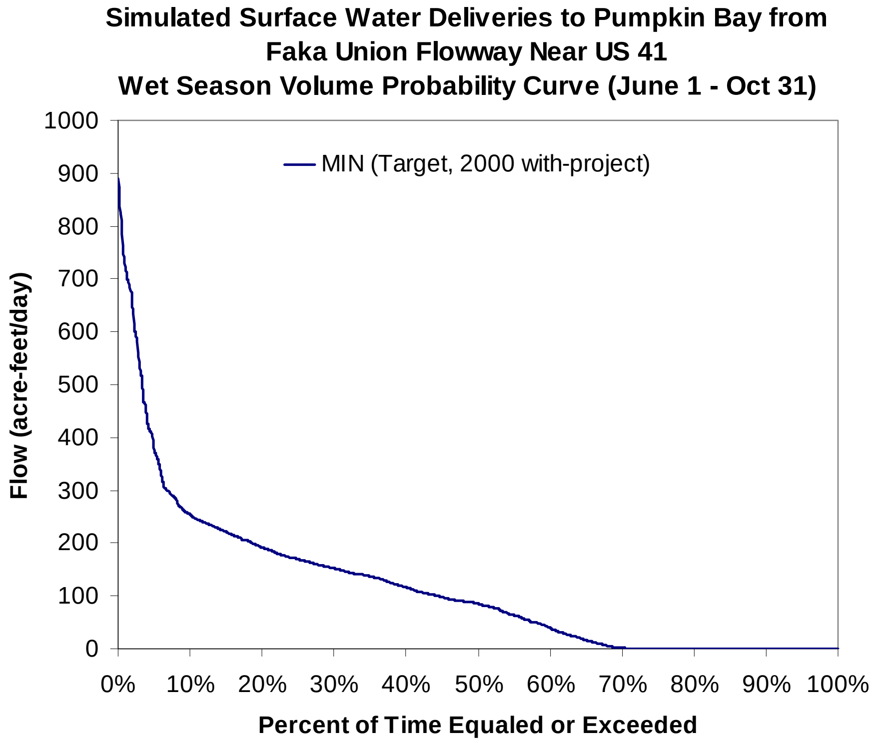

Figure 82. Volume probability curve for surface water inflow along the Faka Union Canal flowway to be reserved for the wet seasons during the period of record (1988 - 2000)

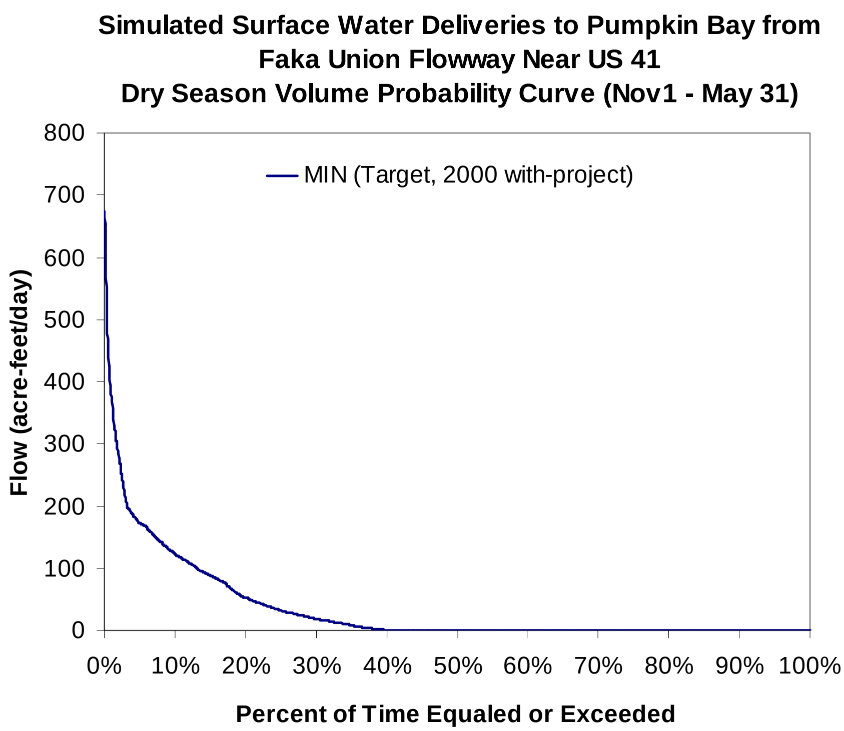

Figure 83. Volume probability curve for surface water inflow along the Faka Union Canal flowway to be reserved for the dry seasons during the period of record (1988 - 2000)

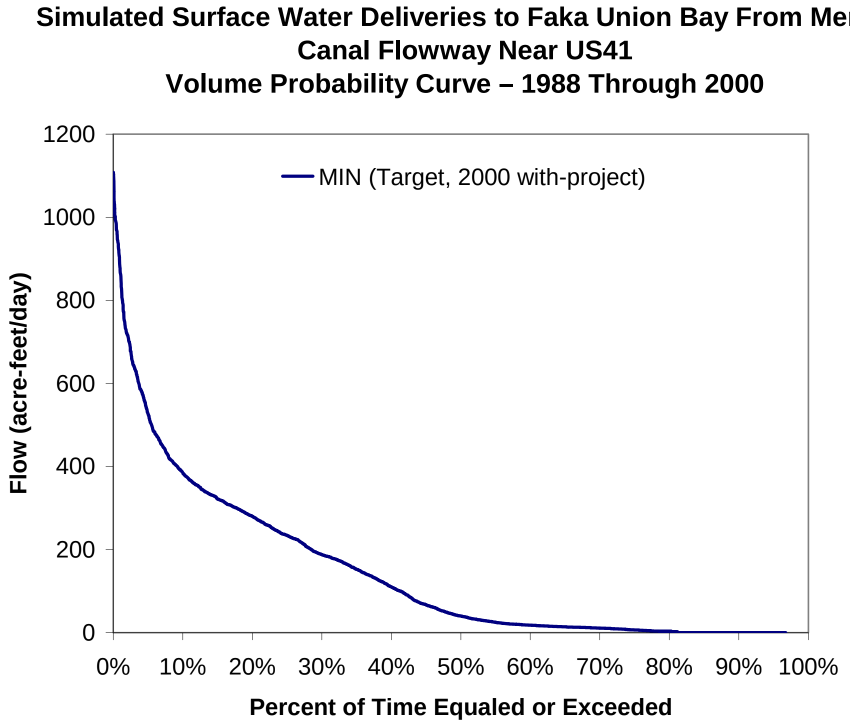

Figure 84. Volume probability curve for surface water inflow along the Merritt Canal flowway to be reserved for the period of record (1988 - 2000)

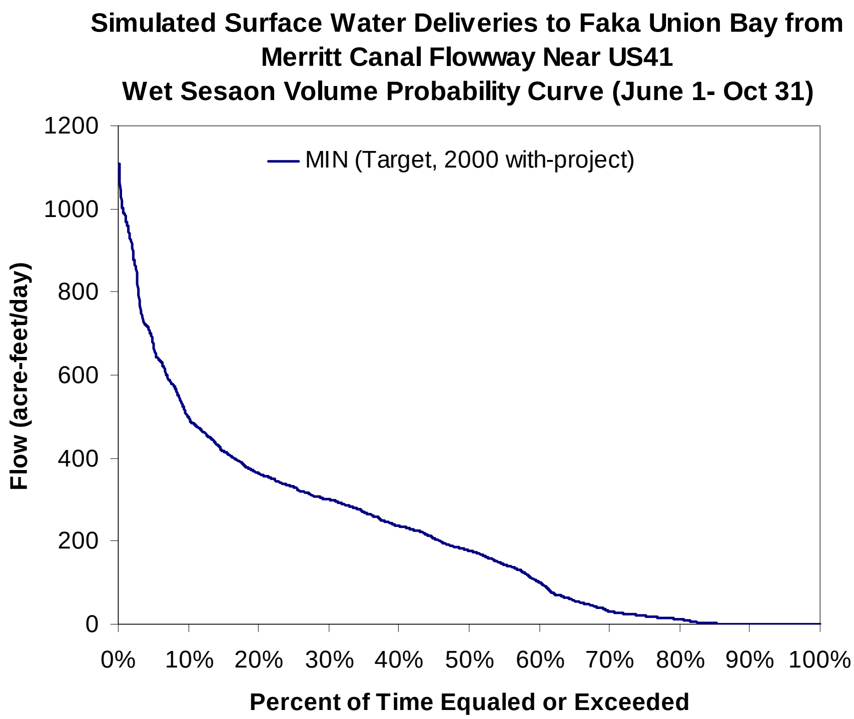

Figure 85. Volume probability curve for surface water inflow along the Merritt Canal flowway to be reserved for the wet seasons during the period of record (1988 - 2000)

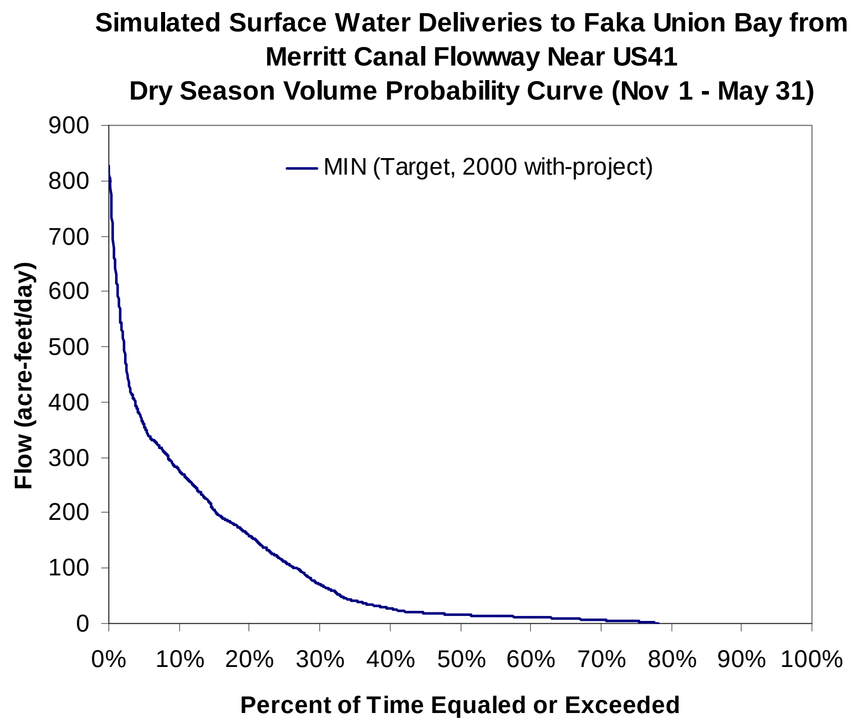

Figure 86. Volume probability curve for surface water inflow along the Merritt Canal flowway to be reserved for the dry seasons during the period of record (1988 - 2000)

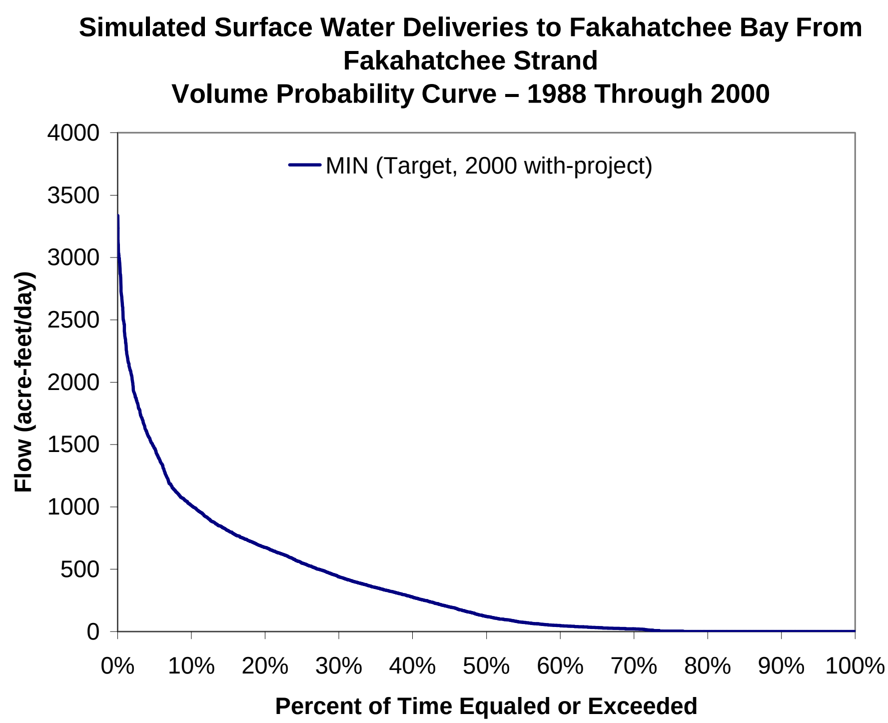

Figure 87. Volume probability curve for surface water inflow from Fakahatchee Strand to be reserved for the period of record (1988 - 2000)

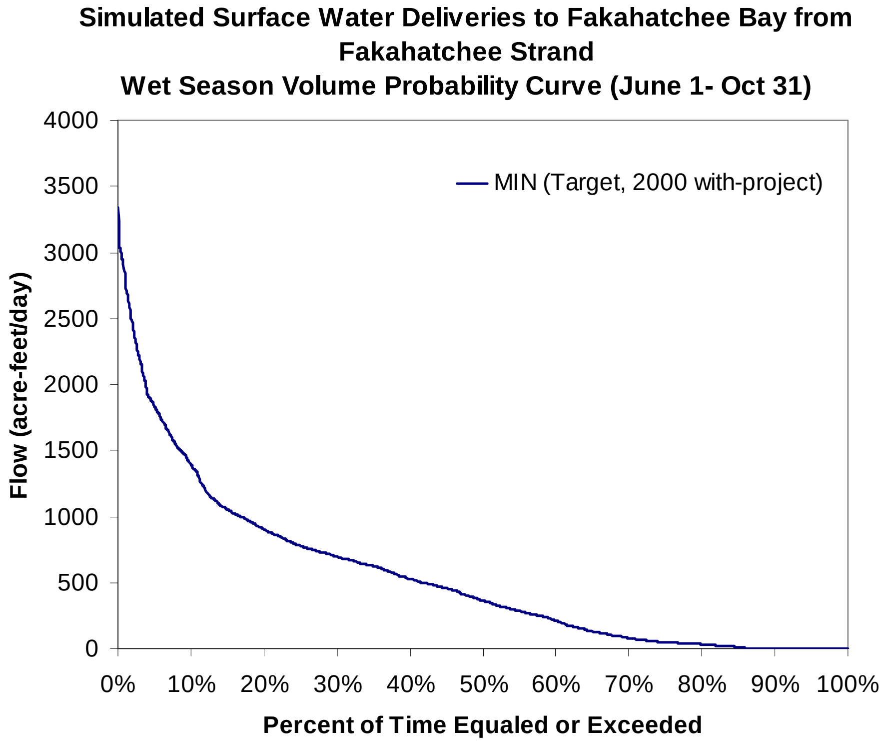

Figure 88. Volume probability curve for surface water inflow from Fakahatchee Strand to be reserved for the wet seasons during the period of record (1988 - 2000)

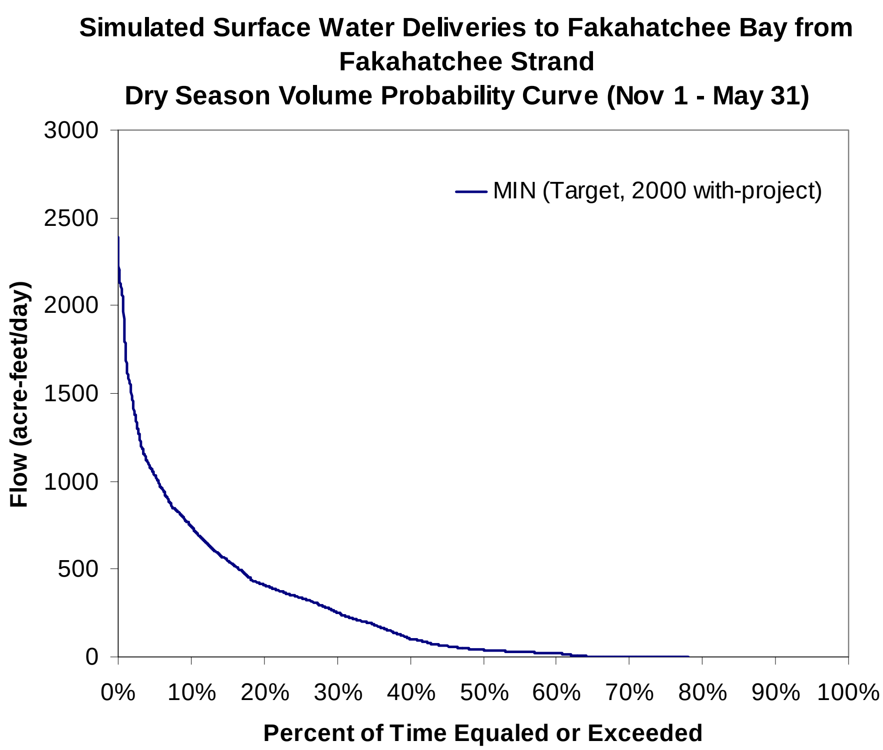

Figure 89. Volume probability curve for surface water inflow from Fakahatchee Strand to be reserved for the dry seasons during the period of record (1988- 2000)

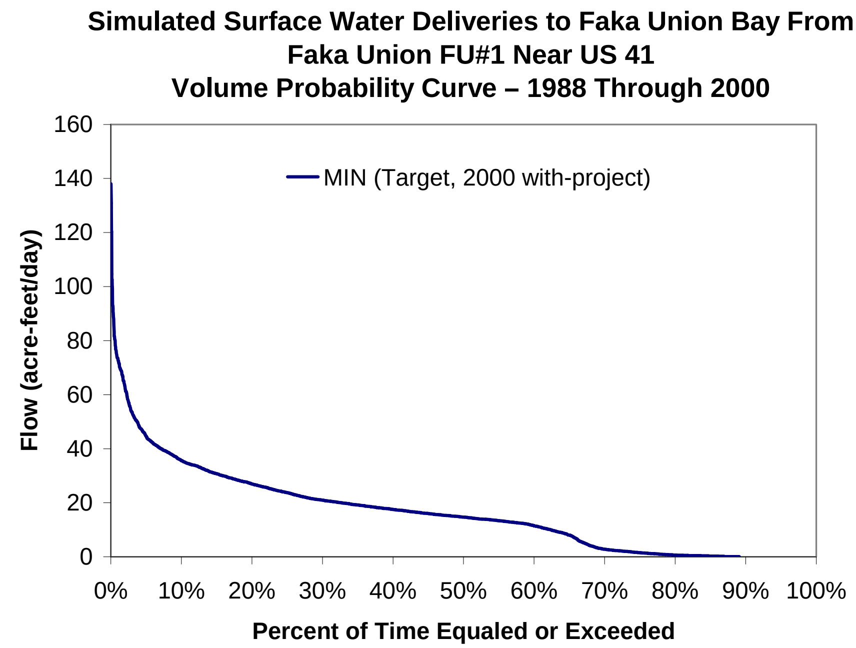

Figure 90. Volume probability curve for surface water inflow from from the FU1 weir on Faka Union Canal to be reserved for the period of record (1988 - 2000)

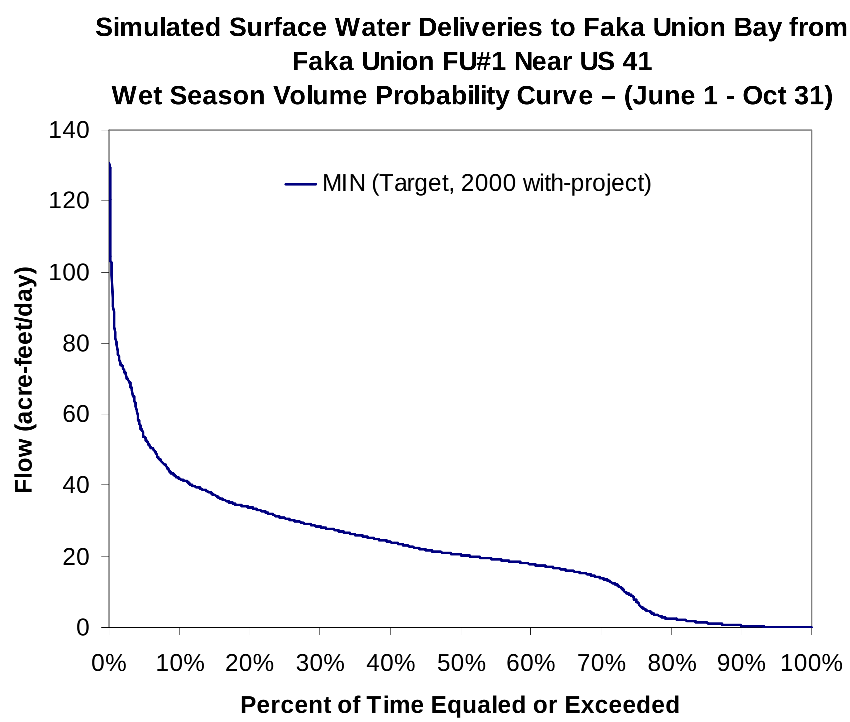

Figure 91. Volume probability curve for surface water inflow from from the FU1 weir on Faka Union Canal to be reserved for the wet seasons during the period of record (1988 - 2000)

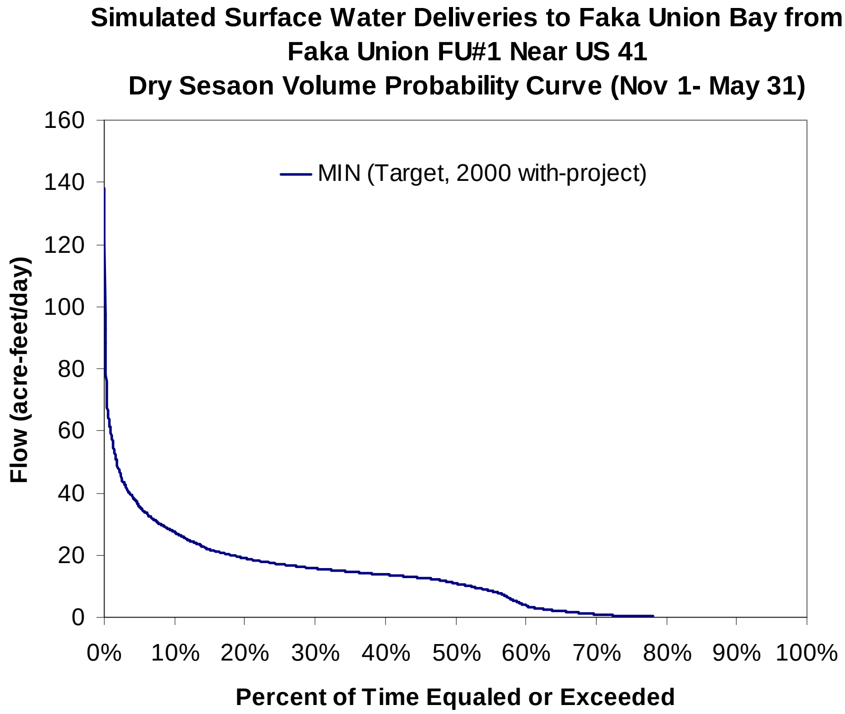

Figure 92. Volume probability curve for surface water inflow from from the FU1 weir on Faka Union Canal to be reserved for the dry seasons during the period of record (1988 - 2000)

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Appendix A. Water Depth and Hydroperiod for Indicator Regions

Comparing pre-drainage (target), 2000 with-project and 2000 without-project water stages for the 32 indicator regions (**Figure A-1**) allows us to see the changes in hydrologic conditions within specific areas of Picayune Strand and the surrounding area. **Table A-1** presents the hydroperiod and seasonal water levels considered optimal for each major southwest Florida plant community. This table also matches indicator regions with plant community type for pre-drainage, 2000 with-project, and 2000 without-project conditions based on the hydrologic characteristics observed in the stage hydrographs (**Figures A-2** through **A-33**) and normalized duration curves (**Figures A-34** through **A-65**) for each of the indicator regions.

Table A-1. Hydrologic regimes for plant communities and indicator regions dominated by each community for pre-drainage, 2000 with-project and 2000 without-project conditions

Plant Communities	Hydroperiod (months inundated)	Seasonal Water Level (inches)		Indicator Regions[1]		
		Wet	Dry	Pre-drainage	2000 With-Project[1]	2000 Without-Project
Xeric Flatwood/Hammock	0	≤-24	-60, -90	26	26	3, 4, 8, 9, 10, 11, 15, 16, 17, 21, 22, 23
Mesic Flatwood/Hammock	≤1	≤2	-46, -76	5, 23	1, 3, 4, 5, 6, 7, 8, 20, 23, 30	1, 5, 6, 7, 14, 20, 24, 26, 30
Hydric Flatwood/Hammock	1 - 2	2 - 6	-30, -60	17, 20, 27	2, 10, 11, 16, 17, 22, 27	2, 13, 27,31
Wet Prairie/Dwarf Cypress	2 - 6	6 - 12	-24, -54	10, 11, 21, 22, 30, 31		28
Marsh	6 - 10	12 - 24	-6, -46	4		
Cypress	6 - 8	12 - 18	-16, -46	3, 6, 8, 12, 13, 18, 25	13, 14, 15, 21, 24, 25, 28, 31	12, 18, 19, 25, 29
Swamp Forest	8 - 10	18 - 24	-6, -36	1, 7, 9 14, 15, 16, 19	9, 12, 18, 19	
Open Water	>10	≥24	< 24, -6	2, 29, 32	29, 32	32

Stage hydrographs for the indicator regions shown in **Figure A-1** represent the time series of modeled weekly average water levels in selected cells in the inland portions of the project (**Figures A-2** through **A-33**). These stage hydrographs are used to compare pre-drainage (target) hydrologic characteristics with the 2000 with-project and 2000 without-project hydrologic characteristics. Water levels in 24 of these simulated well sites have been monitored since October 2003.

[1] The absence of indicator regions in a plant community type in the 2000 with-project condition does not mean that this plant community is not expected to be present following project implementation. Rather, it means that none of the MIKE SHE model cells used as indicator regions are dominated by the plant community following project implementation.

