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BISCAYNE BAY COASTAL WETLANDS FINAL INTEGRATED PROJECT IMPLEMENTATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

PROPOSAL FOR THE BISCAYNE BAY COASTAL WETLANDS PHASE 1 PROJECT

VOLUME 3 OF 6

SEPTEMBER 25, 2012.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

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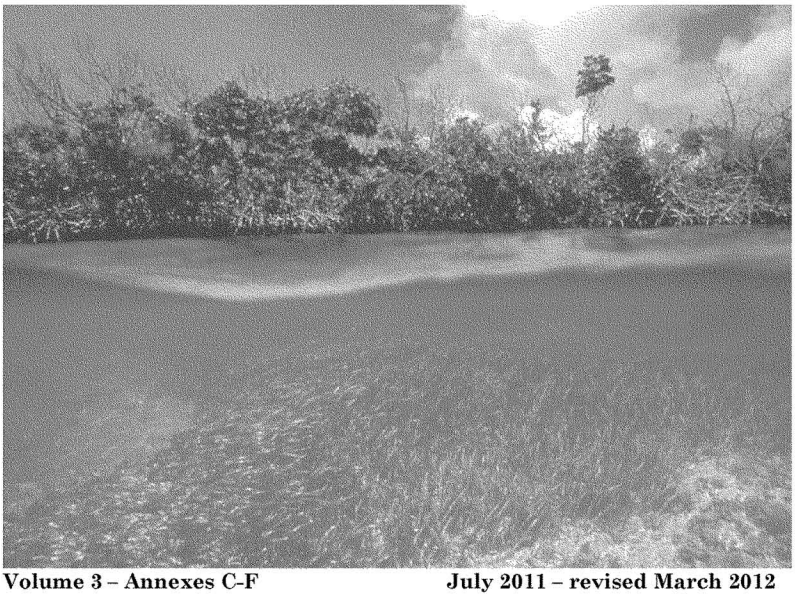
CENTRAL AND SOUTHERN FLORIDA PROJECT
COMPREHENSIVE EVERGLADES RESTORATION PLAN
BISCAYNE BAY COASTAL WETLANDS PHASE 1

FINAL INTEGRATED
PROJECT IMPLEMENTATION REPORT AND
ENVIRONMENTAL IMPACT STATEMENT



Volume 3 – Annexes C-F **July 2011 – revised March 2012**

US Army Corps of Engineers ®

U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

SOUTH FLORIDA WATER
MANAGEMENT DISTRICT

(1)

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CENTRAL AND SOUTHERN FLORIDA PROJECT
BISCAYNE BAY COASTAL WETLANDS
PHASE 1

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SOUTH FLORIDA WATER
MANAGEMENT DISTRICT

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C.0 ANALYSES REQUIRED BY THE WATER RESOURCES DEVELOPMENT ACT AND STATE LAW SAVINGS CLAUSE ANALYSES

This document includes the legal basis and the analyses performed to fulfill the requirements of WRDA 2000 (***Section C.1***) and state law (***Section C.2***) for the Biscayne Bay Coastal Wetlands project Phase 1. It also includes the model calibration and verification reports for the model applied for these analyses (***Section C.3***).

C.1 Analyses Required by the Water Resources Development Act

C.1.1 Legal Basis Background

Federal law and regulation implementing the Comprehensive Everglades Restoration Plan (CERP) require Project Implementation Reports (PIRs) to address certain assurances as part of the project recommendation for approval and implementation. This section addresses provisions of Section 601(h) of the Water Resources Development Act (WRDA) of 2000 and the Programmatic Regulations for the (33 Code of Federal Regulations [CFR] Part 385) for Savings Clause requirements and Project-Specific Assurances.

The following sections describe the specific requirements from WRDA 2000 and the CERP Programmatic Regulations and present the methods and results of the analyses necessary to meet those requirements.

C.1.1.1 Water Resources Development Act 2000

Congress enacted WRDA 2000, Title VI, Section 601, which approved the CERP "as a framework for modifications and operational changes to the Central and Southern Florida Flood (C&SF) Control project that are needed to restore, preserve, and protect the south Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection." Section 601(h) of WRDA 2000, entitled "Assurance of Project Benefits" establishes project-specific assurances to be addressed as part of CERP implementation.

Section 601 (h) (1) of WRDA 2000 provides:

> *IN GENERAL - The overarching objective of the Plan is the restoration, preservation, and protection of the South Florida Ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The Plan shall be implemented to ensure the protection of water quality in, the reduction of the loss of fresh water from, the improvement of the environment of the South Florida Ecosystem and to*

achieve and maintain the benefits to the natural system and human environment described in the Plan, and required pursuant to this section, for as long as the project is authorized.

In this document, ***Sections C.1.1.1 and C.1.1.2*** discuss the Savings Clause and project assurances required by WRDA 2000 to be addressed in each PIR. ***Section C.1.2*** lists the Savings Clause and project assurances provisions of the Comprehensive Everglades Restoration Programmatic Regulations, which provide supplemental information for implementing the WRDA 2000. ***Section C.1.3*** discusses the role of the Draft Guidance Memoranda in the analyses.

C.1.1.1.1 Savings Clause Analyses

The Savings Clause analysis was required by the WRDA 2000 as a means to protect users of legal sources of water supply and flood protection that were in place at the time of enactment. Briefly, Section 601(h)(5) of WRDA 2000, entitled Savings Clause, requires an analysis of each project's effects on legal sources of water supply that were in existence on the date of enactment of WRDA 2000 (*i.e.*, December 2000), and effects on levels of service for flood protection in existence on the date of enactment of WRDA 2000. Section 601(h)(5) states:

(A) NO ELIMINATION OR TRANSFER.–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, including those for –

(i) an agricultural or urban water supply;
(ii) allocation or entitlement to the Seminole Indian Tribe of Florida under section 7 of the Seminole Indian Land Claims Settlement Act of 1987 (25 U.S.C. 1772e);
(iii) the Miccosukee Tribe of Indians of Florida;
(iv) water supply for Everglades National Park; or
(v) water supply for fish and wildlife.

(B) MAINTENANCE OF FLOOD PROTECTION.–Implementation of the Plan shall not reduce levels of service for flood protection that are–

(i) in existence on the date of enactment of this Act; and
(ii) in accordance with applicable law.

(C) NO EFFECT ON TRIBAL COMPACT.–Nothing in this section amends, alters, prevents, or otherwise abrogates rights of the Seminole Indian Tribe of Florida under the compact among the Seminole Tribe of

Florida, the State, and the South Florida Water Management District, defining the scope and use of water rights of the Seminole Tribe of Florida, as codified in section 7 of the Seminole Indian Land Claims Act of 1987 (25 U.S.C. 1772e).

C.1.1.1.2 Project-Specific Assurances

Subsection 601(h)(4) of WRDA 2000, entitled Project-Specific Assurances, contains the following requirements for PIRs:

(A) PROJECT IMPLEMENTATION REPORTS. –
(i) IN GENERAL. – The Secretary (of the Army) and the non-Federal sponsor shall develop project implementation reports in accordance with Section 10.3.1 of the Plan.
(ii) COORDINATION. – In developing a project implementation report, the Secretary and the non-Federal sponsor shall coordinate with appropriate Federal, State, tribal, and local governments.
(iii) REQUIREMENTS. – A project implementation report shall –
(I) be consistent with the Plan and the programmatic regulations promulgated under paragraph (3);
(II) describe how each of the requirements stated in paragraph (3)(B)[sic] is satisfied;
(III) comply with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.);
(IV) identify the appropriate quantity, timing, and distribution of water dedicated and managed for the natural system;
(V) identify the amount of water to be reserved or allocated for the natural system necessary to implement under State law, subclauses (IV) and (VI);
(VI) comply with applicable water quality standards and applicable water quality permitting requirements under subsection (b)(2)(A)(ii);
(VII) be based on the best available science; and
(VIII) include an analysis concerning the cost-effectiveness and engineering feasibility of the project.

C.1.1.2 Programmatic Regulations (33 CODE OF FEDERAL REGULATIONS PART 385)

The following summary of requirements of the Programmatic Regulations provides supplemental information for implementing the Savings Clause and Project Specific Assurances of WRDA 2000.

C.1.1.2.1 Pre-Comprehensive Everglades Restoration Plan Baseline

Section 385.35(a) of the Programmatic Regulations requires the development of a pre-CERP baseline to aid the U.S. Army Corps of Engineers (USACE) and the

South Florida Water Management District (SFWMD) when implementing the Savings Clause to determine if existing legal sources of water would be eliminated or transferred and to demonstrate that the levels of service of flood protection in existence on the date of enactment of WRDA 2000 and in accordance with applicable law would not be reduced by implementation of a project.

The final draft Pre-CERP baseline document was issued by USACE and the SFWMD in April 2005. In accordance with the Programmatic Regulations, the final draft pre-CERP baseline document would be submitted to the Secretary of the Army for approval and concurrence by the Secretary of the Interior and the Governor of the State of Florida.

C.1.1.2.2 Savings Clause-Flood Protection

Section 385.37 of the Programmatic Regulations requires that PIRs include an analysis of the project's impacts on levels of service for flood protection that existed on the date of enactment of WRDA 2000, December 2000, and in accordance with applicable law. These conditions would be included in the pre-CERP baseline (***Section C.1.2.1***).

C.1.1.2.3 Savings Clause-Elimination or Transfer of Existing Legal Sources of Water

Section 385.36 of the Programmatic Regulations requires that PIRs determine if existing legal sources of water are to be eliminated or transferred as a result of project implementation. If a project is expected to result in an elimination or transfer of an existing legal source of water, the PIR shall include an implementation plan that ensures a new source of water of comparable quantity and quality is available to replace the source that is being transferred or eliminated.

C.1.1.2.4 Project Assurances-Identification of Water for the Natural System

Section 385.35(b) of the Programmatic Regulations requires that each PIR identify the quantity, timing and distribution of water to be dedicated and managed for the natural system necessary to meet the restoration goals of CERP. This evaluation considers the availability of the Pre-CERP baseline water and previously reserved water and whether improvements in water quality are necessary. The existing conditions for this project do not include any previously reserved water within the project area.

C.1.1.2.5 Project Assurances-Identification of Water for Other Water-Related Needs

Section 385.35(b) of the Programmatic Regulations requires that procedures be developed for identifying water generated by CERP for use in the human

environment and that the quantity, timing, and distribution of water for other water-related needs be identified in PIRs.

C.1.1.3 Guidance Memoranda

The Programmatic Regulations require the development of six Guidance Memoranda jointly by USACE and SFWMD. Draft Guidance Memoranda dated July 2007 (http://www.evergladesplan.org/pm/program_docs/cerp-guidance-memo.aspx) provided additional information necessary to complete the analyses initially described in WRDA 2000. Because the Guidance Memoranda are still in draft form, the Programmatic Regulations allow for PIRs to be completed prior to their approval to use any method that is deemed appropriate and consistent with applicable law, policy and regulations.

Section C.2.1 of this report contains a description of the assumptions, concepts and methodologies based on the procedures and guidance described in draft Programmatic Regulations Guidance Memorandum #3, Savings Clause Requirements, at the time this PIR was being developed for identifying project effects on:

1. Existing legal sources of water as of the date of enactment of WRDA 2000 on the user categories listed in Section 601(h)(5)(A) .
2. Levels of service for flood protection as required by WRDA 2000.

Section C.2.3 of this report contains a description of the assumptions, concepts and methodologies for identifying water made available by the project for the natural system and for other water related needs of the region. The methodologies are based on the procedures and guidance described in draft Programmatic Regulations Guidance Memorandum #4, Identifying Water Made Available for the Natural System and for Other Water Related Needs, available at the time this PIR was being developed.

Section C.3 of this report summarizes the results of these analyses, including identifying the amount of water made available by the project for the natural system to be reserved or allocated by the State of Florida and the amount of water made available for other water-related needs.

C.1.2 METHODS

The goal of the Biscayne Bay Coastal Wetlands project is to restore or enhance freshwater wetlands, tidal wetlands and nearshore bay habitat in the area of the southeastern watershed of Biscayne Bay. Objectives include:

- Re-establish productive nursery habitat along the shoreline.
- Redistribute freshwater flow to minimize point source discharges into the Bay to improve freshwater and estuarine habitat.
- Restore and improve quantity, quality, timing and distribution of freshwater to the Biscayne Bay, including BNP.
- Preserve and restore spatial extent of natural coastal glades habitat.
- Re-establish connectivity between Biscayne Bay Coastal Wetlands, C-111 Basin, Model Land Basin and other adjacent basins.

C.1.2.1 Key Project Assumptions

The process of identifying water is integral to the specific assurances of Section 601 of WRDA 2000, and ultimately to ensuring that the overarching objectives of the CERP, namely restoration, preservation and protection of the south Florida ecosystem while providing for other water-related needs of the region, including flood protection and water supply. It is assumed that both project objectives and WRDA 2000 requirements are compatible, and that the final design of the project would achieve all objectives.

Project Extent. These analyses and results apply only to Phase 1 of the selected plan for Biscayne Bay Coastal Wetlands project. The Biscayne Bay Coastal Wetlands project Phase 1 is composed of three components: Deering Estate, Cutler Flow Way and L-31E Flow Redistribution.

Absence of Regional or System-wide Effects. Because the Biscayne Bay Coastal Wetlands project Phase 1 is located at the coastline, and does not alter regional operations or water deliveries to coastal structures, it is assumed to produce no system-wide effects. Therefore, only project-level effects were evaluated for elimination or transfer of legal sources, effects on level of service for flood protection, and identification of water made available.

Basins to be Evaluated. Draft Guidance Memorandum #4 requires the identification of the inflow basins that would be affected by a project. Drainage basins located in southeastern Miami-Dade County that would be affected by the project as defined by the SFWMD's ArcHydro Enhanced Database, include C-100, C-1, Goulds, C-102, HARB, C-103 and North Canal.

C.1.2.1.1 Information Used for All Analyses: Pre- Comprehensive Everglades Restoration Plan Baseline, Existing Conditions Baseline and Initial Operating Regime, Next Added Increment, Next Added Increment Baseline

The Savings Clause and project assurances analyses require consideration of five different sets of assumptions at three different points in time including the date of enactment of WRDA 2000, existing conditions at the time of adoption of the Biscayne Bay Coastal Wetlands Selected Plan, and 2050 future conditions:

- The Pre-CERP baseline represents the conditions existing on the date of enactment of WRDA, December 2000;
- The Existing Conditions Baseline (ECB) represents conditions in 2007;
- Initial Operating Regime represents the same conditions as the existing conditions baseline but with the addition of the project features and revised supplemental irrigation and consumptive uses expected in 2010. The initial operating regime represents conditions expected upon initial operation of the project based on projects and features in existence today. For purposes of this project, no additional consumptive uses are assumed to affect water deliveries to the coastal structures;
- The Next Added Increment (NAI) Baseline condition represents the 2050 conditions with no CERP projects included;
- The NAI condition represents the 2050 conditions with the project in place.

Draft Guidance Memorandum #3 and Draft Guidance Memorandum #4 indicate that analyses of the above conditions should be based on hydrological simulations using something like the South Florida Water Management Model (SFWMM). However, due to uncertainty about how accurately the SFWMM simulates both historical and future expected flows in the project area, this PIR does not use SFWMM output, but employs historical data from the period 1986-2007 to develop base, with-project and future conditions. In addition, benefits of the project were assessed using the historical flows. The Biscayne Bay Coastal Wetlands project diverts a portion of the available water from canals at the coast. The historical record of flows from coastal canals into Biscayne Bay is available. The SFWMD maintains a database of the flow records (DBHYDRO) at the coastal canals. The period of flow record varies depending on the monitored site, but reliable records for all sites begin in 1986.

The historical record of flows approximate pre-CERP as the period of record that includes the years 1986 through 2000. The historical record of flows approximate the existing condition since overall, flows during this historical period have remained relatively stable, and do not exhibit significant increases or decreases over time except as a result of natural climatic cycles (***Figure C-1***). Since canal flows within the project area have not declined since the year 2000, the pre-CERP baseline quantities of water are considered to be available. The historical record of flows is assumed to approximate the year 2050 condition as they are not expected to change significantly. This is because any increased demand from the Biscayne Aquifer that may affect canal flows must be offset by other sources such as wastewater reuse or water from the deeper Floridan Aquifer as required by the consumptive use permit issued in 2007. Therefore, historical record of flows from 1986 to 2007 is used for the existing conditions, initial operating regime and the NAI baseline and the NAI. For the pre-CERP baseline, the historical record of flows from 1986 to 2000 is used.

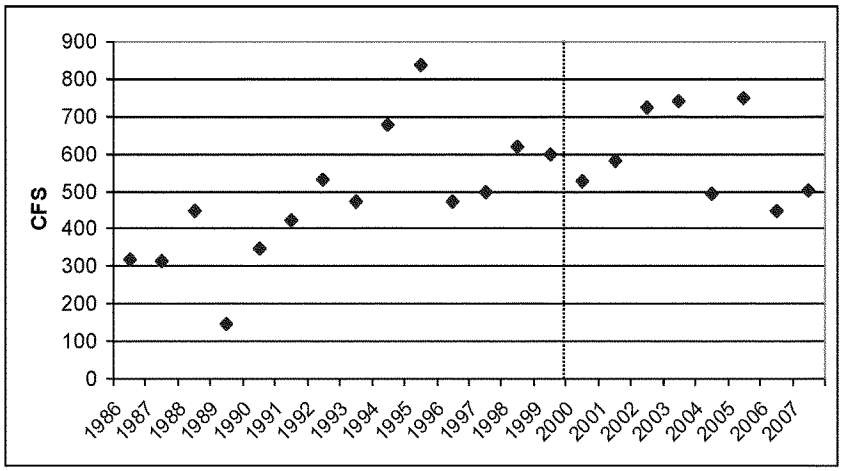


FIGURE C-1: MEAN DAILY TOTAL FLOW (CUBIC FEET PER SECOND) BY YEAR FROM CANALS WITHIN THE PROJECT AREA (C-100, C-1, C-102, MILITARY, C-103) INTO BISCAYNE BAY

Note: The Dashed Line Indicates the Year of Water Resources Development Act of 2000

For purposes of analyzing potential flood impacts, the existing water levels were assumed in the model simulations. Water levels are monitored extensively within the project area, and are maintained within a narrow range by operation of the primary drainage system to provide both flood protection, and protection of the shallow aquifer from saltwater intrusion. The operational criteria that maintain water stage elevations within the canals will remain the same as exists for the Biscayne Bay Coastal Wetlands project Phase 1, including seasonal operations.

C.1.2.1.2 Volume Probability Curves

For purposes of identifying the volume of water for the natural system made available by the project, volume probability curves were produced depicting the range of daily quantities (mean daily flow) of water delivered to the natural system areas and coastal estuary. This period (1986-2007) includes sufficient climatological variability (including natural fluctuations of water) to be viewed as representative of long term hydrologic conditions in the region. Canal flow is estimated by the SFWMD using algorithms that calculate flow through each structure using static input data that describe the physical characteristics of the water control structure, and dynamic data that represent the structure's operational status.

The daily quantity of canal flow from the historical record was compared to the project's physical ability to utilize and divert the available flow. Each day the quantity of water that discharged from a particular canal was compared with specific project facilities that could use the water from the canal. It was assumed that water flow up to the capacity of the facility could be diverted out of the canal. For example, if the facility is a 400 cubic feet per second (cfs) pump station, and 400 cfs of water was discharged, then all of the 400 cfs was considered diverted by the pump station rather than being discharged directly into Biscayne Bay. If less than 400 cfs was discharged, then all of the water was considered diverted. If more than 400 cfs was discharged, then only 400 cfs was considered diverted, and the rest of the water would be discharged into Biscayne Bay from the canal. The daily quantities for all the canals within the project area were summed in a spreadsheet by year. Two curves were produced. One curve indicates the total quantity discharged from the canals, and the other indicates the quantity diverted or made available by the project. Probability curves indicate the probability (percentage of time equaled or exceeded, on the x-axis) that a certain quantity of water is available as a function of historical canal flows. Once sorted, the values are ranked from highest to lowest.

C.1.2.1.3 Assumptions Associated with Operations

Currently, water levels within the project area are managed primarily by operation of gated coastal outfalls of the canals. Operation of the gates by the SFWMD follows criteria that maintain optimal water levels at the coast for flood protection and prevention of saltwater intrusion into the aquifer. Details of the criteria are described in ***Annex D, Project Operating Manual.*** The Biscayne Bay Coastal Wetlands project Phase 1 does not alter the current operating criteria of the existing coastal outfall structures.

C.1.2.2 Savings Clause–Flood Protection and Elimination or Transfer of Existing Legal Sources-Project Level Effects

Each geographic component was analyzed separately for the analysis of potential flooding impacts and described below. Draft guidance in the CERP Guidance Memorandum #3, Section 2.10, Model Selection for Savings Clause Analyses, states

"Since regional models such as the SFWMM consist of large grid cells, only a general indication of flood protection can be determined through regional analysis. For that reason, smaller scale integrated groundwater and surface water models may be necessary for specific analyses of levels of service for flood protection and the PDT should use such models when available."

The Biscayne Bay Coastal Wetlands Project Development Team has followed that guidance and has used a combination of modeling tools (the HEC-RAS,

FESWMS and MODBRANCH) to analyze the level of service for flood protection for each project component described in the following ***C.2.2*** subsections. A formal analysis of potential elimination or transfer of existing legal sources was deemed unnecessary (***Subsection C.2.2.4***).

C.1.2.2.1 Deering Estate Flood Protection Analysis

The Deering Estate component includes two geographic areas: the Powers Addition Parcel a ten-acre parcel at the water source, and the Deering Estate proper adjacent to Biscayne Bay. One-dimensional hydraulic modeling using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software was completed for the discharge pipe from the pump station surge chamber, and the Cutler Drain through the Deering Estate, Powers Addition Parcel and neighboring coastal wetlands to determine head losses and velocities, assess the potential for scour between the spreader structure and the Cutler Drain, and to determine the potential seepage losses from the base of the Cutler Drain, given its high permeability. HEC-RAS Version 3.1.3 is a hydraulic model developed by USACE (2005). This model performs one-dimensional steady- and unsteady-state river hydraulics flow calculations.

C.1.2.2.2 Cutler Flow Way Flood Protection Analysis

Two-dimensional depth-averaged flow modeling of the Cutler Wetlands C-1 Flow Way was completed to evaluate hydraulic flow through the rehydration area and support design of the discharge spreader canal system (URS, 2008). The two-dimensional depth-averaged hydrodynamic Finite Element Surface Water Modeling System (FESWMS) was used to model the rehydration area (Froelich, 1989). The FESWMS modeling was performed within the Surface Water Modeling System (SMS) software interface (EMS-I).

Analytical modeling was conducted to evaluate the flow of freshwater from the spreader canal through the rehydration area to Biscayne Bay. These modeling results were used to evaluate flow distribution, head losses through the target rehydration area and subsequent tailwater conditions at the discharge conveyance channel outlet, and peak water elevations and flow velocities at key points in the rehydration area. The primary means of delivering and distributing water within the rehydration area is the discharge spreader canal and interconnected downstream canals. The modeling analysis consisted of iteratively adjusting the canal alignments, cross-section geometry and bottom elevations until the target objectives were optimized. The modeling analysis is described as iterative because the results from one system configuration were analyzed and used to adjust the design in the next model simulation.

C.1.2.2.3 L-31E Flow Way Flood Protection Analysis

The L-31E component includes four geographic areas:

1) The segment of L-31E between C-102 and the Military Canal (northern segment)
2) The segment between the Military Canal and C-103 (southern segment)
3) The wetland to the northeast of the intersection of L-31E and C-102
4) An impounded wetland west of L-31E between C-103 and North Canal

Each of these segments contains one or more pump stations, and have conveyance features (culverts) through the levee that allow flow from the L-31E Borrow Canal into the saltwater wetlands to the east and eventually into Biscayne Bay. The northern and southern segments of the L-31E were examined in this analysis to determine possible impact to the level of service for flood protection. The HEC-RAS model set-up for the L-31E Flow Way Flood Protection Analysis followed the earlier analysis performed by URS by utilizing the canal invert elevations, bottom width, and side slopes; the culvert invert elevations, diameter, and length; the top of levee elevations; and the Manning's n values determined by URS and documented in their report "*L-31E Culverts Biscayne Bay Coastal Wetlands – Phase 1*" dated June 1, 2007. This HEC-RAS analysis only focused on the existing and proposed culverts and pump operations in the two sections of L-31E to determine the Level of Service for Flood Protection.

Separate HEC-RAS models were constructed for the northern and southern segments to examine water levels along each reach of the L-31E Canal to determine if the level of service for flood protection is diminished or eliminated due to increased water levels. LOSFP was determined to be diminished or eliminated only if the expected water levels would overtop the existing levees on each side of the L-31E Canal. One-dimensional hydraulic analysis was performed for each reach (with associated pumps and culverts) using HEC-RAS Version 3.1.3 (USACE, 2005). L-31E components can be found in the main document in ***Figure 6-4*** (Section 6, page 6-8) for the northern segment and ***Figure 6-5*** (***Section 6***, page 6-9) for the southern segment.

The L-31E Canal was modeled with:

- An invert elevation of -14.0 feet (North American Vertical Datum [NAVD] 88)
- Bottom width of 15 feet
- Side slopes of 1:1 (H:V)
- Manning's n of 0.03 for a clean, straight channel with no rifts or deep pools

The ground surface elevation near the L-31E Canal ranges from about 1.0 feet to 2.2 feet (NAVD88) according to the State's Expedited Construction program analysis "*L-31E Culverts Biscayne Bay Coastal Wetlands–Phase 1*" conducted by URS. From the same report, the elevation of L-31E was modeled with a top of levee of 6.0 feet to 6.3 feet (NAVD88) for the northern segment and 6.5 feet to 7.0 feet (NAVD88) for the southern segment. The ranges listed are the current top of levee elevations for the northern and southern segments of the areas analyzed. No changes or modifications to the top of levee are being considered, so no incremental analysis was done to examine other top of levee elevations than currently exist.

To perform a sensitivity analysis, the starting water surface elevation for Biscayne Bay and the entrance loss coefficients for the culverts (to account for the manatee barriers) were modified. The entrance loss coefficient accounts for the head loss due to friction that occurs as flow enters the culvert. This head loss is increased due to the installation of the manatee barriers which restrict flow into the culverts. An entrance loss coefficient of 0.5 was determined to be an average value for the culverts and 1.0 is the maximum value. Since using both values satisfied the LOSFP (the levees were not overtopped), no more entrance loss coefficients were examined. ***Table C-1*** shows the initial water surface elevation and entrance loss coefficients assumed for the four different model runs. Each of the four runs was made for the northern and southern segments of L-31E.

TABLE C-1: INITIAL WATER SURFACE ELEVATIONS FOR BISCAYNE BAY AND CULVERT ENTRANCE LOSS COEFFICIENTS USED FOR THE L-31E BORROW CANAL MODEL RUNS

Run	Biscayne Bay Initial WSE (feet, NAVD88)	Culvert Entrance Loss Coefficient
1	0.5	0.5
2	0.5	1.0
3	1.0	0.5
4	1.0	1.0

*WSE – Water Surface Elevation

This HEC-RAS analysis built upon the analysis performed by URS and documented in "*L-31E Culverts Biscayne Bay Coastal Wetlands – Phase 1*" dated June 1, 2007. This analysis was to determine changes, if any, in water surface elevations that were due to the installation of additional culverts through the east side of the L-31E Canal. Therefore, sensitivity analysis was performed on the entrance loss of the culverts as well as the water surface elevation in Biscayne Bay. Water Surface Elevation's (WSE's) of 0.5 feet and 1.0 feet

(NAVD88) were chosen as good representations of an average high and extreme high tide water surface elevations for the Biscayne Bay Coastal Wetlands, respectively. High tide elevations were used in the HEC-RAS modeling of L-31E in order to determine a worst case scenario for operating the existing and proposed culverts through the levee to the Bay. These values were estimated from Virginia Key (as well as other sites in or near Biscayne Bay) from the National Oceanic and Atmospheric Administration (NOAA) website and it was agreed by the team that 0.5 feet (NAVD88) was a good high tide elevation and 1.0 feet (NAVD88) was a good extreme high tide elevation.

The WSE of 0.6 feet (NAVD88) was chosen as the initial water surface elevation for both sections of the L-31E Canal to follow the analysis presented in the State Expedited Construction report entitled "*L-31E Culverts Biscayne Bay Coastal Wetlands – Phase 1*" conducted by URS. The State Expedited Construction program and URS analyzed a 21-year period of record for the coastal structures S-21A (C-102), S-20G (Military Canal), and S-20F (C-103) and determined that the headwater data for the structures indicated that the typical high-range stage was approximately 0.6 feet (NAVD88). The report also states that:

> "*...it appears reasonable that the wet year results could be attained with greater frequency maintaining the canal stages at + 0.6 feet NAVD...*"

The L-31E starting WSE of 0.6 feet and Biscayne Bay starting WSE's of 0.5 feet and 1.0 feet are independent of each other since L-31E stages can be controlled by operations and Biscayne Bay WSE's represent a high in extreme high tide. It should be noted that all of the culverts will have flap gates on the downstream end of the culverts which would close when the Biscayne Bay stages exceed the stage in L-31E.

The number of culverts, length, diameters and invert elevations were taken into account for each reach.