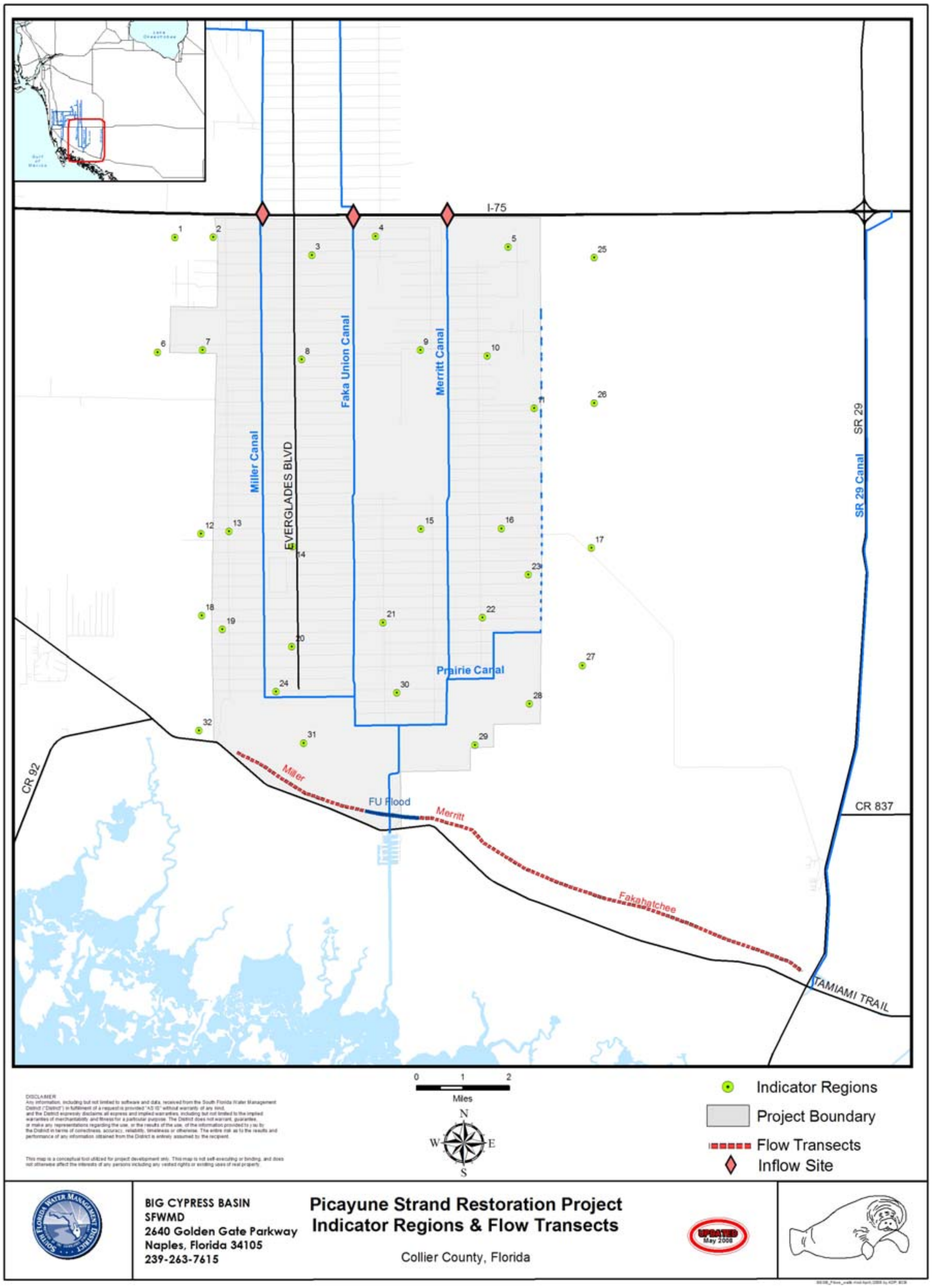


Figure A-1. Indicator regions in and around Picayune Strand

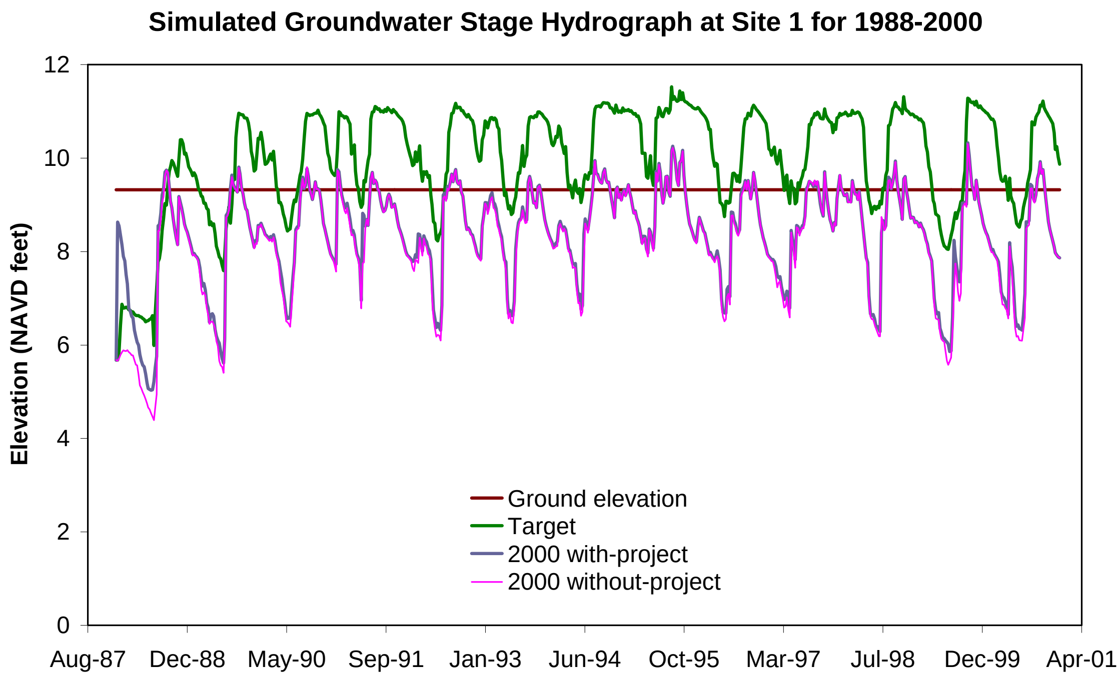


Figure A-2. Simulated groundwater stage hydrograph at Site 1 for 1988 to 2000

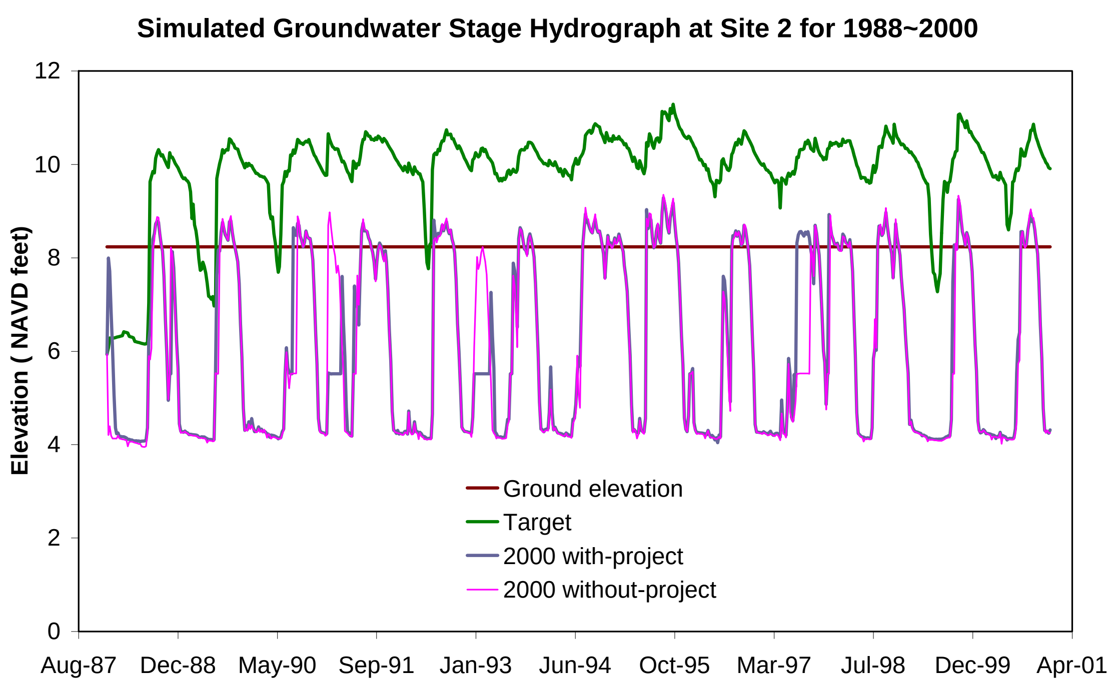


Figure A-3. Simulated groundwater stage hydrograph at Site 2 for 1988 to 2000

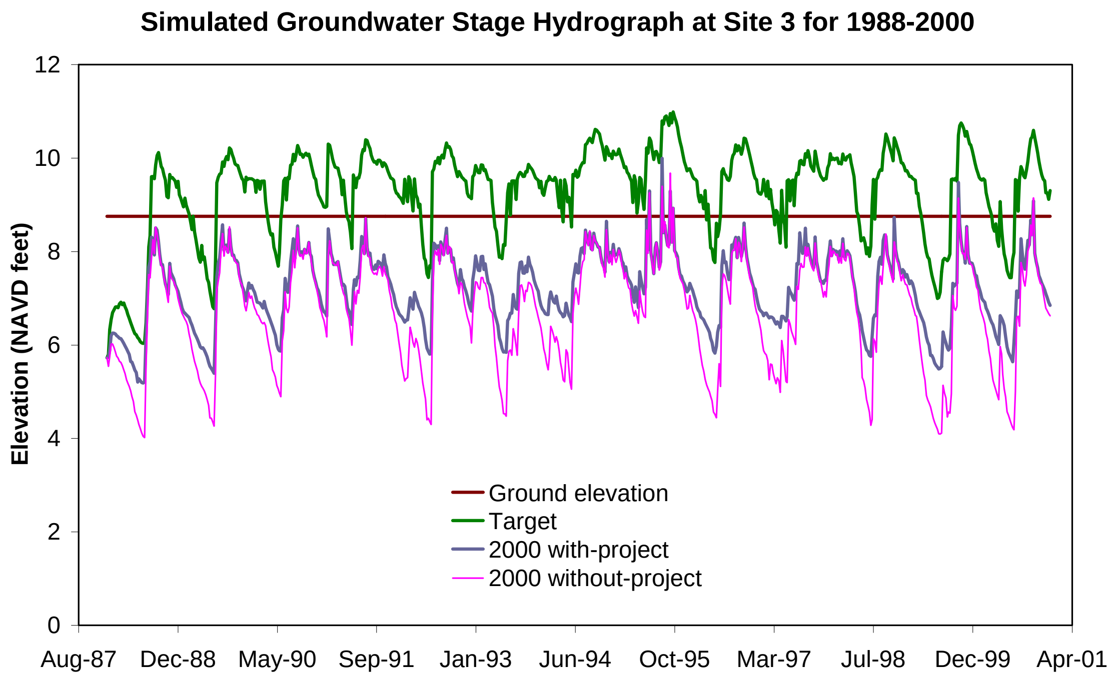


Figure A-4. Simulated groundwater stage hydrograph at Site 3 for 1988 to 2000

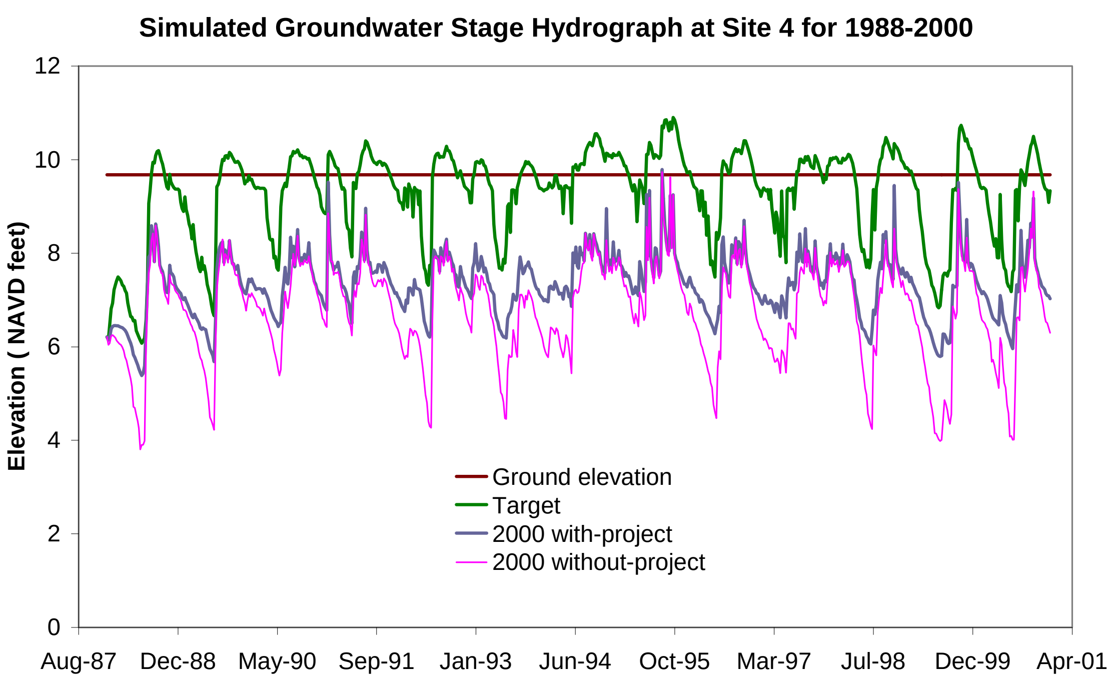


Figure A-5. Simulated groundwater stage hydrograph at Site 4 for 1988 to 2000

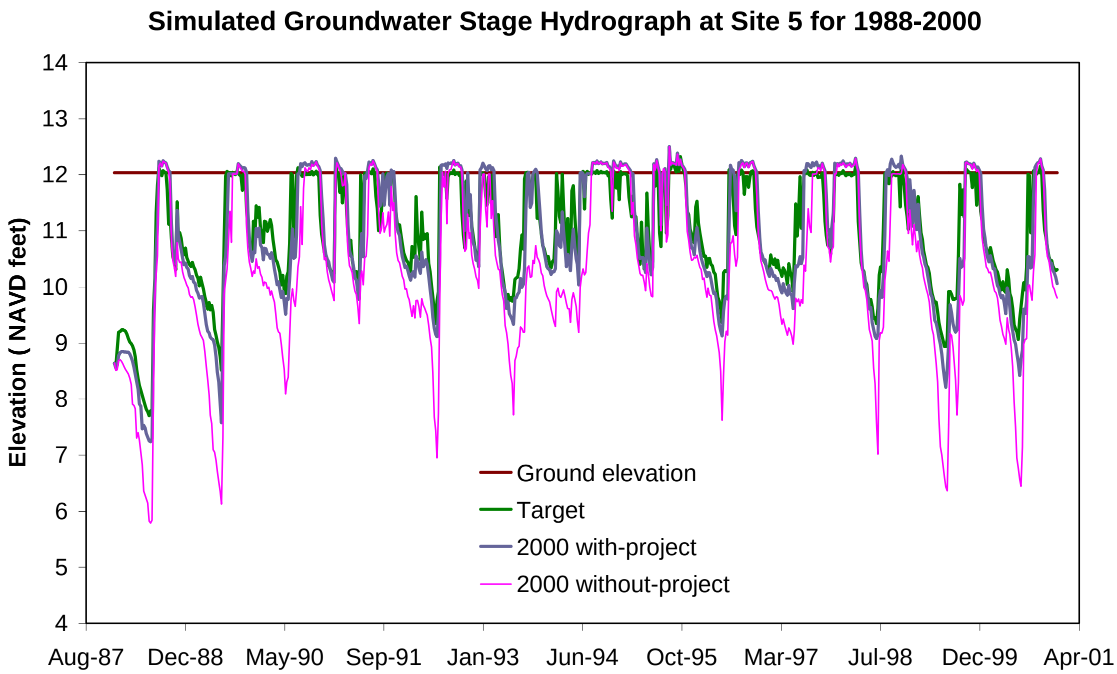


Figure A-6. Simulated groundwater stage hydrograph at Site 5 for 1988 to 2000

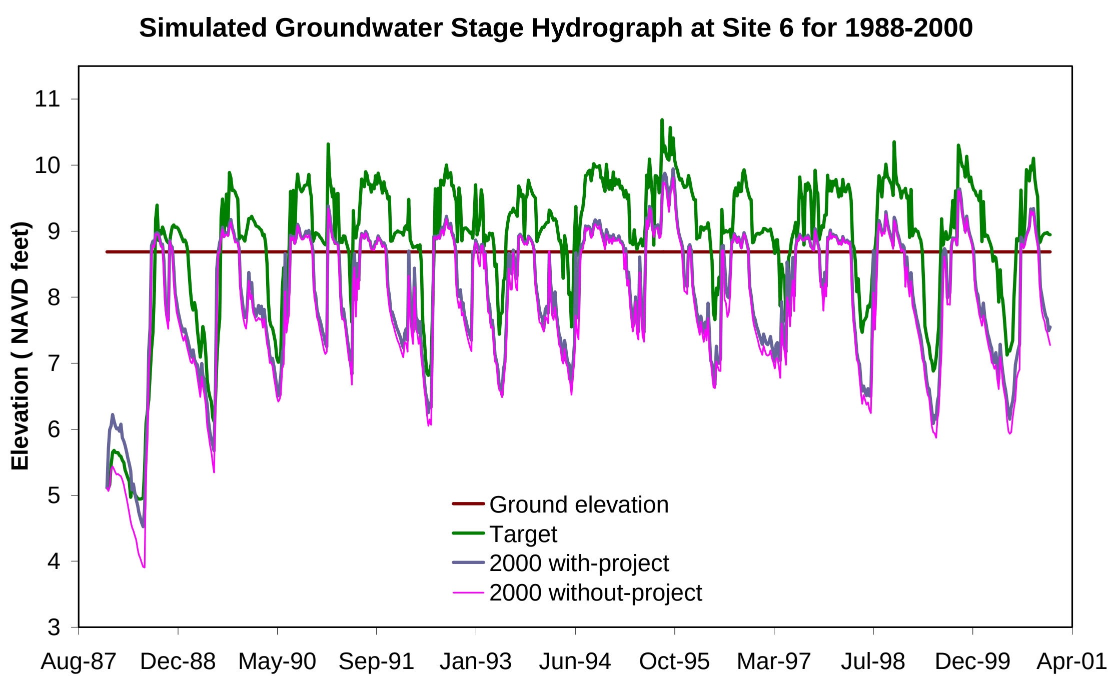


Figure A-7. Simulated groundwater stage hydrograph at Site 6 for 1988 to 2000

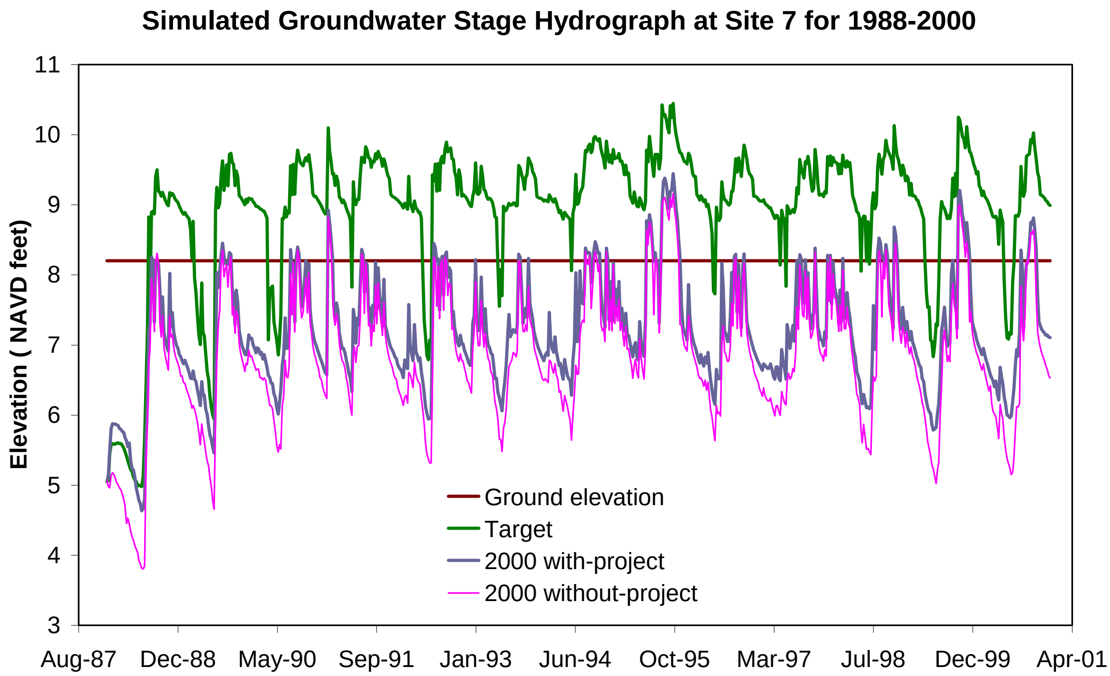


Figure A-8. Simulated groundwater stage hydrograph at Site 7 for 1988 to 2000

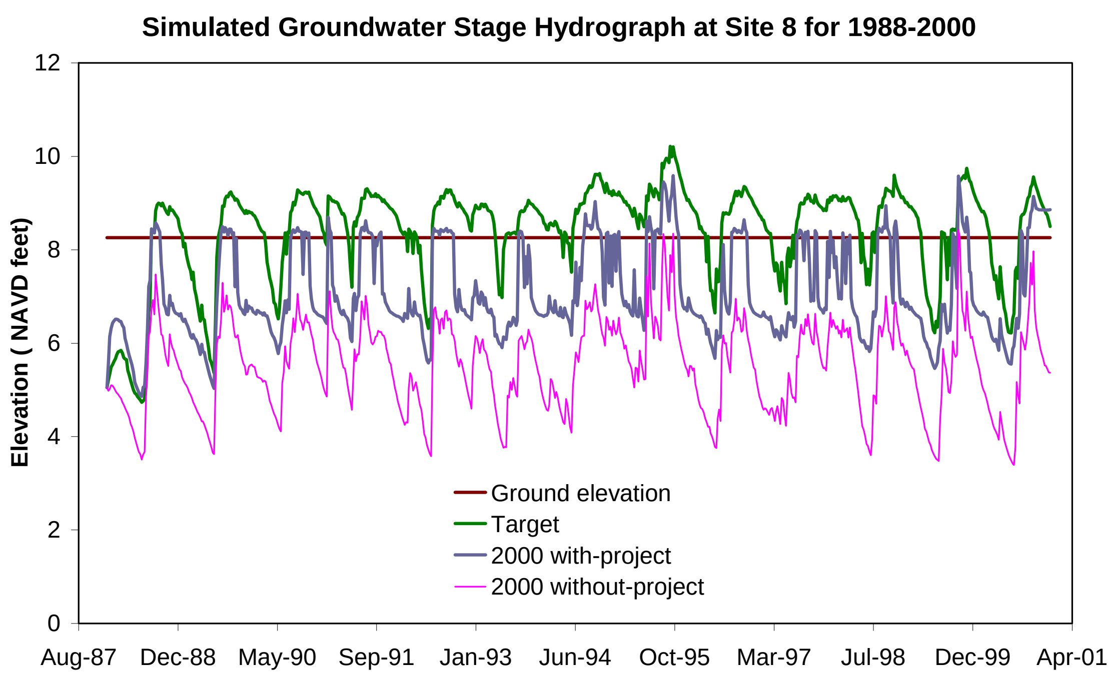


Figure A-9. Simulated groundwater stage hydrograph at Site 8 for 1988 to 2000

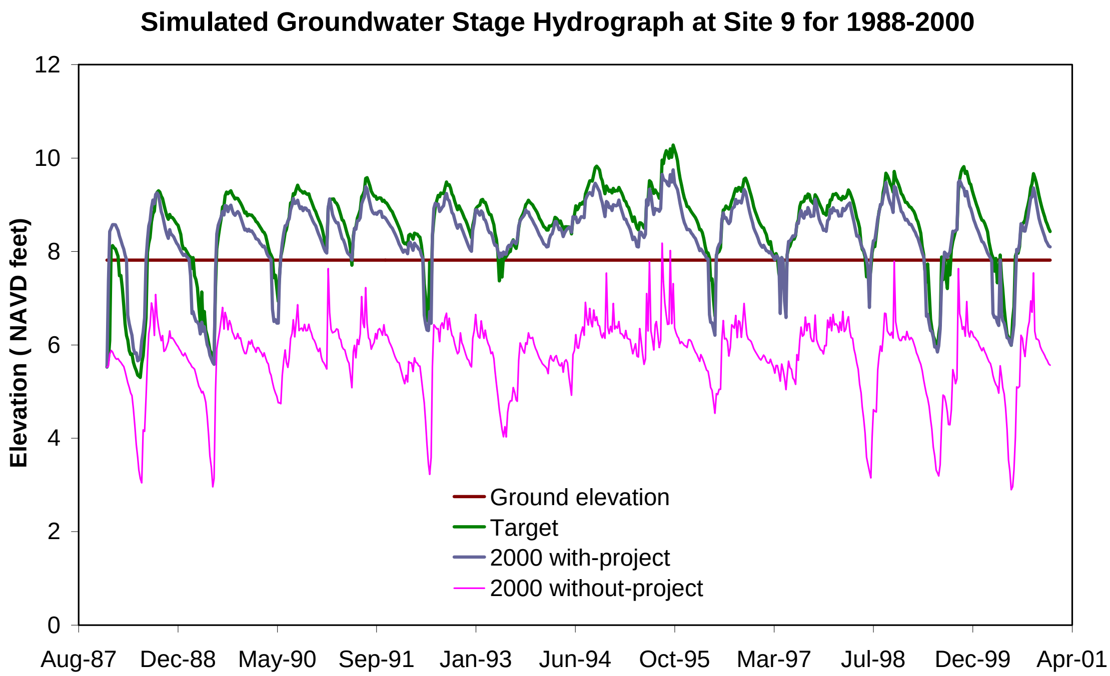


Figure A-10. Simulated groundwater stage hydrograph at Site 9 for 1988 to 2000

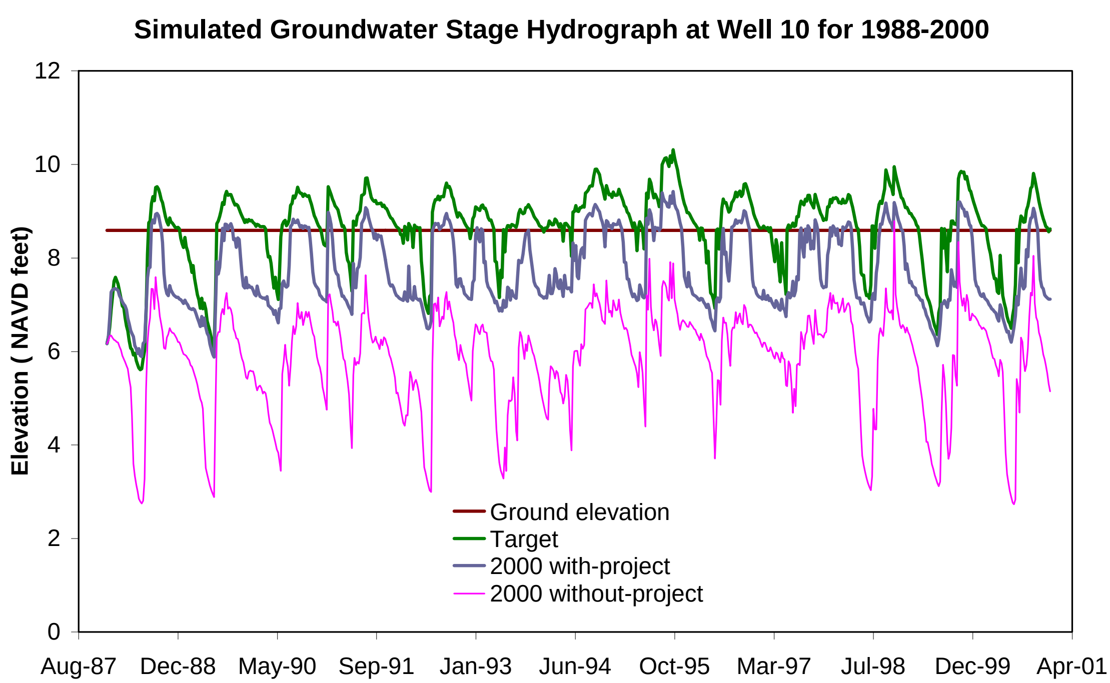


Figure A-11. Simulated groundwater stage hydrograph at Site 10 for 1988 to 2000

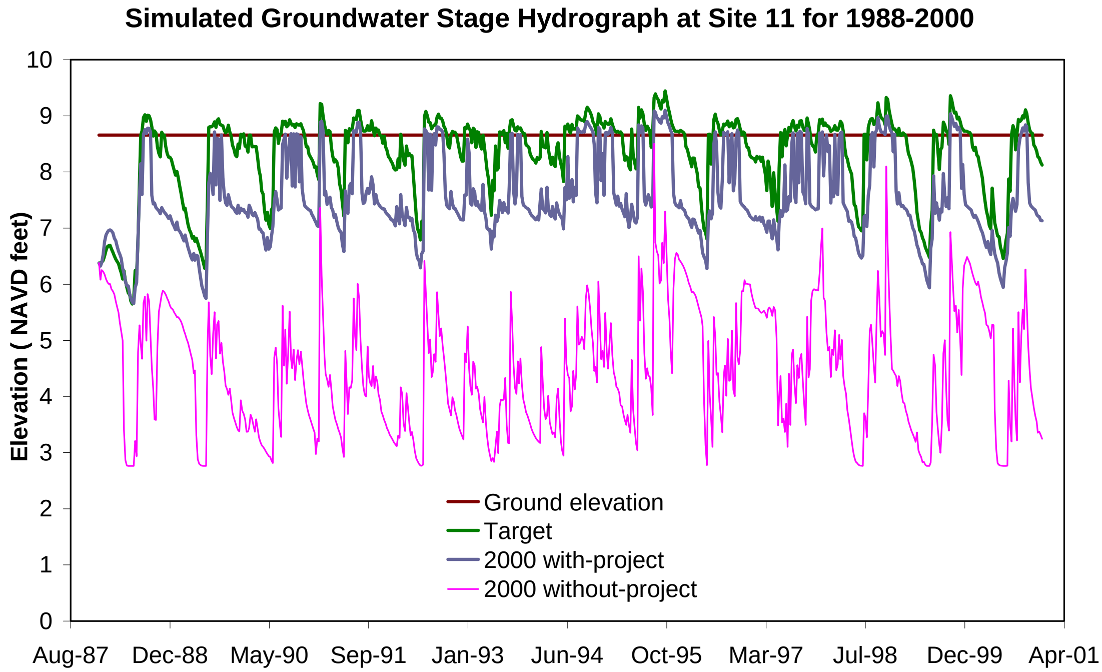


Figure A-12. Simulated groundwater stage hydrograph at Site 11 for 1988 to 2000

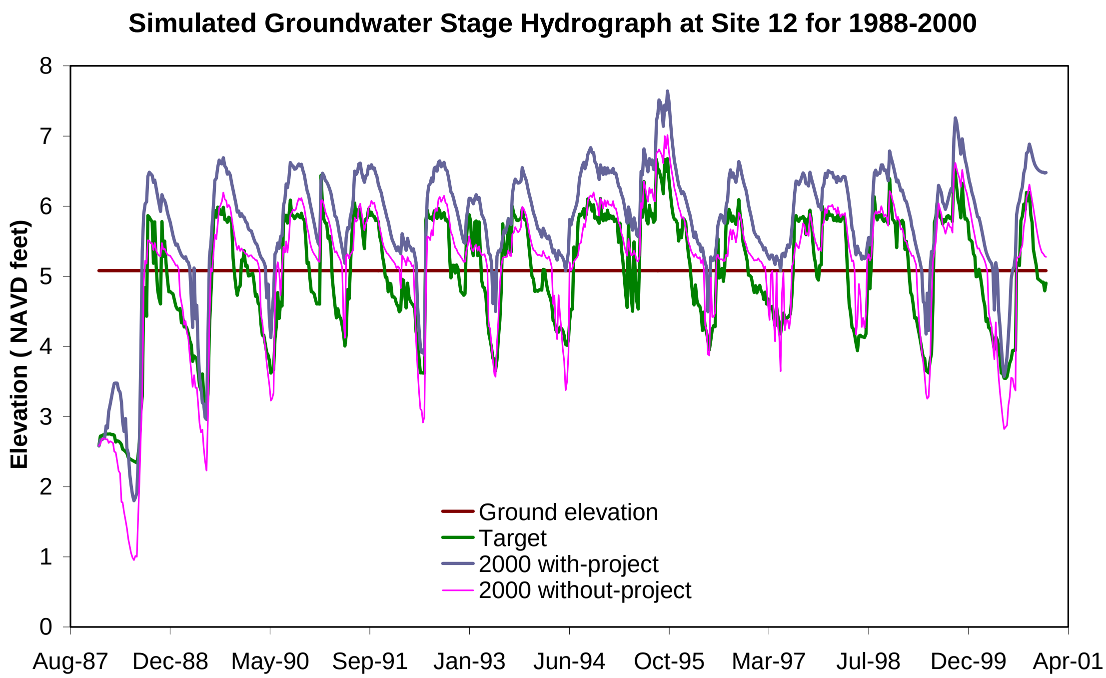


Figure A-13. Simulated groundwater stage hydrograph at Site 12 for 1988 to 2000

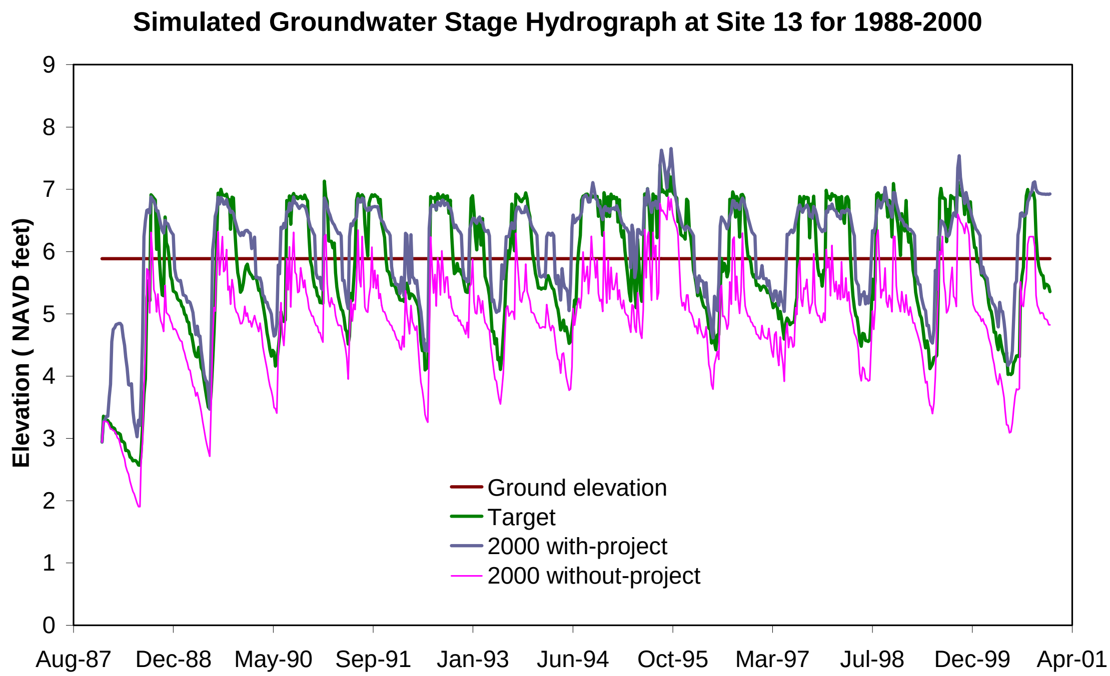


Figure A-14. Simulated groundwater stage hydrograph at Site 13 for 1988 to 2000

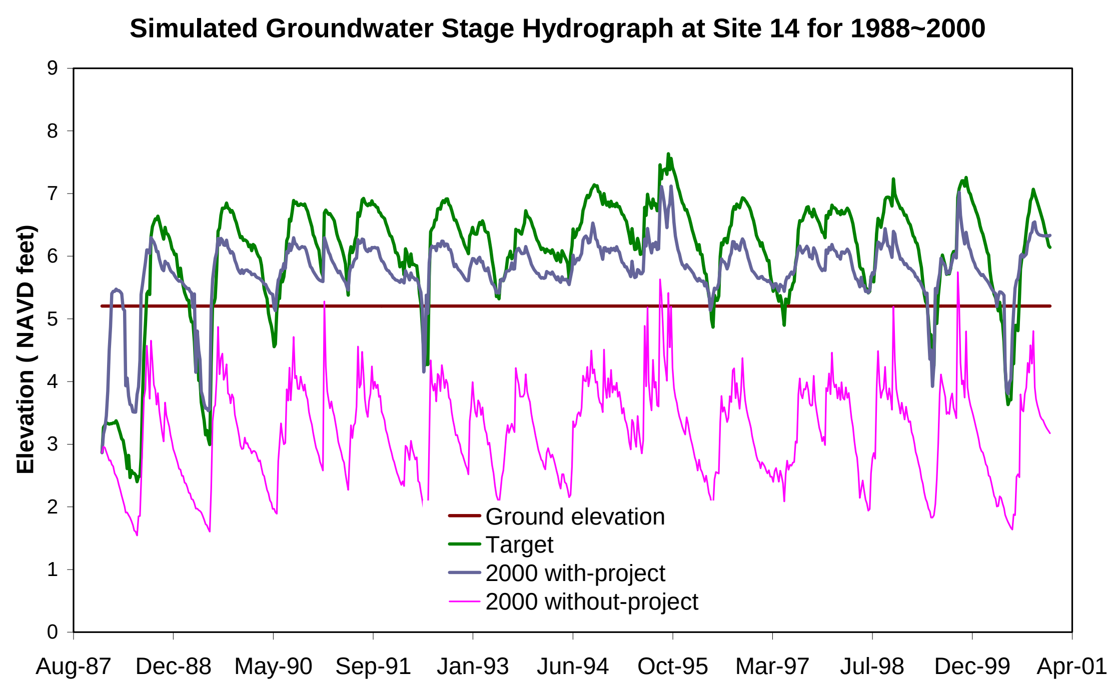


Figure A-15. Simulated groundwater stage hydrograph at Site 14 for 1988 to 2000

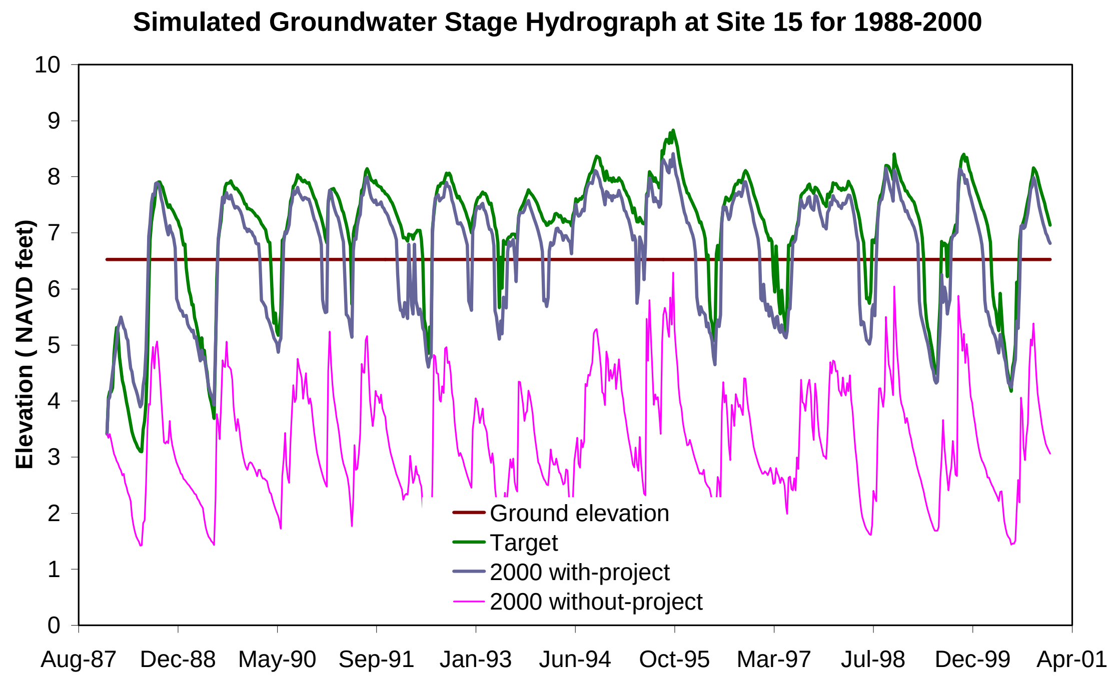


Figure A-16. Simulated groundwater stage hydrograph at Site 15 for 1988 to 2000

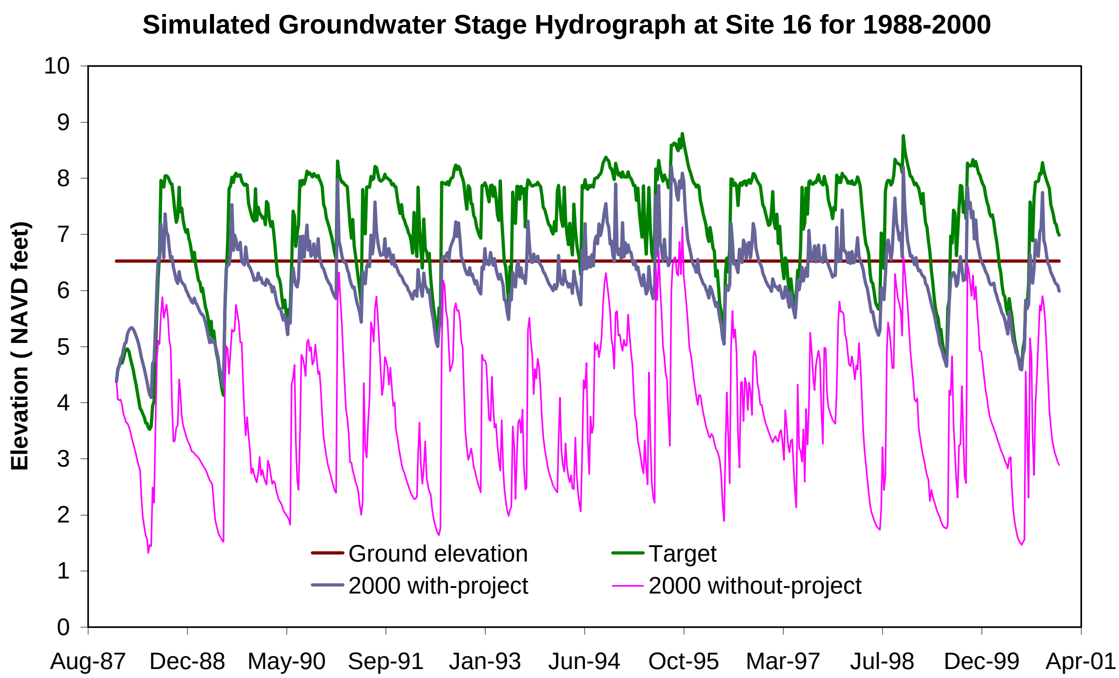


Figure A-17. Simulated groundwater stage hydrograph at Site 16 for 1988 to 2000

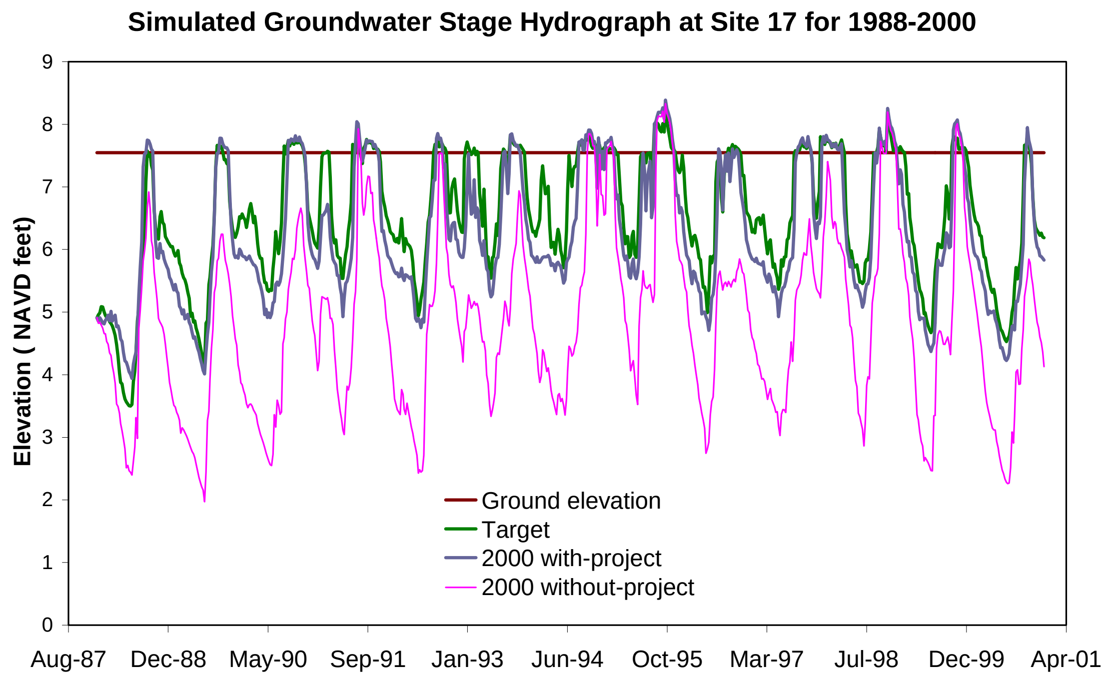


Figure A-18. Simulated groundwater stage hydrograph at Site 17 for 1988 to 2000

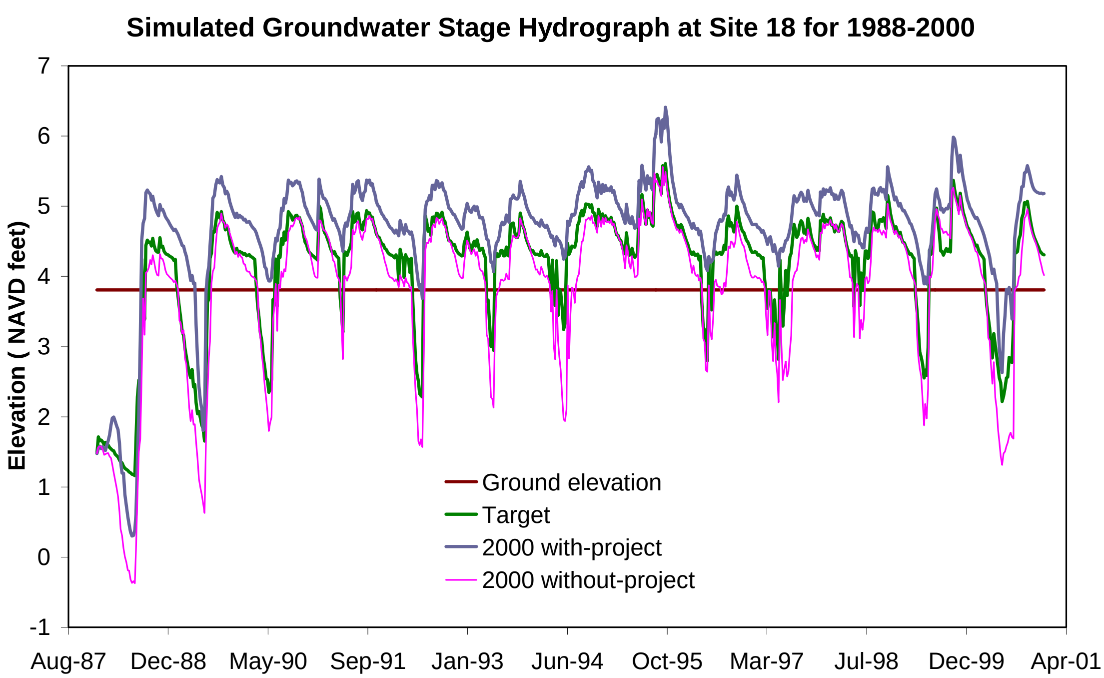