C.1.2.2.3.1 L-31E Northern Segment (C-102 to Military Canal)

The segment of L-31E between C-102 and the Military Canal is about 10,894 feet in length, with five culverts installed through the levee. Two culverts (S-23A and S-23B) would be constructed in advance by the SFWMD. Three additional culverts (S-706A, S-706B, and S-706C) are being proposed under the Biscayne Bay Coastal Wetlands project Phase 1. All culverts would be 36-inch corrugated aluminum alloy culverts (Manning's n of 0.012) with manatee barriers on the upstream side (L-31E canal), flap-gates on the downstream side (saltwater wetlands/Biscayne Bay) to prevent flow of saltwater into the L-31E Canal, and have a square edge entrance with a headwall. Manning's n values of 0.012 were used for corrugated aluminum alloy culverts from the information obtained in the URS report in "L-31E Culverts Biscayne Bay Coastal Wetlands – Phase 1"

dated June 1, 2007. On page 6-1 of that report, it states, "A spiral ribbed construction will be used, resulting in a reduction in Manning's n from 0.024 to 0.012." A schematic diagram of the L-31E Northern Segment is shown in ***Figure 6-4*** of ***Section 6*** of the main document on page 6-8. ***Table C-2*** shows the culvert length, culvert invert elevation, and the distance of the culvert centerline from C-102.

TABLE C-2: CULVERT SPECIFICATIONS FOR THE NORTHERN REACH OF THE L-31E BORROW CANAL

Culvert	Length (feet)	Invert Elevation (feet, NAVD88)	Distance from C-102 (feet)
S-23A	45	-2.5	1,097
S-23B	49	-2.6	3,011
S-706A	50	-2.6	4,006
S-706B	50	-2.6	6,063
S-706C	50	-2.6	8,253

A pump station (S-705) for the northern segment will pump 100 cfs from the C-102 Canal southward into the L-31E Borrow Canal when water is available. Water is considered available for redirection in the northern segment when 100 cfs or more is being discharged out the coastal structure S-21A. Analysis of historic (DBHYDRO) database flows shows that 100 cfs is available for redirection from C-102 to the northern segment of the L-31E Canal for a maximum of 132 consecutive days, which could be considered a worst case scenario. The downstream end of this segment (near the Military Canal) was given a boundary condition of 0.6 feet (NAVD88), meaning the downstream WSE was set and kept constant at 0.6 feet while allowing the upstream portion of the canal to stage up. Biscayne Bay was modeled as a large storage area with the only inflows being through the culverts.

C.1.2.2.3.2 L-31E Southern Segment (Military Canal to C-103)

The segment of L-31E between the Military Canal and C-103 is about 7,010 feet in length, and would have three culverts installed through the levee in addition to two existing culverts. Two of the three new culverts (S-23C and S-23D) would be constructed by the SFWMD. Two culverts are existing (Existing North and Existing South), and one culvert (S-708) is proposed under the Biscayne Bay Coastal Wetlands project Phase 1. All culverts would be 36-inch corrugated aluminum alloy culverts (Manning's n of 0.012) with manatee barriers on the upstream side (L-31E Canal), flap-gates on the downstream side (saltwater wetlands/Biscayne Bay) to prevent flow of saltwater into the L-31E Canal, and having a square edge entrance with a headwall. A schematic diagram of the L-31E Southern Segment is shown in ***Figure 6-5*** of Section 6 of the main

document on page 6-9. ***Table C-3*** below shows the culvert length, culvert invert elevation, and the distance of the culvert centerline from C-103.

TABLE C-3: CULVERT SPECIFICATIONS FOR THE SOUTHERN REACH OF THE L-31E BORROW CANAL

Culvert	Length (feet)	Invert Elevation (feet, NAVD88)	Distance from C-103 (feet)
S-708	50	-2.5	4,956
S-23C	50	-2.5	3,884
S-23D	58	-2.7	2,443
Existing North	60	-2.7	1,330
Existing South	60	-2.7	845

A pump station (S-709) for the southern segment will pump 40 cfs from the C-103 Canal northward into the L-31E Borrow Canal when water is available. Water is considered available for redirection in the southern segment when 40 cfs or more is being discharged out the coastal structure S-20F. Analysis of historic data (DBHYDRO) shows that 40 cfs is available for redirection from C-103 to the southern segment of the L-31E Canal for a maximum of 331 consecutive days, which could be considered a worst case scenario. The downstream end of this segment (near the Military Canal) was given a boundary condition of 0.6 feet (NAVD88), meaning the downstream water surface elevation was set and kept constant at 0.6 feet while allowing the upstream portion of the canal to stage up. Biscayne Bay was modeled as a large storage area with the only inflows being through the culverts.

C.1.2.2.3.3 North Canal Impounded Wetlands

Two sources of information were used to evaluate the potential of the project features for the North Canal Impoundment to produce significant and adverse flood level of service differences on adjacent properties. A MODBRANCH model application simulated operation of the facility for a wet, dry and average rainfall year. A second source of information about potential effects on water stage elevation is empirical data from wells located at a Miami-Dade impoundment test site (storm water treatment and detention area), and located just to the north along Military Canal.

The MODBRANCH model is a hybrid model created from two United States Geological Survey (USGS) models. The first model is MODFLOW, which simulates the ground water hydrodynamics. The second model is BRANCH, which simulates the canal hydrodynamics. The MODFLOW and BRANCH models were "coupled" into MODBRANCH by the USGS in 1993 and it was first employed it in south Florida in 1995. Further modifications have been added by

the Jacksonville District to more accurately model the hydraulic and hydrologic processes of South Florida. A short discussion of the capabilities of MODBRANCH follows; for more detail, the reader is referred to "*Calibration and Verification of the MODBRANCH (MB_2006) Numerical Model of South Florida*" (Evans, 2007) (Attachment 1).

Ground water and overland flow are simulated by the MODFLOW part of MODBRANCH. MODFLOW is a pseudo-three-dimensional, finite difference, ground water model. This model requires defining a model "grid" of specified numbers of rows, columns, and layers. The width of each row or column is determined by required resolution in specific areas. The resolution was predominantly determined by the need to accurately locate canals and sub-surface features. In addition to the normal computation of ground water movement, overland flow (via the Kadlec equation) and levees can also be simulated. Levees are represented by the use of the MODFLOW horizontal flow boundary options. The MODFLOW portion of the model is divided vertically into five layers, with the uppermost layer represented overland flow. Within that layer, flow and stage are computed using the Kadlec equation (Attachment 1B); Darcy's equation is used in the four underlying layers.

Canals and water control structures are simulated by the BRANCH part of model. BRANCH is a one-dimensional model to simulate open channel flow and was developed by the USGS. Canal parameters include cross-section, length and leakage coefficient. Water movement between the canal (BRANCH) and aquifers (MODFLOW) is calculated using the canal and ground water stage differences and the leakage coefficient. The leakage coefficient is a function of the canal sediment thickness and its hydraulic conductivity. Unfortunately, this information is not available for all the canals included in the model domain so an alternative method of estimating the leakage coefficient was needed. During the calibration phase of the model development values for the leakage coefficient were developed based on historical flow and stages, with the range of values between 0.00003/sec and 0.00052/sec. In the MODBRANCH model, values of 0.00024 to 0.00048/sec were used. Further discussion can be found in appendix C of the calibration report, included here as Attachment 1C.

MODBRANCH has the capability to operate canal control structures such as pumps, spillways and culverts using extremely complex, time varying rules. These rules can be time-dependant and can have triggers that are absolute or relative triggers. An absolute trigger is one in which the structure operates based on stage or flow at a specific point; a relative trigger is one in which the structure operates based on the difference between two points.

Another unique feature of the USACE version of MODBRANCH is the ability to remove water from a canal segment and add it to the recharge function of

MODFLOW. This allows simulation of direct discharge from a structure onto the top of the ground. This is the function that was used to move water from the canals into the constructed wetland of the project.

MODBRANCH has the ability to use different time steps for the MODFLOW and the BRANCH portions of the model. The computational time step used in both the BRANCH and MODFLOW portions of the model is 1 hour. Using the same time step increases model stability, although computation time is increased. The simulation time is 396 days, which covers an entire year and has an additional 31 days of "spin-up." The total number of time steps is 9504.

Another issue with this application of MODBRANCH is that model does not have the capability of density driven flow. This is a problem where boundaries are determined by ocean water with a higher density than fresh water. To approximate the effects of a boundary with higher salinity, an "effective freshwater head" was computed and assigned via the General Head Boundary option of MODFLOW. This is described in detail in Attachment 1A.

Simulation of the North Canal wetlands requires levees and pumps to move water from canals into the wetland area. This process has been simulated by MODBRANCH in a number of previous studies. Variations of the MODBRANCH model have been used for over a decade to analyze projects in south Florida. Investigations of the hydrology of the 8.5 Square Mile Area (8.5 SMA), Combined Structural and Operation Plan, and the C-111 Spreader Canal are the most significant of the studies using MODBRANCH. Each of these studies required refinement of input data and source code.

The application of the MODBRANCH model to the North Canal Impounded Wetlands required increasing the resolution in the vicinity of the project. Prior to this application, the highest resolution MODBRANCH model was designated as MB_2006; this model was used for the C-111 Spreader Canal study. ***Figure C-2*** shows the model domain with the area of interest. The model domain is the same as for the C-111 Spreader Canal study; the difference is the increased resolution in the area of interest. The three-dimensional grid of MB_2006 is made of 239 rows, 259 columns, and five layers. While the MB_2008 grid contains the same number of layers, the rows were increased to 246 and the columns to 262. Since the canals (1D) are located by assignment to the cells, additional refinement was required in the branch input files.

The increased resolution in the model is dependent upon the features of the plan and the relationship to the local canals. Both the inputs to the BRANCH and MODFLOW parts of the model were adjusted. In the vicinity of the project, there are four canals: L-31E (east of the project), C-103 (north of the project), North Canal (south of the project) and the BBCW seepage canal (located just

west of the project and connected to C-103 under the plan). The North Canal has a width of about 47 ft (at elevation 3.5' NGVD29). The height (dimension running north and south) of the cell at that point was set to 80 ft. The C-103 canal is 104 ft wide at elevation 4.0 ft and the height of the cell is 150 ft. The L-31E canal is 53 ft wide (elevation of 4.0 ft) and the width (dimension running east and west) is 620 ft. The BBCW seepage canal is 47 ft (elevation 3.5 ft) wide and cell width is 127 ft.

The horizontal sizes of the MODBRANCH grid cells varies from less than 80 to 5000 ft and is dependent on the resolution required. There is always a trade-off between increased resolution and computation time. The model domain, as used in this study, requires over 3 days of computation time per 13 months of simulation. Increasing the cell resolution to match the exact dimensions of each canal would cause a significant increase in computation time. There are over 360 miles of canals in the model domain with widths ranging from ~40 to > 150 ft. In order to for each canal segment to match the associated cell dimension, would require an average cell resolution of about 100 ft. This would increase the total number of 2 dimensional cells from 64,452 to 9,795,400, an increase by a factor of 150. In addition, canal segment lengths are generally the same as the cell dimension in the direction of orientation, the 360 miles of canal would be represented by about 19,000 segments. The current model uses about 3,000 segments. Each branch is limited to being defined by no more than 3 (non-zero length) segments, so 360 miles of branches with each branch ~300 ft long would result in over 6,300 branches. The current model uses less than 1,000 branches. Execution time is strongly dependant on the number of branches and cells. Although the exact relationship between the number of branches/cells and execution time is not defined, experience indicates that a model created to capture the exact sizes of the canals would require many days of computation time. Based on previous studies the resolution of the model was deemed to be adequate for the purpose of the study.

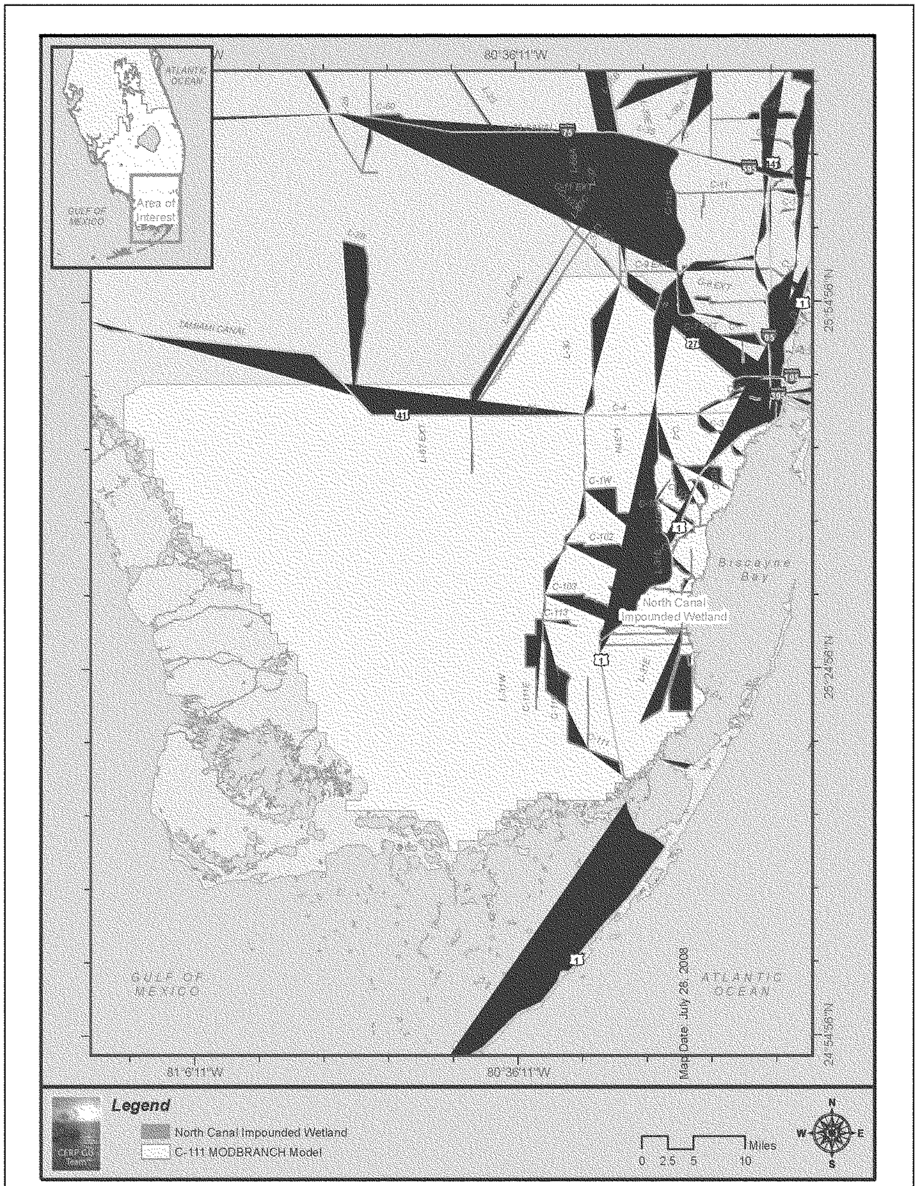


FIGURE C-2: MODBRANCH MB_2008 DOMAIN IN THE BISCAYNE BAY COASTAL WETLANDS PROJECT AREA

Figure C-3 shows the cell resolution in the area of interest with the basic wetland configuration. Additional rows and columns were added to enable a more accurate placement of the wetland levee, C-103, North Canal and the seepage canal (C-711W). In ***Figure C-3***, the magenta lines indicate the cells in the MB_2006 grid; the thinner, dark lines indicate cells in the MB_2008 grid. The various parameters that are assigned to each cell (hydraulic conductivity, Kadlec coefficient and storage) of the new model grid were based on the MB_2006 parameters. The brown lines indicate levees (modeled as "horizontal flow barriers" in MODBRANCH). The fact that the model was essentially changed very little meant that there was no need to recalibrate or re-verify the model because changes to the model were essentially insignificant. The MB_2006 model inputs and calibration/verification results are thoroughly described in "*Calibration and Verification of the MODBRANCH (MB_2006) Numerical Model of South Florida*" (Evans, 2007) (Attachment 1).

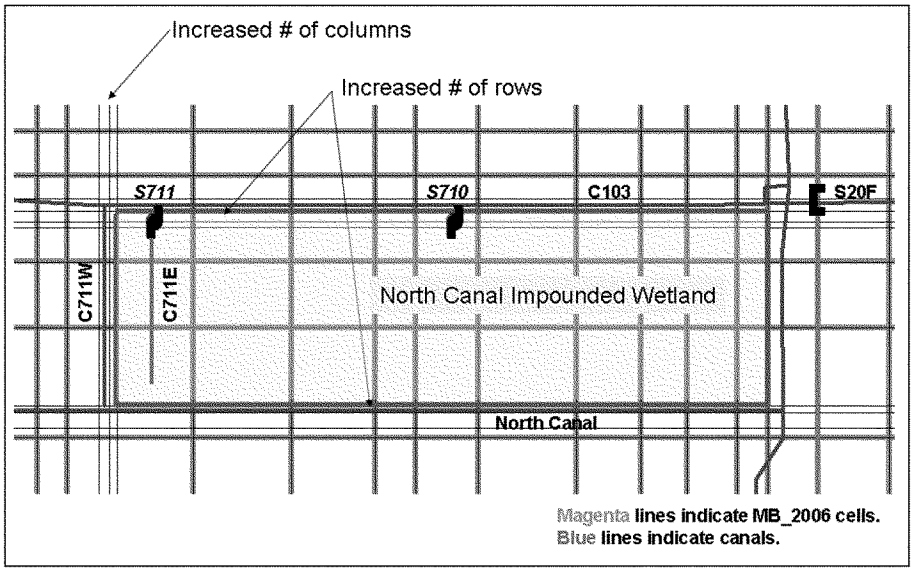


FIGURE C-3: MODBRANCH CELL RESOLUTION IN THE AREA OF INTEREST

Due to the long simulation times, only three distinct years were simulated using MODBRANCH. These were 1978, 1989, and 1995, which represent average, dry and wet rainfall years, respectively. The 1995 year included an event which approximates a 1-in-10 year rainfall event. A continuous run over this period would require between 50 and 60 cpu days. Each simulation began on 1 December of the previous year (i.e. the 1995 simulations started on 1 December

1994) to allow a "spin-up" time of 31 days, which reduces the error in cold-starting the model. Accuracy of the model is discussed in the calibration report. Six configurations were simulated: Alternative 7R/Existing and five alternatives. The five alternatives are variations of the basic configuration shown in ***Figure C-3***. A brief description of each follows.

The first configuration is known as Alternative 7R. This is also referred to as the Existing Condition based on the Interim Operational Plan. ***Figure C-2*** shows the alignment of canals and levees of this configuration. Alternative 7R is intended to represent features in the field, and how the various structures are presently operated. For the purposes of this analysis, existing users in the area should continue to enjoy a level of flood protection comparable to that of the existing condition, defined by SFWMM regional model simulation Alternative 7R.

In each of the five alternatives, a seepage canal (C-711W) was placed immediately west of the western levee. The north end of C-711W tied into C-103, but the south end is not connected to North Canal. Pump station S-711 withdraws water from C-103 which controls the level in C-711W. If C-711W were connected to both C-103 and the North Canal, the pump station would not be capable of capturing seepage into C-711W and the additional water flowing from the North Canal. This would result in increased stages west of the project area. The pumps (S-710 and S-711) extracted water from the canals and discharged into the project area. Levees (both external and internal) were simulated using the MODFLOW horizontal flow barrier option. This meant that they blocked horizontal flow between computational cells in the specific layer they occupied. While it is possible to assign a hydraulic characteristic to each barrier segment that is a function of levee thickness and hydraulic conductivity in this application the barrier is considered impervious to all flow. A more exact description of each alternative follows.

<u>Biscayne Bay Coastal Wetlands 40N 40N</u>: Pumps S-711 and S-710 extract water from C-103 with a maximum pumping rate of 40 cfs each. S-711 discharges into a shallow discharge canal (C-711E) while S-710 discharges immediately south of the northern levee defining the wetland. Note that the water discharged from the pumps is spread over a number of computational elements via a link to the recharge function of MODFLOW. This more accurately resembles real world conditions. The on/off operations of S-711 and S-710 are the same as for S-20F which are designed to maintain C-103 at a specified elevation based on the time of the year. The specified stages are shown in the table below. The operational triggers are maintained for each of the configurations described as follows:

TABLE C-4: SPECIFIED TRIGGER STAGES

Range	Period	Close Trigger Stage, feet (NGVD29)
High	May 1–Oct 14	1.8
Intermediate	Jan 1–Apr 30	1.3
Low	Oct 15–Dec 31	1.0

Biscayne Bay Coastal Wetlands_20N_60N: Pumps S-711 and S-710 again extract water from C-103. The total maximum pumping rate for both pumps is maintained at 80 cfs. However, the maximum rate for S-711 is 20 cfs and for S-710 is 60 cfs. This was done in order to reduce the impact on lands immediately west of the project area.

Biscayne Bay Coastal Wetlands_40N_40S: In this configuration, both pumps have a maximum of 40 cfs. The difference between this and the previous configuration is that S-710 extracts from the North Canal. This was done to determine if this configuration would reduce impacts south of the project.

Biscayne Bay Coastal Wetlands_20N_60S: Same configuration as Biscayne Bay Coastal Wetlands_40N_40S with one difference, the maximum rate for S-711 is 20 cfs and 60 cfs for S-710.

Biscayne Bay Coastal Wetlands_Bob: This is the most radical change in that it involved internal levees to (a) direct water towards the center of the wetland and (b) increase travel time of water from the wetland to the areas outside the project. This configuration was intended to reduce impacts outside the project area. Pump S-711 extracts from C-103; S-710 extracts from North Canal. Maximum rate is 40 cfs each. Both pumps are moved eastward and discharge into different areas of the wetland. Internal levees are used to force water into the center of the wetland. The configuration is shown in ***Figure C-4***.

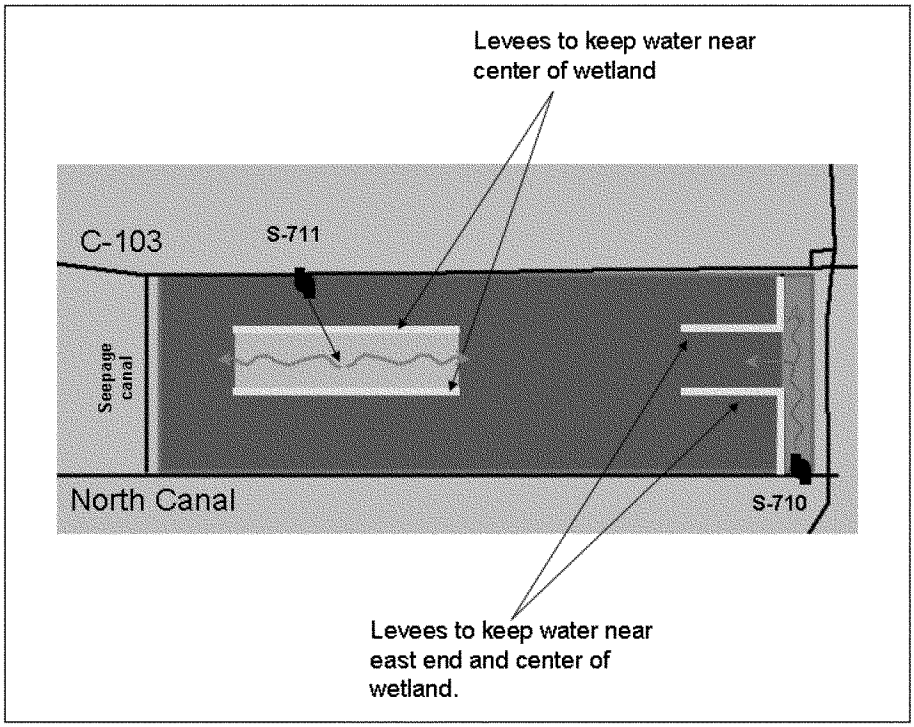


FIGURE C-4: THE BISCAYNE BAY COASTAL WETLANDS "BOB" CONFIGURATION FOR THE NORTH CANAL IMPOUNDMENT

Miami-Dade Department of Environmental Resources Management operates a temporary impoundment located along the north side of Military Canal (***Figure C-5***) known as a Stormwater Treatment Detention Area (STDA). On March 26, 2008; an 80 cfs pump station transferred roughly 55 acre-feet of water from Military Canal into the impoundment. Water levels were recorded at six wells (BBCMW) surrounding and west of the impoundment, and within Military Canal (S-20G).

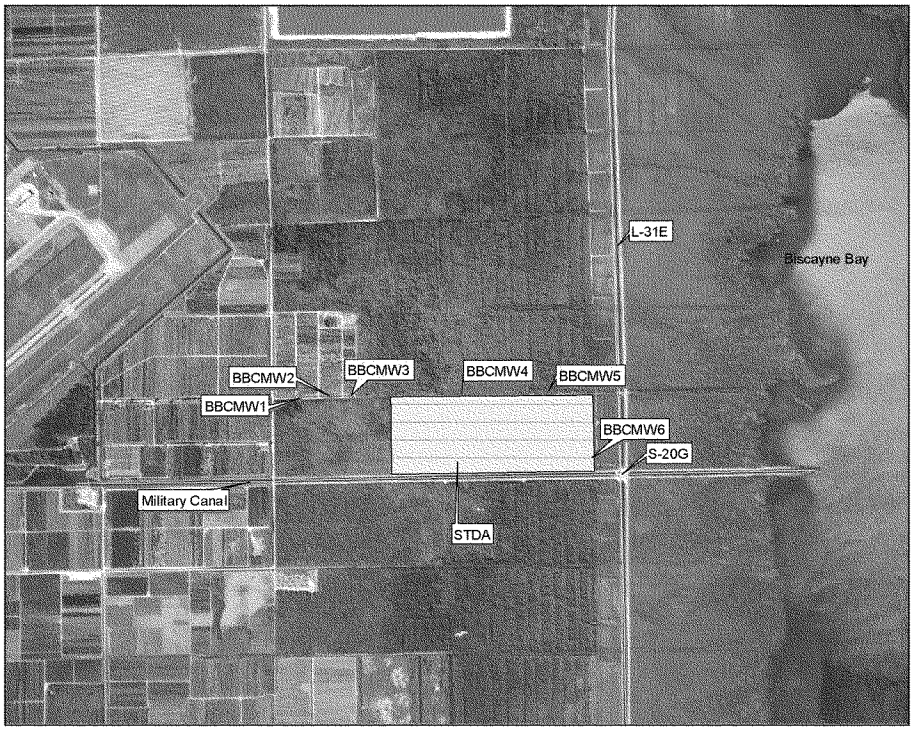


FIGURE C-5: LOCATION OF THE STORMWATER TREATMENT DETENTION AREA IMPOUNDMENT AND MONITORING WELLS

C.1.2.2.4 Elimination or Transfer of Existing Legal Sources Analysis

Existing legal sources in the project area include several public utility wellfields, private wells and agricultural irrigation wells upstream within the drainage basins. All project features such as pumps or culverts to divert water are located downstream of these sources. Capacity and operation of the project features are designed to maintain existing water levels and overall flows to the coast. Project features only divert a portion of the water that would normally be discharged through coastal canal water control structures directly into Biscayne Bay. The quantity of water available is estimated based on discharge through the coastal control structures all of which are downstream of the sources listed above. The SFWMD maintains a database of these flows and water stage elevations for each canal.

Water that flows into Biscayne Bay and BNP through the canals may also be considered an existing legal source that maintains fish and wildlife. While

project features are designed to intercept some of this water, it would be used to restore water flow to historical tributaries of Biscayne Bay, but not transfer it for another use. Therefore, no elimination or transfer of water from Biscayne Bay would occur.

C.1.2.3 Project Assurances-Identifying Water Made Available for the Natural System and for Other Water Related Needs by the Biscayne Bay Coastal Wetlands Project

Identification of water for the natural system is based on the concept that a quantity of water is needed to achieve the benefits of the project, and the overarching objective of restoration, preservation and protection of the south Florida ecosystem. The water made available for the natural system is the water used for the protection of fish and wildlife within natural systems, including water that contributes to meeting hydrologic, water quality, and ecologic targets for restoration of natural systems. The targeted quantity needed in Biscayne Bay was estimated based on maintaining salinity nearshore at 20 practical salinity units (See CBEEM, Annex B; USACE 2003). This is the performance measure used in plan formulation. The Biscayne Bay TABS-MDS model was run for a typical year while maintaining salinity constant, and adding water along the shoreline. The resulting hydrograph indicates that a constant flow of water is required.

C.1.2.3.1 Summary of the Analytical Method Used to Identify Water Made Available

The basic approach used to identify water made available to the natural system was to calculate the quantity of water available to be pumped or diverted into wetlands on a daily basis. Each component of the project relies on features such as culverts or pumps to divert water out of the primary drainage system of canals and into wetlands or natural drainage features. Historical records of canal flow date back to about 1986; therefore, the quantity that could have been diverted by the project features was calculated over the period of record to develop probabilities over a range of climatic conditions. The cumulative quantity diverted by the project was plotted, and the tenth, fiftieth and ninetieth percentiles were identified for the existing condition and condition with project of the total water, water made available for the natural system, and water to be reserved or allocated for the natural system.

C.1.2.3.1.1 Identifying Water Made Available for Other Water Related Needs

The Biscayne Bay Coastal Wetlands Project Phase 1 does not produce water that is available for other water related needs.

C.1.2.3.2 Quality, Timing, and Distribution of Water and Water Quality

Viewed from a programmatic perspective, identification of water for the natural system associated with the CERP involves an analysis of four different aspects of ecological responses to hydrologic changes:

1) Responses to the change in the quantity of water received by the natural system,
2) Responses to the timing of those deliveries,
3) Responses to the distribution of water delivered to the natural system; and
4) Responses to the quality of the water received by the natural system.

In a project specific sense, however, the relative importance of each of these aspects (quantity, timing, distribution, and quality) would vary from project to project depending upon the specific objectives established for the project.

For example, some CERP projects may focus formulation efforts on simply changing the timing (seasonality) or distribution (inflow and outflow points, internal movement) of water delivered to the natural system. Other projects may focus primarily on increasing or decreasing the amount of water delivered to the natural system, while still other projects may focus on improving the quality of the water delivered to the natural system to maintain desirable ecological community structure. All of these aspects (depending upon their applicability to specific projects) are addressed during plan formulation through performance measures and evaluation criteria used to evaluate alternative plans.

To identify the quantity, timing, and distribution of water for the natural system, a probabilistic approach was selected utilizing volume probability curves to depict the distribution of volumes of water that provide natural system benefits as a result of project features through the range of climatic conditions contained within the 27-year period of hydrological record. These volumes of water may include water that is available to meet natural system needs without project features, and the water made available from project features to meet natural system needs.

Water quality is also to be taken into account during plan formulation and evaluation as a project constraint (*i.e.* projects cannot cause or contribute to violations of water quality standards). According to CERP Guidance Memorandum 23.01 "Water Quality Considerations for the Project Implementation Report Phase", projects such as the Biscayne Bay Coastal Wetlands project should include features to reduce nutrients and suspended solids through passive means. The project was formulated to improve water quality by diverting canal discharges into wetlands. Reduction of nutrients was

estimated based on attenuation curves for the area of wetlands affected and volumes of water diverted (Annex C, CBEEM, USACE 2003).

C.1.3 RESULTS

C.1.3.1 Savings Clause-Elimination or Transfer of Existing Legal Sources and Flood Protection-Project Level

C.1.3.1.1 Deering Estate Flood Protection Analysis

The hydraulic modeling results of the C-100A Spur Canal and the Spur Canal extension confirmed that the Spur Canal extension section is adequate to convey the maximum pumping rate of 100 cfs. The canal section is large enough to reduce vegetation growth and potential clogging from branches and other debris, limit canal velocity and accommodate the pump intake depth.

The Cutler Drain or Cutler Canal is a man-made canal excavated through limestone and extending from the vicinity of Old Cutler Road east to the Rock Bridge. Over time, the Cutler Drain has become densely vegetated. The Deering Estate project involves discharging freshwater from the C-100A Spur Canal to the Cutler Drain, routed through a pump station and discharge pipeline, to hydrate the adjacent coastal wetlands. Two bridge structures cross the Cutler Drain, referred to as the Chinese Bridge and Rock Bridge.

A weir structure has been constructed within the Cutler Drain by Miami-Dade County to impound water and restore the historic function of the Deering Glade (Milian Swain, 2005). The weir is situated immediately upstream of the Rock Bridge. Physical constraints within the Cutler Drain limited the total weir length to about 27 feet. The weir crest elevation is +3.47 feet NAVD88.

The rational method (equation that determines peak runoff) was used to calculate the additional flow in the Cutler Drain as a result of additional storm water runoff that could be produced from rainfall over the drainage area. A runoff area of 25 acres was estimated, which resulted in an additional flow of nine cubic feet per second, which would be conveyed through the Cutler Drain and its overbanks. This value was input into the HEC-RAS model to determine any increase in WSE. Model results indicated that this additional flow to the Cutler Drain during storm conditions would result in a nominal one inch increase in WSE. It should be noted that any increase in flow would not cause flooding west of Old Cutler Road as the pump station has a high-water shut-off monitor located within the outlet spreader structure.

The HEC-RAS modeling results estimated the water surface profile through the proposed piping system and Cutler Drain under the various flow conditions. Modeling results are provided for each cross section in ***Table C-5***.

A physical limitation to flow through the Cutler Drain was the allowable maximum WSE near Old Cutler Road. A maximum allowable WSE of +5.27 feet NAVD88 east of Old Cutler Road was utilized. This controlling elevation provided 1.5 feet of freeboard between the lowest crown elevation of Old Cutler Road and the maximum WSE of the Cutler Drain, precluding inundation of the bike path and the Old Cutler Road base from discharge flows to the drain. About six inches of freeboard was provided along the bike path. This freeboard was not expected to impact the integrity of the lightly-loaded bike path, which is designed for occasional vehicular loading. Results presented in ***Table C-5*** for the outlet spreader location (Cross Section 10) indicated that 100 cfs maximum flow rate would maintain the maximum WSE below this controlling WSE of 5.27 feet NAVD88.

TABLE C-5: SIMULATED WATER SURFACE ELEVATIONS FOR THE DEERING ESTATE

Flow Rate (cubic feet per second)*	**34**	**59**	**84**	**109**
Cross Section	**Water Surface Elevation (feet, NAVD88)**			
11 (pump station)	4.40	5.15	6.07	7.17
10 (Downstream of Spreader Structure)	4.20	4.55	4.86	5.12
9	4.20	4.55	4.86	5.12
8 (U/S of Chinese Bridge)	4.19	4.55	4.85	5.11
7	4.19	4.54	4.83	5.09
6	4.17	4.51	4.80	5.06
5	4.14	4.47	4.75	5.01
4	4.11	4.42	4.70	4.95
3	4.10	4.41	4.68	4.92
2 (U/S of weir and Rock Bridge)	4.05	4.29	4.50	4.69
1	0.56	0.97	1.34	1.67

* Flow rate includes a nine-cubic feet per second contribution of runoff from the Cutler Drain Basin during a 100-year storm event.

Seepage losses may be significant due to the potential for high hydraulic conductivity within the Cutler Drain. The analysis therefore considered two different rates of seepage from the Cutler Drain to groundwater to evaluate the impact of seepage on water levels and flow rates within the Cutler Drain. Hydraulic conductivity rates of two feet per hour and 200 feet per hour were selected to represent a range of hydraulic conductivities that may be observed within the Cutler Drain.

Typical water surface profiles for flow through the Cutler Drain for hydraulic conductivities of two feet per hour and 200 feet per hour indicate that the maximum extent of inundation remains within the floodplain of Cutler Drain and the historic slough. The project is designed so that no significant or adverse increase of water elevation occurs near residential areas, park improvements or primary surface roadways.

C.1.3.1.1.1 Cutler Flow Way

Four modeling simulations were used to evaluate the rehydration area canal configuration for each of the four model scenarios previously described. The resulting water surface elevation is for the first scenario, corresponding to 400 cfs and a bay water elevation of +1.4 feet NAVD. Results indicate that during high tide conditions, the entire wetland area is flooded, and the flow is routed through both the ditches in the wetlands and as overland sheet flow. For these conditions most of the water follows the ditch alignments with very little overland flow, except where the land surface is low typically close to the bay.

Results were examined to see if one parcel (GZ300-011) would experience potential additional flooding (above naturally occurring tidal flooding), along the northern boundary of the wetland area. It is not anticipated that the any overtopping would influence the private property to the north under low water elevation conditions. A ditch system in the wetlands to the north would likely intercept any overtopping flow and deliver it to the bay. The results, which confirm the conservative nature of the HEC-RAS simulation, support the conclusion that the private property to the north is not impacted for the 400 cfs flow at low water elevations. Finally, the water elevation at the private property location near the north end of the rehydration area was reviewed and compared to naturally occurring conditions. The results are provided in ***Table C-6***.

TABLE C-6: COMPARISON OF SIMULATED WATER SURFACE ELEVATIONS WITHIN THE NORTHERN PROXIMITY OF THE CUTLER WETLAND REHYDRATION AREA

Scenario	WSE With Project (feet, NAVD)	WSE Natural Conditions (feet, NAVD)
400 cfs high water conditions	+1.401	+1.4
400 cfs low water conditions	dry	dry
100 cfs high water conditions	+1.410	+1.4
100 cfs low water conditions	dry	dry

Key: cfs: cubic feet per second
NAVD: North American Vertical Datum

The water elevation corresponding to natural conditions was the high and low water elevations. It is evident from the results presented in ***Table C-6*** that the project would not impact water elevations in the designated area.

Evaluation of the project's potential impact on the current level of flood protection for each adjacent parcel was conducted using two criteria. Properties were evaluated based on: 1) site drainage characteristics, and 2) the effect of wetland rehydration on water surface elevations within the property boundary of each parcel. A file search was conducted of the SFWMD and Miami-Dade County regulatory files to determine if Environmental Resource Permits were issued for any of the subject parcels within the proximity of the rehydration area. Permit information would contain the specific storm water design criteria and flood prevention criteria that were employed during development of the specific parcel. Data for several parcels adjoining the enlarged rehydration area were obtained as a result of the file review.

Copies of permitting plans, staff reports and storm water design calculations were examined. The results indicated that each parcel for which permit files were available was designed to completely retain storm water runoff on-site in accordance with current permit requirements. Direct discharge into adjacent lake systems or off site into the wetlands was not included in any of the storm water systems. Additionally, these parcels do not rely on detention storage volume from the lake system to comply with permitted storm water or flood protection requirements. Therefore, any inadvertent input of flow from the Biscayne Bay Coastal Wetlands project into this lake system does not reduce the current level of storm water management or flood protection for these parcels.

C.1.3.1.1.2 L-31E Flow Redistribution

The following results are from the HEC-RAS modeling described in ***Section C.2.2.3 "L-31E Flow Way Flood Protection Analysis"***. These results indicate possible water levels along the L-31E Borrow Canal while pumping

available water that would normally be discharged directly to tide as point sources.

C.1.3.1.1.2.1 L-31E Flow Redistribution Northern Segment (C-102 to Military Canal)

Table C-7 shows the WSE at each culvert location of the L-31E Canal between C-102 and the Military Canal. The starting water surface elevation in Biscayne Bay and the culvert entrance loss coefficients were modified to perform a sensitivity analysis on the system. Due to the possibility that 100 cfs could be available for 132 consecutive days, the model was run with a constant inflow for that time period. Output was recorded every two hours.

TABLE C-7: FLOW RATES (CFS) AND WATER SURFACE ELEVATIONS AT EACH CULVERT OF THE L-31E CANAL BETWEEN C-102 AND THE MILITARY CANAL AT THE END OF 132 DAYS

Structure	Q US (CFS)	Q Culvert (CFS)	Q DS (CFS)	WS US (feet, NAVD88)	WS DS (feet, NAVD88)
Culvert Entrance Loss = 0.5 & Biscayne Bay Starting WSE = 0.5					
S-23A	100	20	80	0.8	0.8
S-23B	80	20	60	0.8	0.8
S-706A	60	20	40	0.8	0.8
S-706B	40	20	20	0.8	0.8
S-706C	20	20	0	0.8	0.8
Culvert Entrance Loss = 0.5 & Biscayne Bay Starting WSE = 1.0					
S-23A	100	20	80	1.3	1.3
S-23B	80	20	60	1.3	1.3
S-706A	60	20	40	1.3	1.3
S-706B	40	20	20	1.3	1.3
S-706C	20	20	0	1.3	1.3
Culvert Entrance Loss = 1.0 & Biscayne Bay Starting WSE = 0.5					
S-23A	100	20	80	0.9	0.9
S-23B	80	20	60	0.8	0.9
S-706A	60	20	40	0.8	0.9
S-706B	40	20	20	0.8	0.8
S-706C	20	20	0	0.8	0.8
Culvert Entrance Loss = 1.0 & Biscayne Bay Starting WSE = 1.0					
S-23A	100	20	80	1.4	1.4
S-23B	80	20	60	1.3	1.3
S-706A	60	20	40	1.3	1.3
S-706B	40	20	20	1.3	1.3
S-706C	20	20	0	1.3	1.3

Key: "Q US" is the flow rate in the L-31E canal just upstream of the culvert
"Q Culvert" is the flow rate through the culvert
"Q DS" is the flow rate in the L-31E canal just downstream of the culvert
"WS US" is the water surface elevation in L-31E just upstream of the culvert entrance
"WS DS" is the water surface elevation in L-31E canal just downstream of the culvert entrance

C.1.3.1.1.2.2 L-31E Flow Redistribution Southern Segment (Military Canal to C-103)

Table C-8 shows the WSE at each culvert location of the L-31E Canal between Military Canal and C-103. The starting WSE in Biscayne Bay and the culvert entrance loss coefficients were modified to perform a sensitivity analysis on the system. Due to the possibility that 40 cfs could be available for 331 consecutive days, the model was run with a constant inflow for that time period.

TABLE C-8: FLOW RATES (CFS) AND WATER SURFACE ELEVATIONS AT EACH CULVERT OF THE L-31E CANAL BETWEEN MILITARY CANAL AND C-103 AT THE END OF 331 DAYS

Structure	Q US (CFS)	Q Culvert (CFS)	Q DS (CFS)	WS US (feet, NAVD88)	WS DS (feet, NAVD88)
Culvert Entrance Loss = 0.5 & Biscayne Bay Starting WSE = 0.5					
S-708	40	8	32	0.6	0.6
S-23C	32	8	24	0.6	0.6
S-23D	24	8	16	0.6	0.6
Existing North	16	8	8	0.6	0.6
Existing South	8	8	0	0.6	0.6
Culvert Entrance Loss = 0.5 & Biscayne Bay Starting WSE = 0.5					
S-708	40	8	32	1.1	1.1
S-23C	32	8	24	1.1	1.1
S-23D	24	8	16	1.1	1.1
Existing North	16	8	8	1.1	1.1
Existing South	8	8	0	1.1	1.1
Culvert Entrance Loss = 0.5 & Biscayne Bay Starting WSE = 0.5					
S-708	40	8	32	0.6	0.6
S-23C	32	8	24	0.6	0.6
S-23D	24	8	16	0.6	0.6
Existing North	16	8	8	0.6	0.6
Existing South	8	8	0	0.6	0.6
Culvert Entrance Loss = 0.5 & Biscayne Bay Starting WSE = 0.5					
S-708	40	8	32	1.1	1.1
S-23C	32	8	24	1.1	1.1
S-23D	24	8	16	1.1	1.1
Existing North	16	8	8	1.1	1.1
Existing South	8	8	0	1.1	1.1

Key: "Q US" is the flow rate in the L-31E canal just upstream of the culvert
"Q Culvert" is the flow rate through the culvert
"Q DS" is the flow rate in the L-31E canal just downstream of the culvert
"WS US" is the water surface elevation in L-31E just upstream of the culvert entrance
"WS DS" is the water surface elevation in L-31E canal just downstream of the culvert entrance

As shown in ***Table C-7*** and ***Table C-8***, maximum water surface elevations of 1.4 feet (NAVD88) for the northern segment and 1.1 feet (NAVD88) for the southern

segment could be possible. Limited survey data from (the USACE's survey 03-005 and the SFWMD's survey information) the western bank of the L-31E Borrow Canal, show berm elevations ranging from approximately 1.1 feet to 2.5 feet (NAVD88). Although the simulated water surface elevations could possibly overtop the western levee or berm in some areas according to the available topographic information, it is important to note that operations of the pump stations would be such that the pumps would not operate (would be turned off) when a specified water level (to be determined) is reached near the pump station. These "pump off" triggers would be developed to assure that the water surface in the L-31E Canal would not overtop the western levee/berm, therefore maintaining the current level of service for flood protection.

C.1.3.1.1.2.3 North Canal Impoundment Wetlands

MODBRANCH modeling indicates that the first four alternatives are very similar in results. There would be increases in peak stages in the areas around the wetland. Some, but not all, of the seepage out of the wetland is captured by C-103, North Canal, C-711W and L-31E.

Figure C-6 through ***Figure C-11*** show the areas where the peak stage is greater than the ground elevation (*i.e.* the "depth" greater than 0) in blue, and the areas where peak stage is below the ground elevations (*i.e.* "depth" less than 0) in red for the wet year 1995. The yellow line on all figures is the delineation of wet versus dry areas at peak for the Alternative 7R/Existing Condition simulation. An examination of ***Figure C-6*** through ***Figure C-11*** would indicate where areas are wetter or drier than the Alternative 7R/Existing Condition. A quick look indicates that the area south of the project would experience some increase in flooding with respect to the Alternative 7R/Existing Conditions. The first four alternatives (40N_40N, 40N_40S, 20N_60N, 20N_60S) all indicate about the same degree of flooding with a noticeable increase when the S-710 pump is pumping at 60 cfs and the S-711 is at 20 cfs. The alternative which most closely matches the Alternative 7R/Existing Condition is the Biscayne Bay Coastal Wetland's Bob configuration.

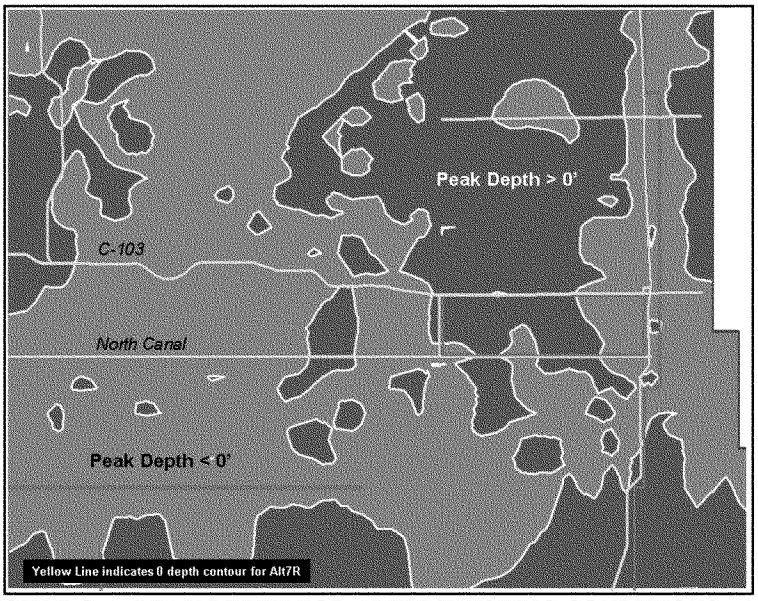


FIGURE C-6: PEAK DEPTH FOR ALT7R/EXISTING CONDITIONS, 1995

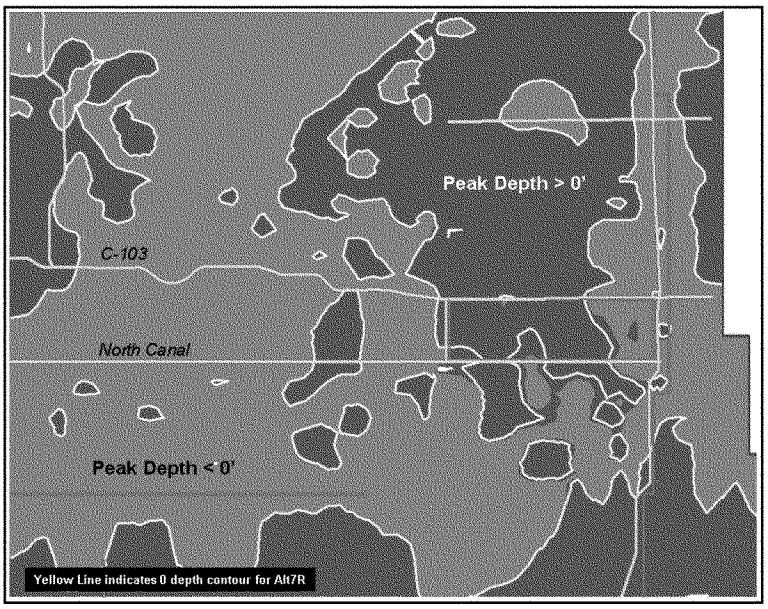


FIGURE C-7: PEAK DEPTH FOR THE BISCAYNE BAY COASTAL WETLANDS_40N_40N CONFIGURATION, 1995

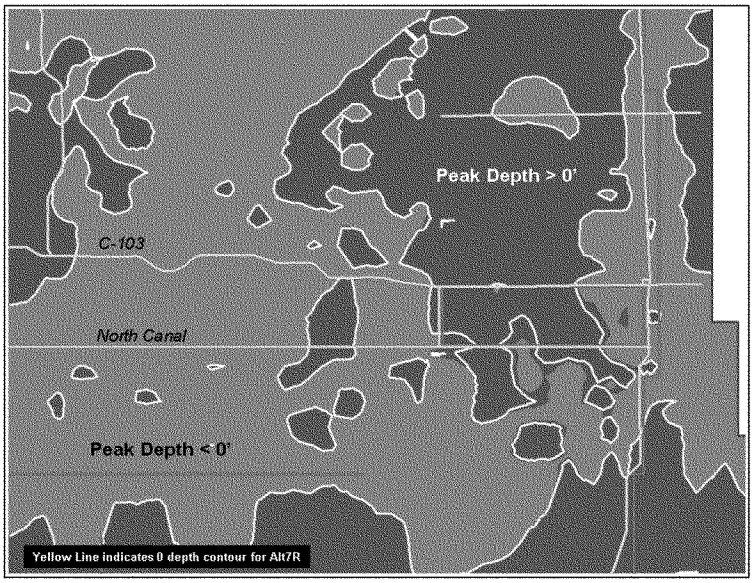


FIGURE C-8: PEAK DEPTH FOR THE BISCAYNE BAY COASTAL WETLANDS_40N_40S CONFIGURATION, 1995

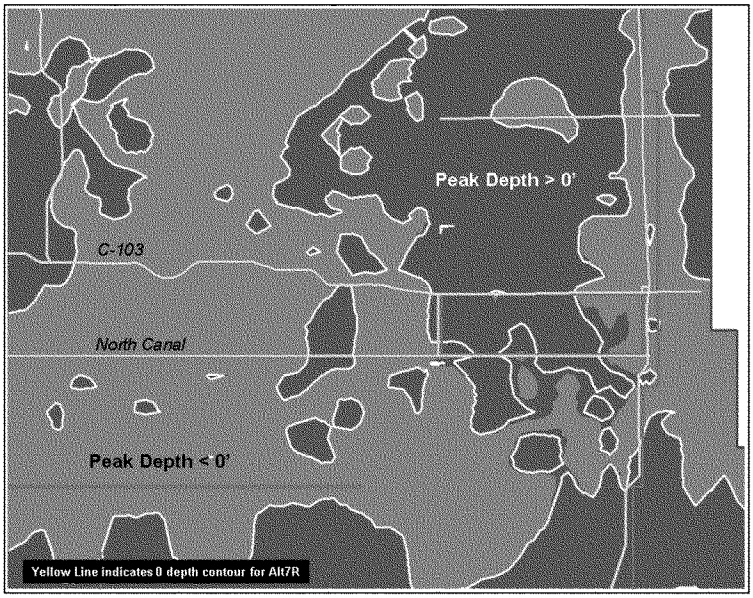


FIGURE C-9: PEAK DEPTH FOR THE BISCAYNE BAY COASTAL WETLANDS_20N_60N CONFIGURATION, 1995

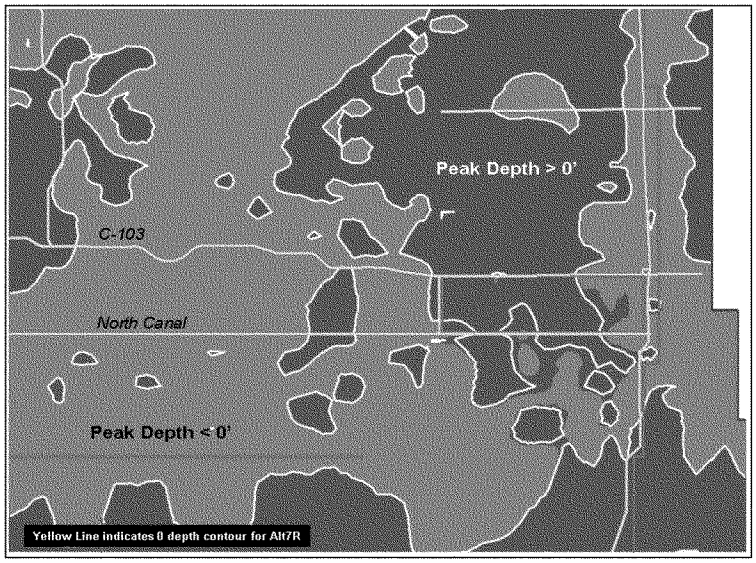


FIGURE C-10: PEAK DEPTH FOR BISCAYNE BAY COASTAL WETLANDS_20N_60S CONFIGURATION, 1995

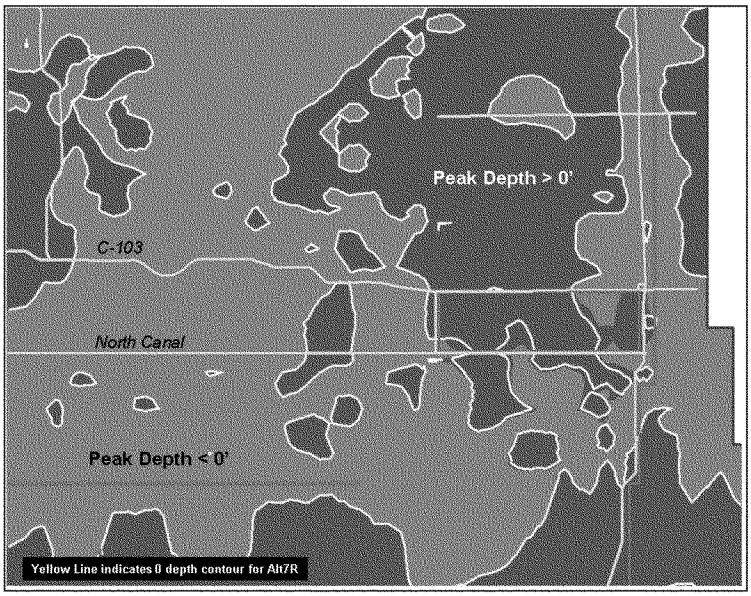


FIGURE C-11: PEAK DEPTH FOR BISCAYNE BAY COASTAL WETLANDS_"BOB" CONFIGURATION, 1995

The results can be quantified if the impacts by the number of acres with peak depth greater than 0.1 foot are defined. ***Table C-9*** lists the number of acres where the peak depth south of the North Canal is greater than 0.1 foot for 1995.

TABLE C-9: COMPARISON OF NORTH CANAL IMPOUNDMENT SIMULATED CONFIGURATIONS AND PEAK WATER DEPTHS ABOVE GROUND SURFACE

Configuration	Acres with Peak Depth > 0.1 feet Above Ground Surface	Increase from Alternative 7R / Existing
Alt7R/Existing	1186	
Biscayne Bay Coastal Wetlands_40N_40N	1323	137
Biscayne Bay Coastal Wetlands_40N_40S	1266	90
Biscayne Bay Coastal Wetlands_20N_60N	1359	173
Biscayne Bay Coastal Wetlands_20N_60S	1272	86
Biscayne Bay Coastal Wetlands_Bob	1206	20

Table C-9 shows that the location of the S-710 pump in the south does reduce the increase in flooding area. This is likely a result of using that reach of the North Canal as a seepage collector. However, the largest reduction is obtained in the Biscayne Bay Coastal Wetlands_Bob configuration, which is a result of directing the water into the center (S-711) and east ends (S-710) of the wetland.

Depth-duration is also an important measure of the effectiveness of an alternative. ***Figure C-12*** shows 22 locations in the vicinity of the project where depth-duration curves were computed based on the model results. Only those locations closest to the project show any significant changes.

Point	Distance from west side of wetland (ft)	GSE (ft NGVD29)
EW a	12,046	3.0
EW b	6,247	3.1
EW c	2,587	3.8
EW d	411	***1.4***

Point	Distance from north side of wetland (ft)	GSE (NS3x)	GSE (NS4x)	GSE (NS5x)
NS3/4/5 a	7,036	2.1	3.8	***2.0***
NS3/4/5 b	3,289	2.4	1.6	1.8
NS3/4/5 c	298	***2***	***1.4***	2.0

Point	Distance from south side of wetland (ft)	GSE (NS3x)	GSE (NS4x)	GSE (NS5x)
NS3/4/5 d	173	***2.3***	***1.7***	2.0
NS3/4/5 e	2,827	3	2.3	2.4
NS3/4/5 f	6,513	3	2.1	1.6

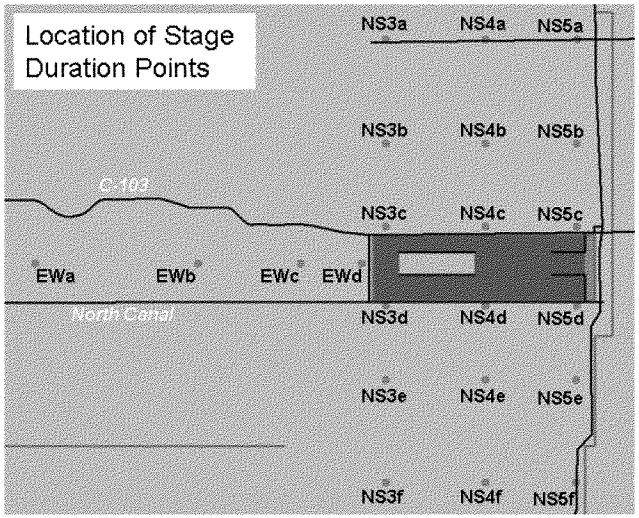


FIGURE C-12: LOCATION OF STAGE-DURATION POINTS

MD 77472 01/04/2013 47

***Figure** C-13* shows the depth-duration curve for point EWd. The Alt7R ("existing") configuration indicates during the wet year of 1995 the water is above ground for about 99 days. The longest period above ground is about 176 days, under both the 40-40N and the 40-40S alternatives. The "bob", 20-60S and 20-60N alternatives are about the same, with wet duration of about 150 days. Note that this point is just over 400 feet west of the project and the local ground elevation is much lower at 1.4 ft NGVD29. All other points west show no significant differences.