Figure A-19. Simulated groundwater stage hydrograph at Site 18 for 1988 to 2000

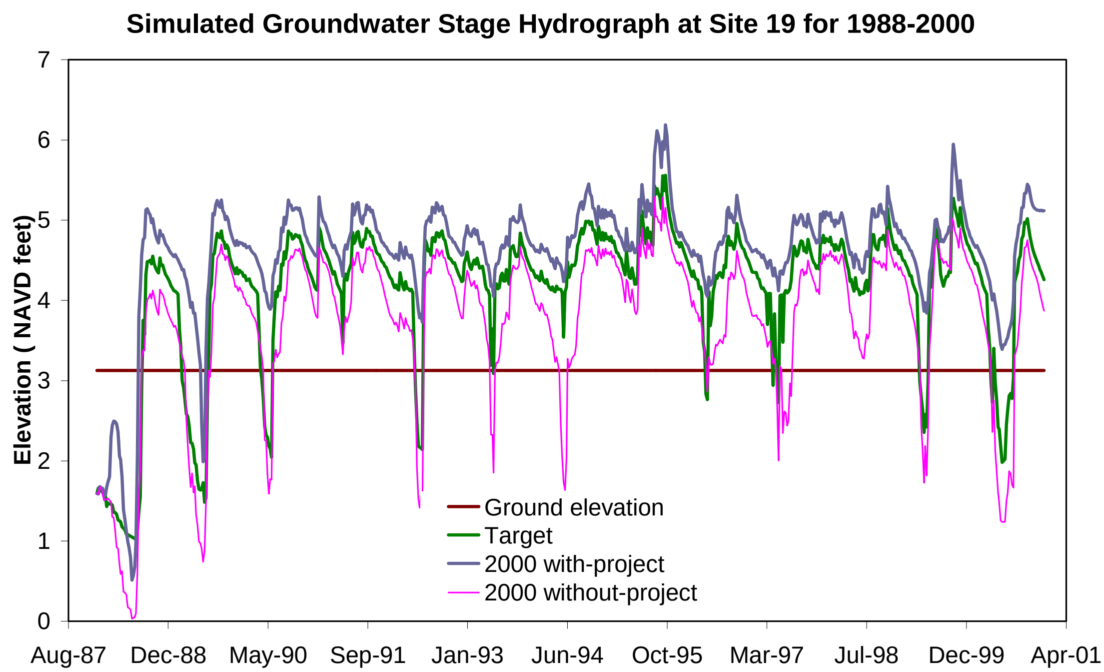


Figure A-20. Simulated groundwater stage hydrograph at Site 19 for 1988 to 2000

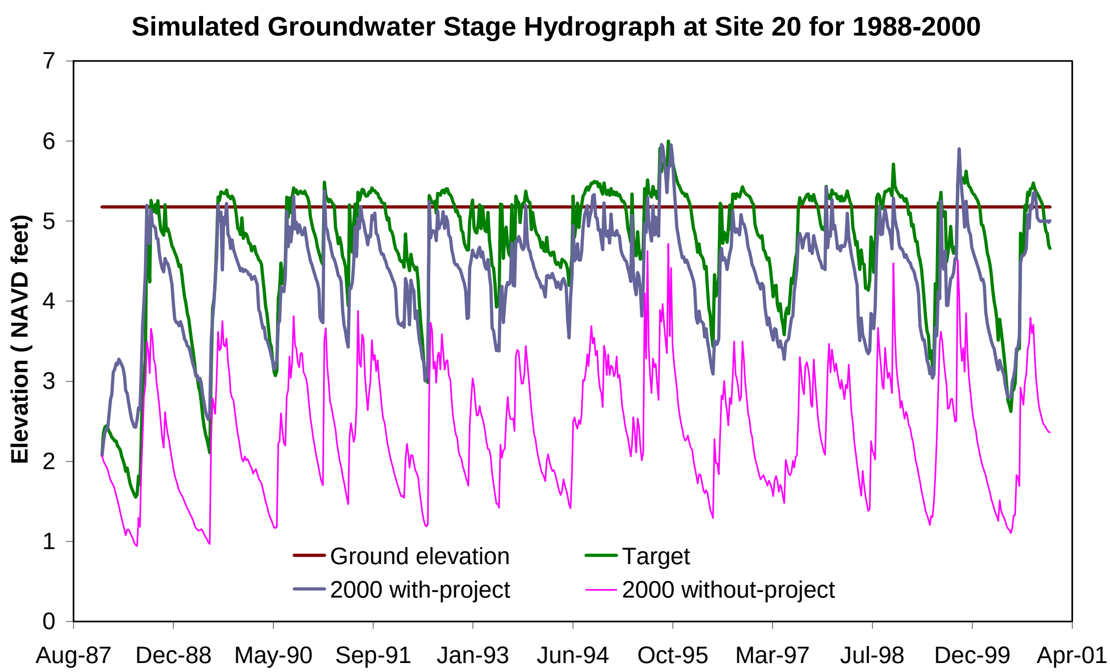


Figure A-21. Simulated groundwater stage hydrograph at Site 20 for 1988 to 2000

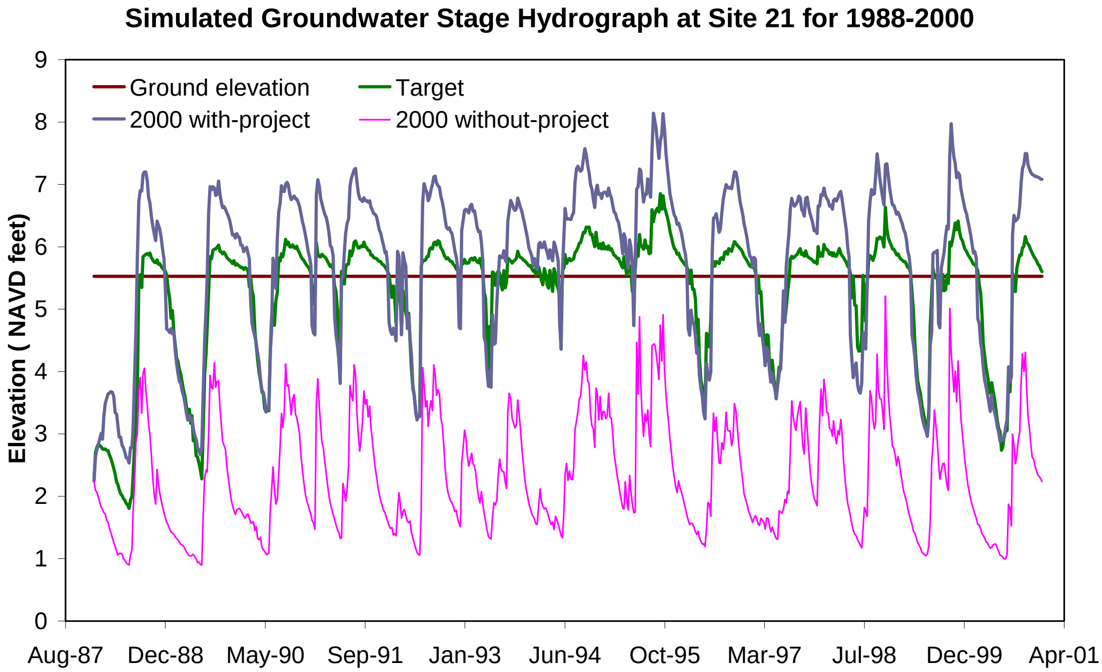


Figure A-22. Simulated groundwater stage hydrograph at Site 21 for 1988 to 2000

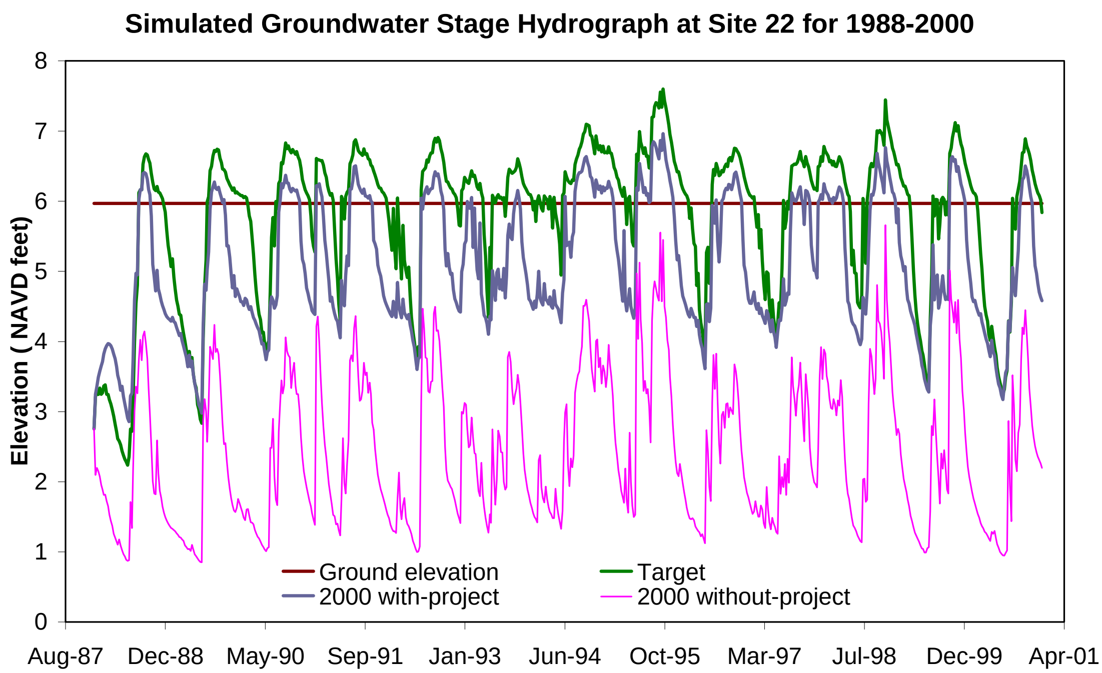


Figure A-23. Simulated groundwater stage hydrograph at Site 22 for 1988 to 2000

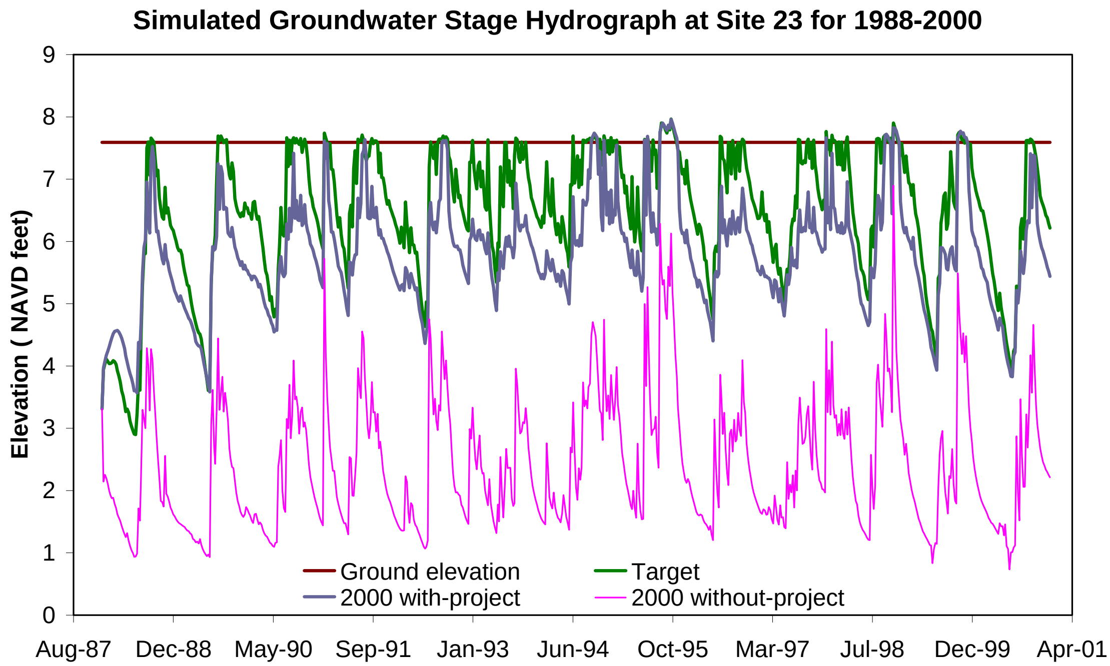


Figure A-24. Simulated groundwater stage hydrograph at Site 23 for 1988 to 2000

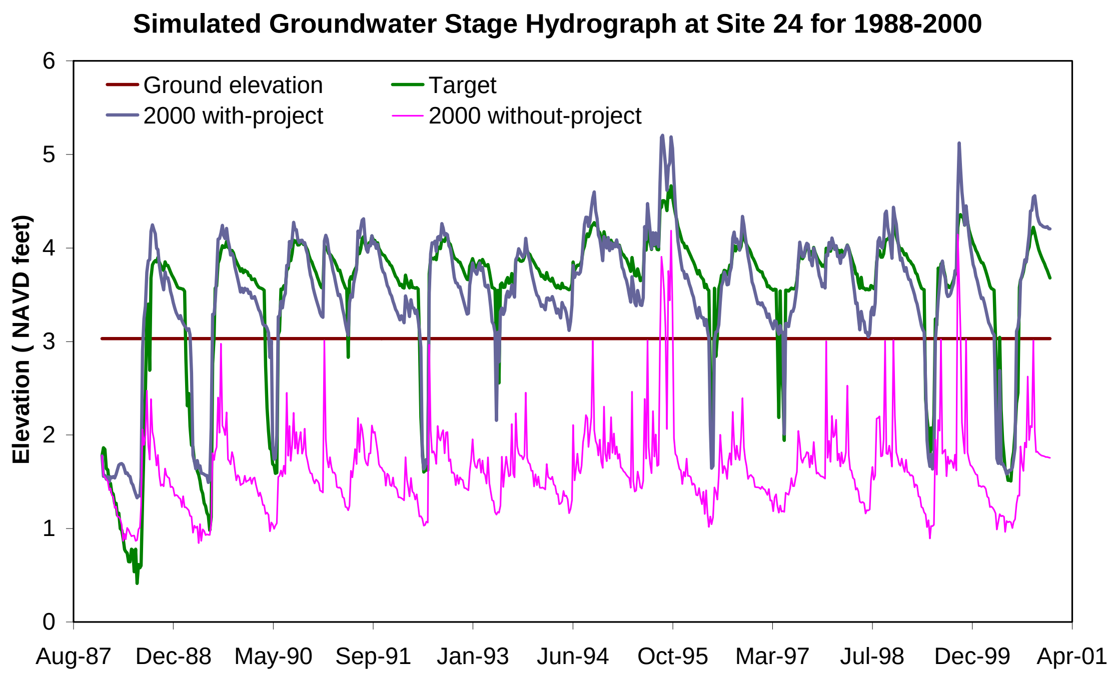


Figure A-25. Simulated groundwater stage hydrograph at Site 24 for 1988 to 2000

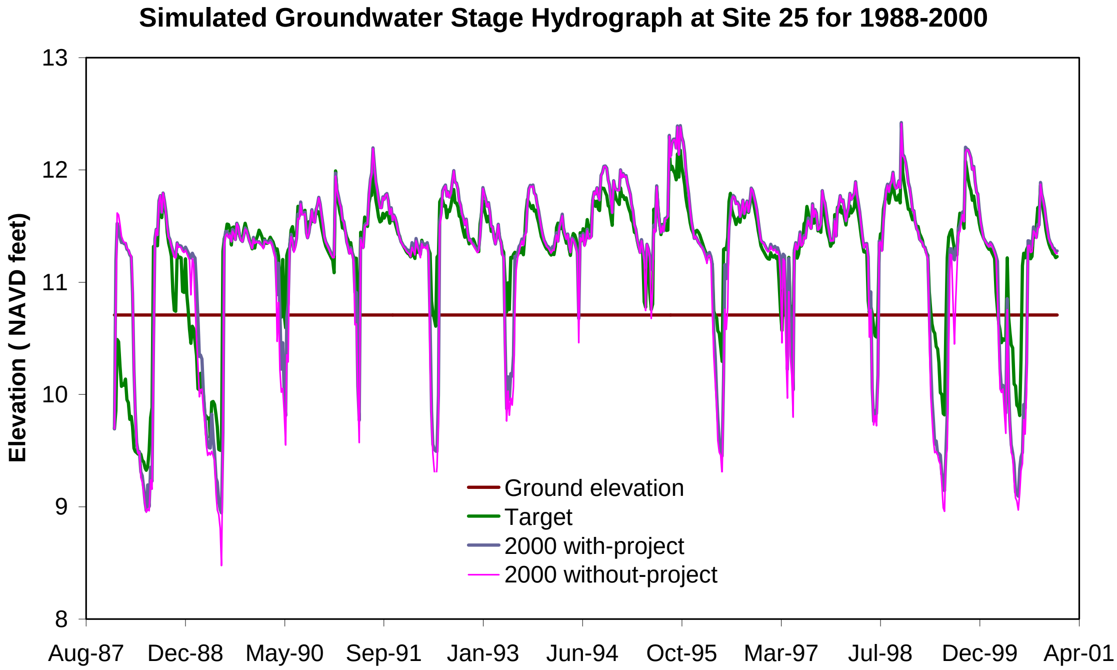


Figure A-26. Simulated groundwater stage hydrograph at Site 25 for 1988 to 2000

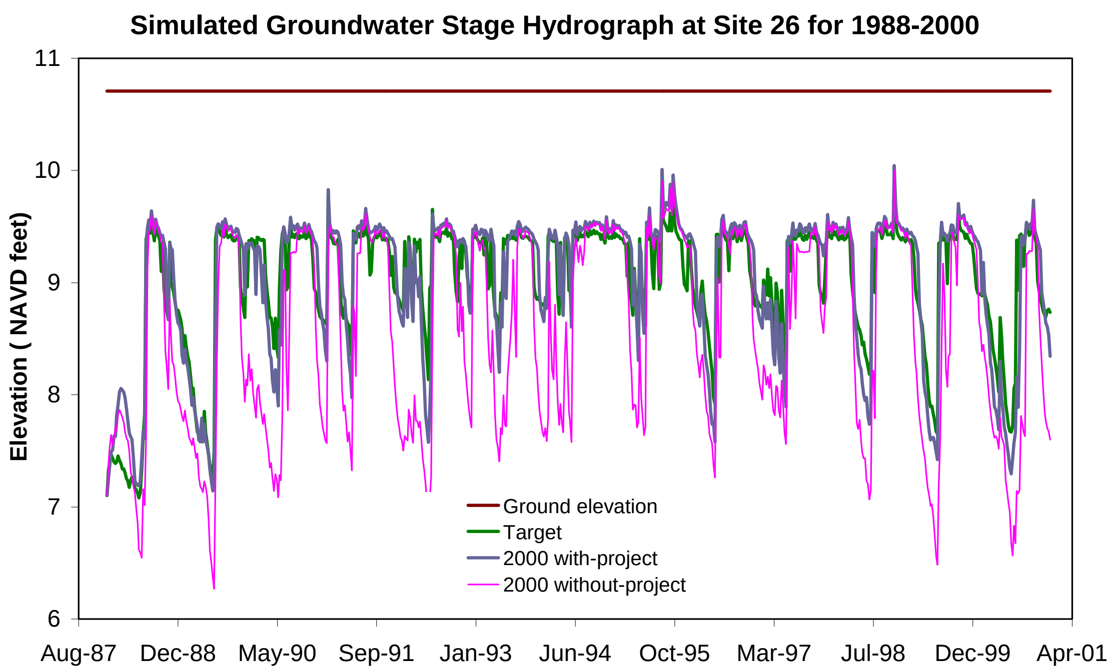


Figure A-27. Simulated groundwater stage hydrograph at Site 26 for 1988 to 2000

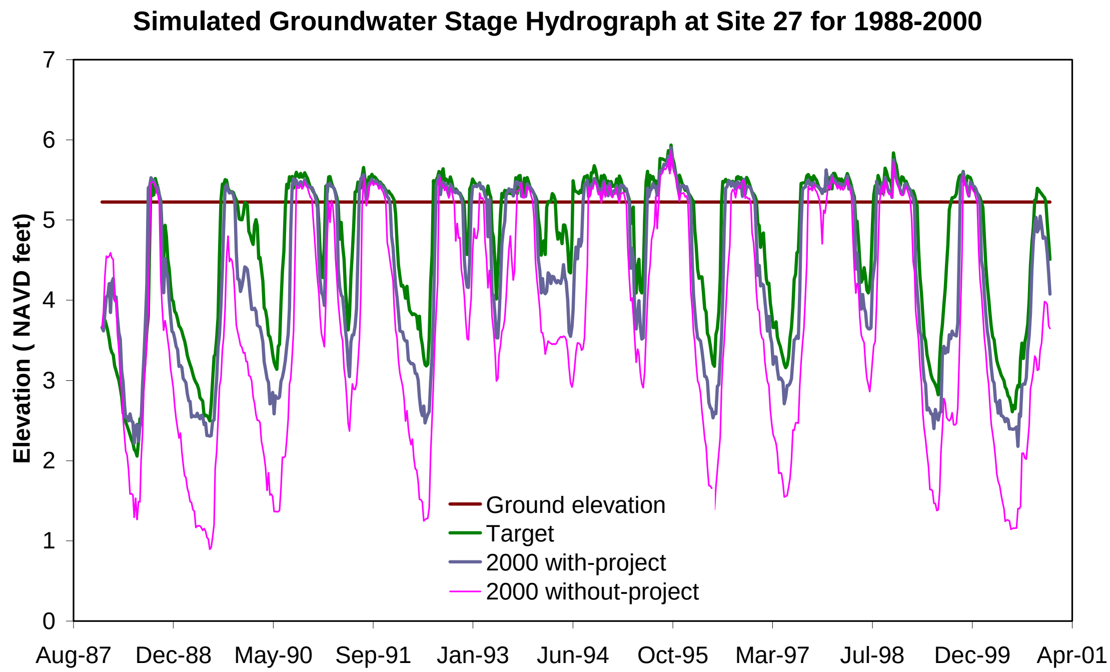


Figure A-28. Simulated groundwater stage hydrograph at Site 27 for 1988 to 2000

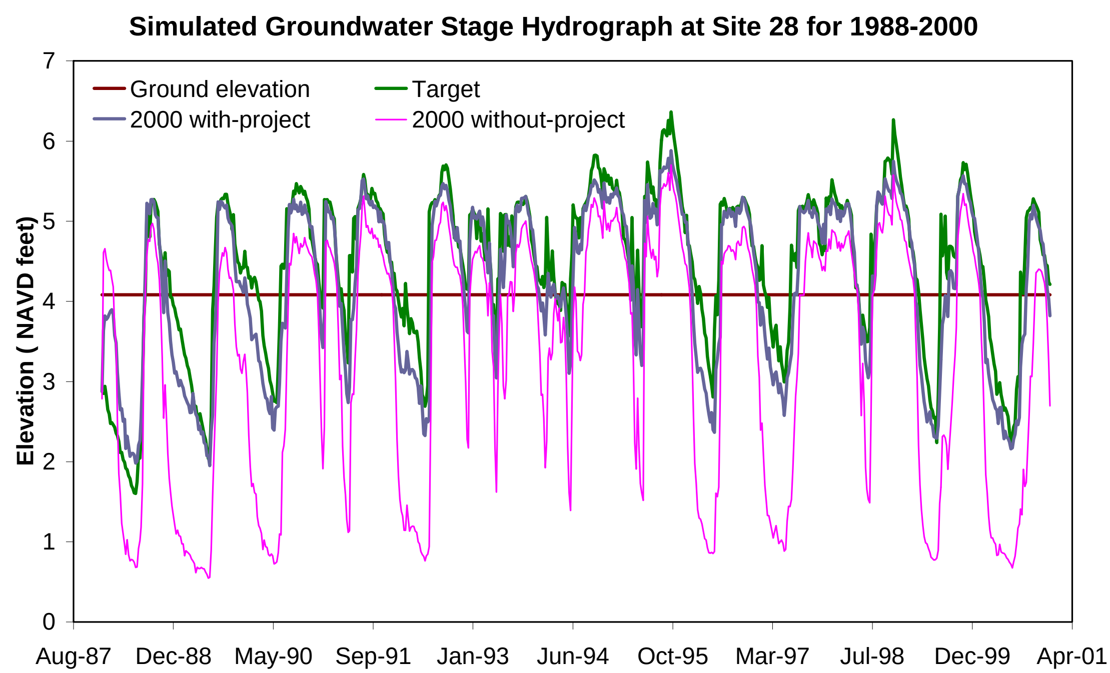


Figure A-29. Simulated groundwater stage hydrograph at Site 28 for 1988 to 2000

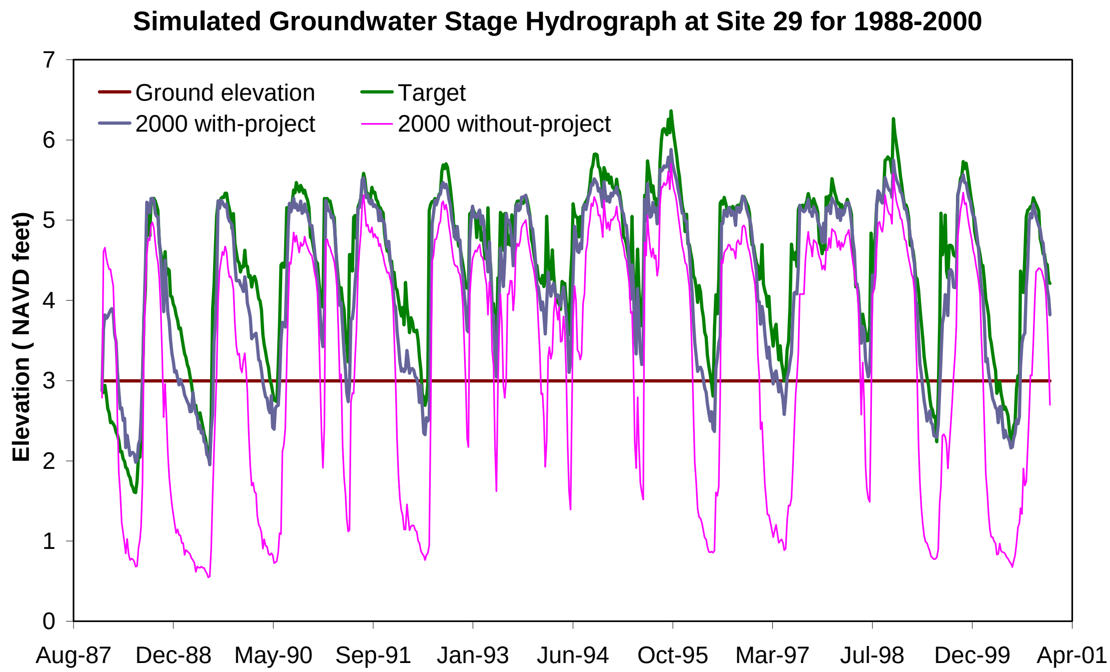


Figure A-30. Simulated groundwater stage hydrograph at Site 29 for 1988 to 2000

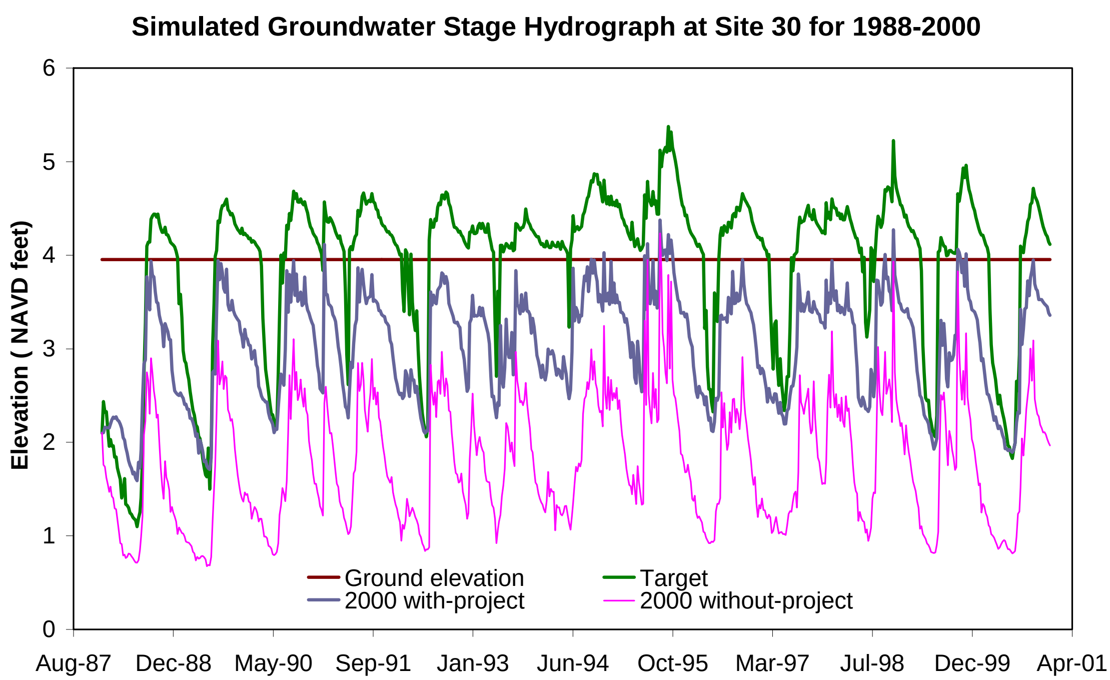


Figure A-31. Simulated groundwater stage hydrograph at Site 30 for 1988 to 2000

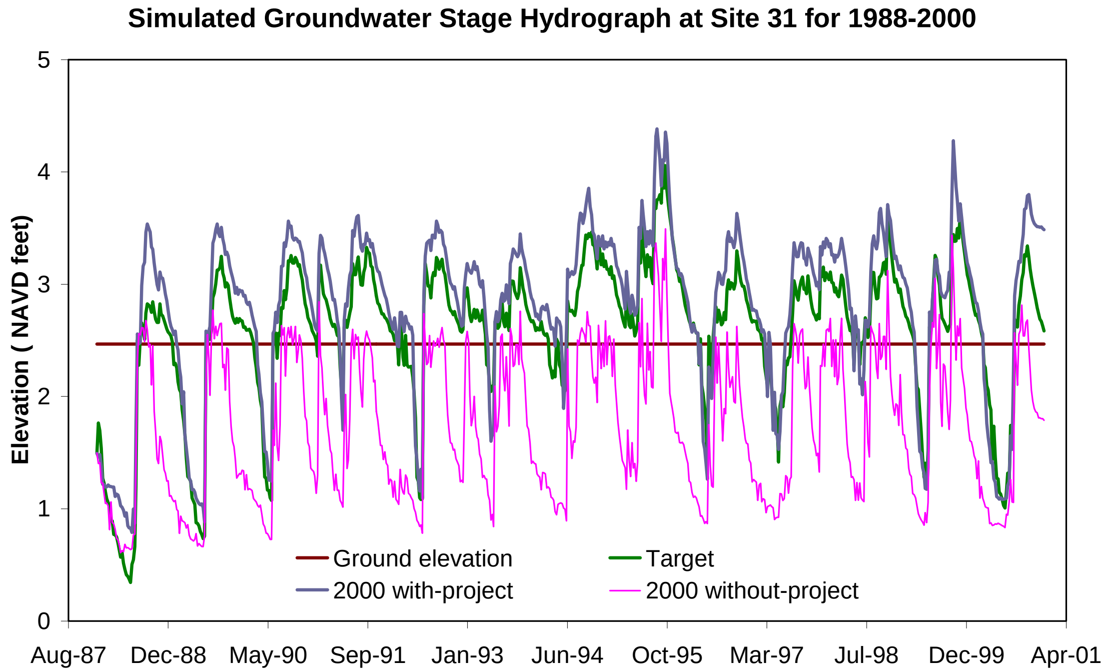


Figure A-32. Simulated groundwater stage hydrograph at Site 31 for 1988 to 2000

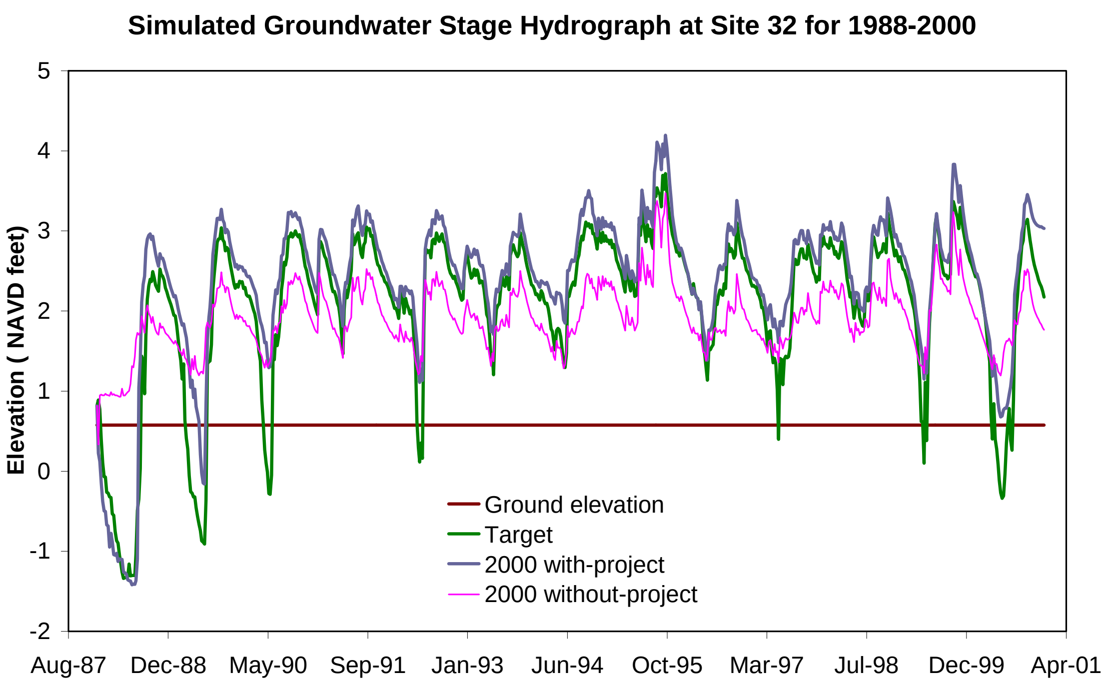


Figure A-33. Simulated groundwater stage hydrograph at Site 32 for 1988 to 2000

Stage duration curves for the 32 Picayune Strand indicator regions shown in **Figure A-1** provide an indication of the cumulative probability that a particular stage is exceeded or not exceeded at each of the sites over the 13 years modeled. From the duration curve, the probability of exceeding a given stage is then easily compared for each simulated condition (**Figures A-34** through **A-65**).