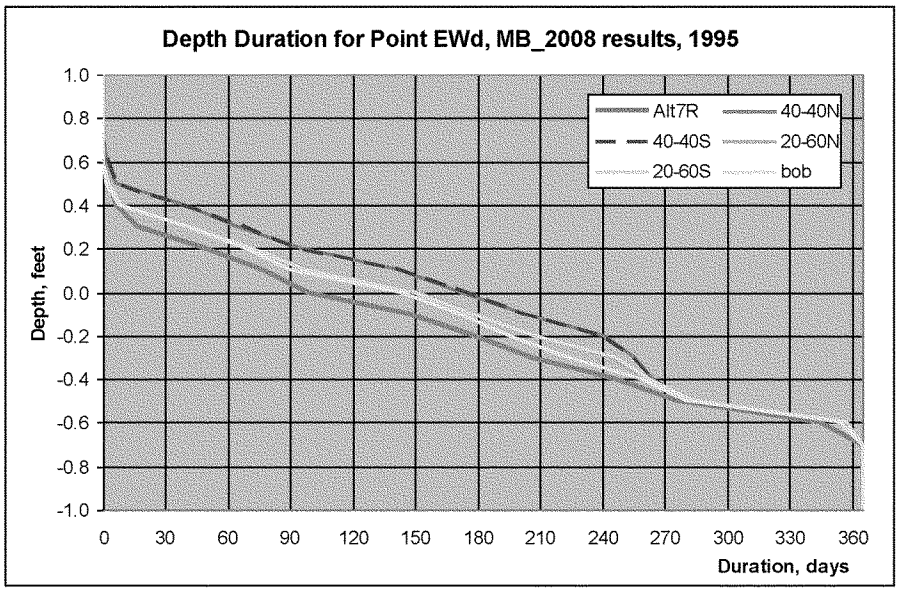


FIGURE C-13: DEPTH-DURATION EWD, 1995

Figure C-14 and ***Figure C-15*** show the locations just north and south, respectively, of the western end of the project. These indicate that although each alternative tends to increase water levels, the stage is still below the local ground surface, with the "bob" alternative being closest to the existing conditions.

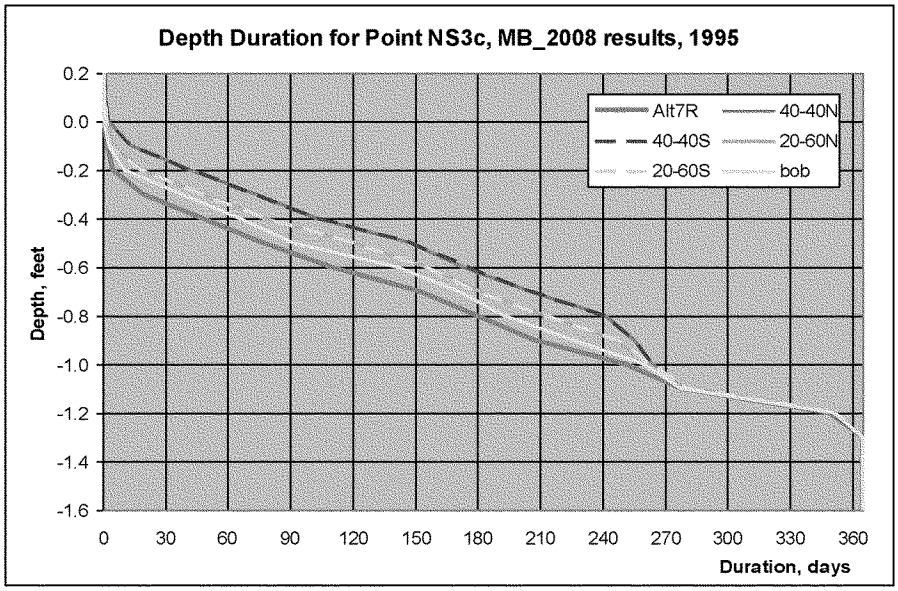


FIGURE C-14: DEPTH-DURATION NS3c, 1995

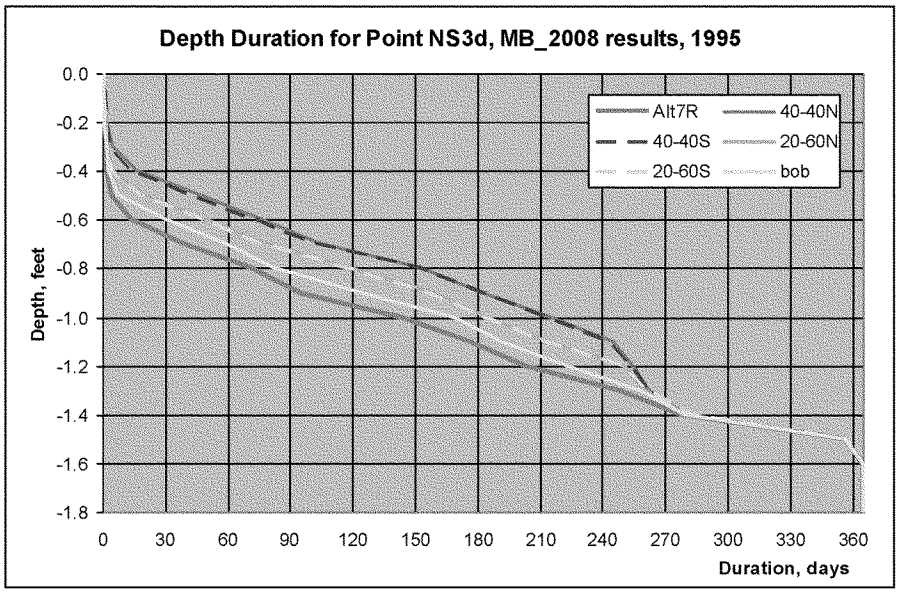


FIGURE C-15: DEPTH-DURATION, NS3D, 1995

Figure C-16 and ***Figure C-17*** show the locations just north and south, respectively, at the center of the project. These indicate a general increase in hydroperiods, with the "bob" alternative showing the least (+29 days) and the 20-60S and 20-60N alternatives the most increase (+213 days). Note that locations NS4c and NS4d have local ground elevations of 1.4 and 1.7 ft NGVD, respectively.

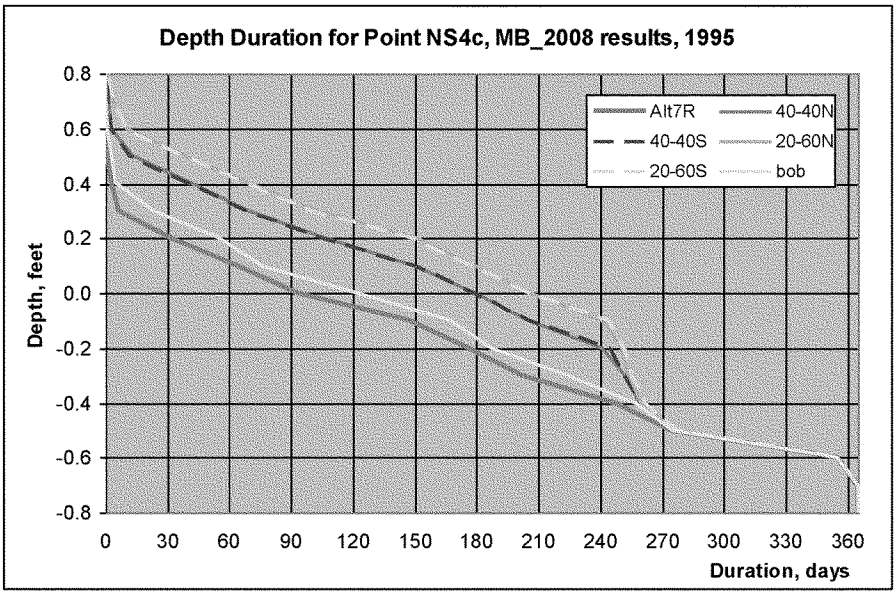


FIGURE C-16: DEPTH-DURATION, NS4C, 1995

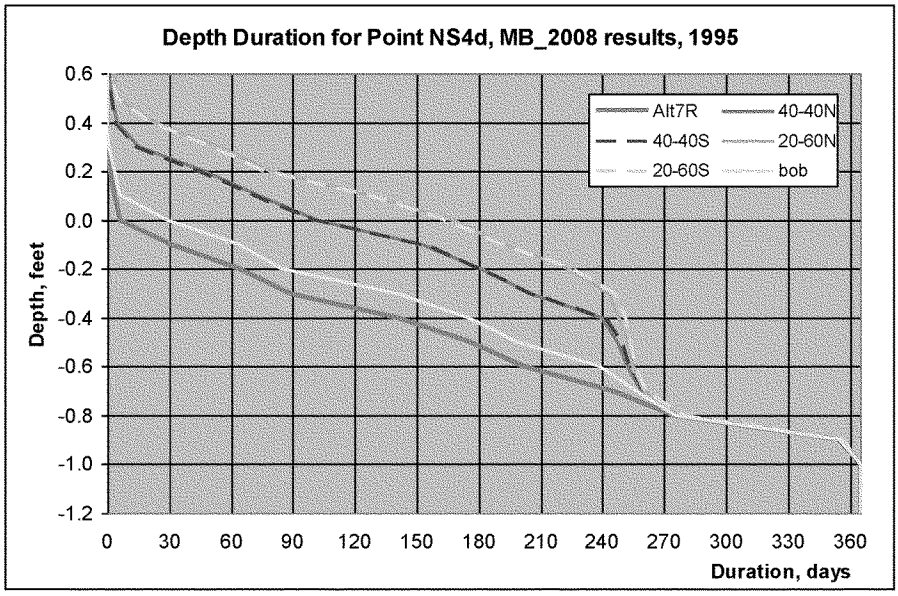


FIGURE C-17: DEPTH-DURATION, NS4D, 1995

Figure C-18 and ***Figure C-19*** show the locations just north and south, respectively, at the east end of the project. These are interesting in that they are the only locations where the "bob" alternative shows the largest increase in stage. However, in both cases, the water level is well below the ground elevations and there is little to no increase in hydroperiod.

It should be noted that the depth-duration period is affected by the local ground elevation.

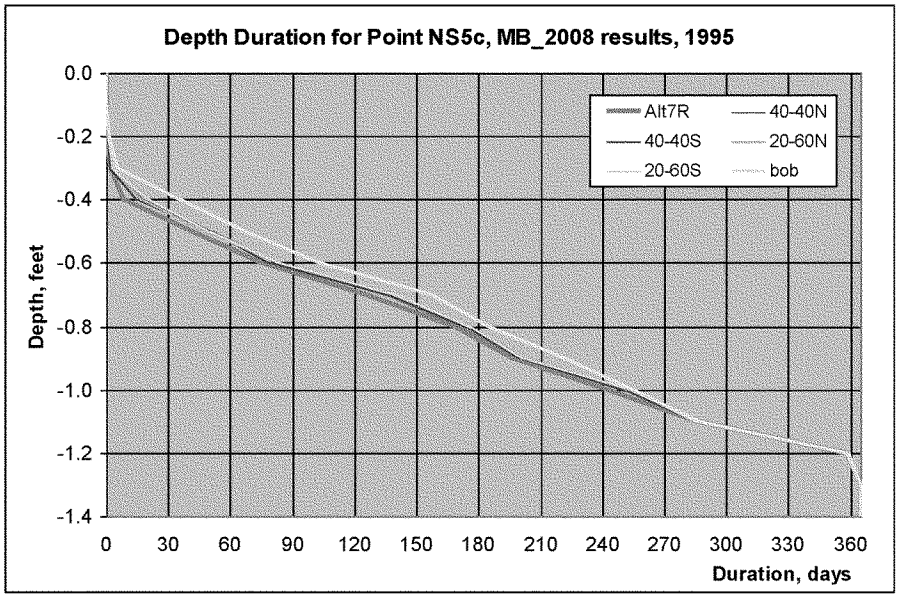


FIGURE C-18: DEPTH-DURATION, NS5C, 1995

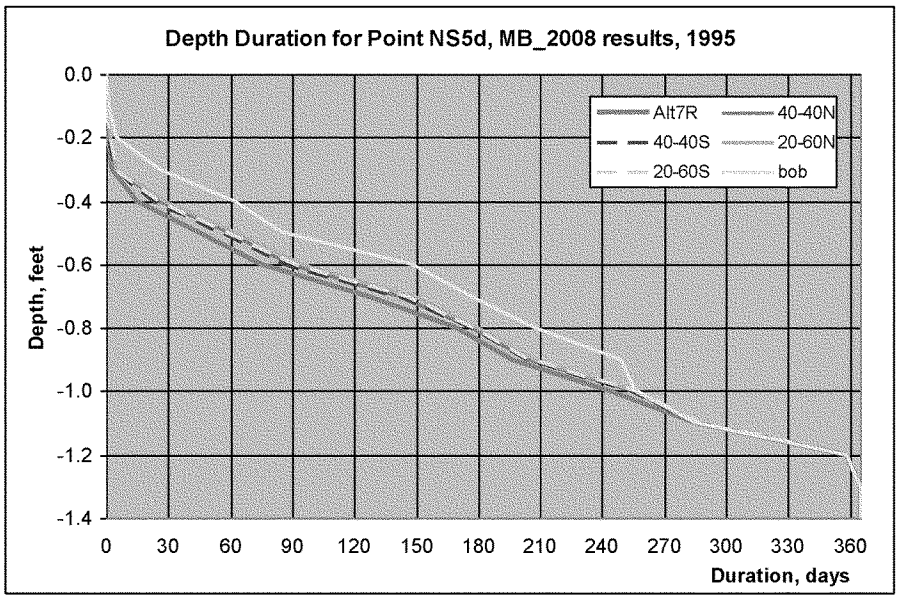


FIGURE C-19: DEPTH-DURATION, NS5D, 1995

The results shown here should be used in a relative or comparative sense that is the basis of the Savings Clause analysis. Due to typical uncertainties in model input parameters such as topography, hydrogeology and rainfall, the area that would experience an increase in flooding based on model results is not definitive from an absolute perspective. The estimated area of impact is determined both by the stages predicted by the model and the topographic data. ***Figure C-20*** shows the standard deviation, within each MODBRANCH cell, of the light detection and ranging (LIDAR) data that were used as a source of topographic information. It is clear that the most accurate values have a standard deviation of +/- 0.25 feet, and some areas have variation of more than one foot. Therefore, one should use these simulated results on a comparative basis, and absent long-term monitoring data for both the base and selected plan conditions, only represent simulated results that are limited by the uncertainties of the assumptions and data used in the model.

The model simulations for the North Canal Impoundment suggest that under some conditions, maximum water stages within the wetland (i.e. 2.0 feet above land surface) may result in small increases of stages immediately outside the impoundment. The model results show that water stages adjacent to the impoundment respond to different configurations. It is likely that by designing an optimum configuration and managing water levels within the impoundment, significant and adverse offsite effects can be eliminated, if necessary.

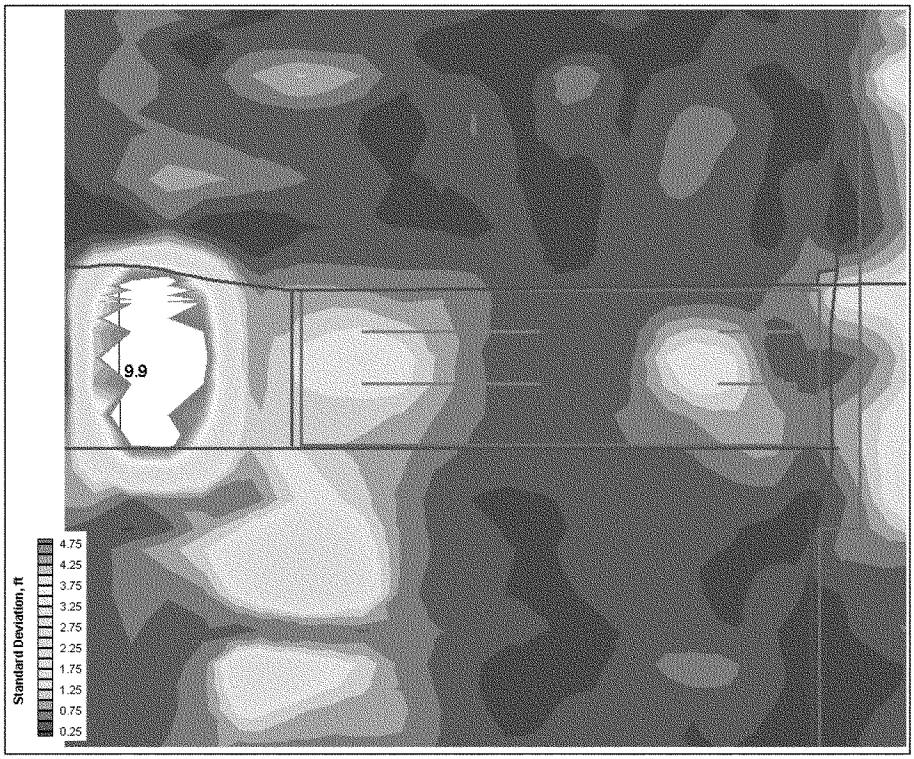


FIGURE C-20: DEPICTION OF THE STANDARD DEVIATION OF THE LIDAR DATA USED TO DEFINE THE MODEL TOPOGRAPHY

Preliminary water stage elevation results from the STDA impoundment test on March 26, 2008 indicated that water levels rose in the wells within or immediately adjacent to the impoundment, but water levels in wells located as close as 600 feet to the west did not change (***Figure C-21***). By chance, storm events occurred just prior and subsequent to the test that caused significant changes in water levels in the monitoring wells. Water levels in wells 1 and 3 declined slightly and remained below water level in the canal throughout the pump test, and for days afterward until a storm event on April 7, 2008. Water level in well 2 closely followed the level within the canal until the April 7, 2008 event.

Based on the results from model simulations and the STDA tests, it is concluded that operation of the North Canal Impoundment Wetland would not significantly or adversely affect the level of service for flood protection of adjacent properties.

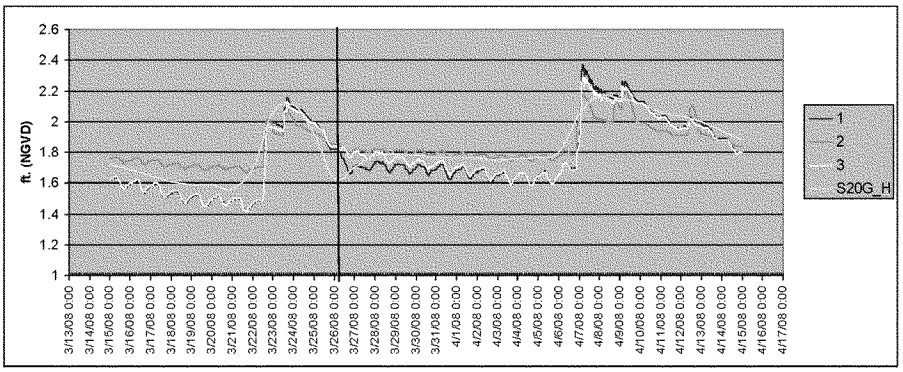


FIGURE C-21: WATER LEVELS AT WELLS BBCMW1, 2, 3 AND HEADWATER AT STRUCTURE S-20G BEFORE, DURING AND AFTER A PUMP TEST ON MARCH 26, 2008

C.1.3.1.2 Elimination or Transfer of Existing Legal Sources

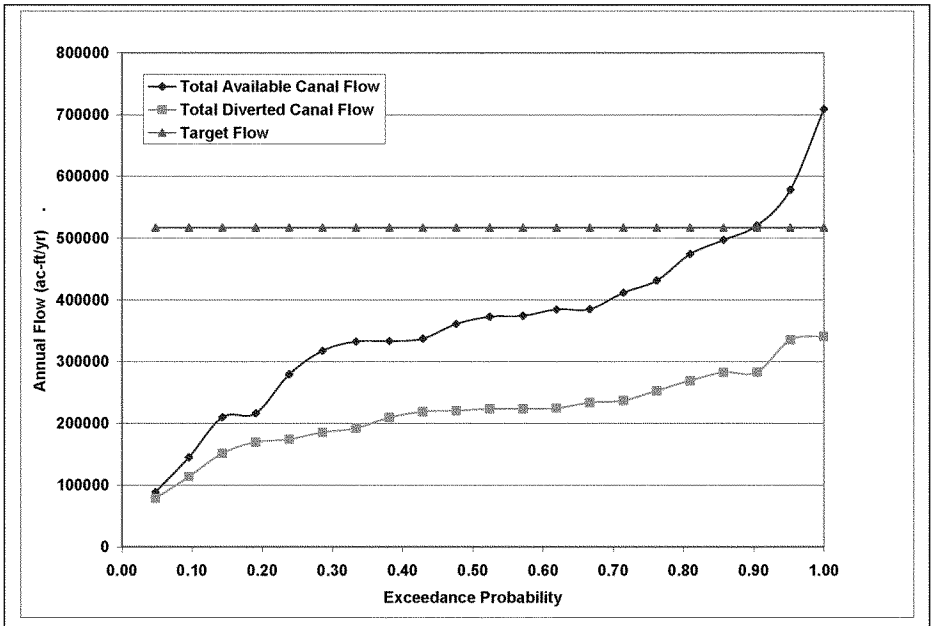
The project results in no elimination or transfer of water from existing legal sources, because canal flows and levels upstream of the coastal control structures would not be affected by project.

C.1.3.1.3 Project Assurances-Identifying Water Made Available by the Project for the Natural System and Other Water Related Needs

Water made available by the Biscayne Bay Coastal Wetlands project Phase 1 was identified by calculating the quantity of water diverted by all the project features (*i.e.* water diverted from canals) on a daily basis. The feature's pump stations were generally sized to accommodate the wet year, wet season median flows which would otherwise be discharged by the coastal structures. The 650 cubic feet per second of total planned pumping capacity has the capability (if run full time) to deliver approximately 91% of the 1,416 acre feet/day which are estimated to be needed to maintain the 20 PSU nearshore target. Unfortunately, excess water is often available only in response to rainfall, and rarely is it available exactly at the design flow rate.

In general, the features in Phase 1 use just a portion of the total amount of canal discharges available on any given day. This is especially true in the wet season when runoff is greatest. The project features are not designed to capture all water available because it would be impractical to install pumps large enough to capture all peak flows. By way of example, S-123 currently has a wet year median wet season discharge of 109 CFS but has historically experienced peak discharges as high as 2753 CFS. Sizing the pumps to capture these types of

flows would increase the pump costs by a factor of approximately 27 and the capacity would go largely un-used. ***Figure C-22*** provides an estimate of the quantity of water the project would divert to the natural system. No water is made available for other water related needs by this project.



Flow data from DBHYDRO is for the Period 1986-2006.

FIGURE C-22: TOTAL CANAL FLOW (C-100, C1, C-102, MILITARY, C-103) TO BISCAYNE BAY AVAILABLE, AND TOTAL FLOW DIVERTED BY THE BISCAYNE BAY COASTAL WETLANDS PROJECT PHASE 1

The targeted quantity needed to maintain twenty practical salinity units (psu) nearshore Biscayne Bay within the project area was approximated to be a more or less constant daily flow of 1,416 acre feet or 517,000 acre-feet per year. ***Table C-10*** indicates the tenth, fiftieth and ninetieth percentiles of the total available flow and the portion diverted by the project.

TABLE C-10: TOTAL WATER AND WATER DIVERTED BY THE PROJECT FOR THE NATURAL SYSTEM
(ACRE FEET PER YEAR)

Percentile:	10th	50th	90th
Total Water	145,072	366,739	520,325
Total Water Made Available by Project	113,619	222,022	282,982

The fraction of available water that the Biscayne Bay Coastal Wetlands project Phase 1 diverts ranges from about 48 percent to 88 percent in a given year. For example, the project would use about 78 percent of the water during a one-in-ten dry flow year, 60 percent during an average year; and 54 percent during a one-in-ten wet flow year. At no time do the project flows exceed the targeted flows. Even all of the water available annually does not meet the targeted annual quantity of 20 psu salinity consistently except at the 90th percentile. Project features are physically capable of diverting about 560,000 acre-feet per year. Additional flows are available to be diverted; however, it is not cost-effective to increase the size of the pump stations to divert peak flows. The timing of water will be altered based on the redistribution of the identified diverted canal flow across the wetlands and ultimately into Biscayne Bay. However, the specific changes to the timing have not been analyzed as part of the Phase I Project.

C.1.3.1.4 Identifying Water to be Reserved or Allocated for the Natural System

The water made available (diverted) by the Biscayne Bay Coastal Wetlands project Phase I for the combined C-100, C-1, C-102 and C-103 basins as indicated in ***Figure C-22*** (total water diverted) ranges from 113, 619 acre – feet per year (tenth percentile) to 282, 982 acre –feet per year (ninetieth percentile). As required by Section 385.35 of the Programmatic Regulations for the Implementation of CERP and CERP Guidance Memoranda #4, "Identifying Water Made Available for the Natural System and for Other Water Related Needs," the water made available (diverted) by Phase I of the Project will be protected using the State of Florida's reservation or allocation authority under state law as is represented by the "Total Diverted Canal Flow" line in ***Figure C-22*** of Annex C. The South Florida Water Management District has further committed to protect the difference between the existing water in the system, identified as the "Total Available Canal Flow" and the "Total Diverted Canal Flow" up to the "Target Flow" line under State's reservation or allocation authority. The State is currently determining the most appropriate means for undertaking this protection of water for the natural system.

The SFWMD will protect the water made available by the Biscayne Bay Coastal Wetlands Project using its reservation or allocation authority as required by the

Water Resources Development Act of 2000 (WRDA 2000) and Section 373.470, F.S. WRDA 2000 requires the water identified in the PIR to be protected prior to execution of a Project Cooperation Agreement, now called a Project Partnership Agreement. This agreement can only be executed after the project has been authorized and funds appropriated by the US Congress as well as funds included in the President's budget. Although the PIR has yet to be finalized, the SFWMD is moving ahead to protect the resources of Biscayne Bay by initiating rule development in 2010. The SFWMD is currently evaluating the state of the science with input from interested stakeholders as part of the process of determining the appropriate tool to protect water for Biscayne Bay.

C.1.3.2 Project Assurances

The overarching objective of the CERP is the restoration, preservation and protection of the south Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The Federal government and the State of Florida are committed to the protection of the appropriate quantity, quality, timing and distribution of water to achieve and maintain the benefits to the natural system described in CERP. As envisioned in WRDA 2000 and the Programmatic Regulations, each PIR would identify this appropriate quantity, quality, timing and distribution of water for the natural system.

The following language sets forth these commitments:

> "The overarching objective of CERP is the restoration, preservation and protection of the south Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection" (WRDA, 2000). The Federal government and the non-Federal sponsor are committed to the protection of the appropriate quantity, quality, timing and distribution of water to ensure the restoration, preservation and protection of the natural system as defined in WRDA 2000, for so long as the project remains authorized. This quantity, quality, timing and distribution of water shall meet applicable water quality standards and be consistent with the natural system restoration goals and purposes of CERP, as the Plan is defined in the programmatic regulations. The non-Federal sponsor would protect the water for the natural system by taking the following actions to achieve the overarching natural system objectives of the Plan:
>
> 1. Ensure, through appropriate and legally enforceable means under Federal law, that the quantity, quality, timing and distribution of existing water that the Federal government and the non-Federal sponsor have determined in this PIR is available to the natural system, would be available at the time the Project Cooperation Agreement for the project is

executed and would remain available for so long as the project remains authorized.

2. Prior to the execution of the Project Cooperation Agreement, reserve or allocate for the natural system the necessary amount of water that would be made available by the project that the Federal government and the non-Federal sponsor have determined in this PIR.
3. After the Project Cooperation Agreement is signed and the project becomes operational, make such revisions under Florida law to this reservation or allocation of water that the Federal government and the non-Federal sponsor determines, as a result of changed circumstances or new information, is beneficial for the natural system.
4. For so long as the project remains authorized, notify and consult with the Secretary of the Army should any revision in the reservation of water or other legally enforceable means of protecting water be proposed by the non-Federal sponsor, so that the Federal government can assure itself that the changed reservation or legally enforceable means of protecting water conform with the non-Federal sponsor's commitments under paragraphs 1 and 2. Any change to a reservation or allocation of water made available by the project shall require an amendment to the Project Cooperation Agreement.

C.1.4 Literature Cited

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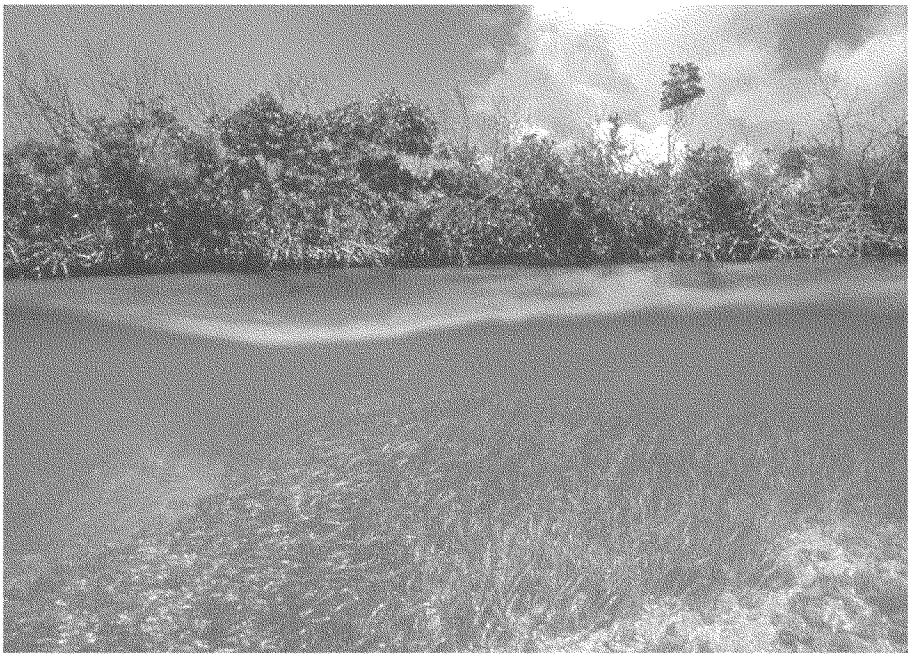
U.S. Congress, Water Resources Development Act of 2000. Public Law-106-541. 11 Dec 2000.