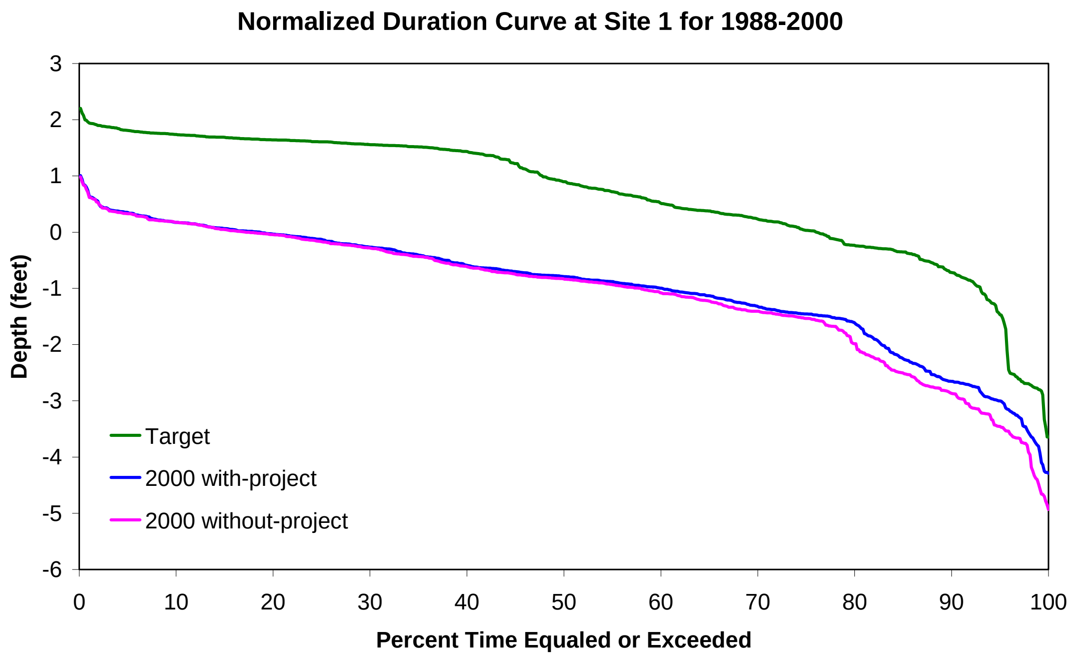


Figure A-34. Normalized duration curve at Site 1 for 1988 to 2000

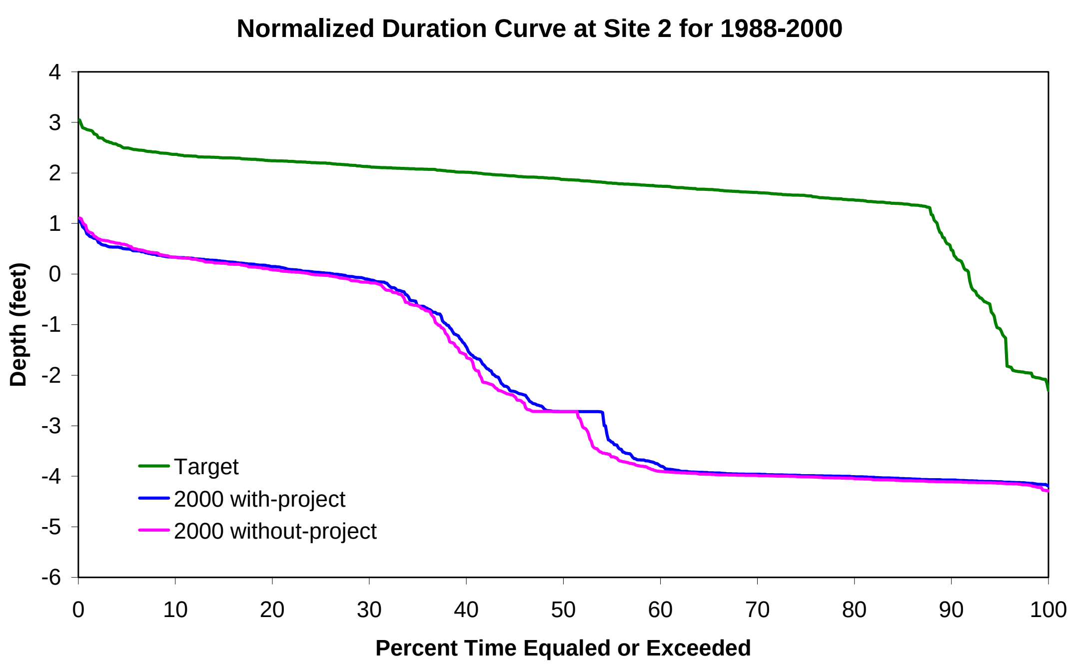


Figure A-35. Normalized duration curve at Site 2 for 1988 to 2000

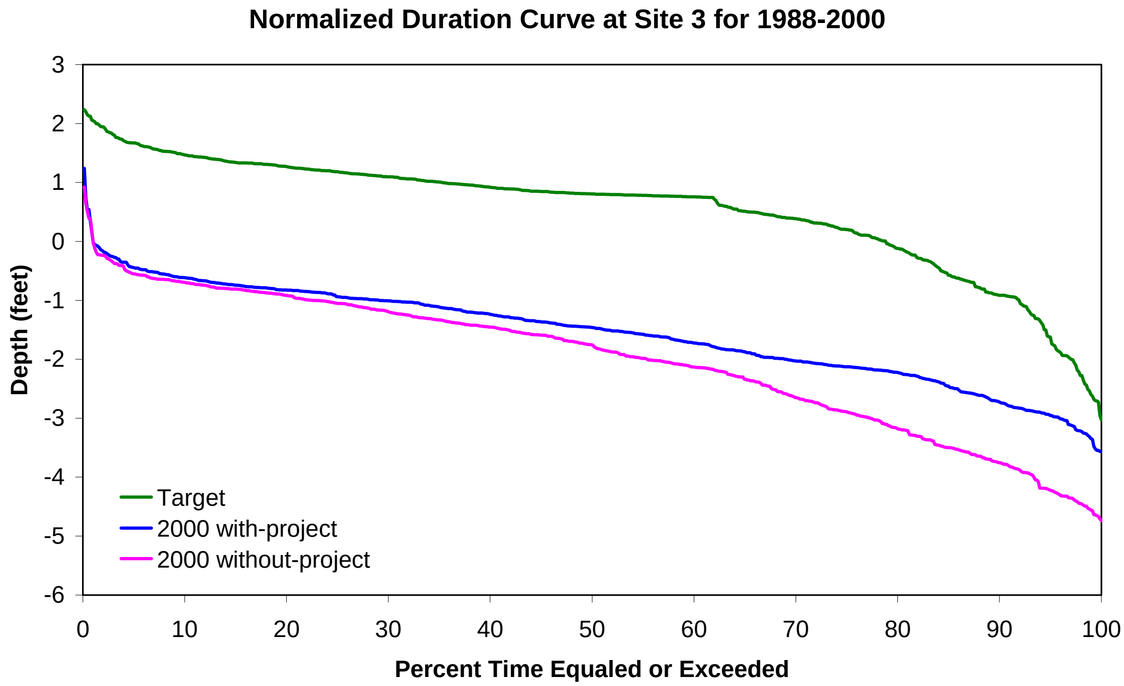


Figure A-36. Normalized duration curve at Site 3 for 1988 to 2000

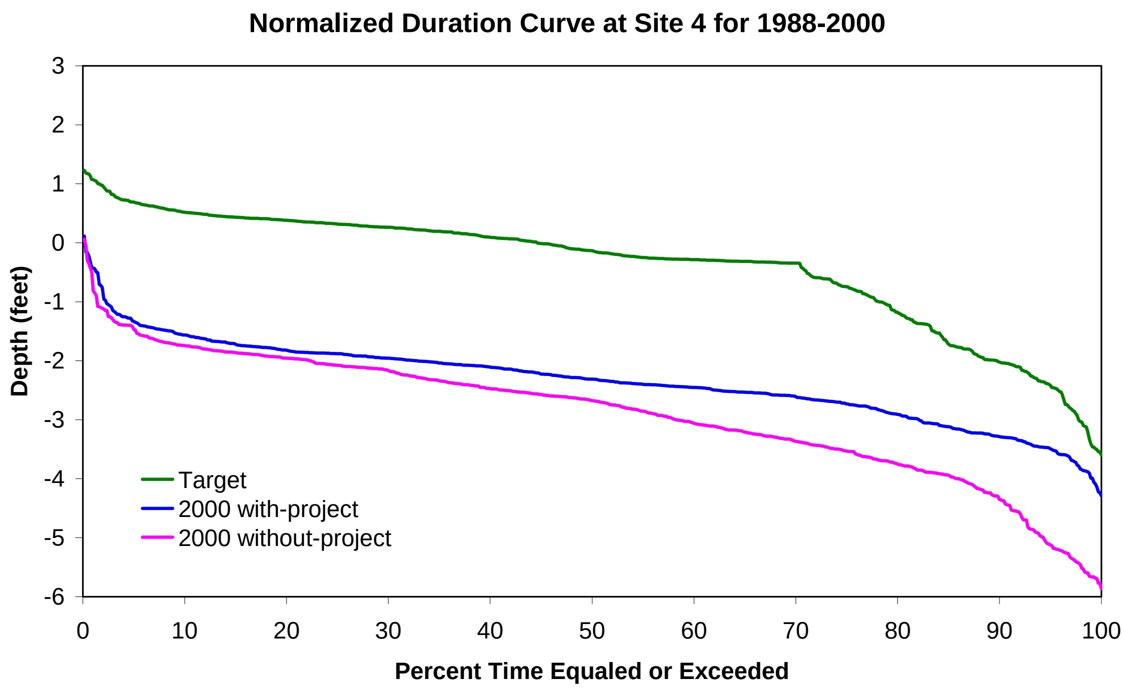


Figure A-37. Normalized duration curve at Site 4 for 1988 to 2000

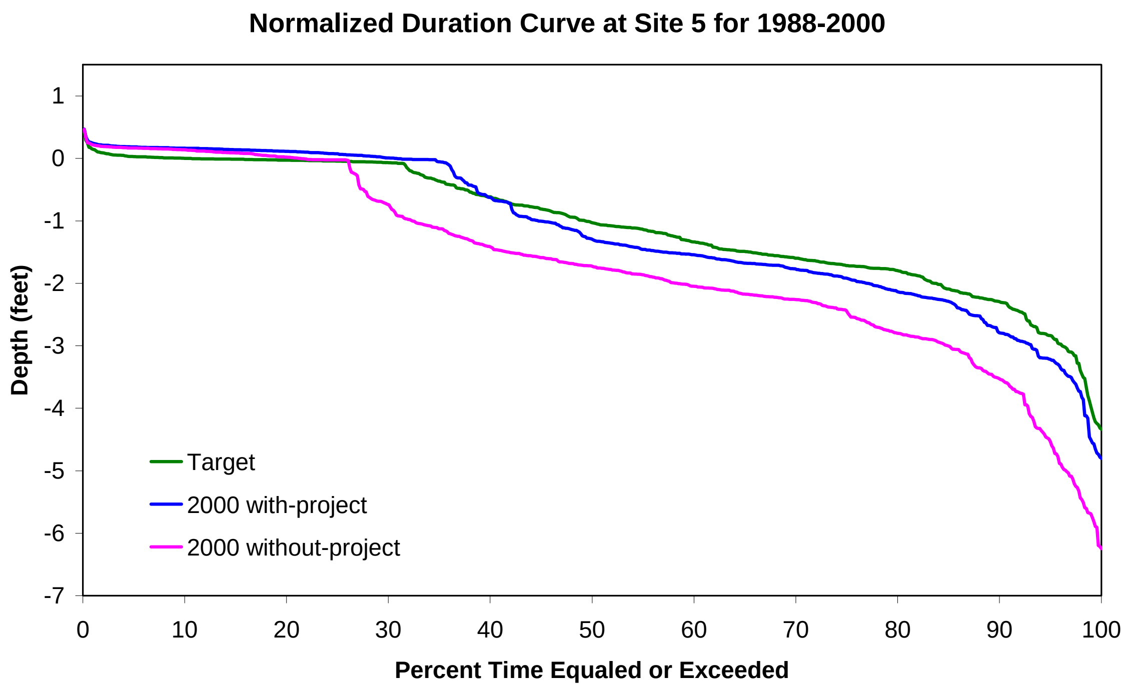


Figure A-38. Normalized duration curve at Site 5 for 1988 to 2000

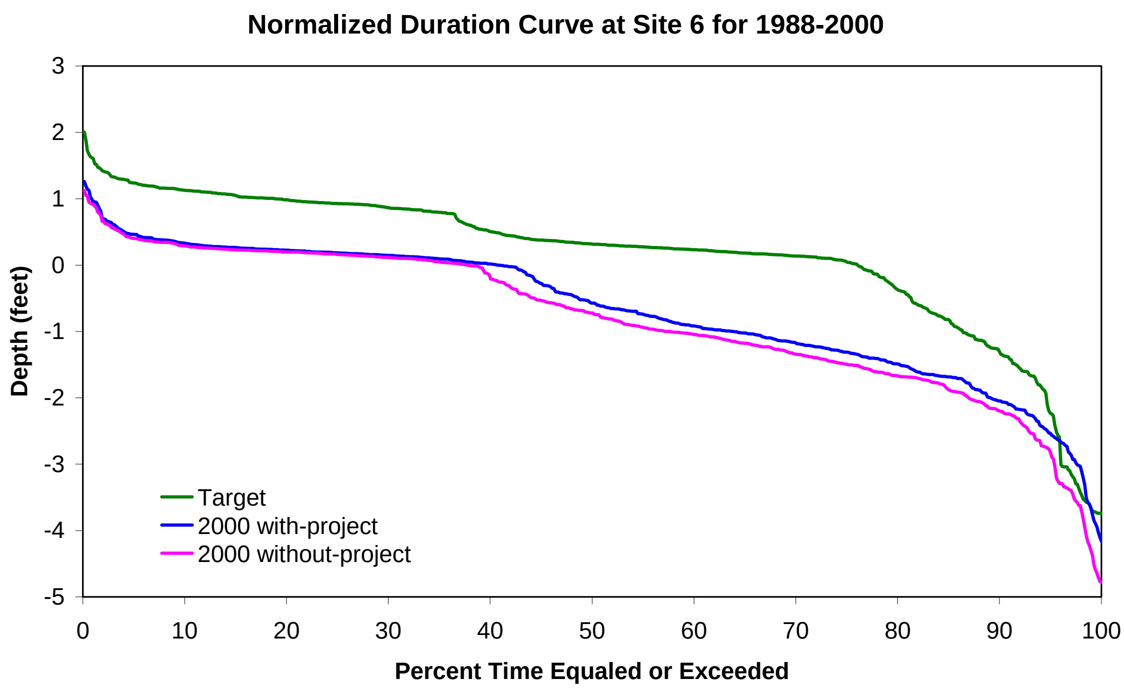


Figure A-39. Normalized duration curve at Site 6 for 1988 to 2000

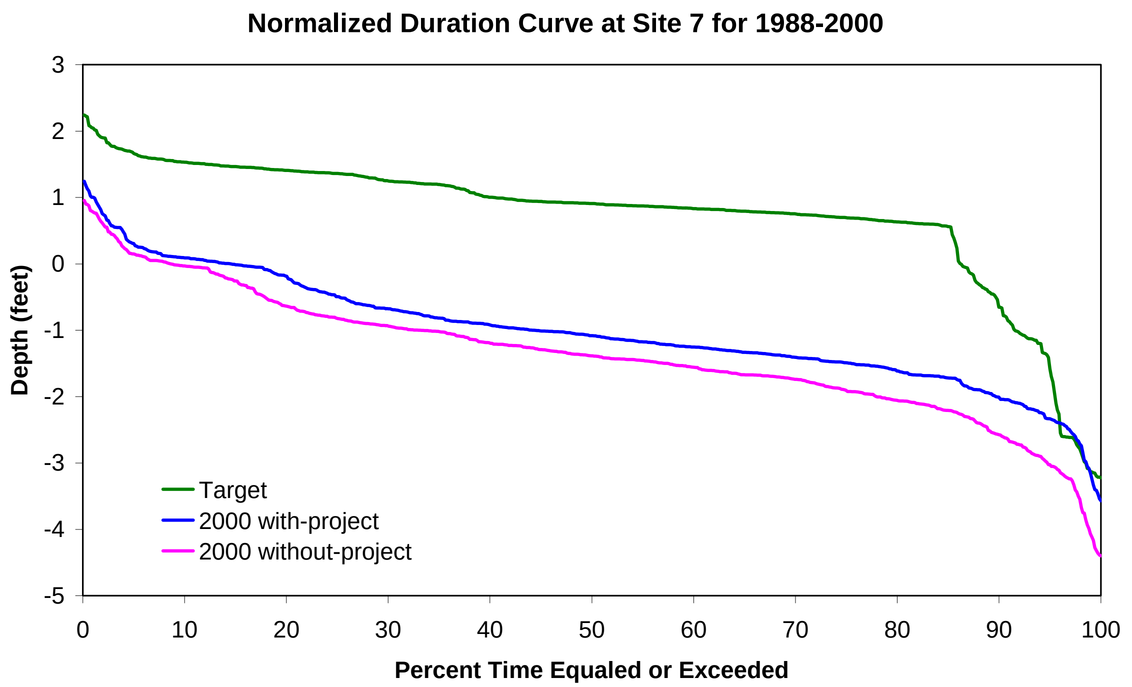


Figure A-40. Normalized duration curve at Site 7 for 1988 to 2000

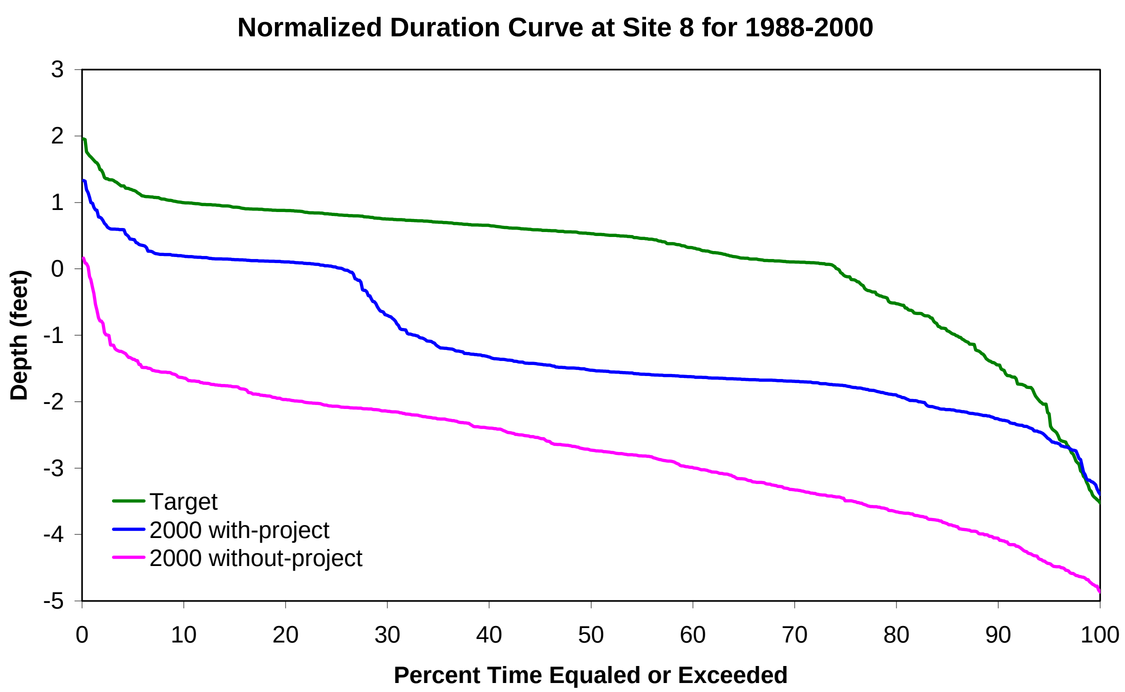


Figure A-41. Normalized duration curve at Site 8 for 1988 to 2000

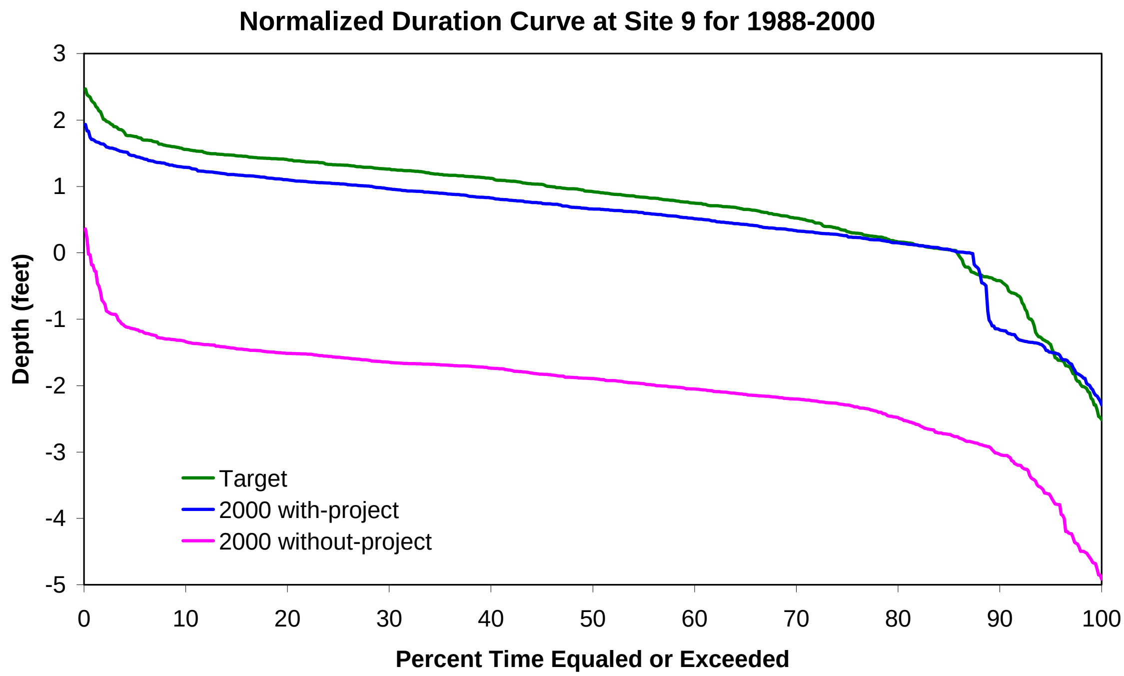


Figure A-42. Normalized duration curve at Site 9 for 1988 to 2000

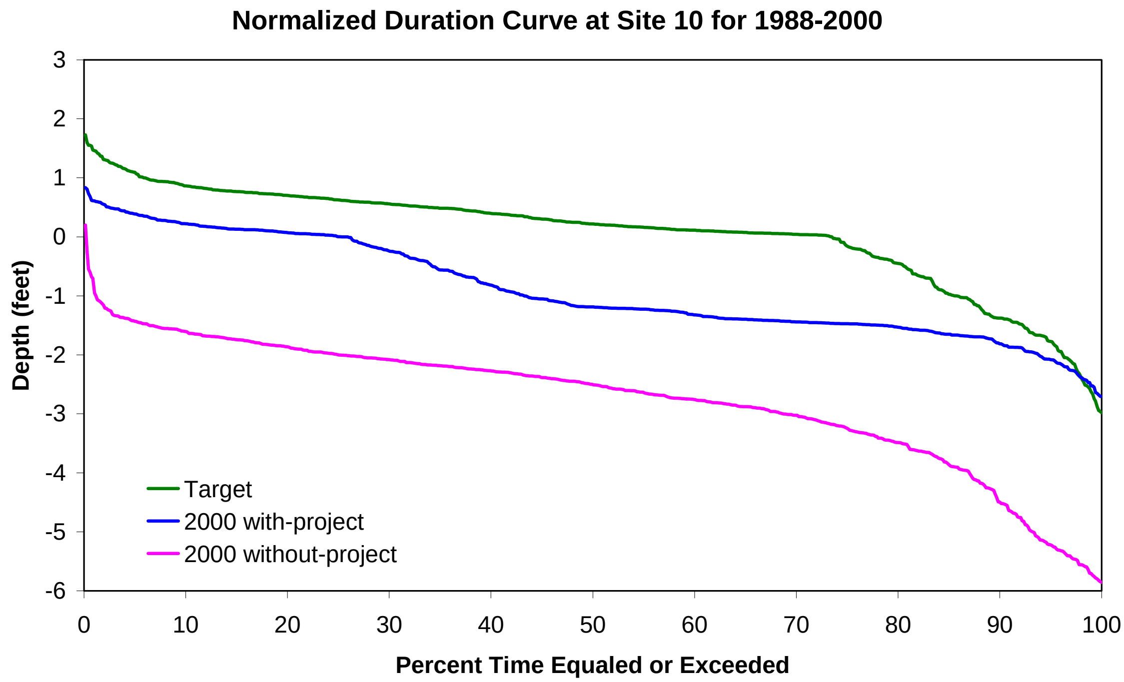


Figure A-43. Normalized duration curve at Site 10 for 1988 to 2000

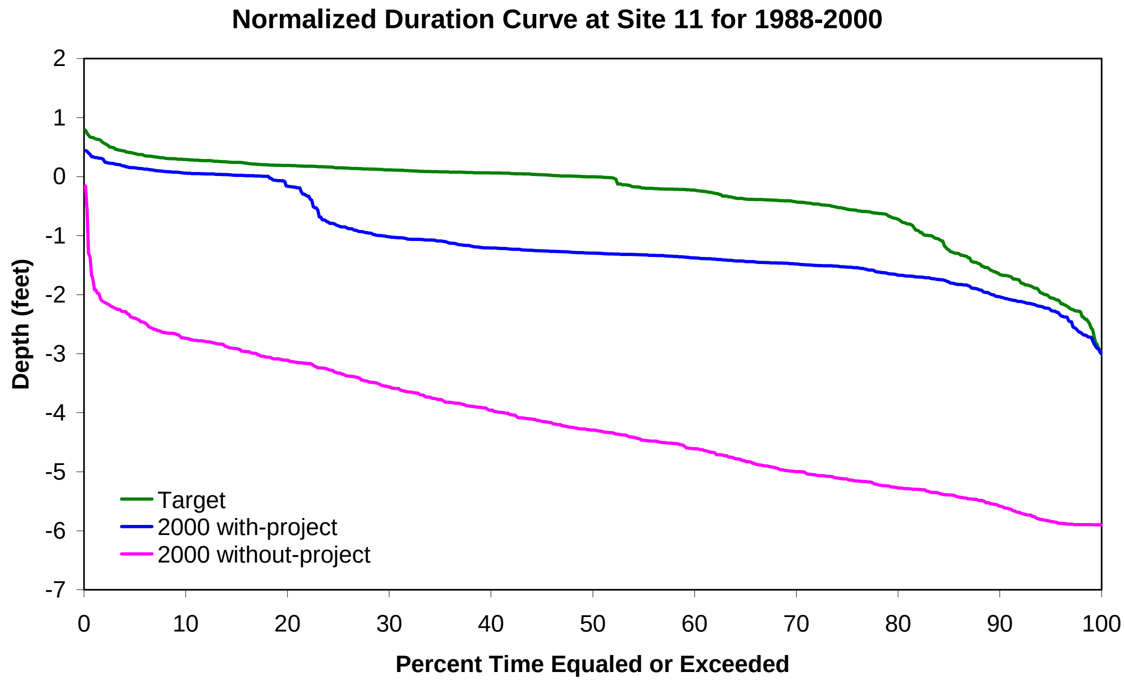