C.2 ANALYSES REQUIRED BY STATE LAW

CENTRAL AND SOUTHERN FLORIDA PROJECT
COMPREHENSIVE EVERGLADES RESTORATION PLAN

BISCAYNE BAY COASTAL WETLANDS

State Compliance Report
Section 373.1501, Florida Statutes



South Florida Water Management District

May 2010

Appendices

Appendix A 1501 Application Conference – July 15, 2009 Meeting Minutes

State Compliance Report
Section 373.1501 Florida Statutes

C.2.1 Introduction

The Biscayne Bay Coastal Wetlands (BBCW) project is a component of the Comprehensive Everglades Restoration Plan (CERP) that provides for the restoration, protection and preservation of the water resources of central and south Florida. The BBCW project consists of three integrated sub-components: Deering Estate Pump Station, Cutler Flow Way and L-31 East Flow Way. The purpose of the Biscayne Bay Coastal Wetlands project is to restore the natural hydrology and ecosystem in an area which has been degraded by regional drainage and land development practices. The environmental goals of the proposed project, known Alternative O Phase 1, are to rehydrate and restore wetlands and nearshore bay habitat by minimizing point source discharges, and to improve the quantity, quality, timing, and distribution of water to freshwater and tidal wetlands and to the bay.

The Biscayne Bay Coastal Wetlands project area is located in southeast Miami-Dade County, south of Miami and east of Florida City and Homestead, within the South Florida Water Management District's (SFWMD) Lower East Coast (LEC) water supply planning region (see ***Figure C-23***). The area is bounded by south-central Biscayne Bay and Biscayne National Park (BNP) to the south and east, and the Atlantic Coastal Ridge, and agricultural and suburban development to the north and west. Florida Power & Light Company's (FPL's) Turkey Point nuclear power plant, Homestead Air Reserve Base and the South Dade Landfill are located in the project area. The project area overlaps several drainage basins, six of which are named for the associated major east-west canals: Canal 100 (C-100), C-1, C-102, C-103, North Canal and Florida City Canal. These canals are operated to reduce the potential for flood damages as well as to limit salinity intrusion into the local groundwater system. To limit flood damages, water managers use the canal system to lower the groundwater elevation which increases runoff storage potential in the canal basins. Additional flood protection is provided by the L-31E Levee and Canal which runs north-south along South Central Biscayne Bay. The eastern-most water control structures are located at the intersection of the L-31E Canal and the major east-west canals. During the dry season, water managers use the east-west canal network to import water from the northwest which increases groundwater elevation and limits saltwater intrusion in to the aquifer.

Existing land use within the study boundaries varies widely from agriculture to high-density, multi-family and industrial urban uses. Urban development is generally concentrated along the lower east coast of Miami-Dade County. Although there remains substantial agricultural acreage in southwestern Miami-Dade County (90,000 acres), rapid population growth and land development practices have resulted in notable western urban sprawl; the predominant land use is single-

family residential. The once significant rural population in the western areas of Miami-Dade County is rapidly evolving into an urbanized population.

The Turkey Point Nuclear Power Plant is located on the edge of Biscayne Bay near the project area. Water used in the reactor is piped in from the Miami-Dade municipal water supply. A separate supply of water that cools the turbine steam supply for reuse comes from a unique, closed system of 36 interconnected canals totaling over 168 miles in length located on FPL property.

Homestead Air Reserve Base borders a portion of the study area on the west, and Biscayne National Park (BNP) borders the study area on the east. Inside the study area boundary there is a landfill toward the northern end of the study area as well as a water treatment facility. The majority of the existing use of the land that is being considered for the project primarily consists of mixed open land with agriculture, degraded wetlands and fallow fields. Agricultural land use includes ornamental trees, with a mix of row crops and nursery crops.

The Restudy identified a need to replace lost overland flow, rehydrate coastal wetlands and reduce point source freshwater discharges to Biscayne Bay using a system of pumps, and interconnections between coastal canals and operational changes to coastal structures. The primary purpose of the Biscayne Bay Coastal Wetlands project is to redistribute freshwater runoff from the watershed away from the existing canal discharges and into the coastal wetlands adjoining Biscayne Bay to provide a more natural and historic overland flow through existing coastal wetlands. The proposed Biscayne Bay Coastal Wetlands Phase I project will include pumps, a spreader canal, canal staging, and several culvert structures to manage flows for optimal restoration opportunities to adjacent freshwater and saltwater wetlands.

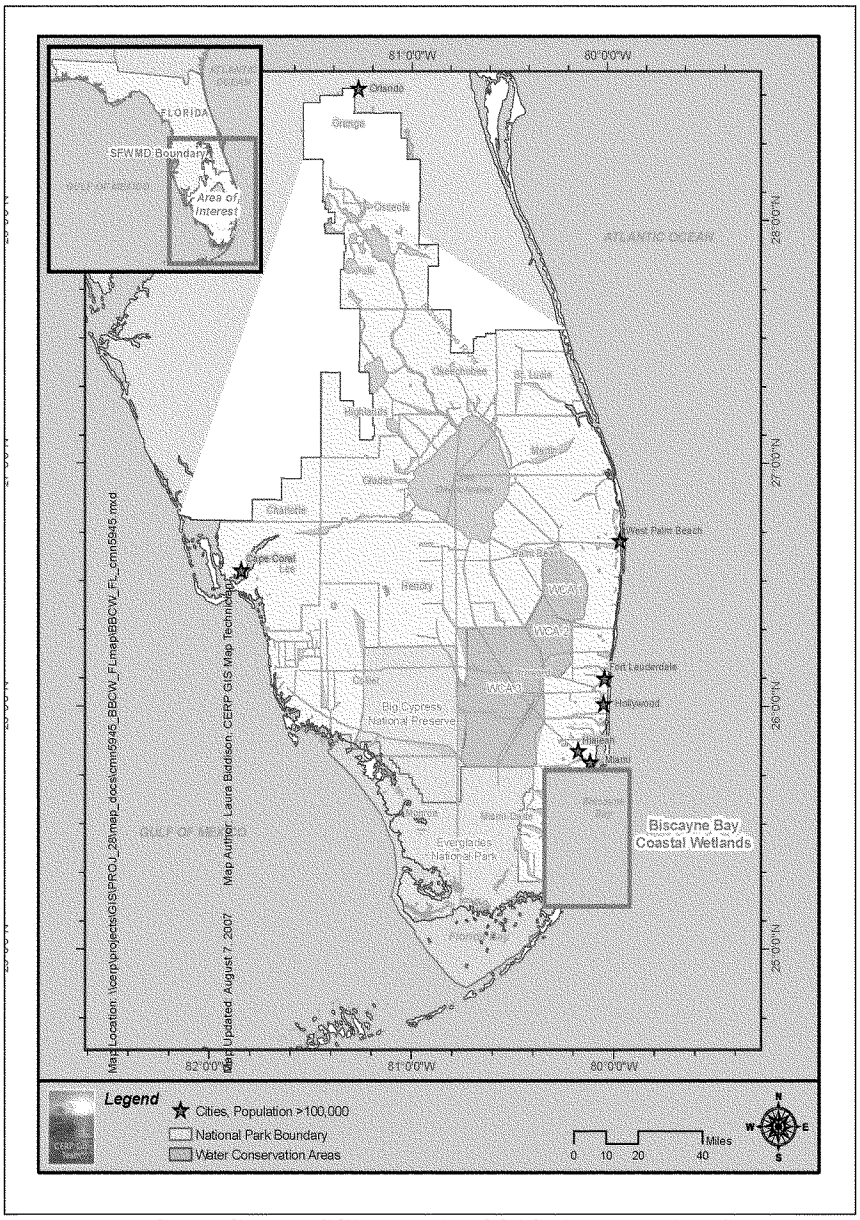


FIGURE C-23: BISCAYNE BAY COASTAL WETLANDS

C.2.1.1 Project Objectives

- Reestablish productive nursery habitat along the shoreline;
- Redistribute freshwater flow to minimize point source discharges to improve freshwater and estuarine habitat;
- Enhance and improve quantity, quality, timing and distribution of freshwater to the Bay and Biscayne National Park;
- Preserve and restore spatial extent of coastal wetlands;
- Restore nearshore and tidal wetland salinity regimes.

C.2.1.2 Project Features

C.2.1.2.1 Deering Estate

- Construction of a 500-foot extension of the C-100A Spur Canal through the Power's Addition Parcel
- Construction of a 100 CFS Pump Station (S-700) on the Power's Addition Parcel to withdraw water from C-100A Spur Canal
- Installation of 538 linear feet of 60" pipe which discharges to the Cutler Drain and ultimately to coastal wetlands located within the Deering Estate

C.2.1.2.2 Cutler Flow Way

- Construction of a 400 CFS Pump Station (S-701) on the C-1 Canal
- Construction of 7000+/- LF of lined conveyance canal to deliver water from the pump station to a proposed spreader
- Installation of Box culverts under SW 97 Ave, SW 87 Ave, and L-31E
- Construction of 13,160 LF of spreader canal
- Plugging of 2500 LF of remnant mosquito ditches

C.2.1.2.3 L-31 East – North Portion

- Construction of a 50 CFS pump station (S-703) on L31E (just north of C-102) w/ outlet spreader
- Construction of 100 CFS pump station (S-705) on L-31E (just south of C-102) to discharge south to L-31E
- Installation of eight flap gated culverts (S-23A, S-23B, S-706A, S-706B, S-706C, S-708, S-23C, & S-23D) to discharge from L-31 to saltwater wetlands east of L-31E
- Installation of an inverted siphon at Military canal to isolate it from L-31E

L-31 East – South Portion

- Construction of a 40 CFS pump station (S-709) to discharge water from C-103 north to L-31E

- Construction of a 40 CFS pump station (S-711) and spreader canal (C-711) to deliver water from C-103 to freshwater wetlands south of C-103
- Construction of 40 CFS pump station (S-710) to deliver water from C-103 to freshwater wetlands south of C-103 (via spreader structure)
- Installation of two flap gated culverts (S-712A & 712B) to discharge from L-31 to saltwater wetlands east of L-31E

As shown on ***Figure C-24***, the initial phase or Phase 1 of the proposed Biscayne Bay Coastal Wetlands project incorporates restoration components primarily intended to benefit estuarine resources in three geographical regions that include the Deering Estate, the Cutler Flow Way, and the L-31E Culverts.

This increment includes the installation/construction of pump stations, spreader swales, storm water treatment areas, flow ways, levees, culverts, and backfilling canals. The subsequent phase (Phase II), to be addressed in a separate document, will include the Barnes Sound Wetlands, remaining L-31 E Canal culverts, and the North Canal Flow Way.

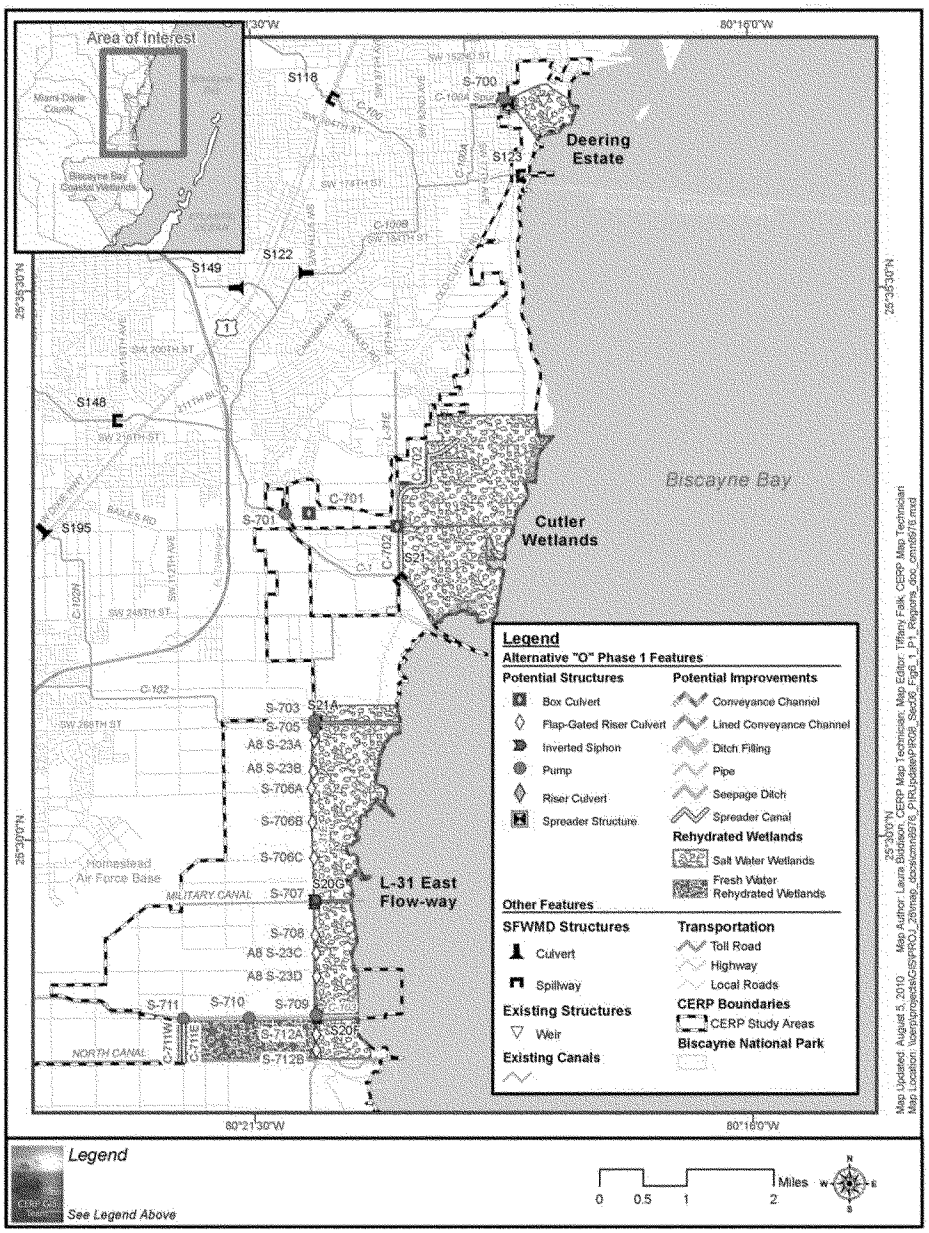


FIGURE C-24: SUMMARY OF PROJECT FEATURES

C.2.1.3 Report Authority

The CERP was approved in Section 601 of Water Resources Development Act of 2000 (WRDA 2000), Public Law No. 106-541, of the 106th Congress:

(b) COMPREHENSIVE EVERGLADES RESTORATION PLAN.–
(1) APPROVAL.–
(A) IN GENERAL.—Except as modified by this section, the Plan is approved as that are needed to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The Plan shall be implemented to ensure the protection of water quality in, the reduction of the loss of fresh water from, and the improvement of the environment of the South Florida ecosystem and to achieve and maintain the benefits to the natural system and human environment described in the Plan, and required pursuant to this section, for as long as the project is authorized.

The authority for the preparation of the Biscayne Bay Coastal Wetlands PIR is contained in Section 601(d) WRDA 2000, which states:

(d) AUTHORIZATION OF FUTURE PROJECTS –
(1) IN GENERAL.–*Except for a project authorized by subsection (b) or (c), any project included in the Plan shall require a specific authorization by Congress.*
(2) SUBMISSION OF REPORT–*Before seeking congressional authorization for a project under paragraph (1), the Secretary shall submit to Congress –*
(A) a description of the project; and
(B) a project implementation report for the project prepared in accordance with subsections (f) and (h).

Section 601(h)(4) of WRDA 2000 further requires that a Project Implementation Report document the following:

(4) PROJECT-SPECIFIC ASSURANCES-
(A) PROJECT IMPLEMENTATION REPORTS-
(i) IN GENERAL- The Secretary and the non-Federal sponsor shall develop project implementation reports in accordance with Section 10.3.1 of the Plan.
(ii) COORDINATION- In developing a project implementation report, the Secretary and the non-Federal sponsor shall coordinate with appropriate Federal, State, tribal, and local governments.
(iii) REQUIREMENTS- A project implementation report shall—

(I) be consistent with the Plan and the programmatic regulations promulgated under paragraph (3);
(II) describe how each of the requirements stated in paragraph (3)(B) is satisfied;
(III) comply with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.);
(IV) identify the appropriate quantity, timing, and distribution of water dedicated and managed for the natural system;
(V) identify the amount of water to be reserved or allocated for the natural system necessary to implement, under State law, sub clauses (IV) and (VI);
(VI) comply with applicable water quality standards and applicable water quality permitting requirements under subsection (b)(2)(A)(ii);
(VII) be based on the best available science; and
(VIII) include an analysis concerning the cost-effectiveness and engineering feasibility of the project.

C.2.1.4 Relationship to Other USACE/Non-Federal Sponsor Efforts, Studies, Documents and Reports

Listed below are brief descriptions of other key projects related to the Biscayne Bay Coastal Wetlands project. Included in the description are the objectives and/or study area.

C.2.1.4.1 C-111 Spreader Canal Project

The CERP C-111 Spreader Canal is intended to improve the delivery of flow to Florida Bay via Taylor Slough, improve hydroperiods within the Southern Glades and Model Lands, and re-establish sheetflow and hydrologic connectivity between natural areas, resulting in improved hydropatterns. The project area is adjacent to the Biscayne Bay Coastal Wetlands area.

C.2.1.4.2 Wastewater Reuse Technology Pilot

The CERP Wastewater Reuse Technology Pilot project will explore the water quality issues associated with discharging reclaimed water into the Biscayne Bay Coastal Wetlands project area. The pilot project will also attempt to identify a level of superior treatment and the appropriate methodologies for that treatment. If the water quality issues surrounding Wastewater Reuse can be resolved, a recommendation for discharge of the treated water to the BBCW project could be made within a subsequent project implementation report (PIR).

C.2.1.4.3 Stormwater Detention and Treatment Area Project

A pilot project has been constructed in the Biscayne Bay Coastal Wetlands by Miami- Dade Department of Environmental Resource Management (DERM) with funding support from the SFWMD, the Florida Department of Environmental Protection (FDEP) and the Homestead Air Reserve Base. The main purpose of the pilot project is to evaluate a method for modifying the timing and delivery of canal discharges to Biscayne Bay in order to minimize the negative ecological effects caused by large pulse discharges of fresh water. Similar to the Wastewater Reuse Technology Pilot project, information learned from this feature will largely assist in decision making associated with a subsequent project implementation report (PIR).

C.2.1.4.4 South Dade Watershed Plan

The purpose of the South Dade Watershed Plan is to formulate an integrated land use and water management strategy for all of the lands that comprise the major drainage basins in southeastern Miami-Dade County: the C-2, C-100, C-1, C-102, C-103, North Canal and Florida City basins. The entire footprint of the Biscayne Bay Coastal Wetlands project is located in the South Dade Watershed Plan area. The South Dade Watershed serves two national parks, as well as urban and agricultural areas. The South Dade Watershed Plan directs the comprehensive growth management of land uses consistent with CERP projects in Miami-Dade County that consider protection of the environment, including land and water resources. To the greatest extent practicable, the BBCW project has been developed to be consistent with the South Dade Watershed Plan.

C.2.2 Water Resource Analysis and Evaluation

Under Subsection 373.1501(5)(a) Florida Statutes (F.S.), the District shall "analyze and evaluate all needs to be met in a comprehensive manner and consider all applicable water resource issues, including water supply, water quality, flood protection, threatened and endangered species, and other natural system and habitat needs."

The BBCW Selected Plan is known as Alternative O Phase 1. The plan encompasses approximately 3900 acres of land, seven pump stations, ten culverts reconnecting wetlands, three miles of spreader canals and plugging 2500 feet of mosquito ditches.

C.2.2.1 Water Supply

Alternative O Phase 1 environmental goals are to rehydrate and restore wetlands and nearshore bay habitat by minimizing point source discharges, and to improve the quantity, quality, timing, and distribution of water to freshwater and tidal wetlands and to the bay. Alternative O Phase 1 includes the use of flow ways,

spreader canals, culverts, piping, weirs, canal plugs; mosquito control ditch plugs (102 total) and pumps.

The permitted consumptive water users outside the geographic footprint of the project components are depicted in ***Figure C-25***. Current uses are primarily agricultural and public water supply. The redistribution of excess stormwater runoff from existing canal discharges will not impact existing legal users including public and agricultural uses. These permitted users do not rely upon existing canal discharges as conditions to meet the 1 in 10 year drought event. Diversion of water will occur only downstream of the coastal control structures and will have no adverse effect on existing legal users.

Therefore, the project will not result in elimination or transfer of water from existing legal sources because canal flows and levels upstream of the coastal control structures would not be affected by the project.

No adverse impacts to water supply are expected from this project.

A detailed discussion of project assurances for water supply can be found in Annex C.

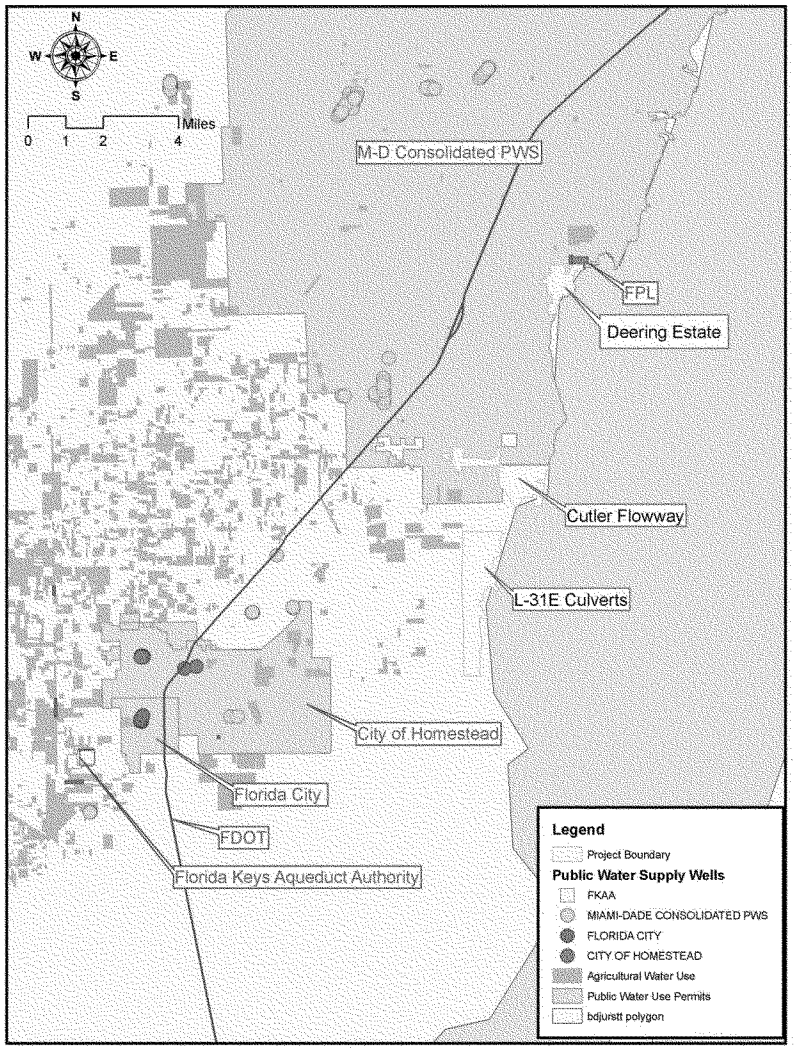


FIGURE C-25: PERMITTED WATER USE

C.2.2.2 Water Quality

The Biscayne Bay Coastal Wetlands Phase I project is intended to contribute to the restoration of Biscayne Bay and adjacent wetlands as part of the overarching CERP. Specifically, the project is intended to redistribute freshwater runoff from the BBCW watershed currently discharged to a network of canals, into the coastal wetlands. Recharging the coastal wetlands will influence the salinity regime within the nearshore areas of the bay making it more favorable habitat for local fish and shellfish populations and will mimic more historic flow patterns into Biscayne Bay.

The salinity regime of the nearshore areas of southwestern Biscayne Bay has been modified significantly due to manmade influences and changes in local hydrology. Today, higher salinities along the shoreline, especially during the dry season, have led to the decline in oyster reefs that once thrived at creek mouths, reduced the suitability of the area for American crocodiles (*Crocodylus acutus*), and have resulted in a shift of fish and macro invertebrate fauna to that more characteristic of marine conditions than estuarine conditions. ***Figure C-26*** and ***Figure C-27*** show the average salinity conditions for May and November 2008, respectively. While these two figures only represent a single year, they represent typical conditions for the dry season with no areas where salinity less than 20 psu and wet season conditions with salinity as low as 5 psu in the area offshore of the C-1, C-102, and C-103 canals.

Restoring the salinity in the nearshore habitat to mesohaline conditions (5 to 20 psu) throughout the year would provide the optimal salinity regime for the flora and fauna that historically inhabited this area

The salinity target for the project is set at 20 practical salinity units (psu), which is at the mid to upper end of the preferred range for most of the above species. Without freshwater discharges the salinity would exceed the 20 psu target. For this performance measure, alternatives were selected which provide the most uniform freshwater discharge in terms of timing and spatial extent for the project.

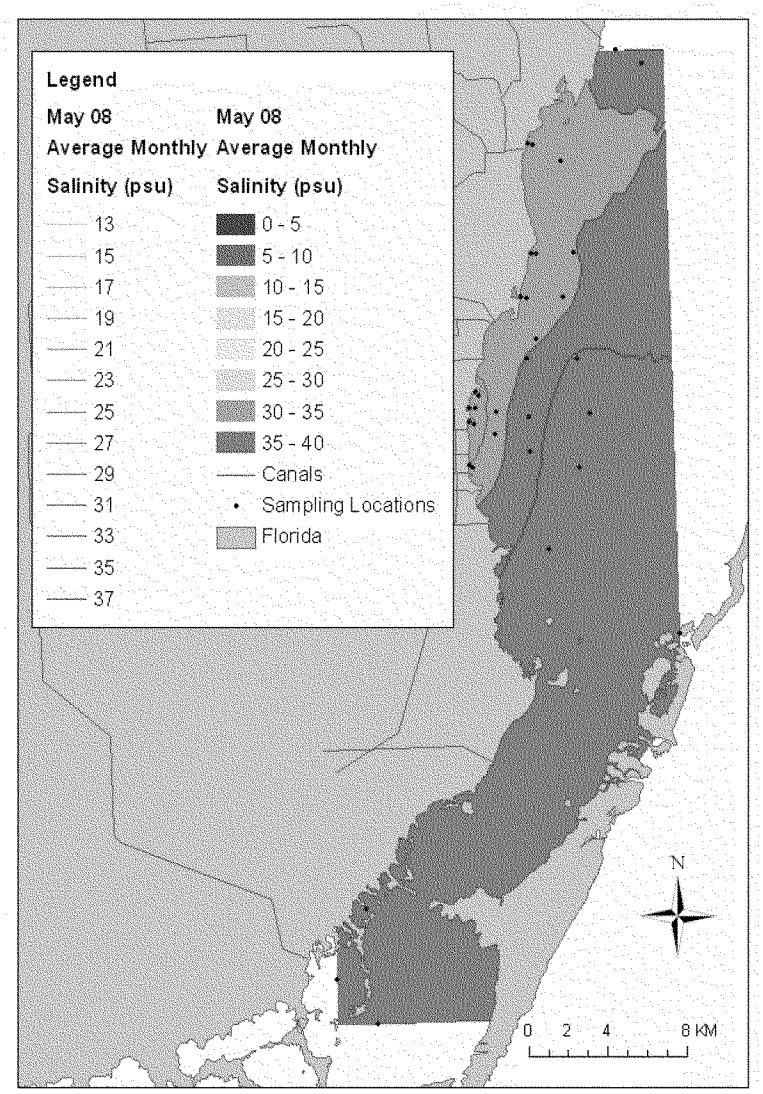


FIGURE C-26: AVERAGE MEASURED SALINITY FOR MAY 2008 IN SOUTH CENTRAL BISCAYNE BAY

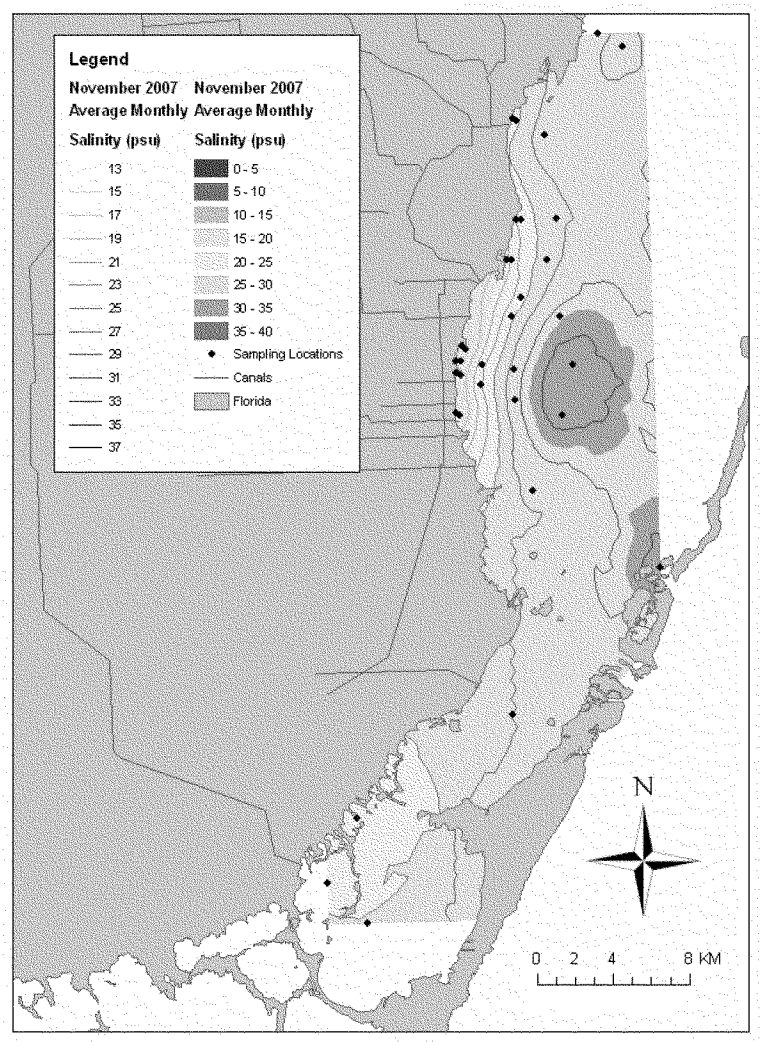


FIGURE C-27: AVERAGE MEASURED SALINITY FOR NOVEMBER 2008 IN SOUTH CENTRAL BISCAYNE BAY

The diversion of direct canal discharges into freshwater and tidal wetland areas should result in a reduction of nutrient loading to the bay with a corresponding increase in nutrient loading to the rehydrated wetlands. The effect of increased nutrient loading to rehydrated wetlands is not expected to result in significant adverse impact to the vegetation in these wetlands primarily because the phosphorus concentrations in the canal water to be diverted are relatively low (<10 ppb TP), and the wetlands should be able to assimilate these concentrations. To evaluate the reduction in nitrate loading to the Bay, the project team estimated the volume of water diverted from the canal system by Alternative O Phase 1 and used a wetland nitrate uptake equation to estimate the reduction in loads delivered to Biscayne Bay. Based on this methodology, it is assumed that as much as 84 percent of the nitrate loading to the Bay may be eliminated by the Selected Plan.