Figure A-44. Normalized duration curve at Site 11 for 1988 to 2000

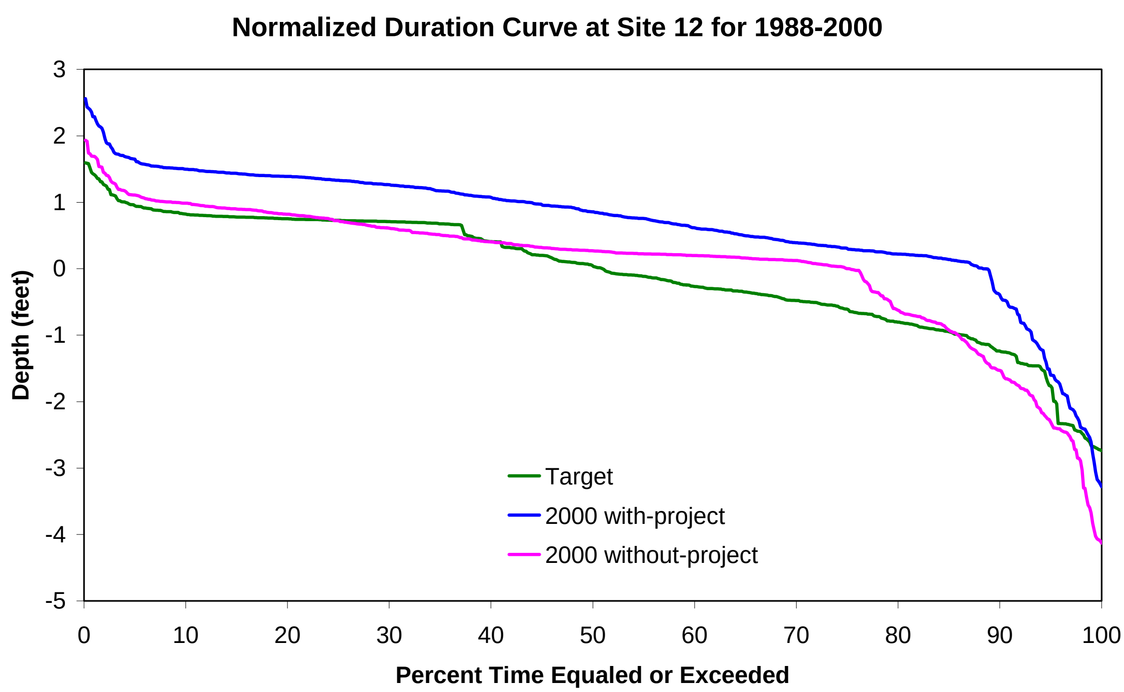


Figure A-45. Normalized duration curve at Site 12 for 1988 to 2000

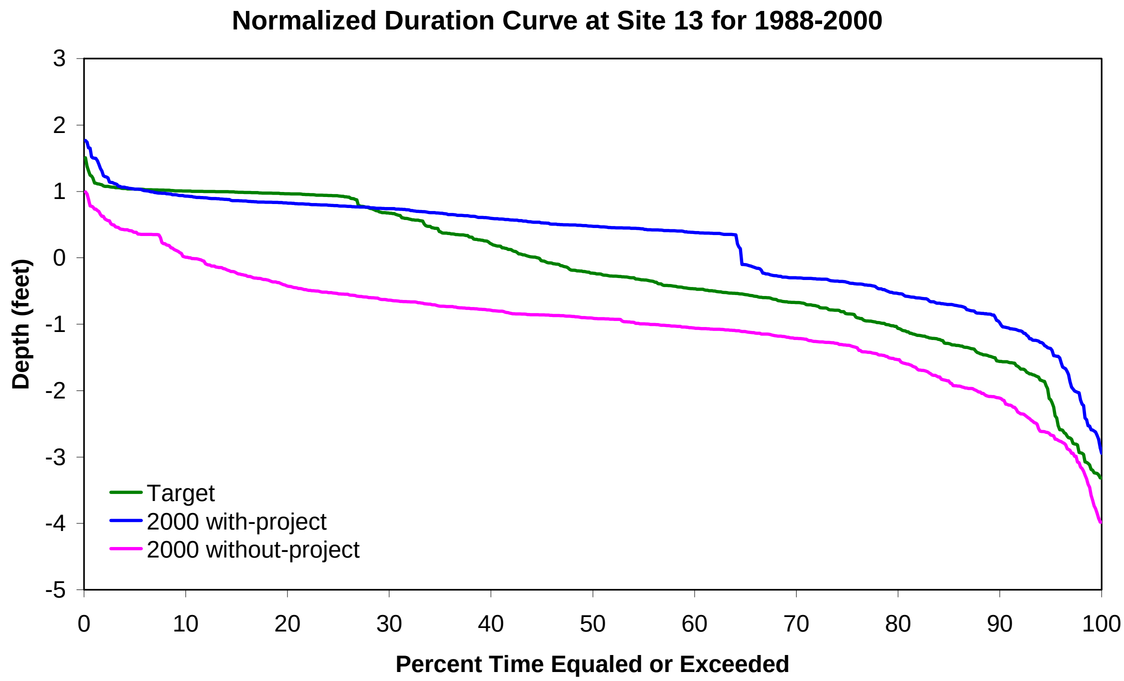


Figure A-46. Normalized duration curve at Site 13 for 1988 to 2000

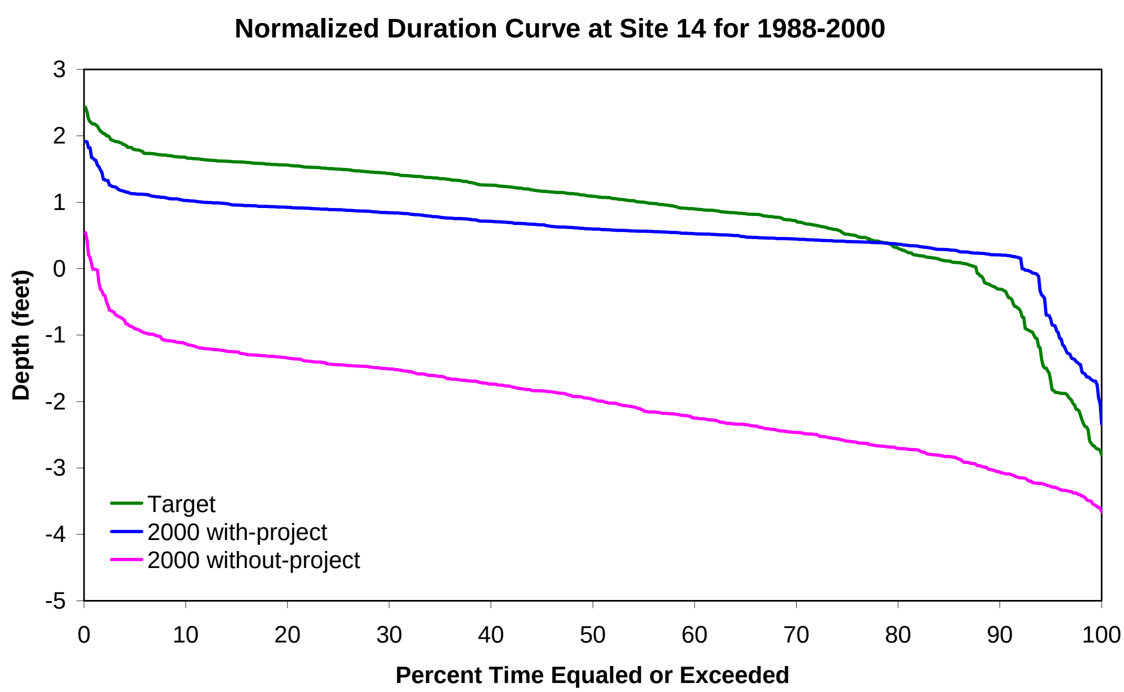


Figure A-47. Normalized duration curve at Site 14 for 1988 to 2000

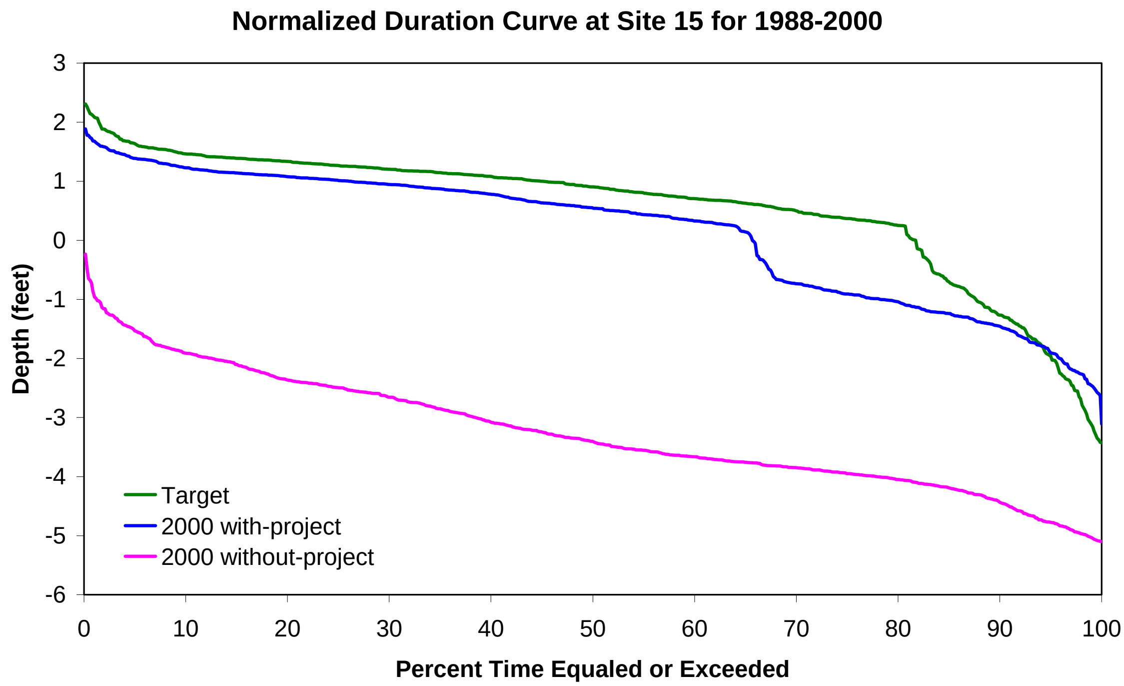


Figure A-48. Normalized duration curve at Site 15 for 1988 to 2000

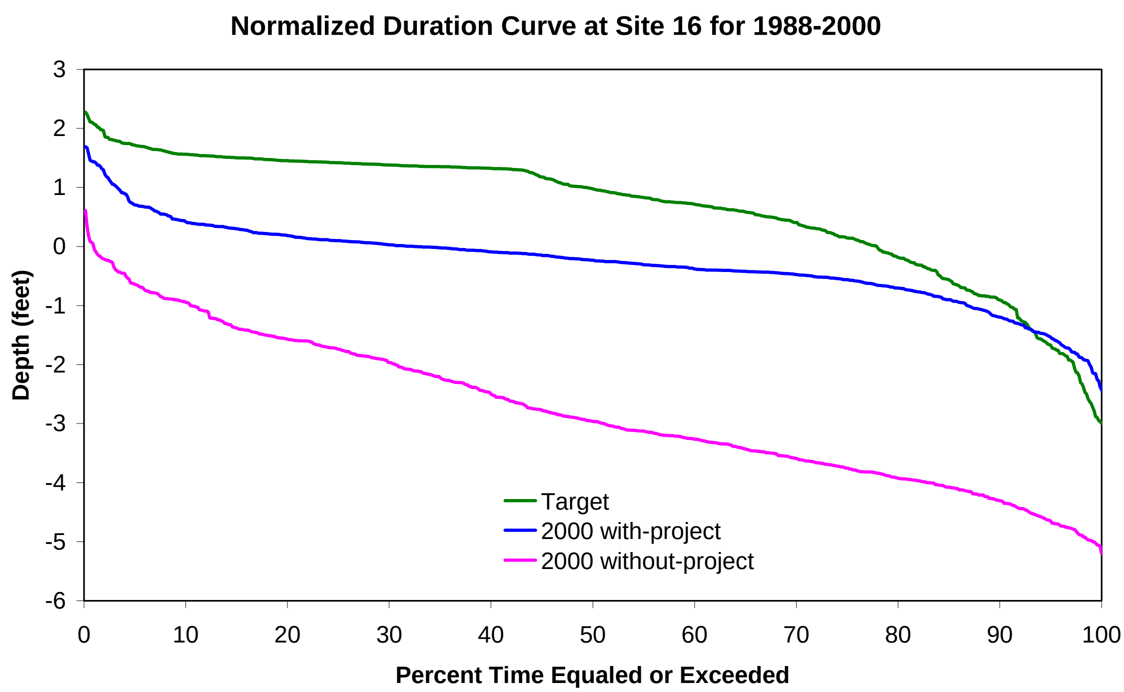


Figure A-49. Normalized duration curve at Site 16 for 1988 to 2000

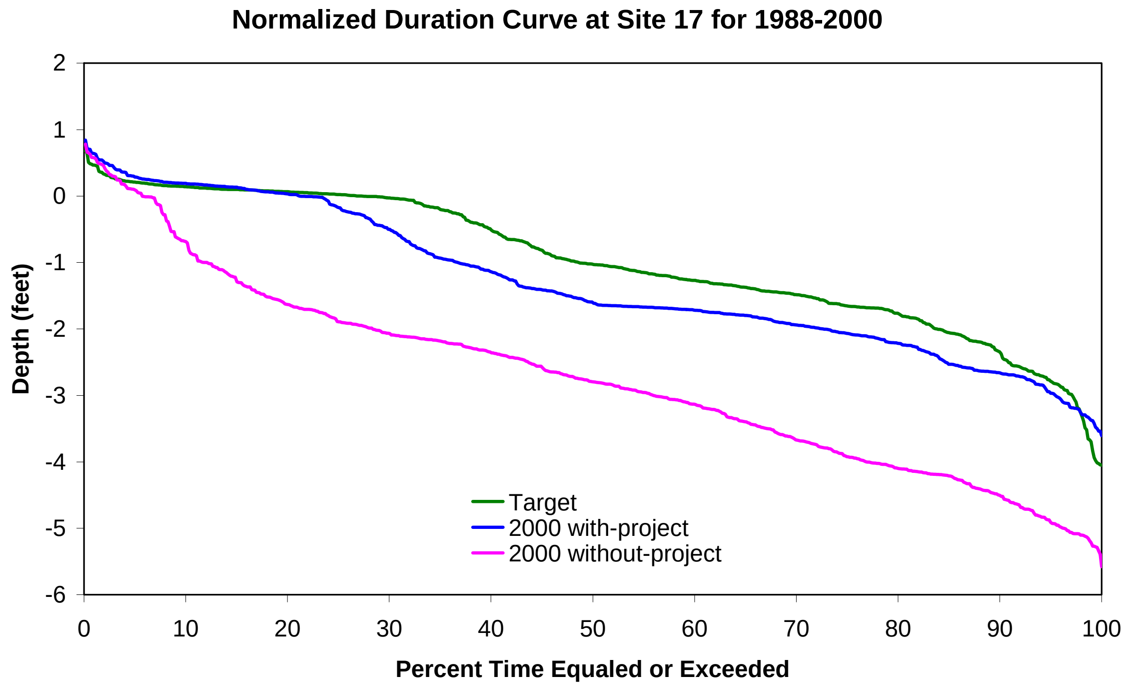


Figure A-50. Normalized duration curve at Site 17 for 1988 to 2000

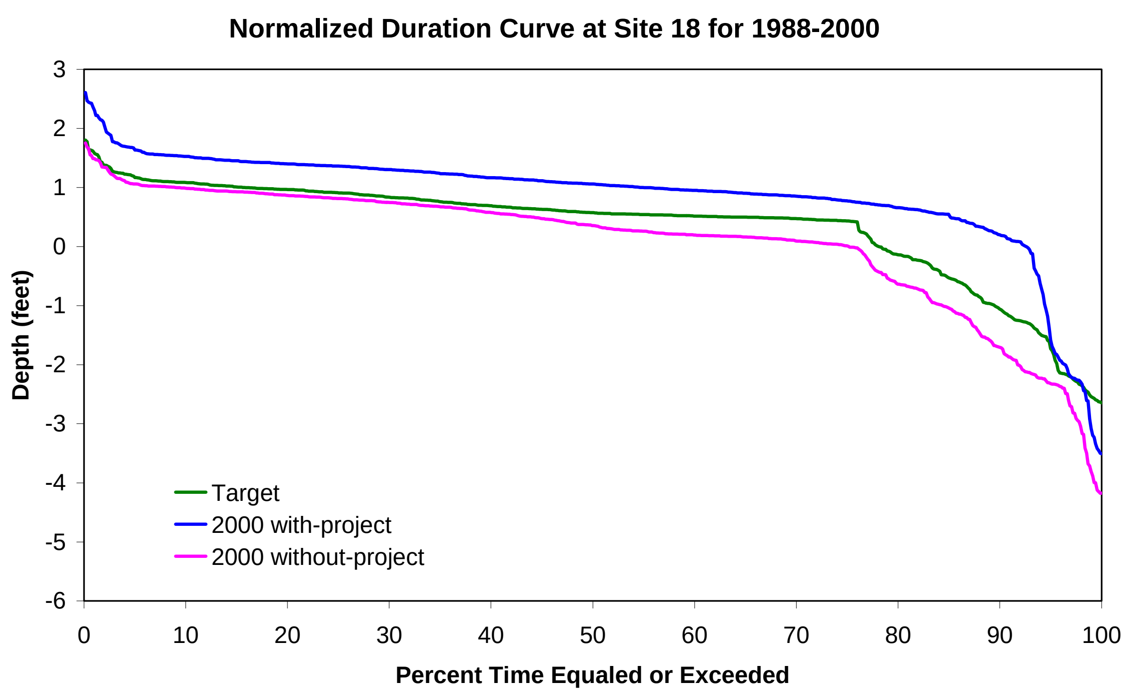


Figure A-51. Normalized duration curve at Site 18 for 1988 to 2000

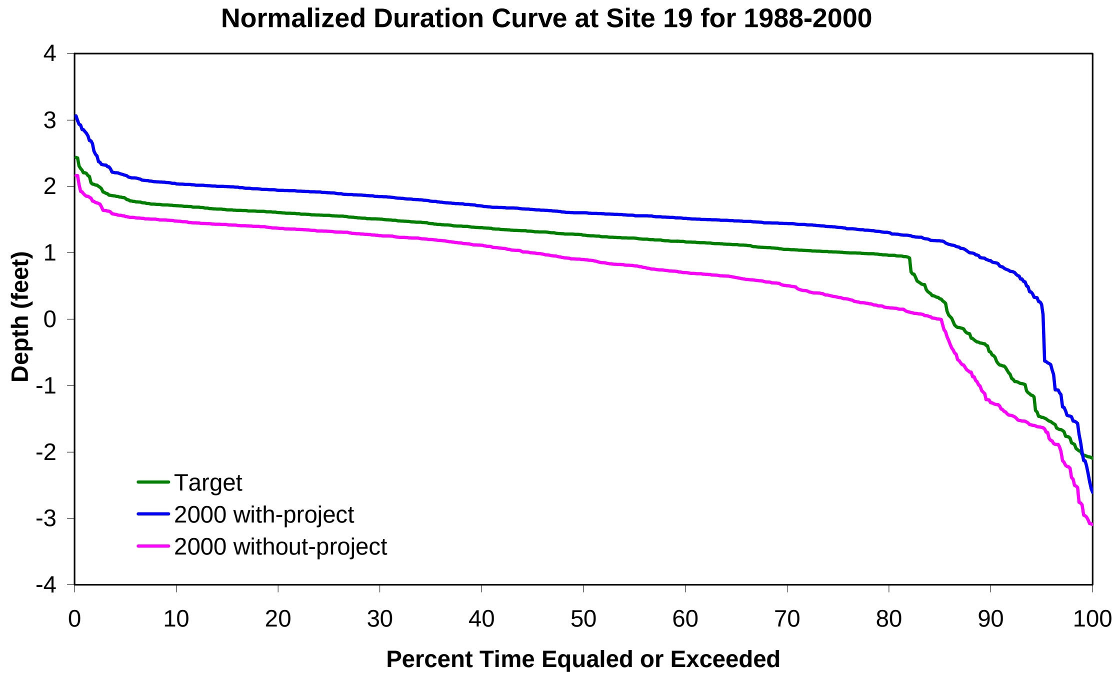


Figure A-52. Normalized duration curve at Site 19 for 1988 to 2000

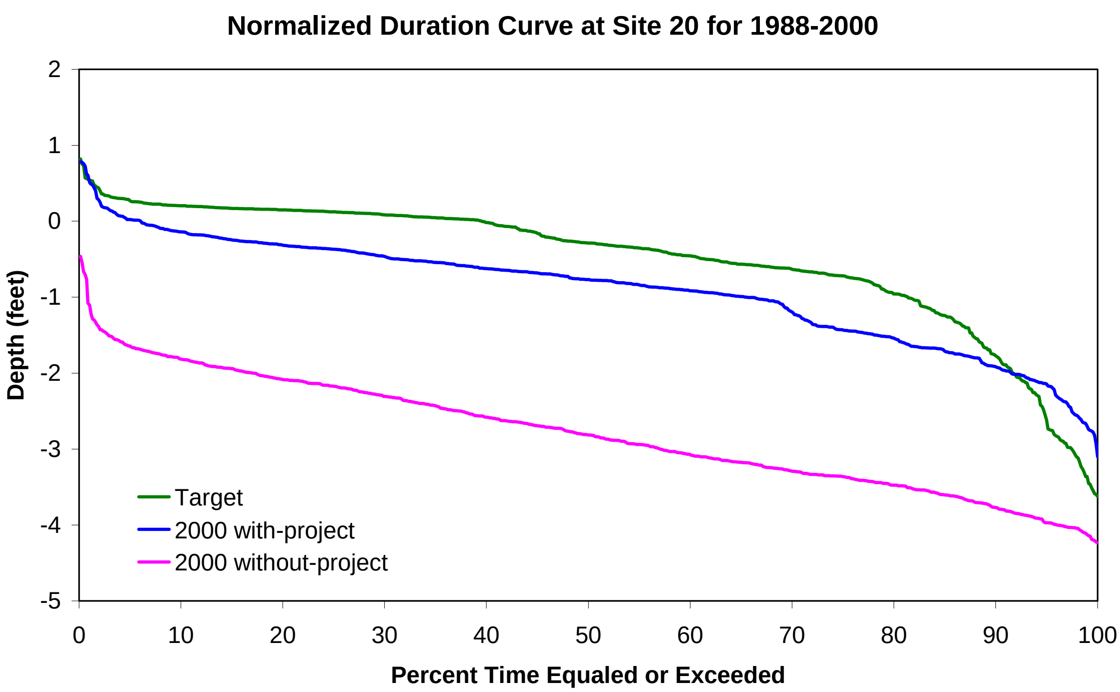
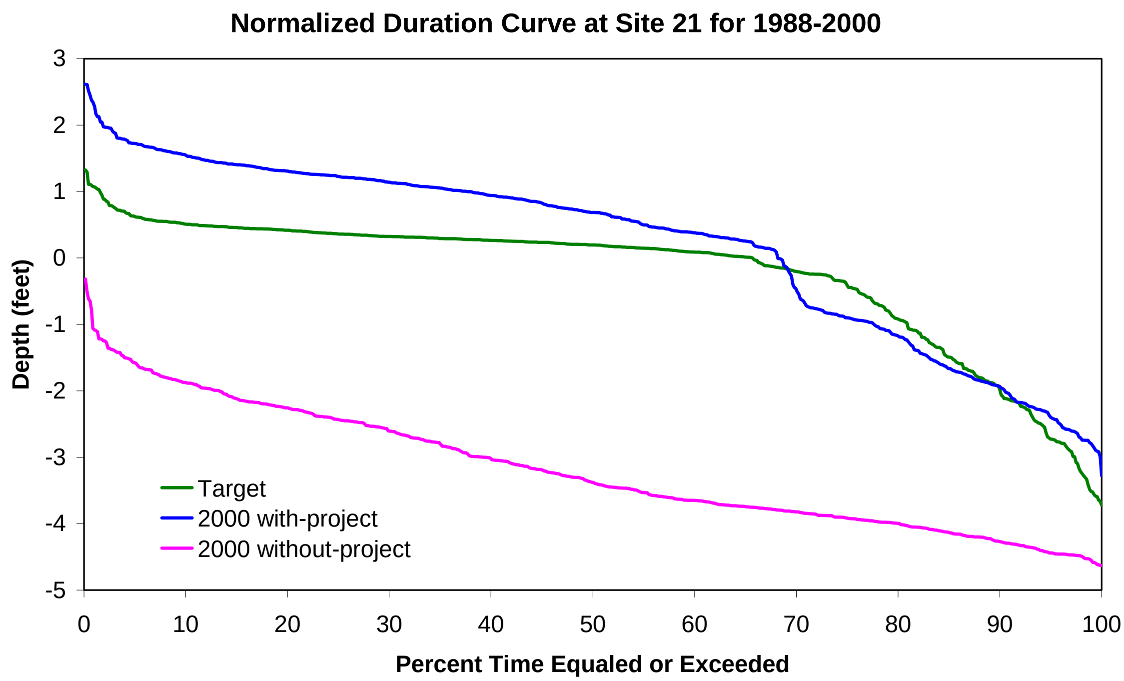


Figure A-53. Normalized duration curve at Site 20 for 1988 to 2000



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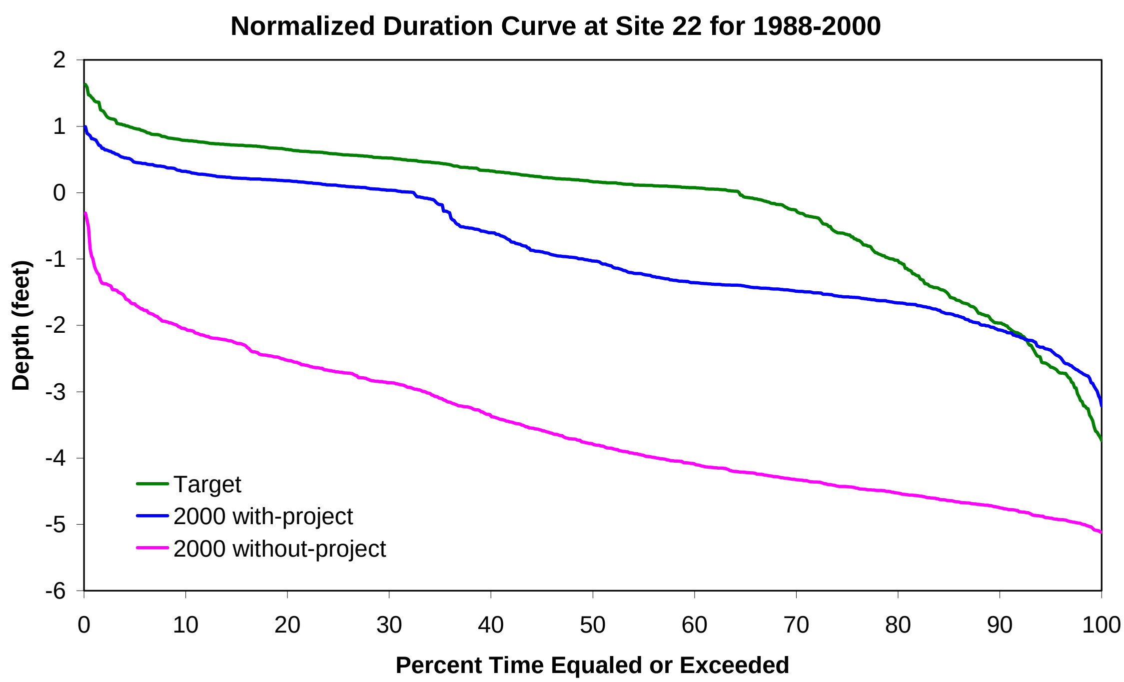

Figure A-55. Normalized duration curve at Site 22 for 1988 to 2000

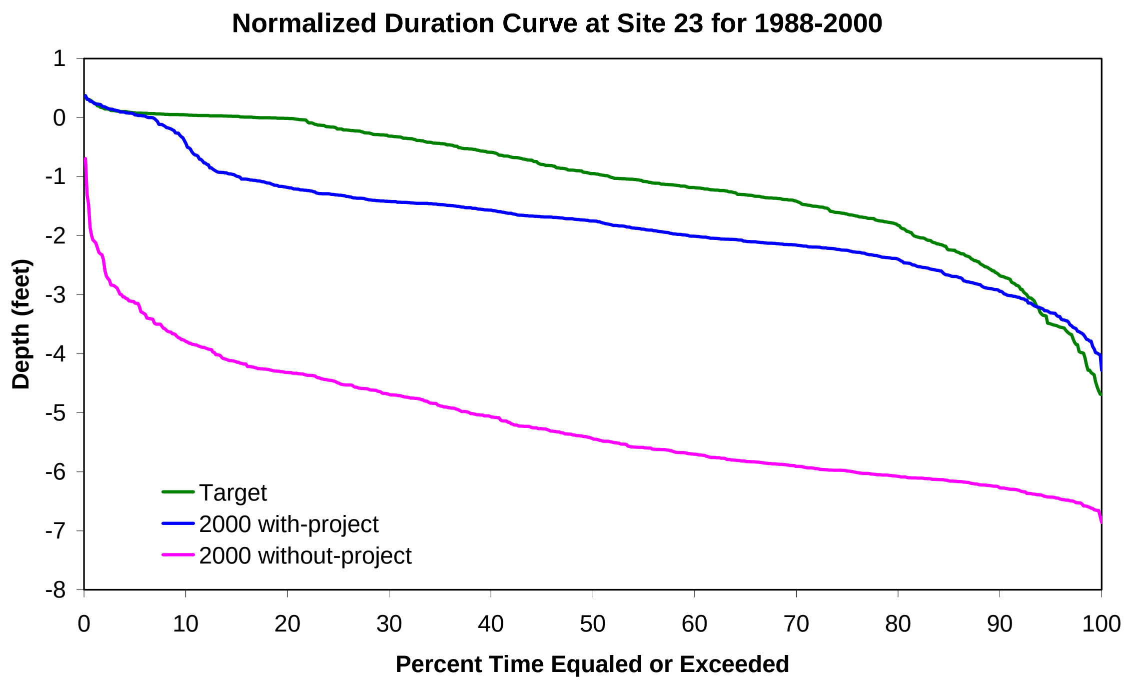

Figure A-56. Normalized duration curve at Site 23 for 1988 to 2000

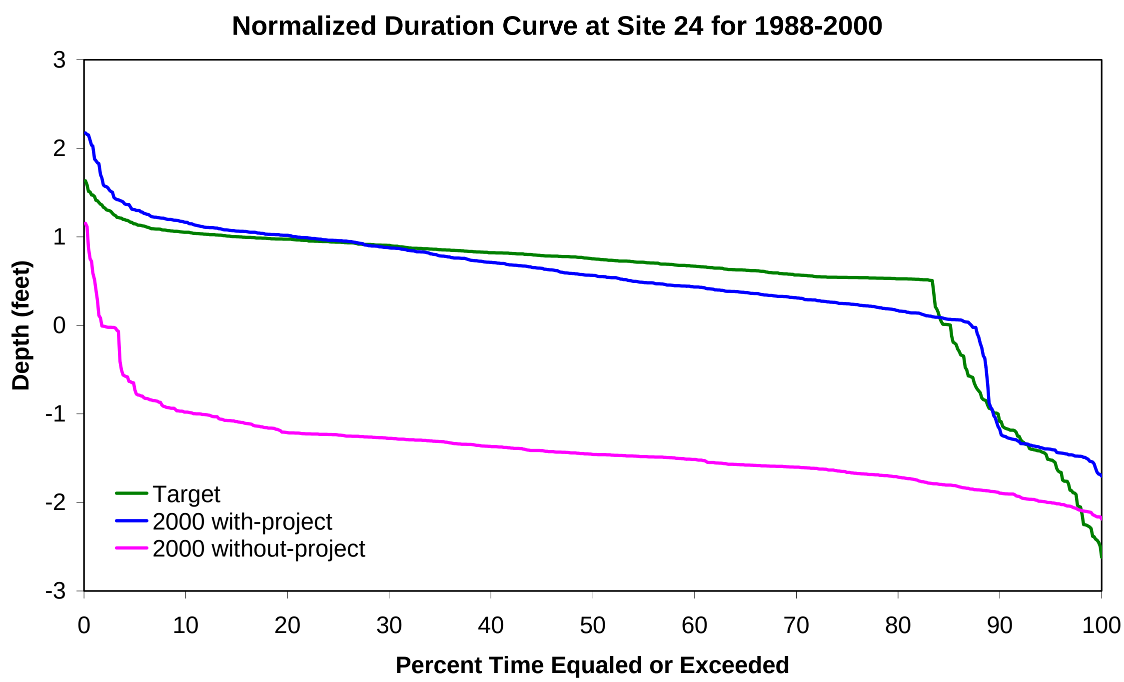

Figure A-57. Normalized duration curve at Site 24 for 1988 to 2000

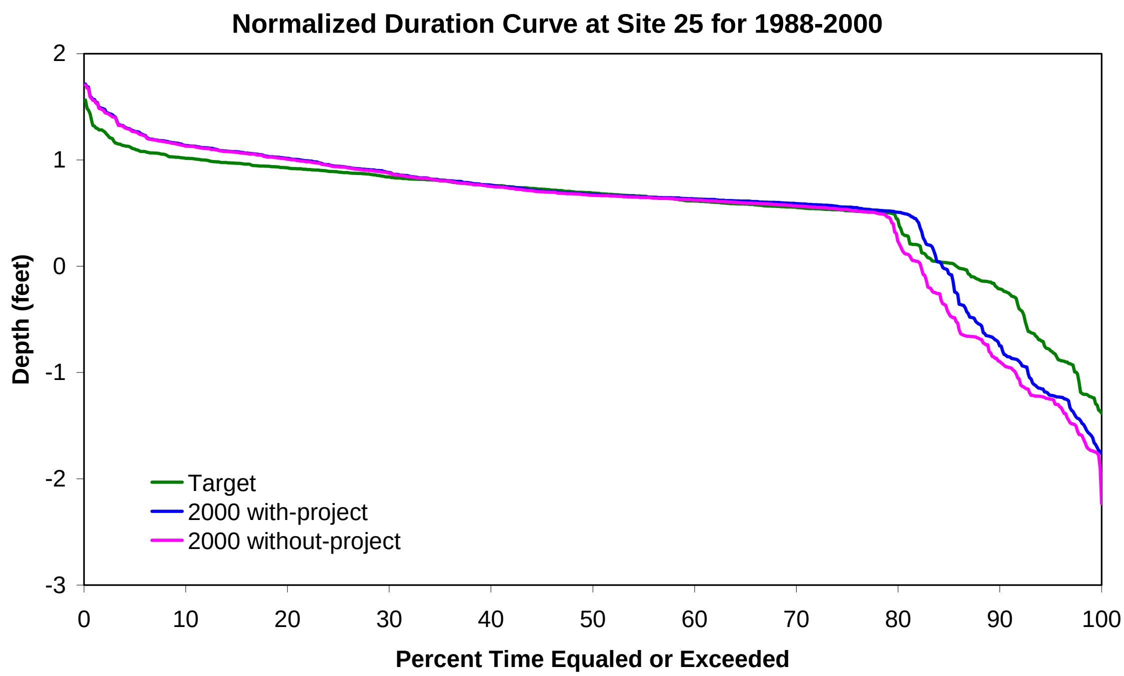

Figure A-58. Normalized duration curve at Site 25 for 1988 to 2000

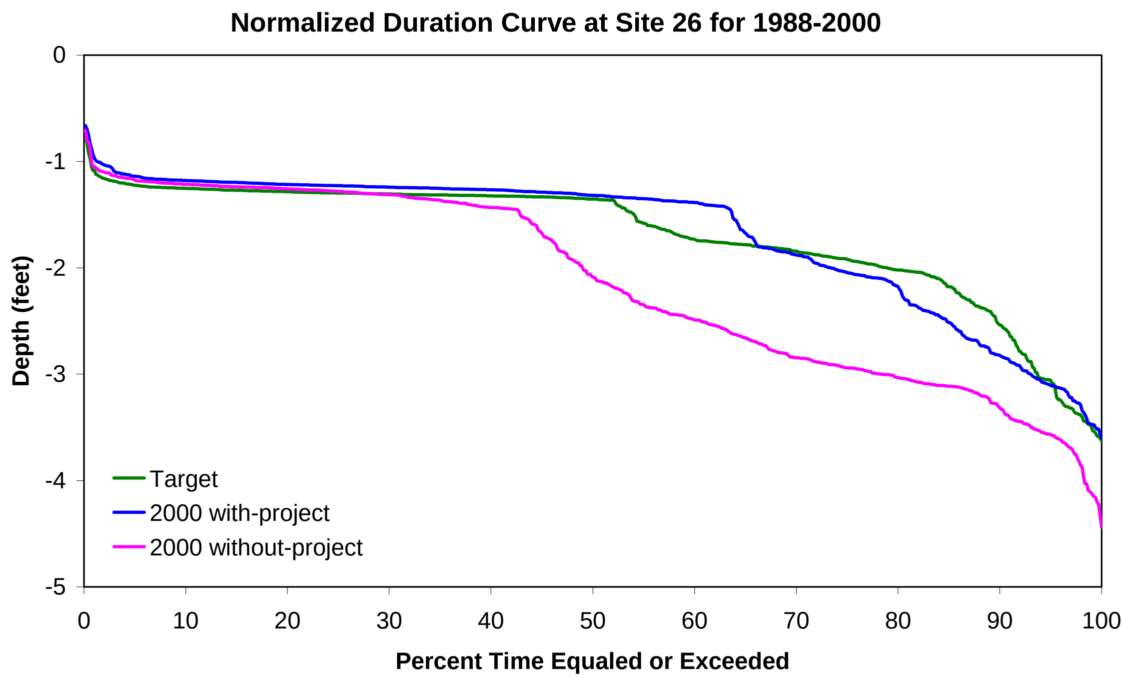

Figure A-59. Normalized duration curve at Site 26 for 1988 to 2000

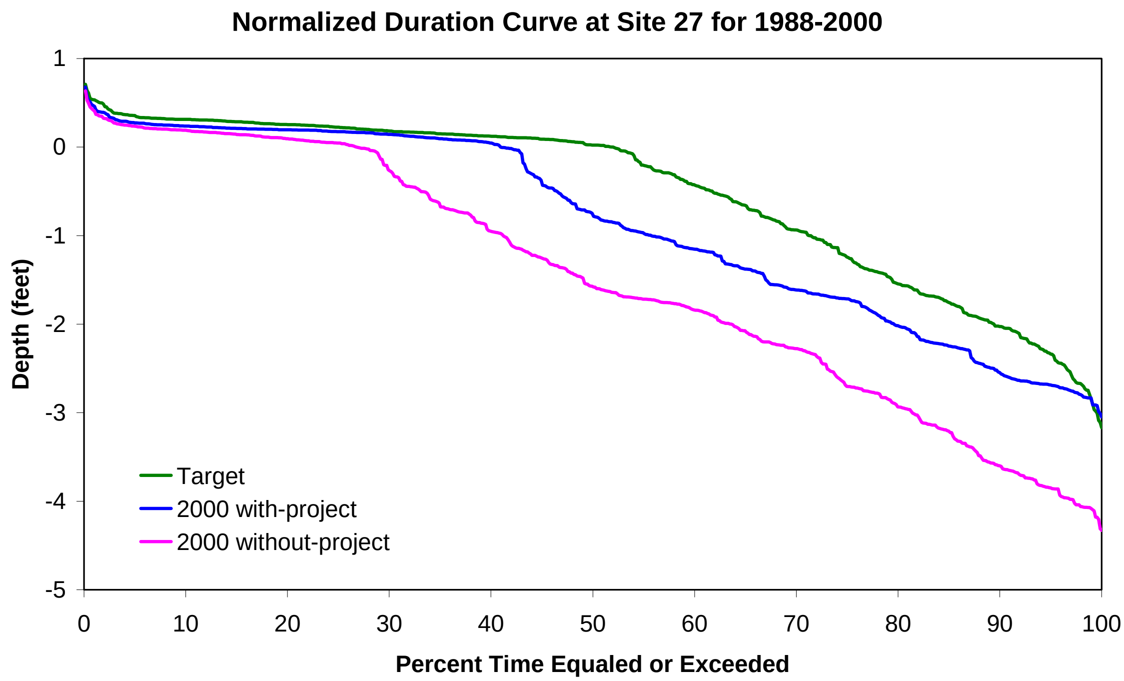

Figure A-60. Normalized duration curve at Site 27 for 1988 to 2000

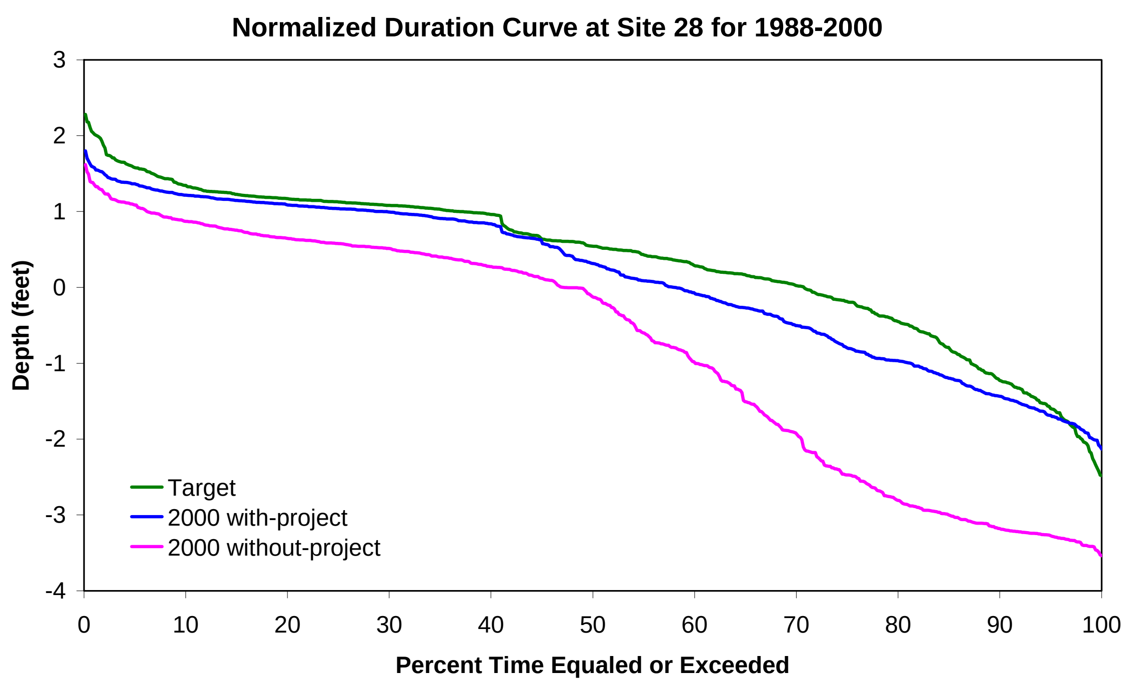

Figure A-61. Normalized duration curve at Site 28 for 1988 to 2000

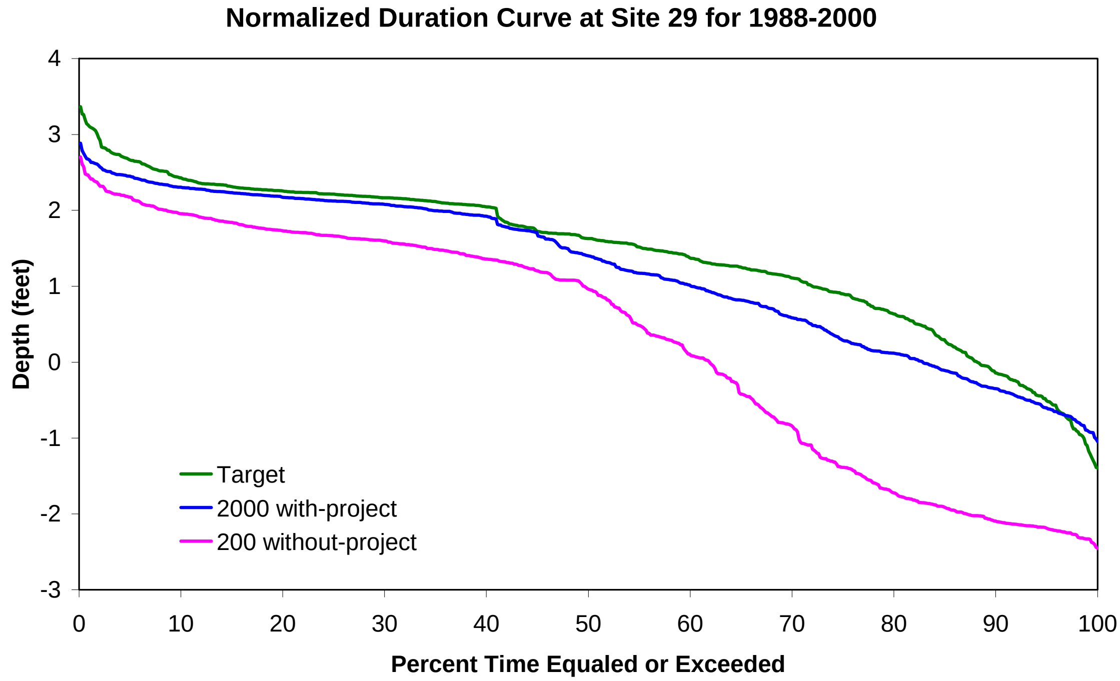

Figure A-62. Normalized duration curve at Site 29 for 1988 to 2000

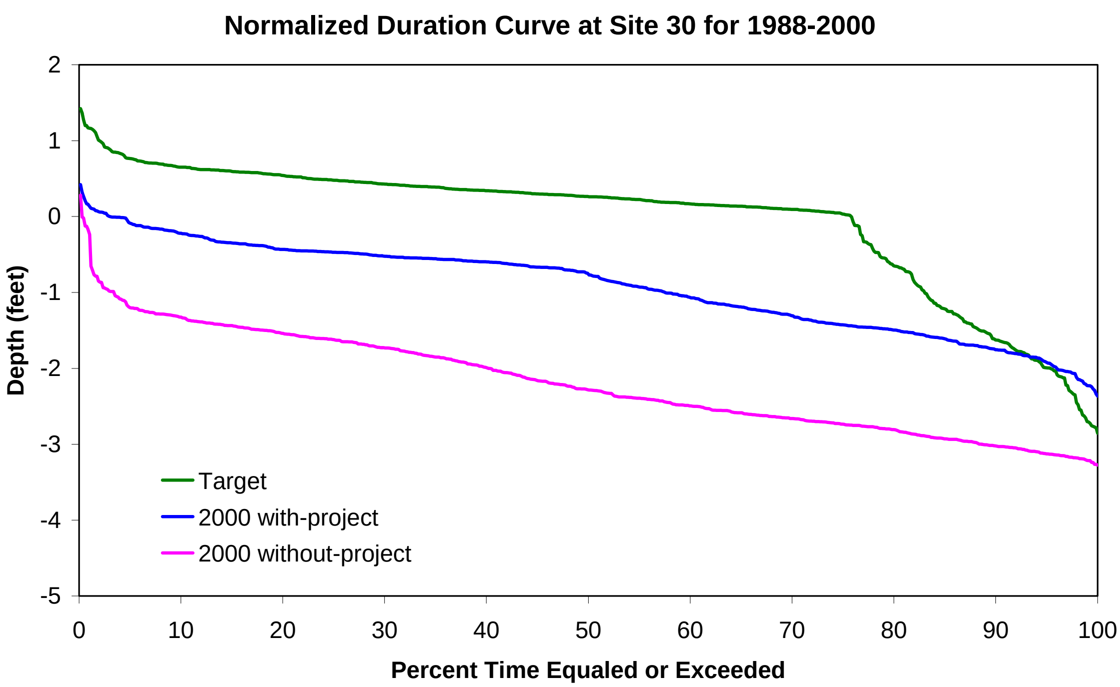

Figure A-63. Normalized duration curve at Site 30 for 1988 to 2000

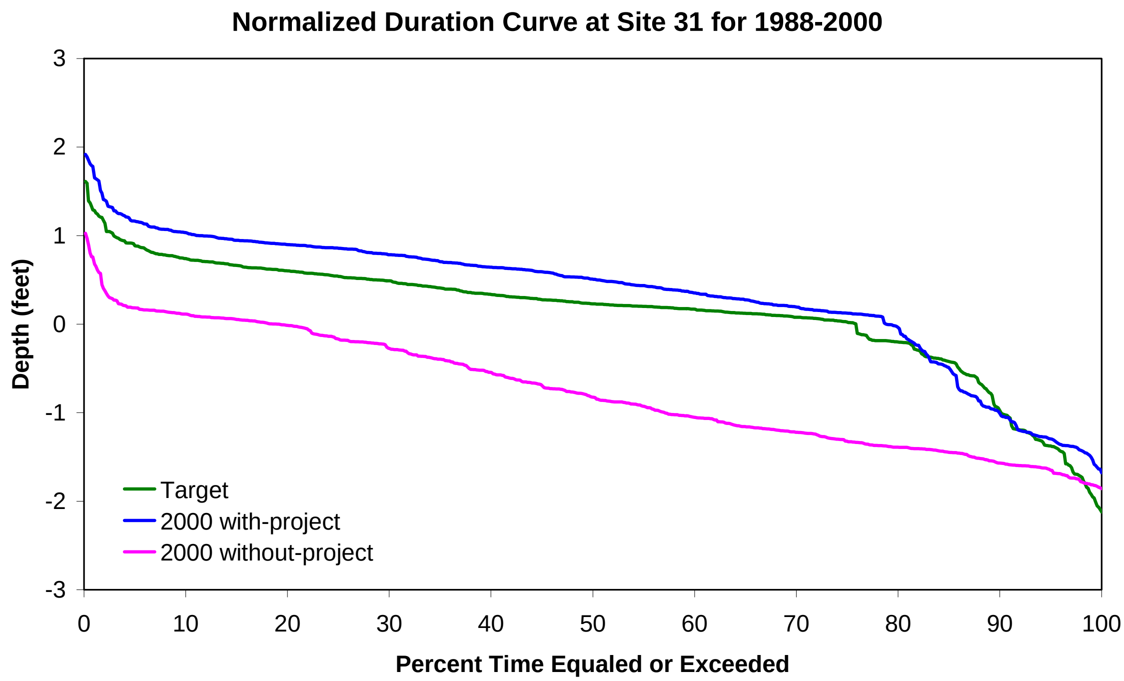

Figure A-64. Normalized duration curve at Site 31 for 1988 to 2000

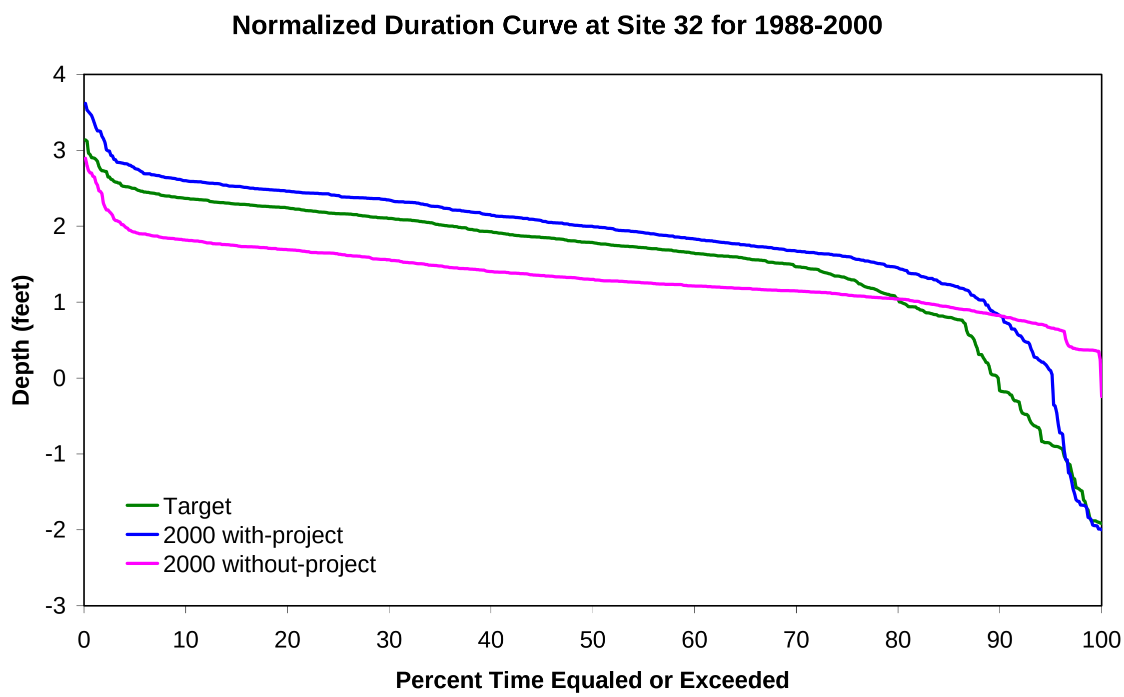

Figure A-65. Normalized duration curve at Site 32 for 1988 to 2000

Appendix B. Surface Water Flows

Figures B-1 through **B-3** illustrates the characteristics of surface water inflows to the project along Miller, Faka Union and Merritt Canals near I-75 for the 13-year period of simulation. This represents the water that will flow along these canals from Northern Golden Gates Estates and elsewhere to Picayune Strand and distributed through the pump stations located at the north end of the project along these canals.

Surface Water Flow Hydrograph at Miller Canal Near I-75
1988 - 2000

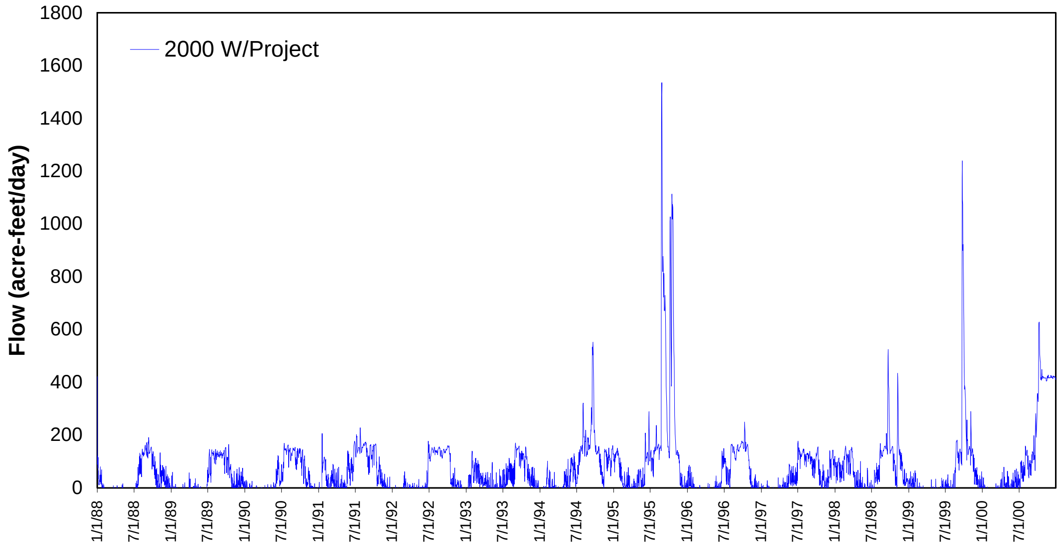

Figure B-1. Flow hydrograph at Miller Canal near I-75 for 1988 through 2000

Surface Water Flow Hydrograph at Faka Canal Near I-75
1988 - 2000

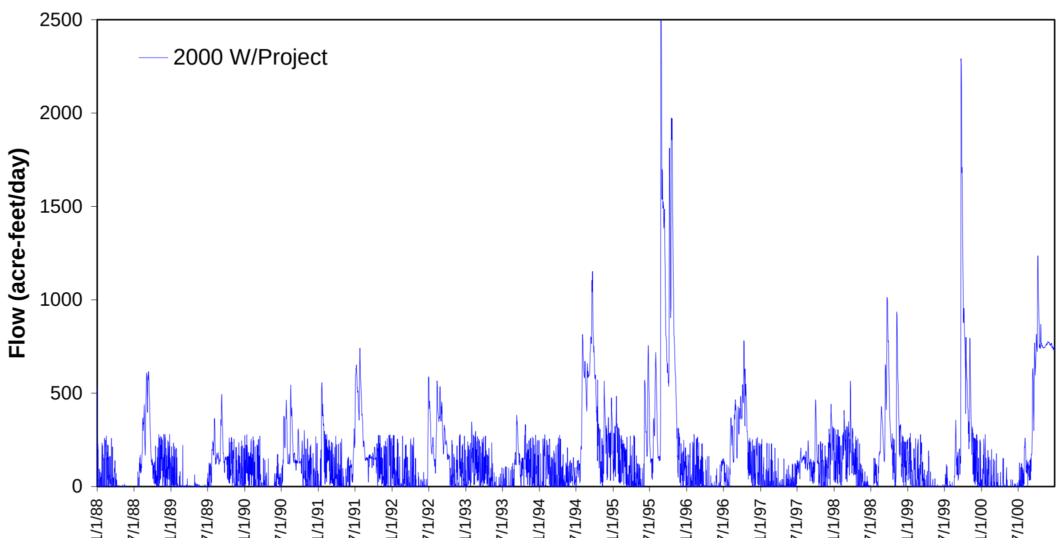

Figure B-2. Flow hydrograph at Faka Union Canal near I-75 for 1988 through 2000

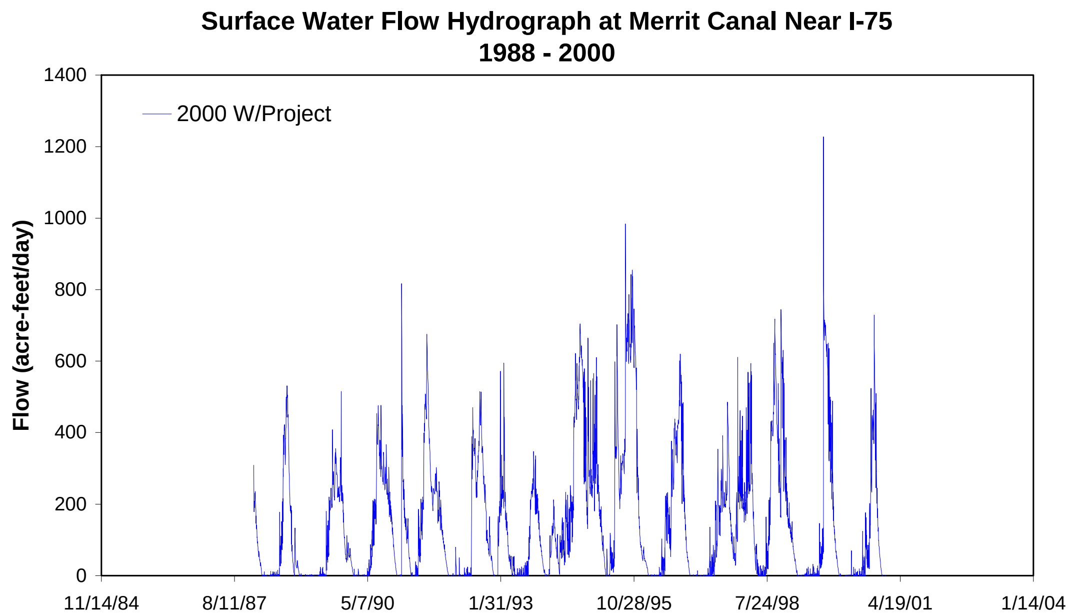

Figure B-3. Flow hydrograph at Merritt Canal near I-75 for 1988 through 2000

The identification and quantification of water for the downstream estuaries are based on flows modeled along the Southern Transect. This flow includes sheet, channel and groundwater flows. **Figure B-4** shows weekly surface water flows for the Southern Transect for the 13-year simulation period. The residual channelized flow of the Faka Union Canal at weir 1, located where the canal crosses US 41, was also quantified for flow input to the Faka Union Bay. Surface flow at this location is presented in **Figure B-5** for 1988 through 2000, the period of hydrologic simulation.

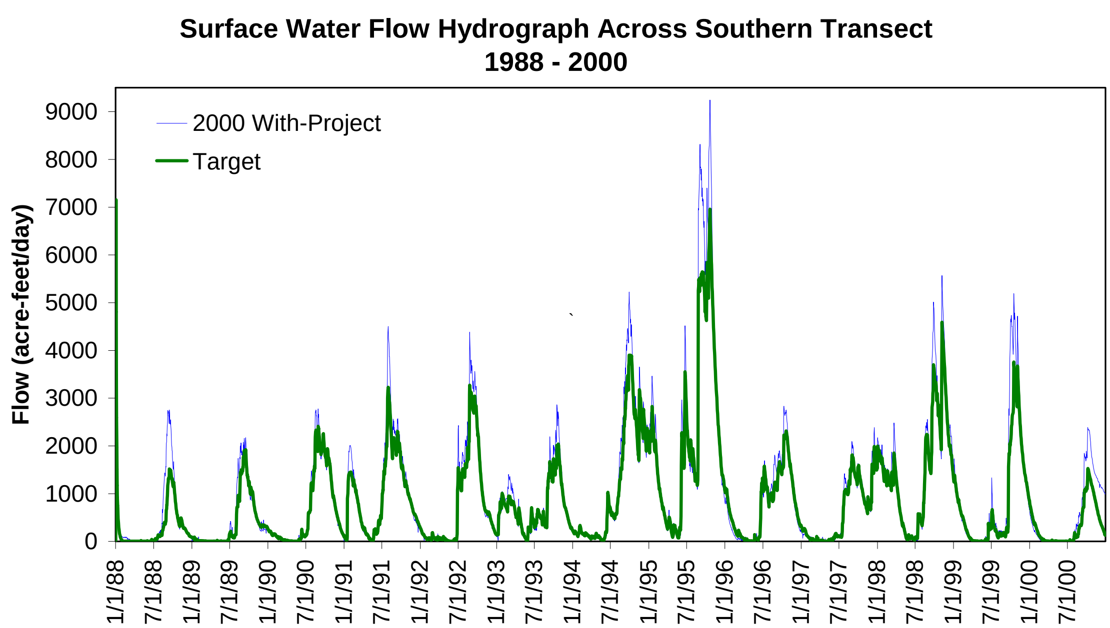

Figure B-4. Flow hydrograph across Southern Transect for 1988 through 2000

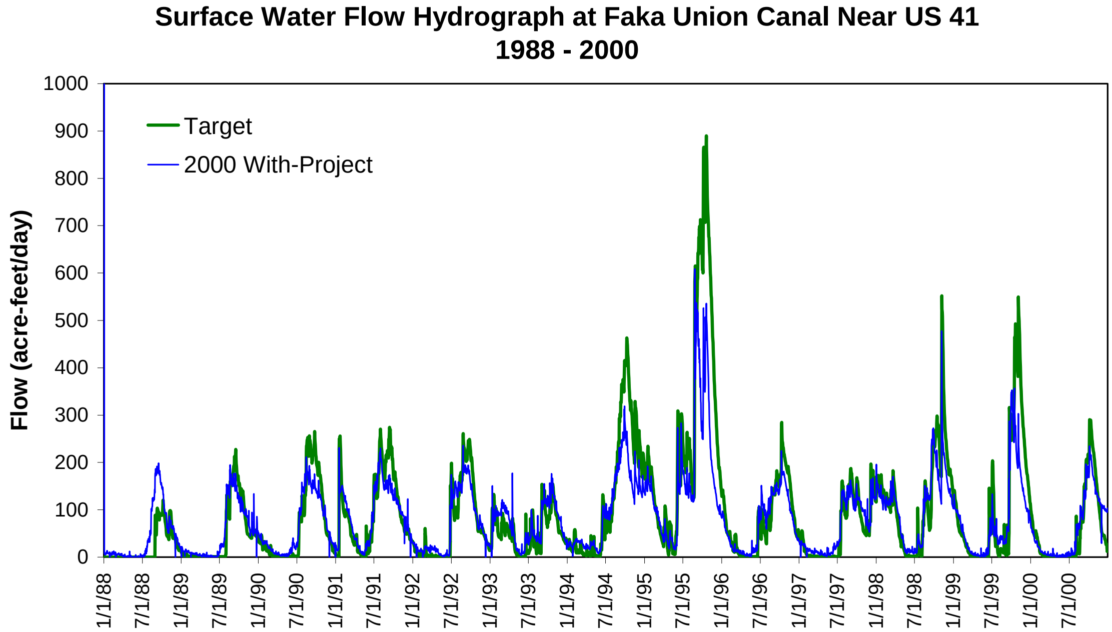

Figure B-5. Flow hydrograph at Faka Union Canal outlet near US 41 for 1988 through 2000

Appendix C
Scientific Peer Review of the Draft Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream Estuaries

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Date:

July 11, 2008

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EXECUTIVE SUMMARY

The South Florida Water Management District (SFWMD) is undertaking the reservation of water for Picayune Strand Restoration Project (PSRP) as a result of commitments made for Comprehensive Everglades Restoration Plan (CERP). A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, that includes a seasonal and a location component for the protection of fish and wildlife for the Picayune Strand and its downstream estuaries. The PRSP encompasses an area of sensitive environmental land centrally located among several nature preserves and wildlife areas that reflects its importance to the ecosystem connectivity of the entire southwest Florida region.

The "*Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream Estuaries*," which the Peer Panel reviewed, highlights key technical information used by SFWMD to establish the relationship between the inland and estuarine hydrology and its associated effects on fish and wildlife. The peer review was conducted in support of the SFWMD rule development process for establishing a water reservation of the area encompassed by the Picayune Strand Restoration Project. The peer review Panel was charged with determining if the technical information contained within the *PSRP Water Reservation Report*, and other supporting documents can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife.

The Peer Panel determined that the supporting data and information used to develop the draft PSRP is technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information that is the foundation of CERP. The panel noted that the data presented to support the linkages between hydrology and the protection of fish and wildlife, especially for the estuarine component of the system were insufficient. However, the appropriate documentation supporting these linkages can be found elsewhere and should be included throughout the report.

The Peer Panel recommends that the SFWMD make explicit the distinction between: the reservation of water sufficient for the restoration of the terrestrial ecosystem and the reservation of water at the southern boundary of the site to restore the estuarine system conditions needed to protect estuarine fish and wildlife. The uncertainty associated with the science supporting the ecological targets and hydrologic modeling for the estuary indicates a conservative and risk averse approach be taken that requires the reservation of all available water for the estuaries at this time.

The Panel also recommends that the SFWMD explicitly state the management goal(s) and objectives for both the terrestrial and estuarine components of this PSRP. These goals and objectives should include quantitative targets and an explicit discussion of the sources of uncertainty so that progress towards meeting the goals can be evaluated within an adaptive management framework.

INTRODUCTION

Regulatory Overview

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. A water reservation is a legal mechanism to set aside water for the protection of fish and wildlife or public health and safety from consumptive water use. The reservation is composed of a quantification of the water to be protected, that includes a seasonal and a location component for the protection of fish and wildlife for the Picayune Strand and its downstream estuaries. 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. 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.

Project Background

The Picayune Strand Restoration Project (PSRP) encompasses an area of sensitive environmental land located southwest of the Florida Panther National Wildlife Refuge, north of the Ten Thousand Islands National Wildlife Refuge and Rookery Bay National Estuarine Research Reserve, east of the South Belle Meade State Conservation and Recreation Lands (CARL), west of the Fakahatchee Strand State Preserve, and northeast of Collier-Seminole State Park. The South Belle Meade CARL project, known simply as “Belle Meade”, and the Southern Golden Gates Estate (SGGE) Project Area have been combined by the State of Florida to form the Picayune Strand State Forest. The central location of the PSRP area among all of these nature preserves and wildlife areas reflects its importance to the ecosystem connectivity of the entire region. The ecological condition of PSRP area affects not only the immediate project area but also significant regional resources including its downstream estuaries.

The Southern Golden Gate Estates (SGGE) was planned as a 55,247-acre residential subdivision beginning in the 1950s. Roads and canals were constructed in the 1960s and early 1970s, but the residential development failed before many of the planned houses were built. These roads and canals have over-drained the area resulting in the reduction of aquifer recharge, increased freshwater shock load discharges to the receiving estuaries to the south, loss of wetlands, invasion by upland and exotic vegetation, loss of ecological connectivity and associated habitat, and increased frequency and intensity of forest fires.

Purpose

The *Water Resources Development Act* (WRDA) *of 2000* requires completion of a Project Implementation Report (PIR) prior to implementation of a Comprehensive Everglades Restoration Plan (CERP) project. The PIR is similar to the traditional feasibility report, which addresses the project's economic and environmental benefits, engineering feasibility, and plan formulation and evaluation. In addition, WRDA 2000 requires additional studies not traditionally included in a feasibility report. These include the Savings Clause and the determination of water to be reserved for the natural system requirement. The Savings Clause requires that, "until a new source of water supply of comparable quantity and quality as that available on the date of enactment of this Act is available to replace the water to be lost as a result of implementation of the Plan, the Secretary and the non-Federal sponsor shall not eliminate or transfer existing legal sources of water…" The Savings Clause also requires that implementation of the plan will not reduce levels of service for flood protection. Further, the identification of water to be reserved for the natural system is another WRDA requirement to be completed during the PIR planning phase.

The "*Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream Estuaries*," which this Peer Panel reviewed, highlights key technical information, contained in the PIR used by SFWMD to establish the relationship between the inland and estuarine hydrology and its associated effects on fish and wildlife. The information contained in this document describes: 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 the pre-drainage condition and the existing condition (2000) with the project features implemented. Finally, it quantifies the water to be reserved under state law.

The management goals of the PSRP are: (1) to reestablish the major pre-drainage characteristics of Picayune Strand plant communities; and (2) to reestablish sheet flow through Picayune Strand and into the coastal estuaries. Meeting these goals will result in the following expected improvements: reversion to historic plant and animal communities, 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, 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.

Peer Review Panel

The peer review Panel was composed of four scientists with backgrounds that complimented the specific ecological systems that are the focus of the restoration: John H. Gentile, Ph.D. (aquatic ecologist with expertise in ecological restoration and risk assessment); Paul Montagna, Ph.D. (estuarine ecologist with expertise in benthos and inflow effects on estuarine communities), Michael Walters, PE, PG, PH (expertise in hydrology) and Jeffrey Klopatek, Ph.D. (expertise in wetland and ecosystem ecology).

The peer review panel conducted all of its work according to the terms of the Florida sunshine law. All meetings and communications among panelists were held at a noticed open meting or through the SFWMD Web Board which is available for public viewing at http://weboard.sfwmd.gov. The Panel participated in aerial and ground tours of the Picayune Strand, Fakahatchee Strand, and downstream estuaries. Panel public deliberations encompassed one and a half days, which was followed by the preparation of this peer review report.

This peer review was conducted in support of the SFWMD rule development process for establishing a water reservation of the area encompassed by the Picayune Strand Restoration Project. The peer review Panel was charged with determining if the technical information contained within the *PSRP Water Reservation Report,* the PIR/EIS; and other supporting documents can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife. For the purposes of this peer review, protection of fish and wildlife means water "ensuring a healthy and sustainable, native fish and wildlife community that can remain healthy and viable through natural cycles of drought, flood, and natural population fluctuation

The panel focused its review on the information contained in the Draft PSRP Water Reservation Report prepared by the SFWMD that describes the methods used to support the water reservation rule. The Panel was also provided supplemental technical documents (e.g., PIR) to facilitate making an assessment of whether best currently available technical information supports the relationship between the predicted waters as a result of the completed project and the anticipated fish and wildlife response. The Panel also requested that additional information, which was met by the SFWMD in a timely manner, be included in the PSRP Water Reservation Report to resolve the Panel's concerns.

PEER REVIEW COMMENTS

Panel Response to SFWMD Technical Questions

1. Does the compiled information, including data, modeling and literature review, provide a reasonable basis for the conclusions reached?

<u>Findings</u>: The purpose of the PSRP is to summarize improvements that would occur for fish and wildlife if the Picayune Strand Restoration project objectives are met and the

water reservation rules are put in place. The document identifies two valued ecosystem components (VECs) the upland terrestrial communities and the downstream estuary community.

Data, models, and literature were reviewed to establish a link between responses of the VECs under conditions that are likely to occur after the project is built. The major component of the study is the hydrology modeling because it predicts the hydrologic outcomes of the project that is an essential first step in the restoration process. The panel has high confidence that the conclusions based on this part of the study are sound and based on reasonable studies.

The link between hydrologic change and VEC response are the most problematic conclusions of the study. The problem with the linkages between hydrology and VECs are manifold, not the least of which is that the direction and timing of ecological succession is notoriously difficult to predict. While the conceptual models provided an integrative understanding of what is likely to occur, stochastic events such as fire and tropical storms have a profound effect on shaping the ecosystem and “re-setting the clock” on succession patterns.

<u>Terrestrial ecology linkages</u>: The renewing of the wetland hydrology of the Picayune Strand, including re-establishing wet season depth and length of hydroperiod is key to the restoration of ecosystem structure of wetland vegetation. The data, modeling, and literature reviewed provide a reasonable basis for the PSRP conclusions reached for the terrestrial model. The predicted hydrology should lead to the reintroduction of many of the pre-existing wetland species as well as enhancing the growth of the present vegetative communities. It follows that the combination of the hydrology and the wetland vegetation under the expected environmental conditions should lead to the re-introduction of the faunal indicators (e.g., amphibians, fish, and avian species) that are indigenous to this region. However, the data and the supporting literature need to be provided to support these conclusions. It appears that many of the predictions of the ecological effects of restoring the hydrology are based on studies that have not been published in the peer-reviewed literature. This in itself is not a “bad” thing, but it requires that supporting figures and tables need to be incorporated into this document. The documentation of these linkages will provide an answer to the overriding question: “What is the pattern of ecological succession in these wetland communities.”

<u>Estuary ecology linkages</u>: The estuary system linkages provided in the draft report are weak relative to the case presented for terrestrial system. For example, in sections 5 and 6 there are numerous figures and tables describing the terrestrial system pre-1960 and in the current time. In contrast, there is only Figure 10, which shows the relationship between flow and salinity at the fixed weir at Port of the Islands on the Faka Union Canal for 2000 to 2002. More details on the flow salinity relationships are provided in Savarese et al. (2004). The salinity flow relationship is important information, but there is no information on the salinity gradients downstream in the estuary or how they might be altered. Subsequent to the workshop, a document entitled “Assessment of Salinities and Bio-Abundance Resulting from Runoff into Faka Union Bay for Picayune Strand

Restoration Project Scenarios" by Wang and Browder (2004) was posted on the web. This document illustrates the modeled relationships developed for runoff and salinity, and hydrodynamics and salinity.

The lack of analysis of salinity is surprising because the "Ten Thousand Islands" area that is affected by this project is completely within the Rookery Bay National Estuarine Research Reserve (NERR), which has been monitoring salinity since 1987. In fact, this is one of the best studied estuarine areas in the entire nation because NEER sites all have a system-wide monitoring program supported by NOAA. The data can be downloaded from the Centralized Data Management Office (http://cdmo.baruch.sc.edu/). There are two relevant stations in Faka Union Bay and Fakahatchee Bay, and other stations in Big Marco Pass, Blackwater River, Henderson Creek, Lower Henderson Creek, Middle Blackwater River, and Upper Henderson Creek. The data available is for salinity, water temperature, water depth, pH, and dissolved oxygen every 15 minutes. The level of nutrients (ammonium, nitrate, nitrite, ortho-phosphate) is measured on a monthly basis at each water quality station, and over a 24-hour period at one of the stations.

Studies linking freshwater flow changes to estuary response have been well developed and documented in the State of Florida. The basic approach of these studies is to: 1) state a specific management goal, 2) derive ecological indicators and performance targets (usually some combination of biological responses to salinity levels) that can measure success to obtaining the goal, and then 3) use a model to determine the flow needed to maintain the desired salinity. The current document does not provide a clear explanation of any of these three items.

For example, Sections 1, 2, and 3 do discuss management issues in very broad terms, but without ever explicitly stating the existing problem, the management goal to solve it, and the benefits of the project. Section 5 describes valued ecosystem components but provides no information on level or salinity requirements, nor does it reference where this information may be found. Appendix A does provide some data on water levels required by some plant species, but there is no explanation (or reference cited) that describes where the numbers come from. The reader is left to wonder: are the numbers in Table 3 and Table A.1 arbitrary? Although nekton and oysters are described in Section 5, there is no analysis provided that indicates what the salinity requirements are for these species. The salinity values given in the text are unsubstantiated, and again, there is no reference as to where the information might be found.

The modeling approach is described in some detail in Section 7. Section 8 simply says nothing about fish and wildlife, and certainly no objective criteria to justify a target. As noted earlier, there is reference to vegetation, and this appears to be the only justification. Section 8 only provides simulations compared to some target that is not justified.

This leads to two questions: Where is the biological justification for salinity targets for oysters, fish, birds, and other wildlife in the estuary portion of the project? What effects will the project have on the estuarine VECs? Part of the answer to both questions is that the information is contained in other documentation. During the peer-review meeting, the panel was provided with several supporting documents that were used to prepare the estuary ecology sections of the draft report. These documents contain much of the information that is needed to improve this section of the report because they form the basis for the conclusions that are reached. Only after reviewing the original PIR and the additional documentation provided to the panel can one be certain that the conclusions of the draft report are sound regarding the link between the project and the estuary.

Recommendations: There is a large body of technical information supporting linkages between hydrology and a variety of ecological attributes (vegetative community succession, fish and wildlife) that can be cited to both inform and support the water reservation proposed in the PSRP. While new or additional studies are not needed, a stronger summary of existing studies, especially those that have occurred in the Rookery Bay NERR should be placed in the report to document the linkage between hydrology and salinity, which is fundamental to the protection of estuarine fish and wildlife. This includes figures and tables that explicitly illustrate what salinity distributions exist and how they might be changed by the project, and relationships between the ecological indicators and salinity. The Panel also recommends that a figure presented at the meeting illustrating the linkage of hydrology and fire to terrestrial vegetative community succession over time be included in the report (Duever et al. 1986, Lockwood et al. 2003).