As indicated in the PIR, Phase I is unlikely to have any effect on total Hg concentrations in fish populations. Any long-term increase in methylmercury production will be from atmospheric deposition, not the project. The District may leverage existing Hg monitoring networks within the vicinity to satisfy CGM 42. If any additional mercury monitoring stations are necessary, they will be detailed in the Water Quality Monitoring Plan. The monitoring plan for mercury and pesticides is provided in Annex E of the PIR. Also, the water quality monitoring plan includes as Appendix 1, detailed mercury and other toxicants (e.g. pesticides) plan. The state permits issued for this project require herbicide tracking (if applied) to be included in the annual report, but not routine sampling. Herbicides would be included as appropriate in the Mercury and Other Toxicants plan in the water quality monitoring plan.

In 1999 under the Biscayne Bay regional sampling network, the District collected samples for oil and grease from 20 stations throughout Miami-Dade County, including multiple stations near and upstream of the BBCW Project area. All samples returned results of less than the detection limit of 1.4 mg/L. In the following 10 years there has been no significant change in land use or industry in the subject area, and this project will not generate or impact any areas that would generate, oil or grease. Base on this information Oil and Grease are not proposed to be monitored for this project.

Water quality monitoring will be conducted to evaluate the BBCW project's performance with regard to restoration goals and regulatory requirements. By rehydrating coastal wetlands and reducing damaging point source freshwater discharge to Biscayne Bay, the project is integral to the health of the south Florida ecosystem.

The monitoring stations described in Annex E of the PIR were established to satisfy requirements of the Comprehensive Everglades Restoration Plan Project Implementation Report and to satisfy requirements of (issued or currently under

review) Department of the Army Section 404 permits and/or State of Florida 373.1502 F.S., Comprehensive Everglades Restoration Plan Regulation Act (CERPRA) permits for Start Up and Operational Phase Monitoring.

Although the Selected Plan for the Biscayne Bay Coastal Wetlands project is not expected to affect most of the parameters listed in the permits, certain parameters (e.g., turbidity, dissolved oxygen and nutrients) listed in the criteria may be temporarily affected by construction and operations activities.

Any short-term impacts to water quality associated with construction of the Selected Plan would be ameliorated by construction sequencing, the use of best management practices (BMPs) for erosion and sedimentation control, and by monitoring during construction. If potentially adverse effects are observed or predicted, longer-term impacts to water quality associated with the operation of project features would be addressed through operational monitoring and adaptive management actions. Upon completion of construction and initiation of operations, water quality and hydrology would be monitored to determine whether project design and operational objectives are being achieved.

The permits and/or agreements that will govern the monitoring requirements of this project are being developed through the permitting process. Permitting for the project components under the State's Expedited Construction program, including four of the L31-E culverts, Deering Estates Pump Station and Cutler Flow Way began with the application submittals to FDEP, U.S. Army Corps of Engineers and Miami-Dade DERM. The Deering Estate project component and the S-23A, B, C, and D culverts within the L-31E project component have received federal, state and local permits (see Summary of Project Features in Section 3 of this report) and Cutler Flow way permits are pending agency issuance. Permitting for the remaining features of the project will occur in the future.

The South Florida Water Management District has received the following permits:

- Comprehensive Everglades Restoration Plan Regulation Act permit for the Biscayne Bay Coastal Wetlands Deering Estate, Permit #0271729-002 (Date of issue: May 23, 2008; Expiration date: May 23, 2013)
- Comprehensive Everglades Restoration Plan Regulation Act permit for the L31E Culverts project, Permit #0271729-001-GL (Date of issue: September 09, 2007; Expiration date: September 09, 2012)
- The Department of the Army 404 Permit #SAJ-1994-1327[IP-TKW] (Date of issue: May 15, 2008; Expiration date: November 13, 2012) for L31 E Culverts.
- The Department of the Army 404 Permit #SAJ-2007-139 for Deering Estates (Date of Issuance: December 18, 2009).

- Miami-Dade Department of Environmental Resource Management Class III Construction permit for Deering Estate Flow way, Phase 1 (Date of issue: September 22, 2008).
- Miami-Dade County Class I Construction Permit for L-31 E Culverts, Phase 1 (Date of issue: February 13, 2009).

In addition to the current Water Quality Monitoring Network (see Annex E), upgraded and new monitoring stations where water quality data will be collected are shown in the following tables:

TABLE C-11: MONITORING REGIME FOR UPGRADED EXISTING CANAL STATIONS

Monitoring Station	Group	Parameters	Collection Method	Frequency
BL03	Physical parameters	Dissolved oxygen, Specific conductivity, pH, Temperature	*In situ* Field measurements	Detailed in individual project monitoring plans
	Nutrients	TP, TKN*, NH3, NOX	Detailed in individual project monitoring plans	
	Other Core Parameters	Turbidity		

Key: TP total phosphorus
TKN total kjeldahl nitrogen
NHE ammonia
NOX nitrogen oxide

TABLE C-12: NEW SURFACE WATER QUALITY MONITORING STATION

Group	Parameters	Collection Method	Frequency	Structure
Nutrients	TP, TKN, NOX, NH3	Detailed in individual project monitoring plans	Detailed in individual project monitoring plans	S-701 S-700
Physical Parameters	Dissolved oxygen, Specific conductance, pH, Temperature	*In situ* Field measurements		
Other Core Parameters	Turbidity	Detailed in individual project monitoring plans		

Key: TKN total kjeldahl nitrogen
TP total phosphorus
NOX nitrogen oxide

TABLE C-13: NEW SURFACE WATER QUALITY MONITORING STATION PARAMETERS

Parameter	Units	Sample Type	Sampling Frequency	Monitoring Station
Ammonia	mg/L	Detailed in individual project monitoring plans	Detailed in individual project monitoring plans	GL03
Salinity	mg/L (psu)			
Color	PCU			
Dissolved Oxygen	mg/L			
pH	SU			
Specific Conductance	uS/cm			
Temperature	Deg C			
Total Phosphorus	mg/L			
Turbidity	NTU			
NOX	mg/L			

Key: Deg C degrees Celcius psu practical salinity units
mg/L milligrams per liter SU standard units
NTU nephelometric turbidity units uS/cm micro-Siemens per centimeter
PCU platinum cobalt units

The monitoring regime for mercury and pesticides is provided in Annex E of the PIR.

C.2.2.3 Flood Protection

None of the Alternative O Phase 1 features are designed to improve flood protection. However, this alternative will maintain the existing level of flood risk management through further optimization of project operations of the existing and proposed control structures. Each project sub-component was analyzed separately. The project team used a combination of modeling tools (the HEC-RAS, FESWMS and MODBRANCH) to perform an analysis of the flood protection impacts of the various project features. Results of these analyses concluded that existing levels of flood protection will not be adversely impacted by implementation of the project. The complete details of the analytical methods used and conclusions reached for each sub-component are explained in Section 5.2 of this report.

Each of the four geographically separate project components was analyzed individually, for potentially significant and adverse impacts to flood protection as described in Annex C. The project is designed so that there would not be any

significant or adverse affects to the pre-CERP level of service for flood protection of adjacent properties.

C.2.2.4 Threatened and Endangered Species

The region supports a variety of wetland-dependent wildlife, including several federal and state-listed endangered and threatened wildlife species. The USFWS has been an active member of the project team for the Biscayne Bay Coastal Wetlands project and has provided guidance through informal consultation during plan formulation and evaluation on the potential effects the proposed project may have on federally-listed threatened and endangered species that may be present in the project study area. USACE has coordinated with the National Marine Fisheries Service, Protected Resource Division, on proposed impacts to species under their purview.

The project is located in areas designated as Essential Fish Habitat (EFH) for corals, coral reef and live bottom habitat, red drum (*Sciaenops ocellatus*), shrimp, spiny lobster (*Panulirus argus*), other coastal migratory pelagic species and the snapper-grouper complex. Species generally present in the Florida region include brown shrimp, pink shrimp, white shrimp, spiny lobster, stone crab, gulf stone crab, red drum, Spanish mackerel, and gray snapper (juvenile and adult). Specifically, essential fish habitat in Biscayne Bay is comprised of seagrasses, estuarine mangroves, intertidal flats, estuarine water column, live/hard bottoms, and coral reefs.

TABLE C-14: BISCAYNE BAY COASTAL WETLANDS PROJECT PHASE I IMPACT ON THREATENED AND ENDANGERED SPECIES

Common Name	Scientific Name	Status	Agency	Not Likely to Adversely Effect	No Effect
Mammals					
Everglades mink	*Mustela vison evergladensis*	T	State		X
Florida mastiff bat	*Eumops glaucinus floridanus*	E	State		X
Florida panther	*Puma concolor coryi*	E	Federal		X
West Indian manatee* (Florida manatee)	*Trichechus manatus*	E	Federal	X	
Birds					
Arctic peregrine falcon	*Falco peregrinus tundrius*	E	State		X
black skimmer	*Rynchops niger*	SC	State		X

Common Name	Scientific Name	Status	Agency	Not Likely to Adversely Effect	No Effect
brown pelican	*Pelecanus occidentalis*	SC	State		X
Cape Sable seaside sparrow	*Amodramus maritimus mirabilis*	E	Federal		X
Everglade snail kite	*Rostrhamus sociabilis plumbeus*	E	Federal		X
least tern	*Sterna antillarum*	T	State		X
limpkin	*Aramus guarauna*	SC	State		X
little blue heron	*Egretta caerulea*	SC	State		X
piping plover	*Charadrius melodus*	T	State		X
reddish egret	*Egretta rufescens*	SC	State		X
roseate spoonbill	*Ajaja ajaja*	SC	State		X
Roseate tern	*Sterna dougallii dougallii*	T	Federal		X
snowy egret	*Egretta thula*	SC	State		X
tri-colored heron	*Egretta tricolor*	SC	State		X
white-crowned pigeon	*Columba leucocephalus*	T	State		X
white ibis	*Eudocimus albus*	SC	State		X
wood stork	*Mycteria americana*	E	Federal	X	
Reptiles					
American alligator	*Alligator mississippiensis*	T/SA	Federal	X	
American crocodile*	*Crocodylus acutus*	T	Federal	X	
Eastern indigo snake	*Drymarchon corais couperi*	T	Federal	X	
gopher tortoise	*Gopherus polyphemus*	SC	State		X
green sea turtle	*Chelonia mydas*	E	Federal	X	
hawksbill sea turtle	*Eretmochelys imbricata*	E	Federal	X	
Kemp's ridley sea turtle	*Lepidochelys kempii*	E	Federal	X	
leatherback sea turtle	*Dermochelys coriacea*	E	Federal	X	
loggerhead sea turtle	*Caretta caretta*	T	Federal	X	
Miami blackheaded snake	*Tantilla oolitica*	T	State		X
Fish					
mangrove rivulus	*Rivulus marmoratus*	SC	State	X	
smalltooth sawfish	*Pristia pectinata*	E	Federal	X	
Invertebrates					
elkhorn coral	*Acropora palmata*	T	Federal		X

Common Name	Scientific Name	Status	Agency	Not Likely to Adversely Effect	No Effect
Florida tree snail	*Liguus fasciatus*	SC	State		X
Schaus swallowtail butterfly	*Heraclides aristodemus ponceanus*	E	Federal	X	
staghorn coral	*Acropora cervicornis*	T	Federal		X
Plants					
beach jacquemontia	*Jacquemontia reclinata*	E	Federal		X
Crenulated lead-plant	*Amorpha crenulata*	E	Federal	X	
deltoid spurge	*Chamaesyce deltoidea deltoidea*	E	Federal	X	
Garber's spurge	*Chamaesycegarberi*	T	Federal	X	
Johnson's seagrass	*Halophila johnsonii*	E	Federal		X
Small's milkpea	*Galactia smallii*	E	Federal	X	
tiny polygala	*Polygala smallii*	E	Federal	X	

* Critical habitat designated for this species
E: Endangered
T: Threatened
SC: Species of Special Concern
SA: Similarity of Appearance species

The proposed redistribution of freshwater flow across a broad front is expected to rehydrate and restore freshwater wetlands, tidal wetlands, and nearshore bay habitat. The project is expected to create conditions that would be conducive to Essential Fish Habitat, and the re-establishment of oysters and other components of the oyster reef community, nursery habitat along the shoreline, and reduced freshwater discharges into the bay. With improvements in water deliveries and water quality, the appropriate environment for sensitive estuarine biota, which are dependent on these conditions, are anticipated to improve. The inter-agency RECOVER Team will monitor the biological indicators to evaluate adaptive management options for the project. Ecological/vegetative monitoring will be conducted in accordance with specific conditions of the permits. However, there are no biological monitoring requirements associated with any of the issued permits.

The U.S. Fish and Wildlife Service's draft Coordination Act Report, dated July 9, 2008 and the Endangered Species Act Section 7 Concurrence letter, dated November 18, 2009 are provided in Annex A.

Generally, the Service supports the BBCW Project and the selected plan as they should provide meaningful hydrologic and ecologic improvements to the nearshore

waters of southwestern Biscayne Bay and the adjacent coastal wetlands. Estuarine resources in the project area will be positively affected by the restoration of a more natural freshwater flow regime. Reduction of harmful point source discharges at major conveyance canals as a result of implementing the BBCW Project will reduce the unnaturally large fluctuations in salinity near canal mouths, resulting in more stable salinity regimes in these areas, which will improve habitat for fish and invertebrates inhabiting the areas near the canal outlets. Reestablishing freshwater inflow to the bay across a broader front along the shoreline should lower salinities thereby resulting in more suitable estuarine habitat for eastern oysters, pink shrimp, spotted seatrout, red drum, and other fish and invertebrates. Lowering salinity along the shoreline should also result in the expansion of shoal grass and widgeon grass in these areas which increases benthic diversity and is a food source for the endangered West Indian manatee. The recommendations provided by the Service on this project are intended to make the project more environmentally compatible and to further enhance the diversity and abundance of fish and wildlife resources in the project area, while assuring that the optimum ecological benefits are delivered to Biscayne Bay and adjacent coastal wetlands consistent with the basic project purpose.

Please refer to Annex A of the draft PIR for a detailed component-by-component analysis.

The final Coordination Act Report is expected to be issued before release of the final PIR.

C.2.2.5 Other Natural System and Habitat Needs

The primary factors influencing the distribution of vegetation in this region are hydropattern, salinity, previous disturbance, and to a lesser extent, nutrient loading and soil type.

The dominant vegetation community in the region is a matrix of sawgrass prairie with tree islands. The tree islands vary in vegetation composition, depending upon elevation. At the highest elevations, the sawgrass prairie alternates with forested wetlands. At the lowest elevations near the coast, mangroves replace the freshwater wetlands. The transition zone between the mangroves and the freshwater prairie is a needle rush-salt grass zone on the freshwater side, but stunted scrub mangrove on the coastal side.

The plant community types present in the South Dade Wetlands Management Area include sawgrass glades, spike rush and beak rush flats, muhly prairie, cypress stands, native-dominated forested wetlands, tree islands, mangrove flats and hydric hammocks. Also present are exotic-dominated forests.

The features of the Biscayne Bay Coastal Wetlands Phase 1 project include pumps, a spreader canal, canal staging, and several culvert structures to manage flows for optimal restoration opportunities to adjacent freshwater and saltwater wetlands. Project construction activities should have minimal adverse impacts to existing vegetative communities and no effect on nearshore habitats. The existing (preconstruction) vegetative communities consist of pine flatwoods; tropical hardwoods; mixed wetland hardwoods; saltwater marshes, freshwater marshes, mangrove swamps;; and vegetated non-forested wetlands. Other existing habitats include abandoned groves; tree nurseries; exotic wetland hardwoods and exotic vegetation such as Brazilian pepper and Australian pine.

Post-construction, the project would consist of approximately 4,800 acres of rehydrated wetlands, restored wetlands, and exotic vegetation removal. The direct effects of this project to existing vegetative communities include the displacement of 18 acres for canal widening and construction along with a minimal loss of vegetation for other project feature construction that includes a small berm, seepage collector ditch, pump structures and associated pump stations. Despite the direct removal of wetland vegetation, this project would compensate for this loss with the restoration and rehydration of approximately 4,800 acres of freshwater and coastal wetlands.

TABLE C-15: DESCRIPTION AND QUANTIFICATION OF HABITATS AFFECTED BY THE BISCAYNE BAY COASTAL WETLANDS PROJECT PHASE I

Project Sub-Region	Construction Features	Vegetative Type	Acres Impacted
Deering Estate	Pump station, spur canal extension	Mixed Forested Wetlands	6.0
C-1 Cutler Flow Way	Pumps, conveyance canal, spreader	Herbaceous Upland Shrub & Brushland Mangrove Swamp Mixed Wetland Hardwoods Mixed Shrubs	0.9 3.9 2.1 31.5 6.7
L-31E	Pumps, spreader, culverts	Mangrove Swamps Mixed Wetland Hardwoods Mixed Shrubs Wetland Forested Mixed Freshwater Marshes	3.0 2.5 3.0 1.4 0.3
Total Acres Affected			**61.3**

The Deering Estate component would ultimately improve water quality in Biscayne Bay by redirecting the freshwater flows across coastal wetlands that currently discharges directly into Biscayne Bay via the C-1 Canal.

The Cutler Wetlands C-1 Flow Way component routes water from the C-1 Canal to a rehydration area. A spreader swale would be created to distribute the water across the rehydration area. This project would include exotic vegetation removal from parcels located along the flow way, and the back-filling of select mosquito ditches located within the rehydration area.

The installation of culverts along L-31E would partially restore historic overland water flows, rehydrate the coastal wetlands, and ultimately improve water quality in Biscayne Bay. The culverts are intended for use without the stop logs within the riser.

As a result of rehydration and overall restoration of freshwater and coastal wetland systems, this project is expected to indirectly benefit natural resources, including threatened and endangered species. Marine organisms associated with hard bottom communities will benefit from the reduction of point-source canal discharges into Biscayne Bay which stabilize water quality and salinities required to improve and sustain the nearshore communities. Sea turtles and manatees, who feed on seagrasses and/or benthic invertebrates in the project area, are also expected to benefit from the redirection and dispersion of fresh water across the wetland systems prior to entering the Bay. The hydrologic monitoring plan as outlined in the PIR and required by permits (if any) will be used to monitor changes that may occur from the project once construction is complete.

Alternative O Phase 1 provides limited hydration to the freshwater wetlands, specifically between the C-103 Canal and the North Canal. Most of the restoration focus, however, is in the coastal wetland communities.

Additional detailed information can be found in Annex A of the draft PIR.

C.2.3 Determination of Project Component Feasibility

Section 373.1501(5)(b), F.S., states that the District shall "determine with reasonable certainty that all project components are feasible based upon standard engineering practices and technologies and are the most efficient and cost-effective of feasible alternatives or combination of alternatives, consistent with Restudy purposes, implementation of project components, and operation of the project."

C.2.3.1 Standard Engineering Practices and Technologies

C.2.3.1.1 Summary of Project Features

The Biscayne Bay Coastal Wetlands project will be implemented in accordance with selected plan – Alternative O Phase 1. The components of Phase 1 are:

C.2.3.1.1.1 Deering Estate Pump Station

The project features of the Deering Estate (see ***Figure C-29***) component include:

- Construction of a 500-foot extension of the C-100A Spur Canal through the Power's Addition Parcel
- Construction of a 100 CFS Pump Station (S-700) on the Power's Addition Parcel to withdraw water from C-100A Spur Canal
- Installation of 538 linear feet of 60" pipe which discharges to the Cutler Drain and ultimately to coastal wetlands located within the Deering Estate

All features listed above have been previously permitted by FDEP, USACE and Miami-Dade County under the State's Expedited Construction program.

C.2.3.1.1.2 Cutler Wetlands

The project features of the Cutler Wetlands (see ***Figure C-30***) component include:

- Construction of a 400 CFS Pump Station (S-701) on the C-1 Canal
- Construction of 7000+/- LF of lined conveyance canal to deliver water from the pump station to a proposed spreader
- Installation of Box culverts under SW 97 Ave, SW 87 Ave, and L-31E
- Construction of 13,160 LF of spreader canal
- Plugging of 2500 LF of remnant mosquito ditches

C.2.3.1.1.3 L-31 East Flow way

The project features of the L-31 East Flow way (see ***Figure C-31*** and ***Figure C-32***) components include:

- Construction of a 50 CFS pump station (S-703) on L31E (just north of C-102) w/ outlet spreader
- Construction of 100 CFS pump station (S-705) on L-31E (just south of C-102) to discharge south to L-31E
- Installation of eight flap gated culverts (S-23A, S-23B, S-706A, S-706B, S-706C, S-708, S-23C, & S-23D) to discharge from L-31 to saltwater wetlands east of L-31E
- Installation of an inverted siphon at Military Canal to isolate it from L-31E
- Construction of a 40 CFS pump station (S-709) to discharge water from C-103 north to L-31E
- Construction of a 40 CFS pump station (S-711) and spreader canal (C-711) to deliver water from C-103 to freshwater wetlands south of C-103
- Construction of 40 CFS pump station (S-710) to deliver water from C-103 to freshwater wetlands south of C-103 (via spreader structure)

- Installation of two flap gated culverts (S-712A & 712B) to discharge from L-31 to saltwater wetlands east of L-31E

S-23A, S-23B, S-23C and S-23D have been previously permitted by FDEP, USACE and Miami-Dade County under the State's Expedited Construction Program.

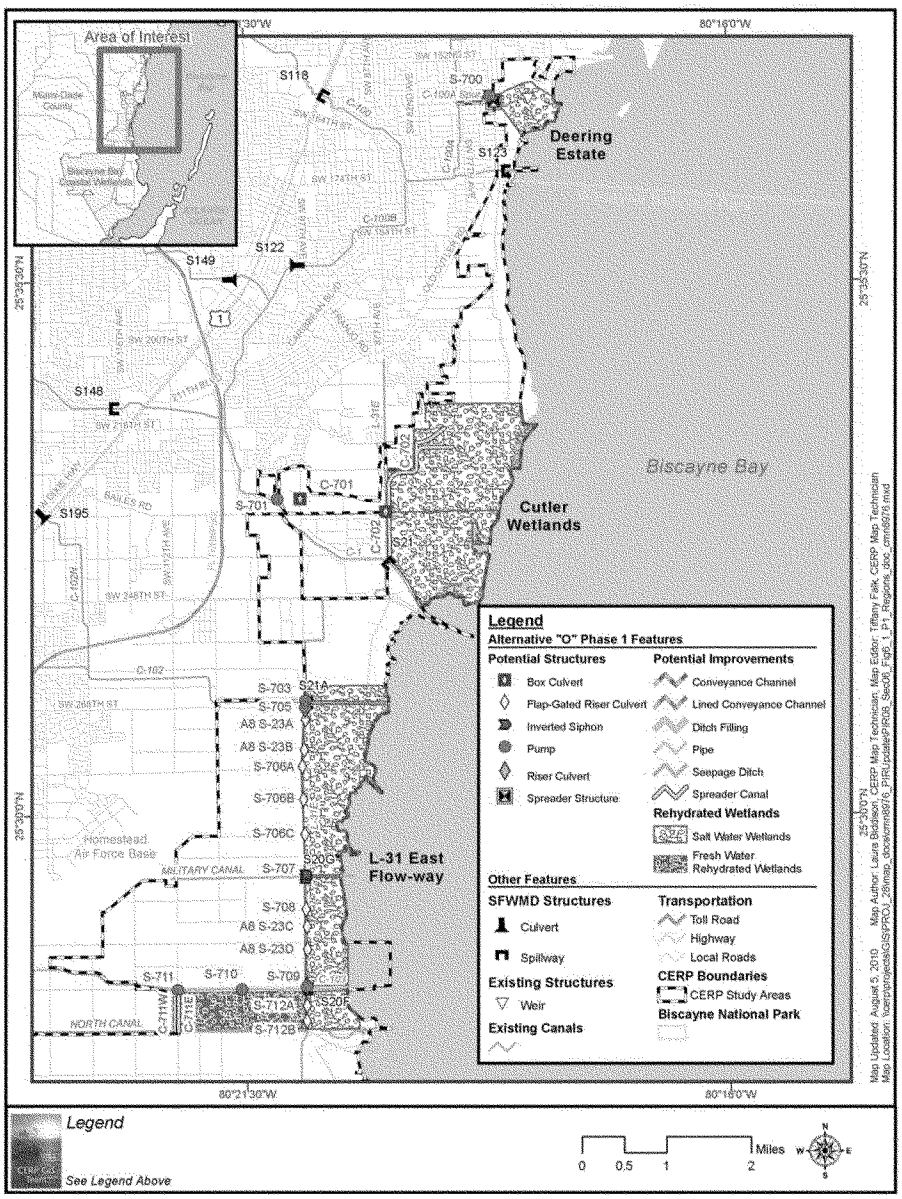


FIGURE C-28: BISCAYNE BAY COASTAL WETLANDS PROJECT COMPONENT MAP

FIGURE C-29: BISCAYNE BAY COASTAL WETLANDS – DEERING ESTATE

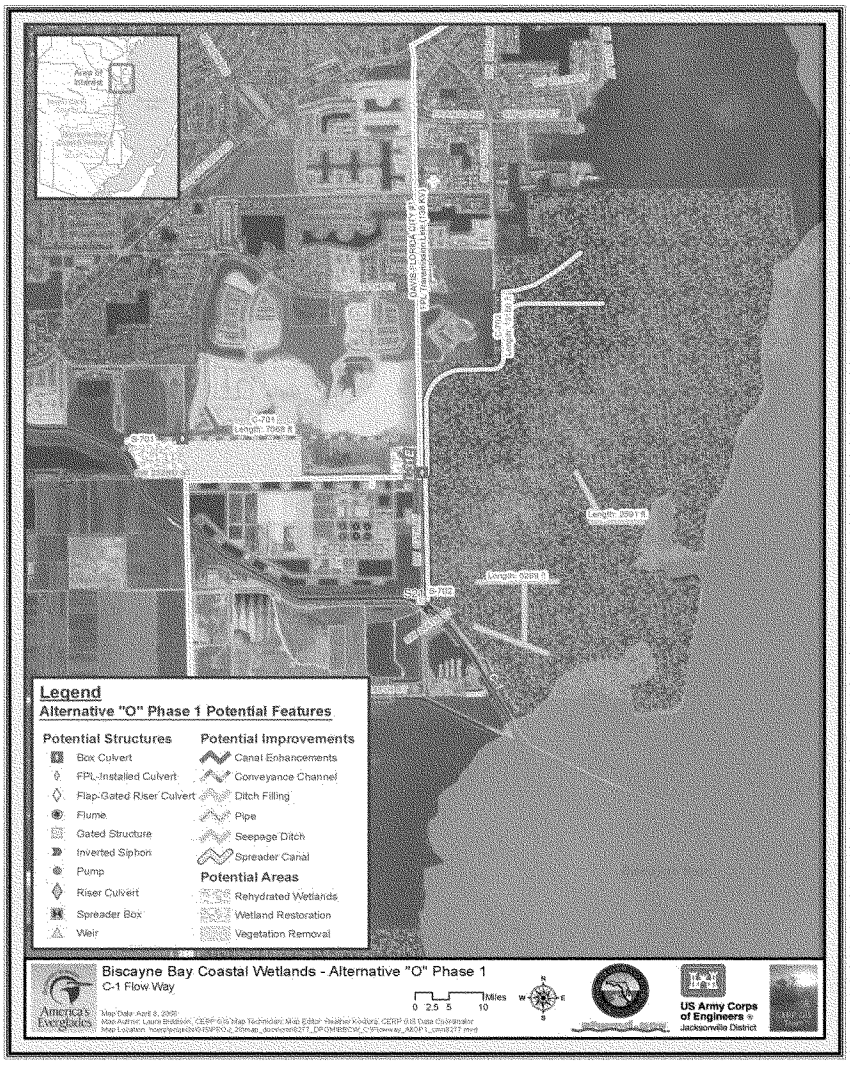


FIGURE C-30: BISCAYNE BAY COASTAL WETLANDS – CUTLER FLOW WAY

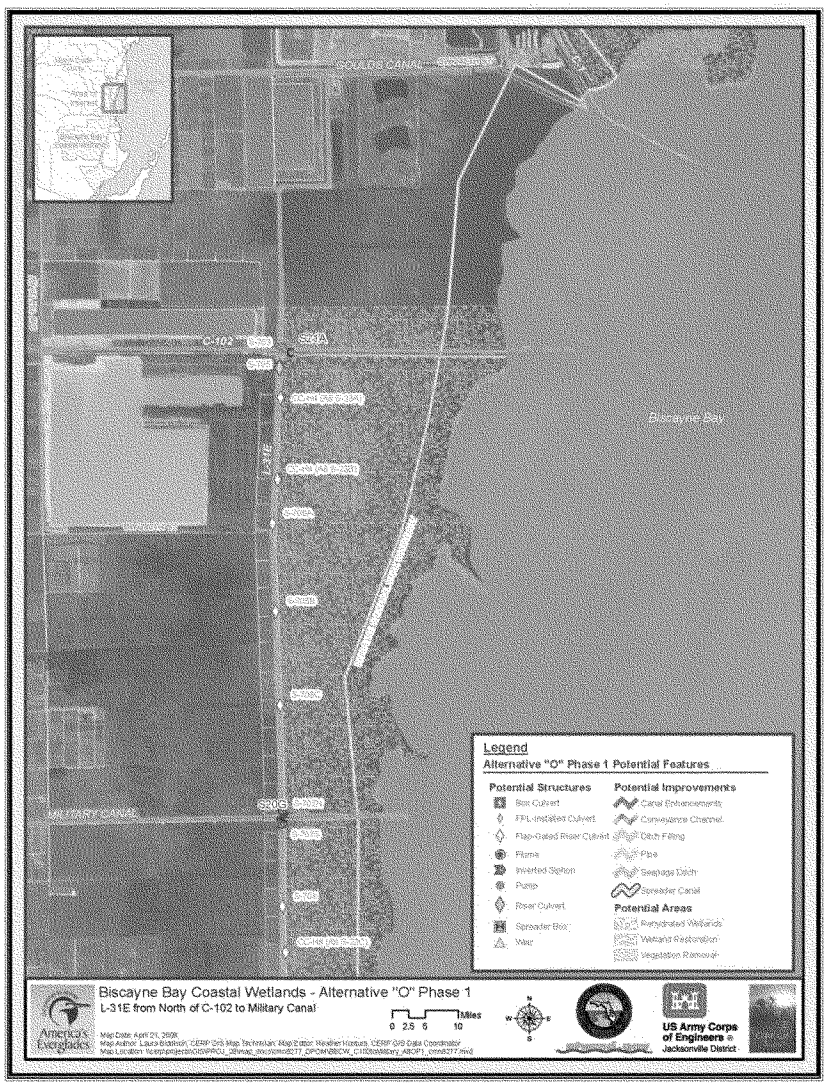


FIGURE C-31: BISCAYNE BAY COASTAL WETLANDS – L-31 E, NORTH OF C-102 TO MILITARY CANAL

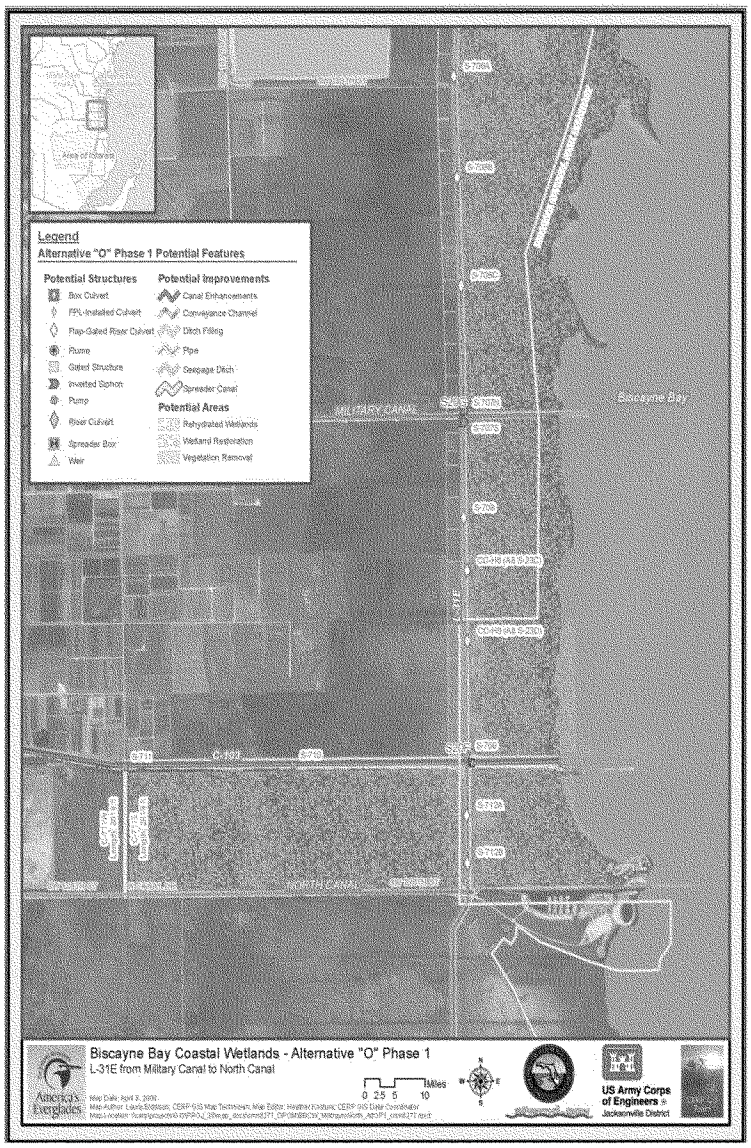


FIGURE C-32: BISCAYNE BAY COASTAL WETLANDS L-31E FROM MILITARY CANAL TO NORTH CANAL

C.2.3.1.2 Engineering and Design

Preliminary design activities, which include survey and geotechnical investigations as well as cultural resources compliance, commenced in early 2004. Planning, engineering and design activities are in accordance with state and federal standard practices, some of which are more particularly described in the USACE/SFWMD Design Criteria Memorandums (DCMs).

Details regarding Engineering and Design can be found in Appendix A of the Project Implementation Report. Additionally, under the State's Expedited Construction program, the SFWMD prepared a Basis of Design Report (BODR) which included the engineering assumptions and conceptual designs for the project features which the SFWMD intended to expedite. Those portions of the project included in the State's Expedited Construction program have either been permitted or are under review by regulatory permitting agencies as previously noted in Section 3 of this report.

Alternative O Phase 1 includes a larger scale project as compared to those features previously permitted by the State's Expedited Construction program features. Certain additional project features have not yet been fully designed. The design of these features, which lack detailed survey and geotechnical investigations, and are scheduled to be completed by USACE after the PIR document has been approved, and will utilize standard engineering practices and technologies.

C.2.3.2 Efficiency and Cost Effectiveness

The cost analysis is based on and follows guidance from the U.S. Army Corps of Engineers Institute for Water Resources publication, Evaluation of Environmental Investment Procedures Manual, Interim: Cost Effectiveness and Incremental Cost Analyses (CE/ICA), May 1995, IWR Report #95-R-1. Costs are based initially on a rough order of magnitude (ROM) and include pre-construction engineering and design and construction costs, interest-during-construction, as well as operations and maintenance costs after construction. The most feasible cost effective plans reflect estimates based on ROM quantities.

The purpose of a CE/ICA is to evaluate and compare the production efficiency of a given set of alternatives, thus helping to identify the plan that reasonably maximizes ecosystem restoration, which is considered the National Ecosystem Restoration (NER) plan. Cost effectiveness analysis begins with a comparison of the costs and outputs of alternative plans to identify the least cost plan for every level of output considered. Alternative plans are compared to identify those that would produce greater levels of output at the same cost, or at a lesser cost, as other alternative plans. Alternative plans identified through this comparison are the cost effective alternative plans. Next, through ICA, the cost effective alternative plans are compared to identify the most economically efficient alternative plans, that is,

the "Best Buy" alternative plans that produce the "biggest bang for the buck." Cost effective plans are compared by examining the additional (incremental) costs for the additional (incremental) amounts of output produced by successively larger cost effective plans. The plans with the lowest incremental costs per unit of output for successively larger levels of output are the best buy plans. The results of these calculations and comparisons of costs and outputs between alternative plans provide a basis for addressing the decision question "Is it worth it?" i.e., are the additional outputs worth the costs incurred to achieve them?

As described in ***Table C-16***, in addition to being cost effective, and a best buy, on a project wide basis, Alternative O Phase 1 is the alternative plan that is cost effective for each of the three ecological zones, when analyzed by zone.

TABLE C-16: RESULTS OF COST EFFECTIVE / INCREMENTAL COST ANALYSIS*

	Alternative O Phase 1	Alternative M	Alternative O	Alternative Q	Alternative YB
Combined Habitat Units	Cost Effective and Best Buy		Cost Effective and Best Buy		
Freshwater Ecological Zone	Cost Effective		Cost Effective and Best Buy	Cost Effective	Cost Effective
Saltwater Ecological Zone	Cost Effective and Best Buy				
Nearshore Ecological Zone	Cost Effective and Best Buy		Cost Effective and Best Buy		

**Section 5.4 of the PIR provides in-depth detail of the cost benefits analysis.*

C.2.3.3 Consistency with Restudy Purposes

The plan formulation process for the current Biscayne Bay Coastal Wetlands project was guided by USACE six-step planning process. A team formed of local, state and Federal agency personnel used the iterative process to identify the merits of individual components and evaluate alternative plans to determine how well the plans met the planning objectives, performance measures and evaluation criteria.

Of the several alternative plans, Alternative YB (Yellow Book) coincided with the Biscayne Bay Coastal Wetlands project as conceptualized in the CERP/Restudy and

included roughly 16,000 acres of land, nine (9) pump stations, approximately 35 culverts reconnecting wetlands, four (4) STAs covering roughly 4000 acres, approximately 14 miles of spreader canals, approximately seven (7) miles of conveyance canals, backfilling approximately five (5) miles of the Military and North canals, and plugging 2000 feet of mosquito ditches.

Alternative O Phase 1 reflects a standalone increment of the Restudy that provides a meaningful first step towards restoration in the study area and provides opportunity to reduce uncertainty for subsequent features. It comprises approximately 3900 acres of land, seven pump stations, approximately ten culverts reconnecting wetlands, approximately three miles of spreader canals, and plugging 2,500 feet of mosquito ditches.

As the Selected Plan, Alternative O Phase 1 is a National Ecosystem Restoration plan that provides a meaningful first step towards restoration in the study area, provides opportunity to reduce uncertainty for subsequent features, capitalizes on State Expedited Construction (aka Acceler8) program constructions and limits risk.

C.2.3.4 Implementation of Project Components

Under the State's Expedited Construction program, two components of the Biscayne Bay Coastal Wetlands project (L-31E Culverts and Deering Estate) have been issued Chapter 373.1502, F.S. construction and operation permits. The Cutler Flow Way permit application is currently under review by the Department. The draft operational protocol for each of these components has been submitted to the Department and has been approved or is under review.

The Draft Project Operating Manual (*see Annex D*) describes the criteria that apply for implementation of the initial operating regime and includes a conceptual discussion of operations necessary to achieve project benefits for the next added increment condition as required by the Comprehensive Everglades Restoration Plan (CERP) Guidance Memorandum #5.

The next version of the operating manual, the Preliminary Project Operating Manual, will describe any operating refinements developed based on the detailed design and construction phases of the project and will represent the water management operations for use during the Operational Testing and Monitoring Period. As defined in the Master Agreement, the Operational Testing and Monitoring Period is "a reasonable, limited, period of time within the period of construction, after physical construction has been completed, during which the authorized CERP project or a functional portion of the authorized CERP project is operated, tested, and monitored, to verify the constructed features perform as designed, and to allow for any adjustments to such features as may be necessary so that such features performed as designed.

Initially the project will be operated in accordance with the Draft Project Operating Manual (DPOM), During the Operational Testing & Monitoring (OT&M) period operations may be modified to optimize performance. Any operational changes will be described in the Final Project Operating Manual (FPOM), which will govern operations following completion of the Operational Testing and Monitoring Phase.

Detailed Operational Protocol/Sequencing can be found in Annex D.

C.2.4 Determination of Project Consistency with Applicable Laws and Regulations

C.2.4.1 Pre-Application Conference

In accordance with Section 373.1501 (5) (c), F.S., a pre-application conference was held on July 15, 2009 at the SFWMD CERP 2 office in West Palm Beach, Florida. Representatives from the following agencies attended the conference:

- USACE
- Florida Department of Environmental Protection (FDEP)
- Miami-Dade Department of Environmental Management (DERM)
- Florida Fish and Wildlife Conservation Commission (FFWCC)
- SFWMD

All attendees as well as Florida Department of Agriculture and Consumer Affairs concur with the meeting minutes of the pre-application conference which are included at the end of this report.

C.2.5 Reasonable Assurances [373.1501(5)(d)]

Under Section 373.1501(5)(d), F.S., the District shall "provide reasonable assurances that the quantity of water available to existing legal users shall not be diminished by implementation of project components so as to adversely impact existing legal users, that existing levels of service for flood protection will not be diminished outside the geographic area of the project component, and that water management practices will continue to adapt to meet the needs of the restored natural environment."

The hydrologic modeling, analytical procedures, and calculations performed for these evaluations were based on the information contained in the procedures developed for the draft programmatic Guidance Memorandum 3 ("Savings Clause Requirements"). Because the Guidance Memorandum 3 has not been finalized, all of the data and information contained in this report is considered to be preliminary and is subject to change as a result of further evaluations that may be performed to maintain consistency with the approved final programmatic guidance memoranda.

Analyses performed to provide reasonable assurances include both groundwater and surface water hydrologic modeling. Analyses associated with State Assurances occur at both the system-wide and project levels to confirm there will be no unexpected impacts to existing legal users of water or significant adverse effects on the level of service for flood protection as a result of the project. There is no predictive groundwater model available that would be capable of measuring changes in groundwater levels resulting from hydroperiod improvements. However, water levels in coastal wetlands will increase due to pumping rates but will not exceed the level necessary to overcome the friction encountered between the discharge points and the tide. While varying throughout the project, the water level increase should generally be less than one foot.

The BBCW project is located at or near the coastline, does not alter the current regional flood protection operations and only affects water deliveries to the southernmost canals in the Central and Southern Project or coastal structures. Therefore, project-level effects were evaluated for elimination or transfer of existing legal sources, effects on level of service for flood protection, and identification of water made available it has been determined to produce no system-wide effects to the C&SF system other than the ecological benefits to the natural system. .

The Biscayne Bay Coastal Wetlands Project Development Team has used a combination of modeling tools (the HEC-RAS, FESWMS and MODBRANCH) to analyze the level of service for flood protection for each project component.

C.2.5.1 Water Supply Assurance

The primary goal of the BBCW project is to re-direct the freshwater currently discharged through man-made canals to coastal wetlands in order to restore a more natural water flow pattern to Biscayne Bay. This project results in no elimination or transfer of water from existing legal users because the canal flows and levels upstream of the coastal control structures will not be affected by the project.

Existing legal users in the project area include several public utility wellfields, private wells and agricultural irrigation wells upstream within the drainage basins. All project features such as pumps or culverts to divert water are located downstream of their sources. Capacity and operation of the project features are designed to maintain existing water levels and overall flows to the coast. Project features only divert a portion of the water that would normally be discharged through coastal canal water control structures directly into Biscayne Bay. The quantity of water available for the natural system is estimated based on discharge through the coastal control structures all of which are downstream of the sources listed above. The SFWMD maintains a public dbHydro database of these flows and water stage elevations for each canal.

C.2.5.2 Flood Protection Assurance

Alternative O Phase 1 design features will maintain the existing level of flood protection through optimization of existing and proposed control structures. A combination of modeling tools was utilized to perform an analysis of the flood protection impacts of the various projects components.

Each of the four geographically separate project components was analyzed individually for potentially significant and adverse impacts to flood protection as described in BBCW PIR Annex C. The project is designed so that there would not be any significant or adverse affects to the existing level of service for flood protection of adjacent properties.

C.2.5.2.1 Deering Estate Flood Protection Analysis

The Deering Estate project involves discharging freshwater from the C-100A Spur Canal to the Cutler Drain, routed through a pump station and discharge pipeline, to hydrate the adjacent coastal wetlands. Two bridge structures cross the Cutler Drain, referred to as the Chinese Bridge and Rock Bridge. The Cutler Drain or Cutler Canal is a man-made canal excavated through limestone and extending from the vicinity of Old Cutler Road east to the Rock Bridge. Over time, the Cutler Drain has become densely vegetated.

The hydraulic modeling results of the C-100A Spur Canal and the Spur Canal extension confirmed that the Spur Canal extension section is adequate to convey the maximum pumping rate of 100 cfs. The canal section is large enough to reduce vegetation growth and potential clogging from branches and other debris, limit canal velocity and accommodate the pump intake depth.

Model results indicated that this additional flow to the Cutler Drain during storm conditions would result in a nominal one inch increase in water surface elevation. It should be noted that any increase in flow would not cause flooding west of Old Cutler Road as the pump station has a high-water shut-off monitor located within the outlet spreader structure.

The HEC-RAS modeling results estimated the water surface profile through the proposed piping system and Cutler Drain under the various flow conditions. Typical water surface profiles for flow through the Cutler Drain for hydraulic conductivities of two feet per hour and 200 feet per hour indicate that the maximum extent of inundation remains within the floodplain of Cutler Drain and the historic slough. The project is designed so that no significant or adverse increase of water elevation occurs near residential areas, park improvements, the Chinese Bridge or primary surface roadways.

C.2.5.2.2 Cutler Flow Way

Evaluation of the project's potential impact on the current level of flood protection for each adjacent parcel was conducted using two criteria. Properties were evaluated based on: 1) site drainage characteristics, and 2) the effect of wetland rehydration on water surface elevations within the property boundary of each parcel.

Four modeling simulations were used to evaluate the rehydration area canal configuration for each of the four model scenarios described in the BBCW PIR. The resulting water surface elevation is for the first scenario, corresponding to 400 cfs and a bay water elevation of +1.4 feet NAVD. Results indicate that during high tide conditions, the entire wetland area is flooded, and the flow is routed through both the ditches in the wetlands and as overland sheet flow. For these conditions most of the water follows the ditch alignments with very little overland flow, except where the land surface is low typically close to the bay.

Maximum water surface elevations of 1.4 feet (NAVD88) for the northern segment and 1.1 feet (NAVD88) for the southern segment could be possible. Limited survey data from (the USACE's survey 03-005 and the SFWMD's survey information) the western bank of the L-31E Borrow Canal, show berm elevations ranging from approximately 1.1 feet to 2.5 feet (NAVD88). Although the simulated water surface elevations could possibly overtop the western levee or berm in some areas according to the available topographic information, it is important to note that operations of the pump stations would be such that the pumps would not operate (would be turned off) when a specified water level (to be determined) is reached near the pump station. These "pump off" triggers would be developed to assure that the water surface in the L-31E Canal would not overtop the western levee/berm, therefore maintaining the current level of service for flood protection.

Results were examined to see if one parcel (GZ300-011) would experience potential additional flooding (above naturally occurring tidal flooding), along the northern boundary of the wetland area. It is not anticipated that any overtopping would influence the private property to the north under low water elevation conditions. A ditch system in the wetlands to the north would intercept any overtopping flow and deliver it to the bay. The results, which confirm the conservative nature of the HEC-RAS simulation, support the conclusion that the private property to the north is not impacted for the 400 cfs flow at low water elevations. Finally, the water elevation at the private property location near the north end of the rehydration area was reviewed and compared to naturally occurring conditions.

C.2.5.2.3 L-31 E (North Canal Impoundment Wetlands)

MODBRANCH modeling indicates that the first four alternatives are very similar in results. There would be increases in peak stages in the areas around the

wetland. Some, but not all, of the seepage out of the wetland is captured by C-103, North Canal, C-711W and L-31E. The impoundment wetland area is surrounded on all four sides by interconnected canals and ditches which flow east to the coastal structure on the C-103 Canal. Any groundwater seepage which might otherwise flow west to upgradient agricultural areas will be intercepted by a north/south ditch or small canals which directly connect via culverts to the C-103 and North Canals. Upgradient stages in the western agricultural areas will not rise above canal stages in the C-103 Canal. As an added protection, and described in the PIR, the selected plan includes a seepage collection canal immediately west of the spreader canal.

See Annex C pages 12-16 for graphs of peak depths.

The results can be quantified if the impacts by the number of acres with peak depth greater than 0.1 foot are defined. The number of acres where the peak depth south of the North Canal is greater than 0.1 foot for 1995 is shown in ***Table C-17*** below.

TABLE C-17: COMPARISON OF NORTH CANAL IMPOUNDMENT SIMULATED CONFIGURATIONS AND PEAK WATER DEPTHS ABOVE GROUND SURFACE

Configuration	Acres with Peak Depth > 0.1 feet Above Ground Surface	Increase from Alternative 7R / Existing
Alt7R/Existing	1186	
Biscayne Bay Coastal Wetlands_40N_40N	1323	137
Biscayne Bay Coastal Wetlands_40N_40S	1266	90
Biscayne Bay Coastal Wetlands_20N_60N	1359	173
Biscayne Bay Coastal Wetlands_20N_60S	1272	86
Biscayne Bay Coastal Wetlands_Bob	1206	20

The location of the S-710 pump in the south does reduce flooding in the area. This is likely a result of using that reach of the North Canal as a seepage collector. However, the largest reduction is obtained in the Biscayne Bay Coastal Wetlands_Bob configuration, which is a result of directing the water into the center (S-711) and east ends (S-710) of the wetland.

Detailed information on this analysis can be found in Appendix C, "Analysis required by Water Resources Development Act of 2000 and State Law" of the draft PIR. This section includes the detailed analysis and results used to determine the

Savings Clause Analysis for Flood Protection and the Elimination or Transfer of Existing Legal Sources of Water.

C.2.5.3 Adaptive Management to Meet the Needs of the Natural Environment

The goal of applying adaptive management for the Biscayne Bay Coastal Wetlands is to assist the project in achieving and/or maximizing its restoration goals and objectives, and to provide feedback and options to adjust management actions, as necessary, to ensure restoration goals are likely to be achieved. It is important to note that adaptive management is a type of process improvement, and the suggested management actions described herein are not self-executing. Moreover, any described operational or design changes would be implemented at the discretion of the leadership of the U.S. Army Corps of Engineers and the Governing Board of the South Florida Water Management District. Adaptive management actions will necessarily be implemented based on consideration of other agency restoration and water management priorities, and the availability of state and Federal funds

The Biscayne Bay Coastal Wetlands Adaptive Management plan has been designed to utilize project-level and system-wide Ecological Monitoring data to determine what changes or additions to management measures and operations are required to attain the project's intended restoration goals and objectives. Specifically, the suggested adaptive management measures should help ensure the restoration of beneficial patterns of freshwater flow, salinity, and water quality to nearshore waters and adjacent wetlands of southwestern Biscayne Bay to achieve the desired community structure, distribution, abundance, and viability of oyster bars, submerged aquatic vegetation, wetland vegetation, and associated biota. This plan facilitates the National Research Council's recent (2006) recommendation for the Incremental Adaptive Restoration approach for Comprehensive Everglades Restoration Plan.

Historically, Biscayne Bay served as the eastern outlet of the Everglades, with freshwater flowing overland to the bay through broad channels (transverse glades), which drained through a system of 20-30 tidally influenced creeks and/or as groundwater through the Biscayne Aquifer. Regional drainage, canal construction and operation (particularly C-100, C-1, C-102, C-103, and C-111), lowered groundwater levels, urban development, construction of roads, levees, and other hydrologic barriers to surface flow has altered this drainage pattern resulting in a much changed estuarine system. The objective of the BBCW Ecological and Water Quality Monitoring Plan is to 1) recreate a more natural pattern of freshwater flow to the estuary via the rehydration of coastal wetlands, 2) improve nearshore salinity patterns, 3) enhance water quality (both nearshore and offshore), and 4) improve structure and viability of associated floral and faunal communities.

The Project Level Monitoring Plan (PLMP) is consistent with, and complimentary to the MAP, neither duplicating nor replacing this program. The plan acknowledges

the guidance present in CGM40, CGM42, and the QASR. The plan details relevance to the performance measures developed by the PDT.

In summary, the conclusions presented in this Section are based on both system-wide and project level analyses and evaluations and confirm there will be no unexpected impacts to existing legal users of water or significant adverse effects on the level of service for flood protection resulting from the project and demonstrate that the project meets the reasonable assurances requirements.

C.2.6 Coordination with Existing Utilities and Public Infrastructure [373.1501(5)(e)]

Section 373.1501(5)(e), F.S., requires the SFWMD to "Ensure that implementation of project components is coordinated with existing utilities and public infrastructure and that impacts to and relocation of existing utility and public infrastructure are minimized."

C.2.6.1 Summary of Utilities & Coordination with Utilities and Public Infrastructure

During the planning process for the BBCW Project over the last several years, there have been extensive coordination efforts with utilities and other entities responsible for public infrastructure in the BBCW Project area in order to avoid and minimize impact to utilities and roads in the project area. Much of this occurred as a result of the SFWMD's efforts to accelerate several of the Phase 1 Components of the Project, including the Deering Estate and Cutler / Lennar Flow Way components, and as part of FPL's pre-application coordination efforts with the SFWMD and other agencies that were associated with FPL's plans to expand its facilities at the Turkey Point Power Plant (TPPP) site.

As described in the Appendix D (Real Estate) of the Draft Integrated PIR and EIS, there are several utilities with underground and aerial facilities in the project area, including FPL, Florida City Gas (FCG), ATT (formerly Bell South), and the Miami-Dade Water and Sewer Department (formerly Miami-Dade Water and Sewer Authority) (MDWASD). In addition, FPL and Florida Gas Transmission, Inc. (FGT) have major electrical and natural gas transmission facilities in this area, primarily in the FPL transmission line corridor adjacent to L-31E.

Coordination with these utilities and other local government entities (such as the cities of Homestead, Florida City, and Village of Palmetto Bay, Cutler Bay) with overlapping or adjacent jurisdictions with the BBCW project is on-going through the PDT process and special meetings when needed.

The SFWMD, Miami-Dade (MD) County, and several other state and federal agencies have also been involved in major coordination efforts with FGT and the Federal Energy Regulatory Commission (FERC) over the last year and a half during the preparation and review of the Draft and Final EIS's for the FGT Phase VIII

Expansion project which included a segment in MD County within the BBCW project area known as Loop 11. As a result of the agencies' coordination efforts with FGT and FERC, modifications to the route and maintenance procedures for the project were made to avoid impacts to the regional canal system and to minimize impacts to sensitive wetlands within the FPL transmission line corridor adjacent to the L-31E Canal.

Over the last several years, much of the coordination with FPL during the PIR planning process was linked to FPL's pre- and post-application coordination activities for the proposed expansion activities at the Turkey Point Power Plant (TPPP). The SFWMD, MD County, and most of the agencies and governmental entities involved in the PIR process are also involved in the on-going review of the associated Comprehensive Plan Amendment, Zoning, Power Plant Siting (PPSA), and Nuclear Regulatory Commission (NRC) applications. As components of the BBCW Project come on line, the District and FPL will continue to arrange for distribution power, as needed, including the removal of any facilities that no longer require power, and any required easement, using an already established process for handling these types of arrangements.

C.2.7 Increased Water Supply Available from Project

Identification of water for the natural system is based on the concept that a quantity of water is needed to achieve the benefits of the project, and the overarching objective of restoration, preservation and protection of the south Florida ecosystem. The water made available for the natural system is the water used for the protection of fish and wildlife within natural systems, including water that contributes to meeting hydrologic, water quality, and ecologic targets for restoration of natural systems. The targeted quantity needed in Biscayne Bay was estimated based on maintaining salinity nearshore at 20 practical salinity units (See CBEEM, Annex B; USACE 2003). This is the performance measure used in plan formulation. The Biscayne Bay TABS-MDS model was run for a typical year while maintaining salinity constant, and adding water along the shoreline.

Viewed from a programmatic perspective, identification of water for the natural system associated with the CERP involves an analysis of four different aspects of ecological responses to hydrologic changes:

1) Responses to the change in the quantity of water received by the natural system;
2) Responses to the timing of those deliveries;
3) Responses to the distribution of water delivered to the natural system; and
4) Responses to the quality of the water received by the natural system.

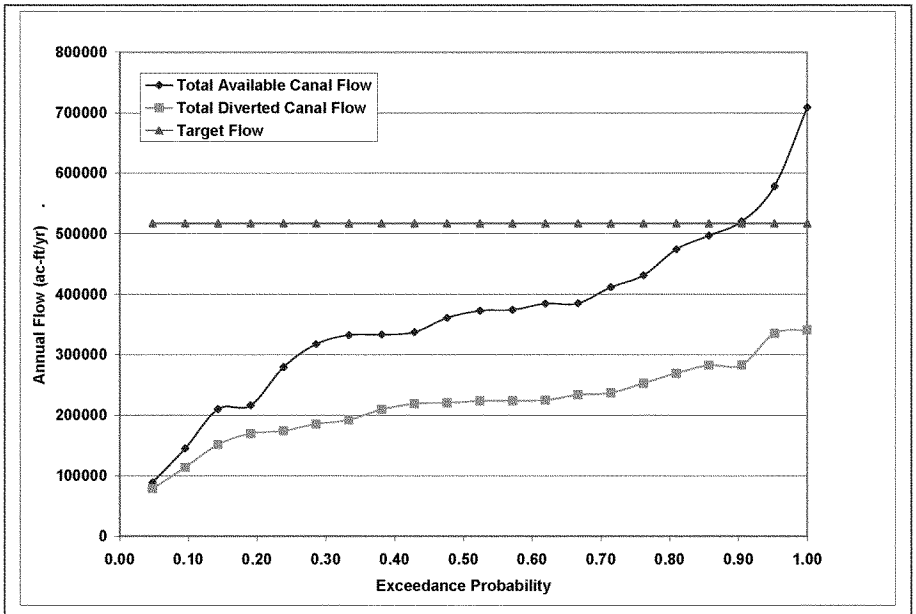
In a project specific sense, however, the relative importance of each of these aspects (quantity, timing, distribution, and quality) would vary from project to project depending upon the specific objectives established for the project.