2. Are the environmental indicators selected for the protection of fish and wildlife for the wetland and estuarine components of the PSRP adequate to meet the project objectives?

Findings: The report generally does a good job of identifying the key indicators of abiotic and biotic conditions that are sensitive to hydrological alterations. Based upon the Conceptual Ecosystem Models (CEMs) referenced in the report and their extensive peer review it is reasonable to conclude that the primary indicators have been identified and are being addressed for the terrestrial system and estuarine system.

Terrestrial: The wetland vegetation and faunal indicators for the wetland systems appear to be adequate. However, the discussion on the use of wetland attributes or indicators yields no information on what will be measured. Basically it states that native wetland vegetation communities and associated faunal species will be used as indicators. The vegetative community indicator, as listed (p. 23, sec. 5.1), includes the vegetation community gradients and mosaic pattern. The listing of vegetation is only by vegetative association (e.g., cypress with hardwoods). There is lack of agreement between Tables 3 and 4 and Figure 7. There needs to be a consistent use of terminology if the vegetation communities are used as indicators. The gradient of communities is probably not a measurable indicator. The mosaic, as listed is also difficult to quantify. When using vegetation as an indicator, structural metrics listed (e.g., species composition, cover types, etc.) should be included. Habitat composition can also be measured through the use satellite or aerial remote imagery.

The Draft PRSP lists wading birds as key indicators as derived from the Big Cypress Regional Ecosystem Conceptual Ecological Model (CEM). However, in the listing of indicators no metrics were listed that could be used to effectively measure the success of restoring these valued ecosystem components. For example, the following is a suggested listing of the desired restoration endpoints or outcomes of wood stock populations taken from Ogden (2004): (1) a substantial increase in the total numbers of nesting pairs for the listed species, as shown by three-year running averages of nesting numbers, (2) a recovery of nesting in the region of the traditional “rookeries”(3) a return to early dry season nesting by Wood Storks, and (4) an increase in the frequency of supra-normal nesting events (i.e., “super colonies”) (From the South Florida Wading Bird Report, Volume 10, November 2004, Gaea E. Crozier and Mark I. Cook, Editors). Thus, the indicators now have a meaningful metric by which to evaluate restoration success. Wading birds in a breeding colony exploit an area of many square kilometers around the colony and to be successful should be surrounded by sufficient foraging habitat. Wading birds can exploit fish from an area only when water depths are within certain ranges. This leads to the use of hydrologic indicators (e.g., recession rate, hydro-period, water depth, etc.) as measures of successful wetland restoration, particularly for the aquatic faunal component of the ecosystem.

One of the groups of aquatic fauna that is a key prey species of wood storks and ibises (as well as a host of mammal predators) is the crayfish. It appears that some research has gone into modeling habitat suitability for this organism. Specifically the ATLSS Crayfish Index Model that incorporates information about crayfish habitat preferences and hydrologically-driven aspects of crayfish ecology to assess the relative impacts of hydrologic scenarios proposed for Everglades Restoration on the occurrence potential for two species of crayfish. This type of information is clearly relevant to the PSRP.

Water Quality: A concern was expressed to the Panel regarding the sufficiency of water quality monitoring to characterize potential ground and surficial aquifer contamination with nutrients from septic systems and irrigation in the Northern Golden Glades Estates. Nutrient transport across the NGGE/SGGE hydrologic boundary could become a future concern as development in the NGGE continues to increase and sheet flow downstream is re-established. Nutrient enrichment and organic matter loading may also become a concern across the terrestrial wetland–estuarine boundary from decaying terrestrial vegetation.

Estuary: The focus of the estuarine portion of the report is on oysters, which is a sound approach given the importance of oysters in this estuary. Although there are no data or models presented in the draft PSRP, this information is presented in supporting documentation, especially Volety and Savarese (2001). While there is additional literature linking oyster health to salinity levels, there is precious little presented for fish species. The reason is simple: oysters are filter feeders and thus, their biology is tightly linked to processes in the over-lying water. This is generally not true for fish. However, Rubec et al. (2006) provides a model of habitat suitability that identifies salinity ranges for fish life stages in the Rookery Bay and Fakahatchee Bays.

Recommendations: The topic of water quality, and especially nutrient enrichment in the estuary, needs to be given additional attention. For estuarine water quality, the District could mirror the Rookery Bay NERR system-wide monitoring program, which includes a spatial array of sondes to measure salinity, temperature, and dissolved oxygen continuously, and monthly collections of nutrient and chlorophyll samples. Matching this program provides two obvious advantages: 1) you can leverage existing monitoring designs with data from a more undisturbed reference system, and 2) the reference system can be used in a direct comparison to changes in the project area. It is important to begin collecting some of this data prior to project implementation to determine if the baseline conditions in the project area are different from conditions in the reference reserve site before the project is built. A site northwest of Faka Union Bay and in the NERR would be an ideal reference site, and this could be coordinated with existing monitoring in the NERR. Adopting this approach would provide a powerful BACI (before/after versus control/impact) sampling design that would enable the district to determine with certainty the effects of the project on water quality.

The best ecological indicator for estuary system response to alterations in hydrology is benthic organisms. Numerous studies in other estuarine areas (including Florida) have shown that benthos have a direct link to freshwater flows and resulting salinities because they are relatively sessile, directly influenced by overlying water quality dynamics, and integrate changes over long time scales. While few people care about worms, clams, and small crustaceans, oysters have all the same attributes of these smaller soft-bottom benthos, and oysters are already identified as a VEC. So, monitoring oyster populations is important for such attributes as size, density, disease, and percent gravid. The water quality that affects oysters must also be monitored.

3. Are there any major environmental indicators not considered in our analyses that could significantly affect the water identified for the protection of fish and wildlife?

Finding: Water quality, which is an excellent indicator focusing on ecosystem processes within the restoration project area, has not been addressed in sufficient detail. There are two issues: (1) the potential nutrient enrichment of the surficial-aquifer within the NGGE resulting from residential development that could seep/flow nutrients into PS and (2) the potential increase in nutrients from decaying terrestrial vegetation resulting from inundation will enrich the proposed sheet flow causing changes in the terrestrial communities and estuarine vegetative communities.

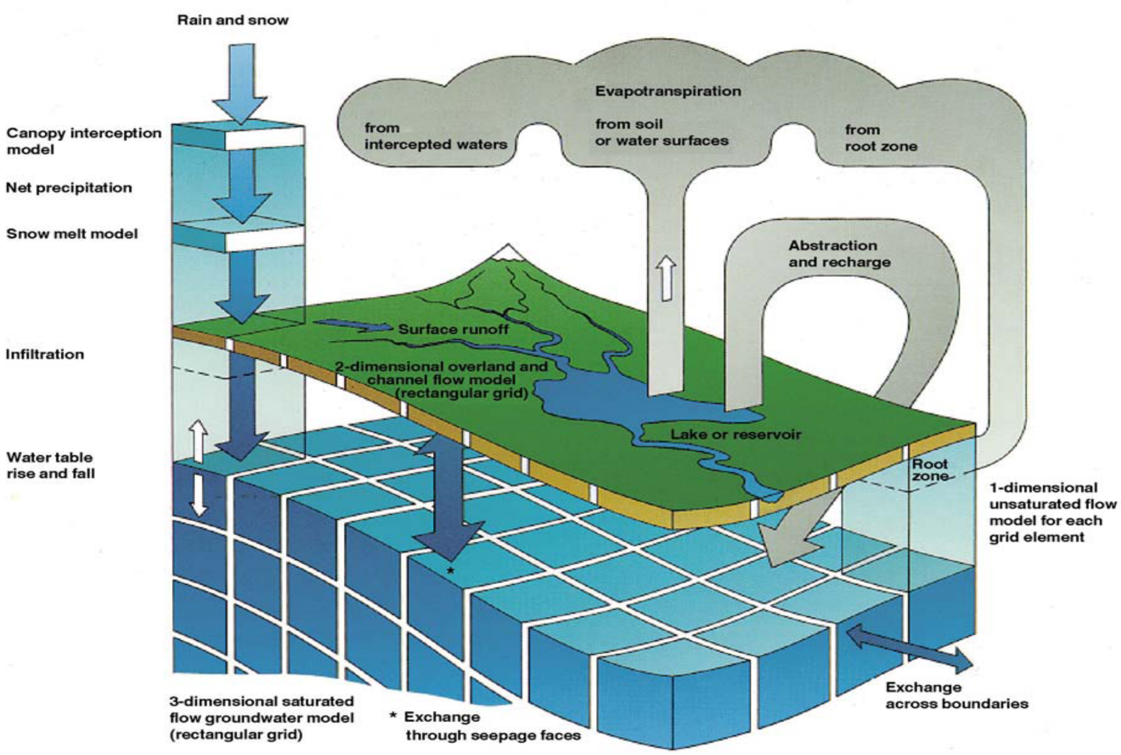
Water quality in the estuary is very important and a direct measure of the effects of the project. Specifically there needs to be spatial profiles of salinity, temperature, dissolved oxygen, and pH over appropriate spatial and temporal scales. Measures of chlorophyll and nutrients are also important to obtain a complete view of water quality indicator changes, but these might be measured on different scales than salinity and temperature.

<u>Recommendation</u>: Leverage the Rookery Bay Estuarine Reserve's more than 20 years of monitoring data that can be used to establish baselines for temperature, dissolved oxygen, nutrients and salinity.

4. Are the hydrologic and ecological models used in the study appropriate for this application?

<u>Finding:</u> The hydrologic model (MIKE SHE / MIKE 11) is appropriate and is the most comprehensive of a suite of models previously used. The model integrates surface and groundwater, simulates flows, and water levels, overland flows and stages in wetlands. All these components are important in simulating conditions in the Picayune Strand. In addition the model includes topography, vegetation, channel and hydro-geologic characteristics.

The hydrologic model algorithm includes standard hydraulic and hydrologic equations for simulating the rainfall runoff process, and dynamic processes including back water. The model components are shown below on a graphic extracted from the DHI (2002) report.



There were no specific examples of ecological models mentioned in the Draft PSRP. However, models have been developed in support of CERP for oysters, wading birds, crayfish, alligators and crocodiles in the southeastern estuaries, and extensive research has been conducted on the spatial and temporal patterns of forage fishes as well as crayfish models which are all linked to hydrologic features especially recession rate.

Terrestrial: There were no ecological models presented in this document other than the relationship of vegetation communities to hyrdo-period and depth. As mentioned in response to Question 1, the conceptual model linking vegetation type to hydrology and fire would be appropriate.

A primary product of the USGS's Across Trophic Level System Simulation (ATLSS) Program is the set of Spatially Explicit Species Index (SESI) models developed for the Greater Everglades that may be applied to the PSRP. Additionally, SFWMD has developed a series of Habitat Suitability Indices for evaluating water management alternatives. These are the types of models expected to be employed in this project. Further examples are the USGS Tides and Inflows in the Mangrove Ecotone (TIME) Model. Surface-water flows in the Picayune Strand with the interface of the Ten Thousand Islands estuary are complex. The use of these models can address the predicted re-diversion patterns of freshwater flows interacting with the tides producing a mixing zone for salt and fresh water.

Estuary: There are no ecological models presented in the document for estuarine species. The conceptual model, presented for the Everglades is incomplete because it does not include oysters as an attribute, and oysters are proposed as a key indicator species for the project. It is recommended to replace the Everglades conceptual model with one more closely resembling the bays and estuaries in the Ten Thousand Islands region. The Wang and Browder (2004) study reviews salinity distributions and a salinity model that was first performed in 1986. No attempt was made to review the original 1986 study.

Recommendation: Clearly the lack of appropriately referenced ecological models must be addressed. For example, a graphic linking hydrology and fire to ecological succession of terrestrial vegetative communities over a wide range of time scales was presented at the meetings and along with explanatory text should be included in the document. A reference should be made, as appropriate, to the wide range of available models mentioned above for both valued ecosystem components as well as supporting prey species.

5. Are the hydrologic and ecological models sufficiently supported by available knowledge, monitoring and research data (e.g., for calibration and validation) such that they yield credible evaluation tools for this application?

Finding: The hydrologic model (MIKE SHE / MIKE 11) was used with best available data. The models are technically supported and have been calibrated for the Picayune Strand, as well as other areas in Florida. Data used included rainfall data spatially distributed by thiessen polygons, LIDAR based topography, NRCS soil database, hydro-geologic characteristics, land use, channel sizes and configuration. The model was calibrated with stream-flow and groundwater data. There are existing ecological models that are relevant for linking hydrological alterations to ecosystem responses (See above) of which some are referenced in supporting documentation (e.g., PIR), but none are referenced in the Draft PSRP. The report would be greatly strengthened by summarizing existing ecological models and implications for linking hydrology and biological responses.

Terrestrial: As referenced in Question 4, virtually no ecological models were presented in this report. However, a USGS sponsored ecological modeling project is ongoing in similar South Florida environments and dealing with the biological indicators. References to these models need to be included. For example, the ATLSS Crayfish Index Model incorporates information about crayfish habitat preferences and hydrologically-driven aspects of crayfish ecology to assess the relative impacts of hydrologic scenarios proposed for Everglades Restoration on the occurrence potential for two species of crayfish. This has direct application to the PSRP.

Estuary: There were no explicit references to ecological models for the estuary portion, yet many exist. In particular, there has been a nice modeling effort of oyster response to freshwater inflow and salinity changes in Texas by Eileen Hofmann and Eric Powell that could be referenced (Dekshenieks et al. 2000, Hofmann et al. 1994, Hofmann and Powell 1998, Powell et al. 1996, Powell et al. 2003, Powell et al. 1994).

Another approach is to use empirical statistical models to relate salinity to biological responses. Again, this has been successful in identifying optimal salinity ranges for benthos in general (Montagna et al. 2002), and a variety of shellfish species and specifically for oysters in southwest Florida (Montagna et al. 2008):

6. *Does the analysis adequately link the hydrology and the predicted ecological changes in a) the inland and b) the estuarine portions of the PSRP?*

The panel determined that the major conclusion of the report is to demonstrate a link between hydrology and predicted ecological changes, so this question was answered in response to Question 1, and additional details are provided here that address directly the issue of linkages between hydrology and ecological change.

Findings: Predicted ecological changes in the inland acreage of the PSRP are based on the hydrological requirements of the native plant communities. Based on this, the linkages are shown between predicted hydrology and POTENTIAL vegetation in Table 3. However, what is not shown is the elimination of the existing, undesirable vegetation, specifically the tremendous acreage of cabbage palms (*Sabal palmetto*). Restoration of the structure of the natural communities includes species composition and relative abundance. Vegetation structure is a result of complex processes integrating, climate, soils, and, hydrology and in this region are influenced by fire. Structure will be developed through successional processes.

The presence of exotic or invasive species can inhibit natural succession processes in ecosystem development and even result in system retrogression. Without control and management of exotic species there is the potential that restoration may be inhibited or fail since exotics have the capacity to drastically alter the natural environment and essential ecosystem processes needed for community establishment. Consequently, the linkages between hydrology and predicted ecological changes are inferences based upon assumptions derived from historical for both this site and other hydrology driven sites within CERP. There were no models presented that would allow for forecasting the effects of various hydrologic scenarios on ecological change.

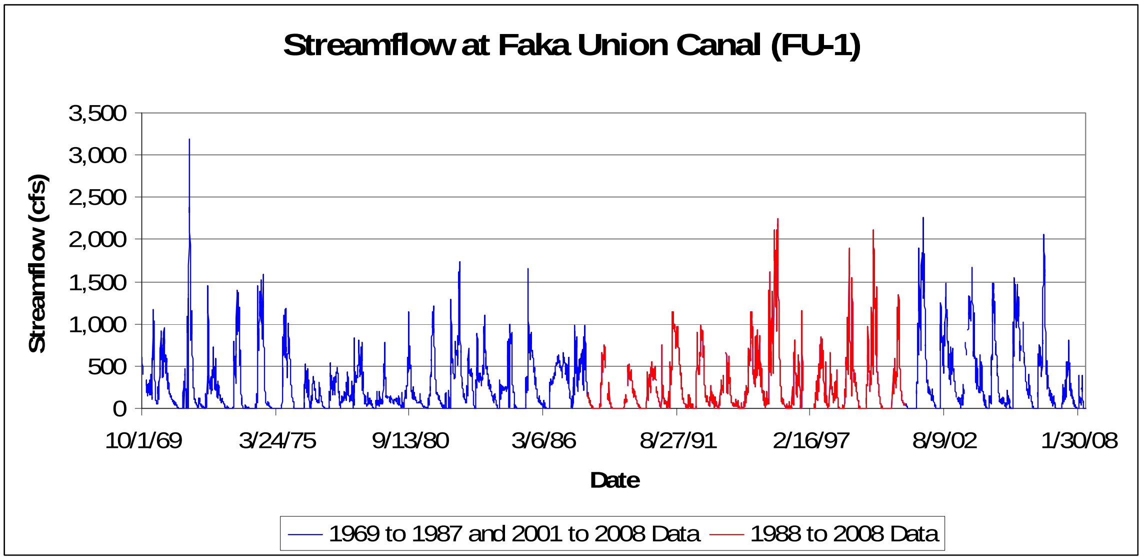
Estuary: The panel concluded that the linkages between hydrology and predicted ecological changes were not sufficiently documented. The report shows a relationship between salinity and flows for the Faka Union Canal and one point in the estuary. Further there were no model predictions of ecological changes for the estuarine portions of the system. The linkages between the predicted changes in hydrology with the estuarine portions of the PSRP were not sufficiently explained nor documented (See Section 8). This was particularly evident given that the water reservation estimates for the estuarine portion of the system were not based on documented ecological targets nor did they address parameter variability and uncertainty. Both targets and uncertainty estimates will be needed to provide defensible forecasts of natural cycles of freshwater and concomitant salinity regimes to all the associated estuaries. Subsequent to the workshop District provided the Panel with the Wang and Browder (2004) model that was used in the study to link the terrestrial and estuarine model in a comprehensive way.

Recommendation: The Panel recommends that the linkages between hydrologic features (flows, hydro-periods, salinity, etc.) and ecological indicators using data developed be fully documented to support the inferences and assumptions. Much of the supporting information can be found elsewhere in CERP and from the extensive Rookery Bay monitoring database. In its present form the PSRP does not make a compelling case supporting these linkages. Only after reviewing supporting documentation, some which is not referenced in the draft report, can one reach the conclusion that the proposed hydrological changes will likely change the ecosystem components as predicted.

Change is difficult to predict with certainty, and this is true for the distribution of ecological indicators, the trajectory of succession, and the amount of time it will take to reach the climax community or desirable ecological endpoint. The District should be prepared for an exercise in adaptive management that might last a very long time.

7. Does the analysis that identifies water for the protection of fish and wildlife adequately address the seasonal and annual hydrologic variability of the PSRP?

Finding: Chapter 8 is the chapter in the PSRP that addresses this topic and is only one page long and does not adequately describe the differences between the pre-drainage conditions (i.e., the target), the current conditions, and the projected conditions with the project. The 13-year simulation may, or may not adequately address the seasonal and annual hydrologic variability. Long-term records should be examined to determine the conditions that occurred in the 13 years. Subsequent to the workshop a time series of long-term data were posted on the web. The data are plotted below.



A cursory review indicates that a period between 1976 and 1980 were in drought conditions and may have been drier than 2000 referenced in the report. The data also shows that 1971 had the largest peak flow and may have been wetter than the year 1995 referenced in the repot. However, the 1988 to 2000 period modeled (red line in graph) did show some variability and may be adequate for the protection of fish and wildlife. The adequacy should be confirmed by a more comprehensive analysis of the seasonal and annual variability during the 13 years for both streamflow, and rainfall. It has been suggested that the PSRP supplement the current volume-probability curves with a second set of graphics the illustrate the cumulative frequency distribution, by year, for average-daily inflows during early and late wet season, early and late dry season, and the total year.

Terrestrial: The report states that the water reservation proposed for the terrestrial wetland component of the PSRP "will improve the wet season hydrology for the terrestrial portions of PS but the water needed for the protection of fish and wildlife will not be fully realized." This indicates that seasonal and annual hydrologic variability has been factored into the hydrologic modeling. Further, the institution of sheet flow throughout the system and removal of canals will result in ~ 80% decrease in discharges volume from the Faka Union Canal, which should improve the salinity in Faka Union Bay such that they more closely reflect the seasonal and annual hydrologic variability. The indication is that the graphics supplied based on the MIKE SHE 11 model seem to adequately address the issue of interannual variability for the terrestrial portion of Picayune Strand.

Estuary: This link is especially weak for the estuarine component of the system and particularly the salinity response in the estuary. However, as noted earlier, this information is available in the supporting documentation and the original EIS. These documents adequately address the issue of interannual variability.

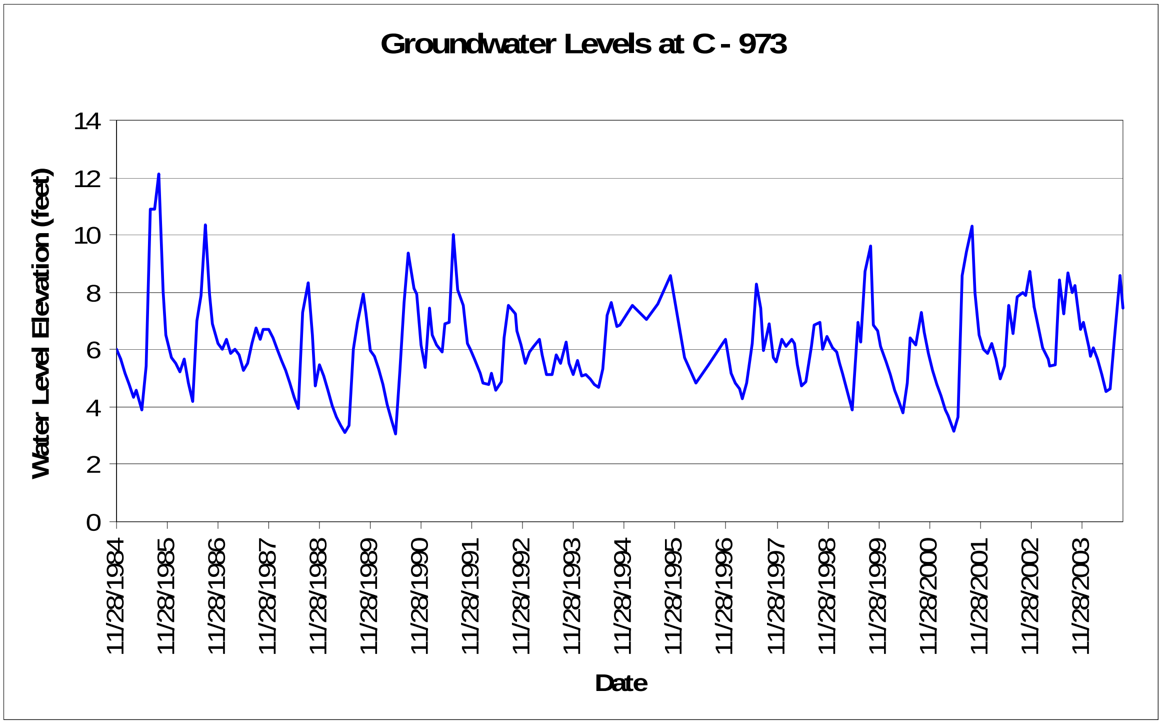
Recommendation: The Panel recommends that Section 8 be revised with fewer figures, choosing one or two to illustrate an important point and with more explanatory text for each figure. The Panel also recommends that alternative approaches be explored for displaying the data that would include the incorporation of "existing conditions" as one of the options to illustrate how significant a change the PSRP will make to the critical hydrological attributes that are responsible for altering and shaping the ecosystem. Section 8 should clearly delineate the hydrologic findings regarding the sufficiency of the proposed water reservation for both the terrestrial and estuarine components of the system. Regarding the latter, specific attention should be given to the uncertainties in the calculation relative to setting a defensible target as well as recognizing that there are uncertainty bounds around the "with project" and "target" model projections. Given these uncertainties the Panel recommends a conservative, risk averse approach be taken that entails reserving all the water possible.

8. Is the water identified for the protection of fish and wildlife technically supported?

Findings: The Panel agrees that the draft PSRP technically supports the concept that the proposed water reserve will be protective of fish and wildlife, as long as the linkages are addressed with respect to the questions above. The water identified as the target (i.e., the green lines in the figures of section 8) is defined as the pre-drainage condition and the documentation of environmental changes since drainage supports the selection of that as a target.

The water identified appears to be technically supported, but a more extensive database is required to support the linkage between the terrestrial and estuarine ecosystems. Additional technical information to support the studies includes an assessment of annual variability in streamflow/rainfall, and an assessment of groundwater level trends in the Northern Golden Gates area. The groundwater levels should be used to determine if there are downward trends attributed to allocated withdrawals. A downward trend may indicate that the model prediction over a 13-year period may not have appropriately identified post 2000 groundwater flowing into the Picayune Strand.

Subsequent to the workshop the data for one well was posted on the web board. In examining the data it was noted that there was no discernable or statistically significant downward trend. Therefore, based on the C-973 well, simulated groundwater flowing into the Picayune Strand from the NGG should be appropriate.



Adaptive Management: Though not discussed in detail at the Peer Review, the Picayune Strand restoration fits under the Adaptive Management rubric that governs all of CERP. This is important because any restoration is, in reality, an experiment and the implementation of such an experiment must have sufficient iterations to allow for management to make the appropriate adjustments. Model predictions start with the development of a quantitative numerical model of the system or processes to be managed. The model predicts what will happen if particular management actions are taken, and includes specific indicators that are measured to determine whether or not the model's predictions are accurate. For example, upon implementation of the PSRP it may be determined that more water may be necessary to restore the planned vegetative, fish and wildlife communities to their desired targets. Information is collected during and after the implementation of management recommendations that is used to further refine the model, which will hopefully generate better predictions in the next management cycle" (Mawdsley and O'Malley 2007. P. 13).

Recommendations: The Panel recommends the following points of clarification: (1) the draft must clearly delineate that there are two water reserves being proposed (not clear from the peer review draft PSRP), one for the terrestrial component and the second for the estuarine component; (2) the draft address the concept of uncertainty for the hydrology, vegetative community succession, and wetland and estuarine fish and wildlife; (3) the linkages between hydrology and ecological components of the system be well documented in order to support the assumptions and inferences on the linkages; and (4) the document be technically edited.

FINDINGS AND RECOMMENDATIONS

The Peer Review Panel commends the District staff for preparing a report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and logical in its flow. In addition, the Panel found the site visit to Picayune Strand invaluable, particularly the helicopter tour of all the relevant ecosystems that are the focus of this restoration. Without the aerial tour it would have been difficult for the Panelists to fully comprehend the spatial extent of the change in the terrestrial vegetation (e.g., cabbage palm monoculture) or the magnitude of the freshwater discharges from the Faka Union Canal into Faka Union Bay as well as the bathymetric complexity of the bays comprising the Ten Thousand Islands National Wildlife Refuge. The subsequent ground tour of the same geographical areas served to reinforce what was seen from the aerial tour and provided an opportunity to view first hand the succession changes resulting from the plugging of the Prairie Canal in 2004. The restoration of Picayune Strand is no small task because of the legal, social, and economic constraints of recommending a water resource use strategy for such a complex and coupled ecosystems.

The supporting data and information used to develop the draft PSPR and PIR is technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information that is the foundation of CERP. The premise of this restoration is that restoring the pre-development/drainage hydrologic features is an essential first step in the restoration of the terrestrial vegetative community and associated freshwater wetland fauna. Further, the elimination of the canal system and the return of the system to overland sheet flow will eliminate the excessive freshwater discharges from the Faka Union canal into Faka Union Bay and more evenly distribute freshwater to the whole estuarine system resulting a more natural salinity regime that will enhance the protection of estuarine fish and wildlife.

Regarding the sufficiency of literature and data supporting the PSRP, the panel noted that the data presented was scientifically sound but at times was insufficient to support the various linkages that are critical to this restoration project. For example, while the hypotheses and assumptions linking hydrology to the protection of fish and wildlife has been documented for other parts of the CERP this information was not used to support similar linkages that are the scientific foundation for this study. The panel recommends that the appropriate documentation supporting the linkage between hydrology and the protection of fish and wildlife, especially for the estuarine system, be included throughout the report.

Second the report needs to make explicit the distinction that there were two separate water reserves being evaluated: (1) the reservation of water sufficient for the restoration of the terrestrial ecosystem including it's vegetative and wetland communities and for the protection of fish and wildlife; and (2) the reservation of water at the southern boundary of the site to restore the estuarine system and protect estuarine fish and wildlife. The uncertainty associated with the science supporting the latter supports a conservative, risk averse approach involving the maximization of the water reservation for the estuaries at this time.

The third issue relates to the adequacy of information was the strategy to be employed in addressing the extensive (~7,000 acres) of cabbage palms, which from a monoculture in the northwestern part of the system. The panel suggests that simply getting the "water right" would be insufficient to restore that part of the system without and explicit discussion of the types of intervention that are planned to accelerate the process. Figure below represents *Sabal* palm monoculture occupying a previous cypress dominated wetland in Picayune Strand Restoration Project.

The Panel agrees that the procedures and analyses are technically appropriate and reasonable, and based on the best information available. The extensive studies comprising the PIR as well as the regulatory and socio-political factors associated with this project were incorporated into the SFWMD's technical analysis and used correctly to support its water reservation rule. There is additional information on salinity profiles, NGGE wells upstream of the project as well as USGS well sites and wells on the Ten Thousand Islands National Wildlife Reserve that the SFWMD can use to support the water reservation rule.

The Panel recommends that the SFWMD clearly articulate and explicitly state the management goal(s) and objectives for both the terrestrial and estuarine components of this PSPR. These goals and objectives should include numerical targets whenever possible so that progress to meeting the goal can be evaluated in an adaptive management process. The absence of clearly articulated goals and objectives made it difficult for the panel to evaluate whether the technical approach proposed by the SFWMD would be successful and over what temporal and spatial scales. Further it is important to place the PSRP within an Adaptive Management framework that establishes baselines, performance measures, and targets for the protection of wetlands and estuary VECs.

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Adaptive Management: *Question 8*

Mawdsley, Jonathan, and Robin O'Malley. 2007. The Wildlife Conservation Project: A Literature Review. The H. John Heinz III Center for Science, Economics and the Environment. http://www.heinzcenter.org/Programs/Reporting/Wildlife_Conservation/index.shtml

APPENDIX

STATEMENT OF WORK FOR PEER REVIEW OF TECHNICAL DOCUMENTATION TO SUPPORT DEVELOPMENT OF WATER RESERVATIONS FOR THE PICAYUNE STRAND

Date:	May 9, 2008
Project Name:	Picayune Strand Water Reservations
Peer Review Facilitator:	Jason Godin, Sr. Environmental Scientist, Water Supply Department
Peer Review Manager:	John Maxted, Senior Supervising Environmental Scientist, Water Supply Department
CERP Project Manager:	Brenda Mills, Lead Planner, Everglades Restoration
Project Technical Lead:	Michael Duever, Lead Environmental Scientist, Big Cypress Service Center
Requesting Offices:	Everglades Restoration Office and Water Supply Department

Introduction

This request for peer review pertains to the draft project technical report entitled "Review of Available Science to Identify Water for the Protection of Fish and Wildlife within the Picayune Strand Restoration Project." This peer review is being conducted to support the rule development process for establishing a water reservation for the area encompassed by the Picayune Strand Restoration Project.

The South Florida Water Management District (SFWMD) is a regional water resource protection and management agency with legal authorities identified by state law, specifically Chapter 373 Florida Statutes (F.S.). Pursuant to Section 373.223 F.S., the Governing Board of the SFWMD has directed staff to develop a reservation or allocation of water to protect water identified for the protection of fish and wildlife in the Picayune Strand Restoration Project.

The purpose of this peer review is to review and determine if the technical information contained within the draft project technical report and other reference materials can be used as a scientific basis for quantifying water needed for the protection of fish and wildlife. For the purposes of this peer review, 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." (Association of Florida Community Developers v. Department of Environmental Protection, Case No. 04-0880RP, Final Order at 17). The fish and wildlife for which a water reservation may be set are existing native communities of fish and wildlife that would use the habitat in its restored state.

Peer Review Overview

The peer review panel shall read the draft technical report and related background information identified in this statement of work, participate in the technical workshop, submit written comments on the draft project technical report, and work with the panel chairperson to develop a final peer review panel report. The panel chairperson shall submit a comprehensive final peer review report to the SFWMD that meets the objectives noted above. This review will include a response to the panel's questions, summarize whether the panel agrees or disagrees with staff's estimation of water needed for protection of fish and wildlife, and recommendation of action to resolve outstanding technical issues. The expert panel is requested to provide specific recommendations to address deficiencies in the information presented in the document. To assist in this process, the panel is requested to address the questions and issues listed in ATTACHMENT A. The panel members shall have no conflicts of interest and will comply with Florida Sunshine Laws (see section 1.2).

Panelist Requirements and Expertise

It is imperative that each panelist shall have the following skills:

- Expertise in one or more of the following: (1) freshwater wetland ecology, (2) ecosystem restoration, (3) estuarine or coastal ecology, (4) hydrology and hydrogeology linking freshwater flow (surface and groundwater) to ecological resources, and (5) application of regional/subregional models for resolving real-world problems in water resource management, including environmental restoration, water supply, and/or drought management.
- Effective communication and writing skills
- Availability to dedicate significant time resources during the peer review period
- Availability to participate in the technical workshop
- Ability to conduct an objective and independent scientific review

In addition to the above requirements, the chairperson must also have excellent communication, writing, and report organization skills. Experience chairing peer review panels and consolidating comments from multiple panelists is preferred. It is preferred, but not required, that each panelist have a demonstrated ability to understand the potential impacts to the hydrologic system in the South Florida region from simulated changes in hydrologic conditions, operational guidelines, and management objectives.

The SFWMD has organized the peer review process in accordance with accepted scientific review practices. Care will be taken in selecting the panelists to assure they are independent of the SFWMD. Panelists should have no substantial personal or professional relationship with the SFWMD or any other organization involved in environmental management in Southwest Florida. The panel can therefore be reasonably assumed to be objective in evaluating materials presented. Such objectivity is the cornerstone of any true independent peer review process. Each panelist shall submit a signed disclosure of potential conflicts of interest and a current curriculum vitae.

Guidelines for Peer Review

All panelists will receive payment for their participation on the panel. The chairperson shall have additional duties and will receive payment accordingly based on an estimate of additional hours for aggregating and reporting panel findings. All panelists shall attend a 3-day workshop in Collier County, Florida (see Table 1). Once individuals have accepted their position and their contract is executed, they shall begin to review the project technical report and supporting reference materials provided in preparation for their participation in the public workshop. All notes and questions about the technical document from each panelist shall be recorded using the web board following the format in section 4.1.2. The workshop is a venue for panelists to work face-to-face with each other and staff and to ask questions and clarify any items as needed.

The web board serves as a repository to allow panelists to submit their comments on the draft project technical report and to distribute documents such as the peer review report. It also allows the SFWMD to disseminate other relevant information about the review, and it allows the general public to closely follow the development of the review. Discussions among panelists relating to this peer review shall occur only during the public workshops or through the web board.

Review of the technical documents by individual panel members shall be done independently prior to the public workshop. The panel will interact with one another to formulate a consensus of opinions at the public workshop. During the final workshop session the panel shall collaborate on recommendations and proposed changes to the technical document. The chairperson shall then write a final peer review report incorporating the SFWMD team responses and the panel's conclusions following the workshop.

The panel members will comply with s.286.011, F.S. (ATTACHMENT B) and therefore may not have discussions amongst each other outside the public forum. A publicly accessed web board provided by the SFWMD (http://webboard.sfwmd.gov/default.asp?boardid=picayunepeerreview) shall provide the only means of communication between panel members outside of a public workshop. The peer review panel web board shall be used by the panelists and the public to post questions to the SFWMD Project Team and to post their work in progress following the format in section 4.1.2. This web board will be conducted in accordance with Florida's 'government in the sunshine' statutes. Panelists are required to read the information on the sunshine laws contained in ATTACHMENT B. Panelists may post materials, but may not respond to, or have discussions with, other members of the panel or have discussions via a liaison. SFWMD staff will provide a set of instructions for using the web board to each panelist.

Summary of Time Line and Responsibilities

Table 1: Time Line and Responsibilities

Task/Action	Responsible Party	Deliverable & Due Date for 2008
Execution of Purchase Order	Procurement	
Send Materials to Panelists	SFWMD	On or about June 3
Task 1: Acknowledgement of Receipt of Materials	Panelist	Within 48 hours of receiving materials
Task 2: Questions for SFWMD	Chairperson and panelists	June 17
Task 3. Field excursion (1-day) and Workshop (2-days)	Panelists, chairperson and SFWMD team	3 days; June 24-26
Task 4: Peer Review Report	Chairperson report to SFWMD	July 12

Scope of Work

Duties and Tasks of Panel and Chairperson

During this project, the panelists will complete all tasks listed below. These tasks follow Florida Statute 373.223(4) and SFWMD rule 62-40.474 (https://www.flrules.org/gateway/readFile.asp?sid=0&tid=3439152&type=1&file=62-40.474.doc).

Duties for Panelists

1. Review and evaluate the technical documentation (e.g., explanation of methods and approach used, tools, data sources, and assumptions)

2. Review all scientific or technical data, methodologies, and models used.

3. Review all scientific and technical analyses. Identify strengths and weaknesses of the analyses.

4. Review and evaluate materials provided to the panel during the course of the peer review process. All materials (excluding reference/background materials) provided up to the final peer review workshop shall be included in the evaluation by the panel.

5. Actively participate in the technical workshop.

6. Respond to topic questions listed in **ATTACHMENT A**.

7. Contribute to the Peer Review Report.

In addition to the panelist duties described above, the chairperson shall also perform the following duties:

1. Submit a draft workshop agenda. SFWMD will be taking minutes during each day of the workshop.

2. Assign tasks to panelists for completion of various sections the draft peer review report and ensure that they fully understand the requirements for each task.

3. Organize materials from other panelists and submit a draft peer review report and final peer review report. Each panelist shall read and review the materials provided independently, and then the panelists shall collaborate with the chairperson to develop the peer review report during the public workshop and through the web board. The chairperson shall coordinate all the activities and products of the panel. The chairperson shall be the editor of the peer review report and shall compile and reconcile the contributions from the other panelists.

4. Panel concurrence on each topic is recommended but not required. In the event that differences of opinion cannot be reconciled by the chairperson, then they may be reported as such or as minority opinions.

Work Breakdown Structure

Tasks for Panel

Task 1. Receipt of Materials

The technical documentation will be delivered to the panel for review at the start of this purchase order. The panelists shall acknowledge that they have read the statement of work and agree to the terms therein along with receipt of the following:

1. Documentation entitled, "Review of Available Science to Identify Water to be Reserved for the Protection of Fish and Wildlife within the Picayune Strand Restoration Project."

2. Reference materials contained in ATTACHMENT D.

The panelist shall mail a signed and dated acknowledgment form (ATTACHMENT C) to the SFWMD once receiving a copy of the technical documentation. The panelists shall read the statement of work and begin review of the project technical report and supporting reference materials (ATTACHMENT D). The reference materials are provided so the panelists may become familiar with tools, data, or other information that was synthesized in the technical document. The reference material is provided only as informative reference material; it is not under review and is not necessary that it be reviewed. Some of the reference material will be provided in the form of links to PDF files on the SFWMD's web site, or ftp site, or links to other web sites.

Deliverable 1: Acknowledge receipt of materials by emailing the SFWMD peer review facilitator

<u>Due Date</u>: 48 hours after receiving materials. A signed form (ATTACHMENT C) should be mailed to the SFWMD peer review facilitator.

Questions for SFWMD

The panelists shall provide questions to be considered by the SFWMD team in preparation for the workshop using the classification listed in Table 2. The panelists will develop specific and general questions regarding items in the project technical report and post them on the web board one week prior to the public workshop (June 17).

Table 2: Format for Questions

Major issues for discussion	
Minor issues requiring further clarification	
Typos and editorial comments in documentation	To be provided on electronic copy of documentation
Major strengths	

The panel shall review the project technical report in regards to its approach and review the documentation itself. The panel shall provide comments and recommendations on, but not limited to, the following:

- Format and clarity of the documentation in explanation of technical approach, data sources and assumptions, overall structure, and readability of text, tables, and figures.
- Suitability of analyses for its intended application.
- Capabilities, limitations, and future improvements.
- In areas where the panel identifies deficiencies, specific recommendations to resolve the deficiencies are required to facilitate revision of the documentation.

It is recognized that each member of the panel shall comment most substantively on areas within their primary expertise, but comments are welcome on other appropriate aspects of the technical document. In addition to comments and recommendations, the peer review report shall include responses to the topic questions. The responses by the panel shall be stated in the most unambiguous manner possible. The peer review report shall address the questions listed in ATTACHMENT A.

<u>Deliverable 2A</u>: A list of initial questions and concerns from each panelist will be post on the web board 1 week prior to the workshop.

<u>Due Date</u>: June 17

<u>Deliverable 2B</u>: For the chairperson only – a categorized list of the single set of outstanding questions from the panel that require written response from the SFWMD team at the last day of the workshop. This list would contain questions that were not fully addressed at the workshop and needed to finalize the peer review report.

<u>Due Date</u>: June 26, the last day of the peer review workshop

Task 3. Peer Review Workshop

The peer review workshop will last 2 days after the 1-day field trip. All portions of the 2-day workshop are open to the public. The field trip is not a public forum and therefore the panelist shall not discuss their review of the project with each other. The workshop shall be held to allow the panelists to meet in person and work together to reach consensus on all portions of the peer review report. The panel shall work collaboratively. Up to one half day portion of the workshop shall be dedicated to incorporating the SFWMD team's responses to the panel questions. The panel shall also consider other comments and clarifications made by the SFWMD team. Time will also be allocated for comments from the public. The final part of the workshop will include an executive panel session. During this time, the chairperson will compile a list of any outstanding questions needed to complete the peer review report and give to the SFWMD team prior to the conclusion of the workshop. At the conclusion of the workshop, the peer review report should be nearly finalized. The chairperson is responsible for coordinating and delivering the peer review report. A field excursion will be held prior to public workshops, which will include a helicopter tour of the project area. All participating panelists will be required to sign a liability waiver (ATTACHMENT E). Panelists need to plan to be in Collier County, Florida for a total of three 8-hour working days. The final peer review report is due two weeks after the peer review workshop (July 12).

The agenda for the workshop will be developed through consultation between the SFWMD and the chairperson. The SFWMD shall post a draft agenda on the web board one week prior to the start of the workshop. Final comments to the agenda shall be posted to the web board no later than two business days prior to the start of the workshop. The agenda will include, at a minimum, the following items:

1. SFWMD presentation covering introductions, a brief overview, and meeting logistics
2. Question-and-answer session between the panel and SFWMD team.
3. Review of schedule and logistics for the peer review report.
4. SFWMD responses to panel questions.
5. Time allocated for comments from the public.

6. An executive work session for the panel to discuss and reach consensus on the peer review report. During this time the chairperson should compile a list of any outstanding questions needed to complete the peer review report and give to the SFWMD team prior to the end of the executive work session.

The peer review workshop will be conducted between the hours 9AM–5:00PM with up to a one-hour break for lunch each day. Lunch is not provided during the workshop.

Deliverable 3: Panelists will make their own travel arrangements to Collier County, Florida and actively participate in the workshop and field excursion. "Active participation" is defined as adhering to ground rules established by the workshop facilitator, attending all presentations, letting presenters know when any part of the presentation is not understood, be familiar with the SFWMD expectations for the peer review, and be ready to work within the schedule and through the logistics for the peer review. Personal appearance at the workshop is required. No panelist shall be allowed to attend via teleconference.

Due Date: The workshop will be June 24-26.

Task 4. Develop Peer Review Report

The peer review report is the primary product of this statement of work. The panel shall work collaboratively during the public workshop and through the web board to produce the peer review report. The chairperson shall seek consensus among the panelists. Each panelist is responsible for cooperating with the chairperson in the development of the peer review report.

The chairperson shall be the editor of this report and shall coordinate all the activities of the panel to this end. Panelists shall provide their products to the chairperson in a timely fashion closely following the review schedule developed during the kick-off teleconference. Panelists shall be contributors to the peer review report.

The peer review report shall include an executive summary, which includes the panel's recommendations. The SFWMD team's responses to these recommendations shall be included in the peer review report as part of the executive summary. The peer review report shall include responses to topic questions posed in ATTACHMENT A. The questions posed by the panel in Task 2, at the workshop and from the web board will be answered by the SFWMD team in a question/answer format. All questions will be answered in writing on the web board. The peer review report shall include minutes taken by the SFWMD from the public workshops as an appendix. The peer review report shall also summarize the key points made during the workshop. A video or audio tape of the meeting will also be made for SFWMD records.

The peer review report will at a minimum include the following sections (section names can be modified):

1. Executive Summary

2. Introduction

3. Panel responses to the questions in ATTACHMENT A

4. Overall Findings and Recommendations

5. Appendices

    a. Scope of Work for Peer Review

    b. Minutes From Workshop Meetings

The peer review report shall use a Microsoft Word template for styles and formatting. Questions regarding the use of the template will be addressed to the peer review facilitator. The peer review report shall display line numbers for each page and display page numbers. (See page set up layout options in Microsoft Word).

Deliverable 4: Deliver the peer review report. The report shall be written in Microsoft Word and posted to the web board and emailed to the peer review facilitator.

Due Date: Chairperson shall post the peer review report on or prior to July 12 and mail a signed copy to the SFWMD.

Task 5. Presentation to SFWMD Governing Board

The Chairperson shall prepare and present an overview of the peer review report to the SFWMD Governing Board on August 13, 2008.

Deliverable 5: Peer Review presentation to SFWMD Governing Board during monthly August meeting.

Due Date: Presentation on August 13, 2008

Duties and Tasks of SFWMD

The technical documentation and internet paths to background materials will be delivered to each panelist by SFWMD staff. SFWMD will perform the following duties, with the responsible person in parenthesis (see Section 8):

1. Prepare the technical documents to be distributed to the panel (project technical lead)

2. Post background materials to panelists and provide the project technical report (peer review facilitator)

3. Finalize workshop agenda (peer review manager)

4. Handle logistics for the field trip and workshop (peer review facilitator)

5. Take minutes of the workshops and post on web board(peer review facilitator)

6. Respond to panelists' questions and comments at the workshop (project technical lead)

7. Establish and monitor web board (peer review facilitator)

8. Review and approve all deliverables associated with this scope of work (all).

9. Staff will provide support to the panel during the workshop. The chairperson should inform SFWMD personnel what technical assistance they anticipate needing prior to the workshop.

10. The SFWMD will videotape or tape record the final workshop meeting (peer review facilitator).

The SFWMD agrees to perform its duties within the timeframes of this statement of work.

Evaluation Criteria for Acceptance of Deliverables

Task 1 Criteria for the acceptance of the Task 1 deliverable is acknowledgment of receipt of review materials and signing off on scope of work.

Task 2 Criteria for the acceptance of the Task 2A deliverable is the compilation of questions prior to June 17. The panel's questions, concerns, and information to the SFWMD should reflect thoughtful reading of the documents provided. Criteria for the acceptance of the Task 2B deliverable is the timely submittal of a compiled and sorted list of comments and outstanding questions to the SFWMD from the chairperson at the conclusion of the peer review workshop.

Task 3 Criteria for the acceptance of the Task 3 deliverable is active participation in the peer review workshop.

Task 4 Criteria for the acceptance of the Task 4 deliverable will be the submittal of the peer review report, representing a consensus view of the entire panel. The final panel peer review report shall respond to all the questions posed in ATTACHMENT A and to additional questions or issues raised in the workshop. It will also reflect a thoughtful and substantive evaluation of the technical document. The report should be completely objective in its evaluation and written so that it can be understood by a broad audience. The report shall include an executive summary. The peer review report shall also summarize the key points made during the peer review workshop and include constructive steps to be taken to correct any deficiencies identified by the panel.

Payment for Services

A summery of deliverables and schedule by task associated with this project is set forth below in Table 3. Each panelist must provide a cost for each item in Table 3. Panelists are responsible for making and paying for their own travel and meal arrangements. Based on the hourly unit rate, the total task cost for each task in Table 3 should be completed. The unit rate shall include the costs incurred for travel, meals, phone calls, overhead, etc. All deliverables submitted hereunder are subject to review and approval by the SFWMD. Upon satisfactory completion of all services required, the panelists will be paid at the specified hourly unit rate that includes all labor and expenses.

The chairperson hereby agrees to provide the SFWMD all deliverables described in the statement of work in Microsoft Word format. Acceptability of all work will be based on the judgment of the SFWMD that the work is technically defensible, accurate, precise, and timely.

After issuance of the purchase orders, payment will be made following receipt and acceptance by the SFWMD of project deliverables in accordance with the schedule set forth below, and after receipt of an invoice. Payment by the SFWMD for all work completed herein will not exceed the TOTAL in the table below. The Panelist should submit invoices to the peer review manager for approval upon completion of all the indicated tasks in Table 3.

Table 3: Schedule of Deliverables and Rate Schedule

Task Number	Deliverables	Due Date	Estimated Hours	Unit cost	Task Cost	Payment
Task 1A	Acknowledgement of Materials	48 hours after receiving materials				
Task 1B	Initial review of materials	Wednesday, June 04, 2008	8	$ 880.00	$ 462.04	$ 4,110.00 (25%)
Task 2	Questions for SFWMD	Tuesday, June 17, 2008	20	$ 2,200.00	$ 1,155.10	$ 4,110.00 (25%)
Task 3	Workshop and Field excursion	Tuesday, June 24, 2008 through Thursday, June 26, 2008 (3 days)	24	$ 2,640.00	$ 1,386.12	
Task 4	Peer Review Report	Friday, July 11, 2008	30	$ 3,300.00	$ 1,732.65	$ 4,110.00 (25%)
Task 5	Governing Board Presentation	Thursday, September 11	16	$ 1,760.00	$ 924.08	$ 4,110.00 (25%)
		TOTAL	**98**	**$ 10,780.00**	**$ 5,660.00**	**$ 16,440.00**

8 Definitions

Key terms have been defined to aid in the readability of this statement of work. These terms are as follows:

Chairperson	Panelist who leads the peer review process and prepares the final report
SFWMD	South Florida Water Management District
SFWMD District HQ	Headquarters of the South Florida Water Management District: 3301 Gun Club Road, West Palm Beach, FL 33406
Email Addresses	Addresses to be used by chairperson to submit panel products to the SFWMD.
Kick-off Meeting	Public teleconference meeting of the panel. Attendance of panel members is required. The public may ask questions during the public comment session.
Mailing Address	Water Supply Department, Mail Code 4350, South Florida Water Management District, P.O. Box 24680, West Palm Beach, FL, 33416-4680
SFWMD Team	A team of scientists and planners from the SFWMD
Panel	The peer review panel, a group of three experts (2 panelists and 1 chairperson) assembled to peer review the project technical report
Panelist	A member of the peer review panel
Peer Review Facilitator	Responsible for implementation of this statement of work under the direction of the peer review manager. Activities include being the point of contact for inquiries and mailings, scheduling and tracking of completed tasks, booking of meeting rooms and field trips, setting up and maintenance of the web board, procurement, and all other logistical considerations.
Peer Review Manager	Responsible for overseeing the peer review to ensure that work is completed on schedule and in accordance with the statement of work and established standards for peer review in support of SFWMD rulemaking.
Project Technical Lead	Responsible for the completion of the project technical report and all support materials to be reviewed by the panel, the selection of the panel questions, selection of the panel and chairperson, and overseeing all technical elements of the peer review.
CERP Project Manager	Responsible for managing inter-departmental meetings, communications, and internal review of

	documents related to the peer review as well as coordinating with senior management.
Reference Materials	This includes a set of important supporting reference documents that can be downloaded from a SFWMD website.
Peer Review Report	Peer review documentation prepared by the panel to be submitted to the SFWMD as the final product of the peer review.
Project Technical Report	Technical report summarizing the project for the panel, to be prepared by the project technical lead.
SFWMD	South Florida Water Management District
Web Board	An Internet site implemented by the SFWMD and accessible to the public at: http://WebBoard.sfwmd.gov:8080/~picayunepeerreview. This site will be used as repository for all draft/final chapters and versions of peer review report and agendas for the workshop and teleconference. Under Florida's Sunshine Law, it is mandatory that all communications between two or more panelists occur in a forum open to the public. However no discussions, between panelists, can occur on the web board prior to the workshop to insure an independent review. Data may be posted and read by members of the board, SFWMD staff as well as the public. Anyone experiencing difficulty in accessing the web board should contact the web board administrator. Discussions on posted items shall occur during teleconferences and workshop.
Web Board Administrator	The peer review facilitator will assist anyone with difficulties posting or reading web board messages.
Workshop	A public meeting of the panel to be held in Collier County, Florida at the Rookery Bay National Estuarine Research Reserve (http://www.rookerybay.org/) 300 Tower Rd, Naples, FL. Personal attendance of panel members is required. Presentations will be given by the SFWMD to answer questions from the panel and the public. The panel shall discuss and work on peer review and tasks for peer review reports.

ATTACHMENT A
Panel Technical Questions

1. Does the compiled information, including data, modeling and literature review, provide a reasonable basis for the conclusions reached?

2. Are the environmental indicators selected for the protection of fish and wildlife for the wetland and estuarine components of the PSRP adequate to meet the project objectives?

3. Are there any major environmental indicators not considered in our analyses that could significantly affect the water identified for the protection of fish and wildlife?

4. Are the hydrologic and ecological models used in the study appropriate for this application?

5. Are the hydrologic and ecological models sufficiently supported by available knowledge, monitoring and research data (e.g., for calibration and validation) such that they yield credible evaluation tools for this application?

6. Does the analysis adequately link the hydrology and the predicted ecological changes in a) the inland and b) the estuarine portions of the PSRP?

7. Does the analysis that identifies water for the protection of fish and wildlife adequately address the seasonal and annual hydrologic variability of the PSRP?

8. Is the water identified for the protection of fish and wildlife technically supported?

ATTACHMENT B
Sunshine Rules

General links:
http://myfloridalegal.com/pages.nsf/main/b2f05db987e9d14c85256cc7000b28f6!OpenDocument
https://my.sfwmd.gov/portal/page?_pageid=2934,19738785,2934_19738944&_dad=portal&_schema=PORTAL

Statute link:
http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=Ch0286/SEC011.HTM&Title=-%3e2007-%3eCh0286-%3eSection%20011

ATTACHMENT C
Task 1
Acknowledgement – Receipt of Draft Documentation and Background Materials

1. I have read the statement of work and I will complete my assigned tasks.

2. I received the draft documentation and background materials on ______________
Date

______________________________ ____________________________________
Name Signed

Please mail to:
Jason Godin
Senior Environmental Scientist
SFWMD
Water Supply Department
Mail Code 4350
West Palm Beach, FL 33416-4680

ATTACHMENT D
Reference / Background Materials

1. Picayune Strand (Southern Golden Gate Estates) Hydrologic Restoration; Final Project Implementation Report (PIR); November 2004 (USACE/SFWMD 2004); available at: http://www.evergladesplan.org/pm/projects/docs_30_sgge_pir_final.aspx

2. 2008 South Florida Environmental Report Appendix 7A-2: Picayune Strand Restoration Project Baseline; available at: https://my.sfwmd.gov/pls/portal/docs/PAGE/PG_GRP_SFWMD_SFER/PORTLET_SFER/TAB2236041/VOLUME1/appendices/v1_app_7a-2.pdf

ATTACHMENT E
Liability Waiver

WHEREAS, ________________________________("PARTICIPANT") has
[Print full name]
voluntarily requested, from the South Florida Water Management District ("DISTRICT"), to participate in ____
___________________________ on or about _____________ which may involve the use
(Types of activities) (Date)
of DISTRICT transportation (automobiles, airboats, aircraft, and other transportation) and other equipment, as well as use of canals, property, and surrounding rights of way owned and operated by the DISTRICT; and

WHEREAS, DISTRICT is willing to allow use of its transportation, equipment, canals, property, and surrounding rights of way to facilitate the above identified activities upon the representations and conditions that PARTICIPANT agrees to abide by all safety procedures, agrees to obey all directions and demands of DISTRICT personnel, if any, and PARTICIPANT specifically acknowledges and assumes any and all risks associated with the above identified activities;

NOW THEREFORE, in consideration of the premises set forth above, I hereby release and agree to indemnify and hold harmless the District (including, but not limited to its Governing Board members, employees, agents, attorneys, legal representatives, and their successors and assigns) from all liability, personal injuries, claims, damages, attorneys fees, costs, judgments, claims bills, etc. (under the laws of the State of Florida, and of any other state of the United States of America and/or of the United States of America) arising, in whole or in part, from the acts, omissions, or negligence of the District or any third person that arises out of or is related to the above referenced use of District transportation, equipment, canals, right of ways, personal property and real property.

____ ____

PARTICIPANT'S SIGNATURE DATE

____ ____

PRINT PARTICIPANT'S NAME WITNESS SIGNATURE

____ ____

PRINT PARTICIPANT'S ADDRESS PRINT PARTICIPANT'S PHONE

____

PRINT PARTICIPANT'S CITY & ZIP

Appendix D. Response to Panel Recommendations

The South Florida Water Management District (SFWMD) convened a peer review panel to review the *Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream* Estuaries (SFWMD 2008). The peer review panel determined that the supporting data and information used to develop the draft report is "technically sound and the inferences and assumptions made regarding the linkages between hydrology and the protection of fish and wildlife are based upon sound scientific information that is the foundation of CERP." The panel noted that the technical document did not present sufficient data to support the linkages between hydrology and the protection of fish and wildlife. The panel made the following recommendations to improve the technical document. Following each recommendation (in bold and italic font), is a summary of the SFWMD's response to the recommendation. The report submitted by the peer review panel (Gentile et al. 2008) is included as Appendix C of this document.

Purpose, Goals and Performance Measures

Make explicit the distinction between the reservation of water sufficient for the restoration of the terrestrial ecosystem and the reservation of water at the southern boundary of the site to restore the estuarine system conditions needed to protect estuarine fish and wildlife.

The following text was added to the Introduction:

> *There are two distinct quantities of water to be reserved: water for the protection of fish and wildlife within the boundary of the Picayune Strand Restoration Project and water for the protection of estuarine fish and wildlife found in the Fakahatchee Estuary.*

Similar text was added in other sections where the water reservation was discussed.

Explicitly state the management goal(s) and objectives for both the terrestrial and estuarine components of the Picayune Strand Restoration Project. Sections 1, 2, and 3 do discuss management issues in very broad terms, but without ever explicitly stating the existing problem, the management goal to solve it, and the benefits of the project.

The purpose of this document is to provide technical information on water reservations for the Picayune Strand Restoration Project, not to justify or describe the project itself. Even so, management goals, existing problems and benefits of the project are already discussed in the document. Section 3.3 Achievement of Project Objectives states the management goals for the Picayune Strand Restoration Project. At this point in time, these goals remain very broad, but more specific information on the estuarine system has been provided. More explicit objectives have not yet been defined. Sections 4 and 5 describe the existing problems as well as the benefits the project will provide to alleviate these problems.

Goals and objectives should include numerical targets whenever possible so that progress to meeting the goal can be evaluated in an adaptive management process.

A table presenting plant community acreages MIKE SHE pre-drainage, existing, future without-project and future with-project (restoration) conditions has been included in Section 4. Also figures were included in this section showing plant community distribution for these four conditions.

Specific freshwater flows and salinity envelopes are provided in Section 5.

It is important to place the Picayune Strand Restoration Project within an adaptive management framework that establishes baselines, performance measures and targets for the protection of wetlands and estuary valued ecosystem components.

We agree, but this subject is beyond the scope of water reservations and was not addressed in the document. Adaptive management is an important part of CERP implementation and is addressed in separate reports for this project and CERP in general.

Include an explicit discussion of the sources of uncertainty so that progress towards meeting the goals can be evaluated within an adaptive management framework.

A section detailing uncertainty associated with defining predevelopment biotic targets and predicting with-project restoration success was added to Section 6.

A section detailing uncertainty associated with the hydrologic modeling was added to Section 7.

The discussion on the use of wetland attributes or indicators yields no information on what will be measured. The gradient of communities is probably not a measurable indicator. The mosaic, as listed is also difficult to quantify. When using vegetation as an indicator, structural metrics listed (e.g., species composition, cover types, etc.) should be included. Habitat composition can also be measured through the use satellite or aerial remote imagery.

A subsection was added to Section 6 detailing the vegetation monitoring program that has been established for Picayune Strand, the salt marsh south of Picayune Strand, and surrounding reference areas.

Linkages between Hydrology and Valued Ecosystem Components

Linkages between hydrologic features (flows, hydro-periods, salinity, etc.) and ecological indicators need to be fully documented to support the inferences and assumptions.

Text, tables and figures were added to the inland plant community discussion in Section 4 that provide this linkage for the inland valued ecosystem component.

Section 5, the estuarine section, now contains a much more detailed description of the linkage between flows, salinity levels and valued ecosystem components.

Section 5 describes valued ecosystem components but provides no information on level or salinity requirements, nor does it reference where this information may be found.

Appendix A provides some data on water levels required by some plant species, but there is no explanation (or reference cited) that describes where the numbers come from. The reader is left to wonder: are the numbers in Table 3 and Table A-1 arbitrary?

Table 3 has been removed and replaced with a table that describes the water levels used in the modeling. This new table is consistent with Table A-1.

Terrestrial Linkages

There is lack of agreement between Tables 3 and 4 and Figure 7. There needs to be a consistent use of terminology if the vegetation communities are used as indicators.

Table 3 was removed and replace with tables showing plant community acreages for each of the MIKE SHE conditions used when evaluating this project: pre-drainage, existing, future without-project, and future with-project (restoration).

Incorporate supporting figures and tables from wetland community studies used to establish reservations into the document. The documentation of these linkages will provide an answer to the overriding question: "What is the pattern of ecological succession in these wetland communities."

Text and figures were added to Section 4 that explain the pattern of ecological succession in these wetland communities and how succession models were applied to Picayune Strand restoration. The discussion clearly documents linkages between hydrologic conditions and plant communities.

The combination of the hydrology and the wetland vegetation under the expected environmental conditions should lead to the re-introduction of the faunal indicators (e.g., amphibians, fish, and avian species) that are indigenous to this region. However, the data and the supporting literature need to be provided to support these conclusions.

This level of information is not yet available for the region.

Wading birds are listed as key indicators as derived from the Big Cypress Regional Ecosystem Conceptual Ecological Model. However, in the listing of indicators no metrics were listed that could be used to effectively measure the success of restoring these valued ecosystem components. Hydrologic indicators (e.g., recession rate, hydro-period, water depth, etc.) can be used as measures of successful wetland restoration, particularly for the aquatic faunal component of the ecosystem. Crayfish can be used to assess relative impacts of hydrologic scenerios.

Specific hydrologic indicators for wading birds in the region have not been developed.

Estuarine Linkages

Although nekton and oysters are described in Section 5, there is no analysis provided that indicates what the salinity requirements are for these species. The salinity values given in the text are unsubstantiated, and again, there is no reference as to where the information might be found.

An analysis is now provided in Section 5 detailing the salinity requirements for nekton and oysters.

No model predictions were included of ecological changes for the estuarine portions of the system. Water reservation estimates for the estuarine portion of the system were not based on documented ecological targets nor did they address parameter variability and uncertainty. Both targets and uncertainty estimates will be needed to provide defensible forecasts of natural cycles of freshwater and concomitant salinity regimes to all the associated estuaries.

Model predictions for the estuarine system are now discussed in Section 5.

Include biological justification for salinity targets for oysters, fish, birds and other wildlife in the estuarine portion of the project. Detail the effects the project will have on the estuarine valued ecosystem components.

Biological justification is now provided in Section 5 for salinity targets.

More details on the flow-salinity relationships are provided in Savarese et al. (2004) and should be incorporated into the document.

The information from Savarese et al. (2004), as well as information from other publications on flow-salinity relationships, has been incorporated into Section 5.

Rubec et al. (2006) provides a model of habitat suitability that identifies salinity ranges for fish life stages in the Rookery Bay and Fakahatchee Bays.

This specific model was not used to determine water reservations.

The salinity-flow relationship is important information, but there is no information on the salinity gradients downstream in the estuary or how they might be altered. Subsequent to the workshop, a document entitled "Assessment of Salinities and Bio-Abundance Resulting from Runoff into Faka Union Bay for Picayune Strand Restoration Project Scenarios" by Wang and Browder (2004) was posted on the web. This document illustrates the modeled relationships developed for runoff and salinity, and hydrodynamics and salinity. Information from this document should be incorporated.

Information from Wang and Browder (2004) has now been incorporated into the document.

A stronger summary of existing studies, especially those that have occurred in the Rookery Bay National Estuarine Research Reserve, should be placed in the report to document the linkage between hydrology and salinity, which is fundamental to the protection of estuarine fish and wildlife. This includes figures and tables that explicitly illustrate what salinity distributions exist and how they might be changed by the project, and relationships between the ecological indicators and salinity.

Information, including figures, have been included from studies conducted by or for the Rookery Bay National Estuarine Research Reserve.

The best ecological indicator for estuary system response to alterations in hydrology is benthic organisms. Oysters are already identified as a valued ecosystem component. So, monitoring oyster populations is important for such attributes as size, density, disease, and percent gravid.

These specific characteristics of oysters are now discussed in Section 5.

The focus of the estuarine portion of the report is on oysters, which is a sound approach given the importance of oysters in this estuary. Data or models need to be presented in the supporting documentation, especially those presented by Volety and Savarese (2001).

Additional data and models, including those presented by Voley and Savarese (2001), are now presented in Section 5.

Ecological Models

The lack of appropriately referenced ecological models must be addressed. The report would be greatly strengthened by summarizing existing ecological models and implications for linking hydrology and biological responses. A reference should be made, as appropriate, to the wide range of available models for both valued ecosystem components as well as supporting prey species including the following models:

- ***Models developed in support of CERP for oysters, wading birds, crayfish, fish, alligators and crocodiles***

- ***A graphic linking hydrology and fire to ecological succession of terrestrial vegetative communities over a wide range of time scales was presented at the meetings (Duever et al. 1986, Lockwood et al. 2003) and, along with explanatory text, should be included in the document.***

This figure, along with others, and explanatory text has been added to Section 5 and 4, respectively.

- ***Spatially explicit species index (SESI) models developed for the Greater for use with the Across Trophic Level System Simulation (ATLSS)***

- ***Habitat suitability indices developed by SFWMD for evaluating water management alternatives.***

- ***USGS Tides and Inflows in the Mangrove Ecotone (TIME) Model***

- ***Modeling effort of oyster response to freshwater inflow and salinity changes in Texas developed by Eileen Hofmann and Eric Powell (Dekshenieks et al. 2000, Hofmann et al. 1994, Hofmann and Powell 1998, Powell et al. 1996, Powell et al. 2003, Powell et al. 1994)***

- ***Empirical statistical models can be used to relate salinity to biological responses such as models developed by Montagnafor identifying optimal salinity ranges for benthos in general (Montagna et al. 2002) and a variety of shellfish species including oysters in southwest Florida (Montagna et al. 2008)***

Unless indicated above, this information was not included in the revised report. It goes beyond the scope of this water reservations technical document.

Undesirable Plant Species

The elimination of the existing, undesirable vegetation, specifically the tremendous acreage of cabbage palms (Sabal palmetto) is needed for restoration of desired plant communities. The report does not address this issue. Simply getting the "water right" would be insufficient to restore that part of the system without and explicit discussion of the types of intervention that are planned to accelerate the process.

Text discussing the nuisance plant control is incorporated into the uncertainty discussion that was added to Section 6.

Water Quality

Water quality has not been addressed in sufficient detail within the terrestrial system. Potential nutrient enrichment of the surficial-aquifer within the Northern Golden Gate Estates resulting from residential development could seep/flow nutrients into Picayune Strand. Nutrients can potentially increase from decaying terrestrial vegetation resulting from inundation.

This information is not necessary to establish the water reservation, which identifies quantities of water, not quality.

Water quality has not been addressed in sufficient detail within the estuarine system. Spatial profiles of salinity, temperature, dissolved oxygen, and pH over appropriate spatial and temporal scales need to be determined for the estuarine system. Measures of chlorophyll and nutrients are also important to obtain a complete view of water quality indicator changes, but these might be measured on different scales than salinity and temperature. The Rookery Bay Estuarine Reserve's more than 20 years of monitoring data should be leveraged and used to establish baselines for temperature, dissolved oxygen, nutrients and salinity.

This information is not necessary to establish the water reservation, which addresses quantities of water, not quality.

The water quality that affects oysters must also be monitored.

This information is not necessary to establish the water reservation, which addresses quantities of water, not quality.

Data Discussion and Display

Section 8 should be revised with fewer figures, choosing one or two to illustrate an important point and with more explanatory text for each figure.

This section was broken into two sections and almost completely redone to better illustrate the analyses performed to determine water to be reserved for the protection of fish and wildlife.

Alternative approaches should be explored for displaying the data that would include the incorporation of "existing conditions" as one of the options to illustrate how significant a change the Picayune Strand Restoration Project will make to the critical hydrological attributes that are responsible for altering and shaping the ecosystem.

Existing (2000 without-project) conditions were added to the volume probability curves that are still be used in the chapter. Also, two additional figures have been added. These figures compare the volumes of surface and groundwater inflow into the Picayune Strand Restoration Project under the 2000 without- and 2000 with-project conditions.

Section 8 should clearly delineate the hydrologic findings regarding the sufficiency of the proposed water reservation for both the terrestrial and estuarine components of the system. Specific attention should be given to the uncertainties in the calculation relative to setting a defensible target as well as recognizing that there are uncertainty bounds around the "with project" and "target" model projections. Given these uncertainties the panel recommends a conservative, risk averse approach be taken that entails reserving all the water possible.

Section 8 says nothing about fish and wildlife, and certainly no objective criteria to justify a target. There is reference to vegetation, which appears to be the only justification. Section 8 only provides simulations compared to some target that is not justified.

Section 8 was split into two sections. The following text was added/expanded in Section 9:

> *Based on an analysis of the information presented in this document, while the project will improve the hydrology within the inland 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 volume of water in the with-project simulations shown on Figures 69 through 77 is necessary for the protection of fish and wildlife and will be protected under state rule.*
>
> *The project is effective in redistributing the flows across the southern boundary of the Picayune Strand Restoration Area 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.*

The differences between pre-drainage conditions (i.e., the target), current conditions, and projected conditions with the project are not adequately described in the document. The 13-year simulation may, or may not adequately address the seasonal and annual hydrologic variability. A more comprehensive analysis of the seasonal and annual variability during the 13 years for both stream flow and rainfall. The current volume-probability curves could be supplemented with a second set of graphics illustrating the cumulative frequency distribution, by year for average daily inflows during early and late wet season, early and late dry season, and the total year.

A more detailed discussion of why the 13-year period of record was chosen has been added to Section 7. This section includes figures of annual variability of rainfall versus stream flow in the watershed and annual rainfall graphs of areas within or near the watershed.

Plant community acreages for the different conditions are included in Section 4.

The water identified appears to be technically supported, but a more extensive database is required to support the linkage between the terrestrial and estuarine ecosystems.

An extensive database is not yet available. The water reservations will be revisited every 5 years to incorporate any new data gathered.

Additional technical information to support the studies includes an assessment of annual variability in streamflow/rainfall, and an assessment of groundwater level trends in the Northern Golden Gates Estates area. The groundwater levels should be used to determine if there are downward trends attributed to allocated withdrawals. A downward trend may indicate that the model prediction over a 13-year period may not have appropriately identified post 2000 groundwater flowing into Picayune Strand.

Texts and figures have been added showing surface water and groundwater inflows and outflows for the with- and without-project conditions.

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