For example, some CERP projects may focus formulation efforts on simply changing the timing (seasonality) or distribution (inflow and outflow points, internal movement) of water delivered to the natural system. Other projects may focus primarily on increasing or decreasing the amount of water delivered to the natural system, while still other projects may focus on improving the quality of the water delivered to the natural system to maintain desirable ecological community structure. All of these aspects (depending upon their applicability to specific projects) were addressed during plan formulation through performance measures and evaluation criteria used to evaluate alternative plans.

To identify the quantity, timing, and distribution of water for the natural system, a probabilistic approach was selected utilizing volume probability curves to depict the distribution of volumes of water that provide natural system benefits as a result of project features through the range of climatic conditions contained within the 27-year period of hydrological record. These volumes of water may include water that is available to meet natural system needs without project features, and the water made available from project features to meet natural system needs.

Water quality is also to be taken into account during plan formulation and evaluation as a project constraint (*i.e.* projects cannot cause or contribute to violations of water quality standards). As described earlier in Section 2.2 and 2.5 of this report, the project was formulated to provide ancillary water quality benefits by diverting canal discharges into wetlands. Reduction of nutrients was estimated based on attenuation curves for the area of wetlands affected and volumes of water diverted (see ***Annex C,*** CBEEM, USACE, 2003).

Water made available by the BBCW project Phase 1 was identified by calculating the quantity of water diverted by all the project features (i.e., water diverted from canals) on a daily basis. In general, the features in Phase 1 use just a portion of the total amount available on any given day. This is especially true in the wet season when runoff is greatest. The project features are not designed to capture all water available because it would be impractical to install pumps large enough to capture all peak flows. During the dry season, benefits to the Bay will result from fresh water deliveries that were captured from wet season peak flows. ***Figure C-33*** from Annex C provides an estimate of the quantity of water the project would divert to the natural system. No water is made available for other water-related needs by this project.



Flow data from DBHYDRO is for the Period 1986-2006.

FIGURE C-33: TOTAL CANAL FLOW (C-100, C1, C-102, MILITARY, C-103) TO BISCAYNE BAY AVAILABLE, AND TOTAL FLOW DIVERTED BY THE BISCAYNE BAY COASTAL WETLANDS PROJECT PHASE I

The targeted quantity needed to maintain twenty practical salinity units (20 psu) in the nearshore Biscayne Bay zone within the project area was approximated to be an average daily flow of 1,416 acre feet or 517,000 acre-feet per year. ***Table C-18*** indicates the tenth, fiftieth and ninetieth percentiles of the total available flow and the portion diverted by the project.

TABLE C-18: TOTAL WATER AND WATER DIVERTED BY THE PROJECT FOR THE NATURAL SYSTEM (ACRE FEET PER YEAR)

Percentile	10th	50th	90th
Total Water	145,072	366,739	520,325
Total Water Made Available by Project	113,619	222,022	282,982

The fraction of available water that the Biscayne Bay Coastal Wetlands project Phase 1 diverts ranges from about 48 to 88% in any given year. For example, the project would use about 78% of the water during a one-in-ten dry flow year, 60% during an average year; and 54% during a one-in-ten wet flow year. At no time would the project flows exceed targeted flows. Project features are physically capable of diverting about 560,000 acre-feet per year. Additional flows are available to be diverted; however, it is not cost-effective to increase the size of the pump stations to divert peak flows.

The water made available (diverted) by the Biscayne Bay Coastal Wetlands project Phase I for the combined C-100, C-1, C-102 and C-103 basins as indicated in ***Table C-18*** (total water diverted) ranges from 113, 619 acre – feet per year (tenth percentile) to 282,982 acre –feet per year (ninetieth percentile). As required by Section 385.35 of the Programmatic Regulations for the Implementation of CERP and CERP Guidance Memoranda #4, "Identifying Water Made Available for the Natural System and for Other Water Related Needs," the water made available (diverted) by Phase I of the Project will be protected using the State of Florida's reservation or allocation authority under state law as is represented by the "Total Diverted Canal Flow" line in ***Figure C-33***. The South Florida Water Management District has further committed to protect the difference between the existing water in the system, identified as the "Total Available Canal Flow" and the "Total Diverted Canal Flow" up to the "Target Flow" line under State's reservation or allocation authority. The State is currently determining the most appropriate means for undertaking this protection of water for the natural system.

The SFWMD will protect the water made available by the Biscayne Bay Coastal Wetlands Project using its reservation or allocation authority as required by the Water Resources Development Act of 2000 (WRDA 2000) and Section 373.470, F.S. WRDA 2000 requires the water identified in the PIR to be protected prior to execution of a Project Cooperation Agreement, now called a Project Partnership Agreement. This agreement can only be executed after the project has been authorized and funds appropriated by the US Congress as well as funds included in the President's budget. Although the PIR has yet to be finalized, the SFWMD is moving ahead to protect the resources of Biscayne Bay by initiating rule development in 2010. The SFWMD is currently evaluating the state of the science with input from interested stakeholders as part of the process of determining the appropriate tool to protect water for Biscayne Bay.

Water levels in the coastal wetlands will increase in response to pumping rates, and will not exceed the level necessary to overcome the friction encountered between the discharge points and tide. While varying throughout the project, this level should generally be less than one foot.

The SFWMD would protect water for Biscayne Bay based on the best available science to support the identification of water for the natural system at the time such protection is undertaken. The SFWMD is engaged in an ongoing effort to collect and analyze the best available information, which will be the basis for defining flows to the natural system in Biscayne Bay.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Biscayne Bay Coastal Wetlands
1501 Pre-Application Meeting

Meeting Summary/Minutes
SFWMD CERP 2 Office
Wednesday, July 15, 2009

Time: 10:00 to 12:00 pm

Attendees:

SFWMD	Dewey Worth, Brenda Mills, Nirmala Jeyakumar, John Shaffer, Laura Reilly, Rick Alleman (via teleconference), Christopher Pettit (via teleconference), Brenda Mills, Georgia Vince, Raymond Sciortino
USACE	Alisa Zarbo, Eunice Ford, Rudy Wynn (via teleconference)
FDEP	Tracy Robb, Erin Steurer (via teleconference), Stacey Feken (via teleconference), Inger Hansen
Miami-Dade DERM	Matt Davis (via teleconference)
FWC	Erin McDevitt

A pre-application meeting was held for the Biscayne Bay Coastal Wetlands project, in accordance with Florida Statutes 373.1501 (5)(c)(a), on July 15, 2009, at the SFWMD CERP 2 Office, in West Palm Beach, Florida.

I. Introductions

John Shaffer, the Planning Phase Project Manager, welcomed the attendees to the pre-application meeting. The attendees introduced themselves and the agencies they represented.

II. Project Overview

A. Project Goals, Benefits and Constraints

Mr. Shaffer stated that the goal of the project goal is to redirect significant quantities of fresh water, which are currently being discharged to Biscayne Bay through man-made canals, to coastal wetlands in order to

re-establish healthy salinity patterns, and productive nursery habitats within these wetlands.

Mr. Shaffer stated that the environmental benefits which are anticipated to be achieved through implementing the project are:

- The project is anticipated to divert 59 percent of the annual average discharge from four coastal structures (S-123, S-21, S-21A, S-20F) into freshwater and saltwater wetlands.
- This diversion is predicted to reduce future nitrate loading to the bay by 50%.
- This diversion is also predicted to increase the acres of saltwater wetlands with salinity below 20 parts per thousand (ppt) from approximately 2,000 acres to 3,600.
- The project is expected to re-hydrate 190 acres of freshwater wetlands.
- The project includes 500 acres of invasive exotic vegetation management.
- The project is predicted to result in a 10% increase (78 acres) in the amount of near shore habitat able to meet target salinities.

Mr. Shaffer stated that the major constraints for the project are:

- The project cannot diminish the existing levels of service for flood protection to agricultural and urban lands.
- The project cannot adversely impact existing legal users of water.
- The project cannot adversely affect listed endangered or threatened species.

B. Selected Plan (Alternative "O" Phase I)

Mr. Shaffer described the features of the Selected Plan for the project, which are identified as Alternative "O" Phase I in the PIR. The Selected Plan involves three component projects which include the Deering Estate Flow Way, Cutler Wetlands Flow Way, and L-31E Flow Way.

The Deering Estate Flow way project involves the following:

- Construction of a 500 ft extension of the C-100A Spur Canal through the Power's Addition Parcel
- Construction of a 100 cfs Pump Station (S-700) on the Power's Addition Parcel to withdraw water from C-100A Spur Canal
- Installation of 538 linear feet of 60" pipe which discharges to the Cutler Drain and ultimately to coastal wetlands located within the Deering Estate

The Cutler Wetlands Flow way project involves the following:

- Construction of a 400 CFS Pump Station (S-701) on the C-1 Canal
- Construction of 7000+/- LF of lined conveyance canal to deliver water from the pump station to a proposed spreader
- Installation of Box culverts under SW 97 Ave, SW 87 Ave, and L-31E
- Construction of 13,160 LF of spreader canal
- Plugging of 2500 LF of remnant mosquito ditches

The L-31E Culverts North project involves the following:

- Construction of a 50 CFS pump station (S-703) on L31E (just north of C-102) w/ outlet spreader
- Construction of 100 CFS pump station (S-705) on L-31E (just south of C-102) to discharge south to L-31E
- Installation of eight flap gated culverts (S-23A, S-23B, S-706A, S-706B, S-706C, S-708, S-23C, & S-23D) to discharge from L-31 to saltwater wetlands east of L-31E
- Installation of an inverted siphon at Military canal to isolate it from L-31E

The L-31E Culverts South project involves the following:

- Construction of a 40 cfs pump station (S-709) to discharge water from C-103 north to L-31E
- Construction of a 40 CFS pump station (S-711) and spreader canal (C-711) to deliver water from C-103 to freshwater wetlands south of C-103
- Construction of 40 CFS pump station (S-710) to deliver water from C-103 to freshwater wetlands south of C-103 (via spreader structure)
- Installation of two flap gated culverts (S-712A & 712B) to discharge from L-31 to saltwater wetlands east of L-31E

III. Project Compliance with Florida Statute 373.1501

A. Comprehensive Needs Analysis

Mr. Shaffer explained the level of analysis performed for water resource issues related to the project, including: water supply, water quality, flood protection, threatened & endangered species and other natural system & habitat needs. Mr. Shaffer explained how each of these issues would be addressed in the 1501 Report, currently being prepared.

B. Project Component Feasibility

Mr. Shaffer explained how the project meets the requirements for feasibility which include: use of standard practices & technologies, efficiency & cost effectiveness, consistency with Restudy and consistency with CERP. Mr. Shaffer explained how each of these requirements would be addressed in the 1501 Report, currently being prepared.

C. Consistent with Applicable Law & Can be Permitted

Mr. Shaffer explained how the project meets the requirements for a 1501 Pre-Application conference, state participation and federal participation.

D. Reasonable Assurances

Mr. Shaffer explained how the project will satisfy the reasonable assurances criteria, including no impacts to existing legal water users, no impacts to existing level of service for flood protection and meeting adaptation needs of the restored natural environment.

E. Coordination with Local Utilities and Public Infrastructure

Mr. Shaffer explained that utility coordination for the project will be addressed in section 6 of the 1501 Report. Mr. Shaffer stated that the District has coordinated with or will coordinate with the following Utilities for the project: Florida Power & Light (FPL), Miami Dade Water & Sewer (WASA), Florida Department of Transportation (FDOT), Town of Cutler Bay.

V. Agency Discussion

Mr. Shaffer presented a proposed schedule for obtaining a Record of Decision.

Mr. Davis mentioned that Miami-DERM is interested in/will be participating in the 1501 process for this project. His agency is responsible for, among other things, ensuring that wellfields will not be affected by potential salt water intrusion (since groundwater levels may be lowered); though he did note that they don't anticipate a problem resulting from this project.

Ms. Feken explained that the 1501 and Clearinghouse briefing has historically been held concurrently. The briefing is not a requirement or typically held for Clearinghouse review of Federal projects, but Clearinghouse members are invited to the 1501 briefing since review is typically held current with the release of a PIR for CERP projects. She recommended that the 1501 Briefing be

combined with the Clearinghouse Briefing, and held prior to, or concurrent with, release of the Draft PIR. Ms. Feken and Ms. Steurer also stated that FDEP would provide the District with a revised recommended 1501 schedule.

Ms. Hansen recommended that the District coordinate the project with the agricultural community (Florida Farm Bureau). Ms. Feken also expressed the importance of coordinating with FDACS for 1501 reviews.

Ms. Robb recommended that the District coordinate the project with the Village of Palmetto Bay for Deering Estate project component.

Ms. McDevitt recommended that the District coordinate with the project with CAMA by contacting Pam Sweeny. The District asked whether or not DEP typically includes CAMA in the 1501 reviews. Ms. Feken replied that coordination with programs such as CAMA and Parks was decided on a project by project basis. For BBCW, DEP will include CAMA in the internal review due to the Aquatic Preserves in the vicinity of the project area.

Ms. Reilly, Mr. Worth and Ms. McDevitt discussed the need for the District to coordinate with the National Park Service (Biscayne National Park), DEP's CAMA, USFWS, and FDACS.

Ms. Vince and Ms. Hansen discussed the issue of the District purchasing by fee simple the Lennar mitigation parcel and providing mitigation for impacts to the parcel associated with the construction of the Cutler Flow Way project component. Ms. Vince explained the issue was still being resolved.

Ms. Feken stated that concerns about impacts to water bodies classified as Outstanding Florida Waters within the vicinity of the project, such as Biscayne Bay, need to be addressed in the 1501 Report. She noted that the water quality slide discusses phosphorus and asked whether the District will address the impacts of the project (beneficial and potentially adverse) on nitrogen loading to the bay. Rick Alleman replied that was being addressed in the report. It was noted that Emerging Pollutants of Concern had also been identified as a potential issue due to the possibility of hydrating the coastal wetlands with reuse water in future project phases (pending the outcome of the Wastewater Reuse Technology Pilot Project).

Ms. Feken also stressed how important it is to have a thorough discussion of requirements listed the 1501 5(d) section in the State Compliance Report. These requirements are scrutinized in the 1501 process and not the 1502 process. SFWMD stated that, to the extent that the CGM does not conflict with its policies, they will follow the guidance and model the State Compliance Reports accordingly.

Ms. Robb asked if the existing District structures within the project area of the L-31E Culverts project component will remain in place. Mr. Worth responded that the project has been designed to work with the existing canal structures; therefore they will remain in place.

A question was raised regarding the potential effects of Turkey Point's plans to install Rainey wells as part of their planned expansion. Representatives from SFWMD responded that FP&L must analyze the proposed impacts of the wells on the adjacent marshes including the BBCW project, and that should the wells be constructed, and have unintended adverse impacts on the adjacent marsh, they would likely have similar effects on the BBCW project, all of which would need to be addressed by FP&L.

Ms. Feken noted that a draft CGM (CGM 21) was available for the 1501 process and stressed the importance of the District using that as guidance to prepare the State Compliance Report. Ms. Mills noted that revisions were being made to the CERP Programmatic Regulations, which could affect guidance on the analyses necessary to provide the assurances required by state law. However, she and Dewey Worth agreed that the draft CGM should be used as guidance given that possible constraint.

The attendees talked about how the 1501 Report should include some discussion of the multiple PIRs or project phases associated with the project.

ACTION ITEMS

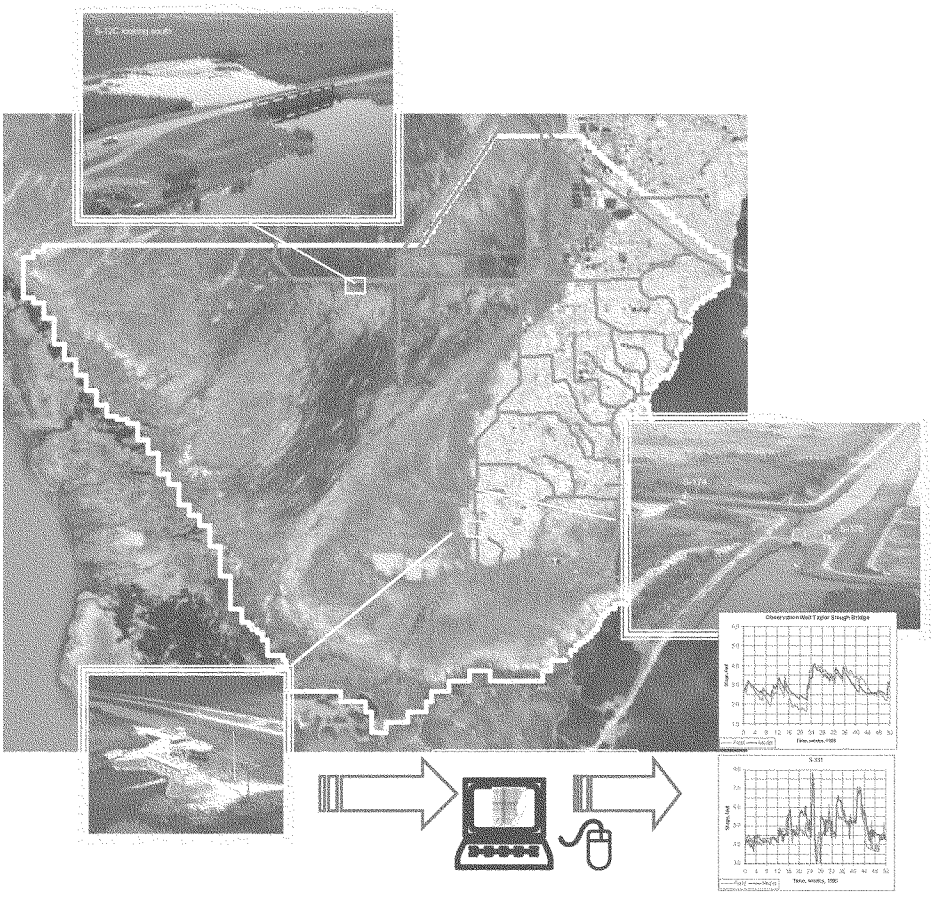
- Preparation of meeting minutes to be distributed to all the agencies that attended and give them the opportunity to review and make comments with regards to the accuracy of the minutes.
- DEP to send the latest version of draft CGM 21 to the SFWMD (Ms. Steurer sent this to Ms. Reilly subsequent to the meeting).
- SFWMD to follow up and coordinate with the agencies not present during the meeting (including the National Park Service (Biscayne National Park), DEP's CAMA Office, USFWS, and FDACS) to ensure they have the opportunity to weigh in and provide the SFWMD with information necessary for the District's determination per 1501(5)(c), F.S. All agencies not in attendance were furnished with a copy of the draft meeting minutes for review and comment.
- DEP to send comments on 1501 milestones in the proposed project schedule to the SFWMD (Ms. Steurer sent these to Ms. Reilly subsequent to the meeting).

Adjourn

The meeting ended at approximately 12:00 p.m.

C.3 ATTACHMENT 1: CALIBRATION AND VERIFICATION OF THE MODBRANCH (MB_2006) NUMERICAL MODEL OF SOUTH FLORIDA

Calibration and Verification of the MODBRANCH (MB_2006) Numerical Model of South Florida



Robert A. Evans, Jr.

U. S. Army Corps of Engineers
Jacksonville District
July 2007

Preface

The work reported herein was performed at the Jacksonville District, U.S. Army Corps of Engineers, as part of the Comprehensive Everglades Restoration Program (CERP). This report presents the results of the calibration and verification of the MODBRANCH numerical model of the South Florida area.

The work was conducted from 2005 to 2007 under the direction of the following personnel Russ Weeks, Chief of the Hydrologic Modeling Section; Sean Smith, Chief of the Water Resources Engineering Branch; and Steve Duba, Chief of the Engineering Division.

COL Robert Carpenter and COL Paul Grosskruger were Commanders of the Jacksonville District during the period of development.

INTRODUCTION

The U.S. Army Corps of Engineers (Jacksonville District) previously used the MODBRANCH model in studies of South Dade County[1], and the CSOP study[2]. The domain of the South Dade model included the area south of a line approximately 3 miles north of the L-29 and C-4 canals extending to Florida Bay. The western and eastern boundaries of that model were a line approximately 4 miles west of the L-67 extension and Biscayne Bay, respectively. The domain of the model used in the CSOP study (the "PDM model") was bounded by the Biscayne Bay to the east; Florida Bay to the south; and, the Gulf of Mexico to the west. The northern boundary is roughly 2 miles north and parallel to the following canals: C-6, L-30, and L-29.

Several ongoing projects required the use of a MODBRANCH model: the C-111 Spreader Canal (C-111SC) and the ENP Seepage Management (ENPSM) project. The latter project requires the simulation of a ground water flow barrier from S-335 to G-211, along the western sides of the lower L-30 and the L31N canals. The model boundary of the PDM model is too close to this project area for the model to be useful. In order to "kill two birds with one stone", it was decided to extend the PDM model boundary further into WCA-3B so that the new model (MB_2006) would be suitable for both projects, thus saving the time and costs of building two separate, but similar models.

The new model was developed as a tool to determine impacts of canals, structures, and water use on the system. The MODBRANCH model is a hybrid model created from two USGS models. The first model is MODFLOW, which simulates the ground water hydrodynamics. The second model is BRANCH, which simulates the canal hydrodynamics. The MODFLOW and BRANCH models were "coupled" into MODBRANCH by Swain and Wexler[3] in 1993. Swain, Howie, and Dixon[4] first employed it in south Florida in 1995. Further modifications were added by CESAJ to more accurately model the area of South Florida.

Two years were selected for the calibration and verification process. These years represented dry and wet periods and were 1989 and 1995, respectively.

MODEL DOMAIN AND DESCRIPTION

Figure 1 shows the model domain superimposed on a "false color" LANDSAT photograph of the area. The model domain includes Water Conservation Area 3B (WCA3B), the Pennsuco wetland area and parts of both Miami-Dade and Monroe counties. The figure illustrates the surficial complexity of the area. Land elevations vary from the high Atlantic Ridge (>10 ft. NGVD29) to the low Everglades. Land use varies from urban to suburban to agricultural to wilderness.

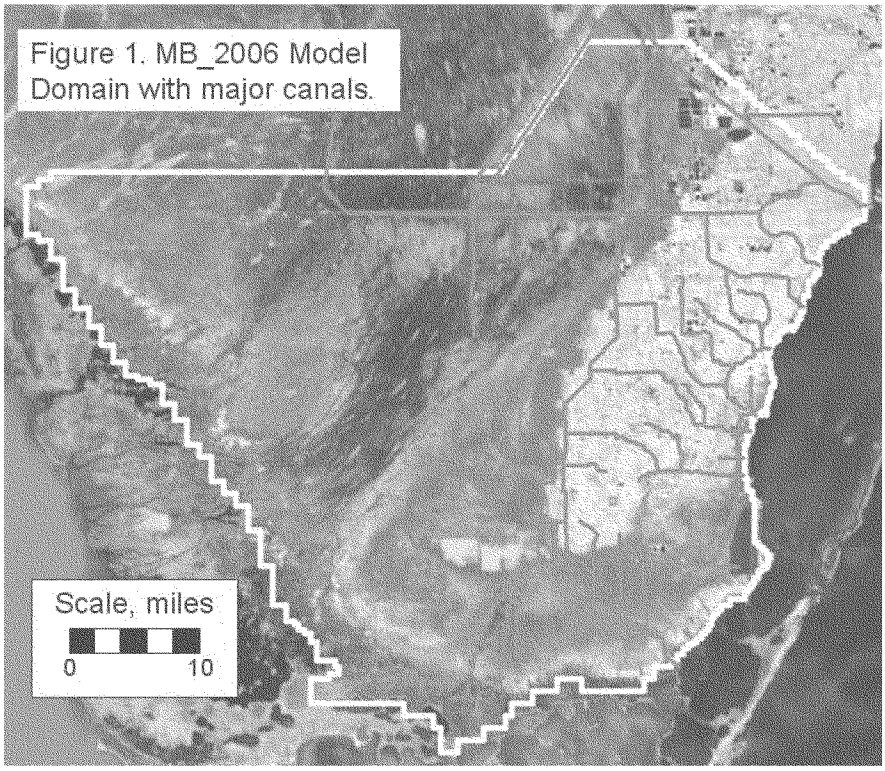


Figure 1. MB_2006 Model Domain with major canals.

GROUND WATER AND OVERLAND FLOW

Ground water and overland flow are simulated by the MODFLOW part of MODBRANCH. MODFLOW is a pseudo-three-dimensional, finite difference, ground water model[5]. This model requires defining a model "grid" of specified numbers of rows, columns, and layers. The width of each row or column is determined by required resolution in specific areas. The resolution was predominantly determined by the need to accurately locate canals and sub-surface features.. The model grid is shown in figure 2 with major canals superimposed in red. The model is bounded by the Biscayne Bay to the east; Florida Bay to the south; and, the Gulf of Mexico to the west. The northern boundary is roughly 2 miles north and parallel to the following canals: C-6, L-30, and L-29. This model also includes that part of WCA-3B up to L-67c (but not including L-67c). The model grid is made up of 239 rows, 259 columns, and 5 layers. The grid resolution varies horizontally from a minimum of 207 feet to a maximum of 5000 feet. Levees are defined by using the *horizontal flow barrier* package of MODFLOW.

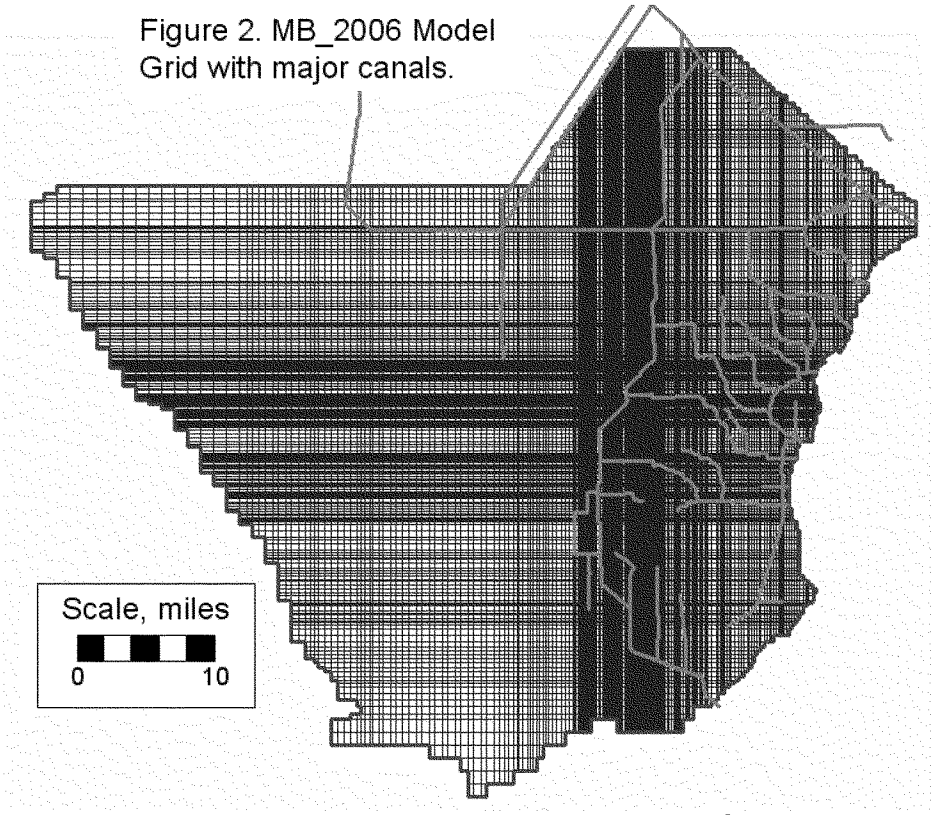


Figure 2. MB_2006 Model Grid with major canals.

The primary aquifers in the study area are the Biscayne and the Gray Limestone aquifers. The Biscayne aquifer is the dominant feature in the eastern part of the model while the Gray Limestone aquifer is the dominant feature of the west. Other hydrogeologic layers include the Gray Limestone confining unit and the surficial sediments (peat, muck, caprock, fine sand, marl, and marsh sediments).

THE BISCAYNE AQUIFER

The Biscayne Aquifer, of Pleistocene age, is the main potable aquifer in South Florida. It covers an area of approximately 4,000 square miles including all of Dade County[6]. The Biscayne Aquifer consists of beds of highly permeable (K~3,000 to 45,000 feet per day) limestone and sandy-limestone of marine origin. The bottom of the Biscayne Aquifer is characterized by an abrupt change in sediment type where clays and marls of the Tamiami Formation or Hawthorn Formation are present. The Biscayne Aquifer is mostly an unconfined aquifer, although segments may exhibit semi-confined conditions initially. In general, the Biscayne Aquifer is well connected to surface water features including the various drainage canals that are located in the study area.

THE GRAY LIMESTONE AQUIFER

The Gray Limestone aquifer is a less permeable formation than the Biscayne aquifer, although not insignificant. The hydraulic conductivity ranges from 200 to 7,000 feet per day. The characteristics of this aquifer are the dominant hydrogeological feature in the western part of the model domain. It is comprised mainly of the Ochopee Limestone of the Tamiami Formation. There are some areas where the formation is comprised of a permeable part of an unnamed formation that is mainly quartz sand. In some regions there is a fairly good confining unit overlaying the Gray Limestone Aquifer. Within the model domain, this confining unit (known as the "gray limestone confining unit") is mainly in the Miami-Dade County area.

MODEL STRATIGRAPHY

The stratigraphic sequence of aquifers varies throughout the model and is not uniform. There are "lenses" and "pinch-out" zones that are not known, but are obviously present. In order to build MODFLOW input files that described the layering certain assumptions had to be made. The domain was divided into five regions (see figure 3). Each region was assigned a specific sequence of layers, as shown in Table 1.

Note that the first layer is designated as "overland flow." The MODFLOW equations are modified in this layer to simulate overland flow instead of ground water flow. The use of the Kadlec equation is discussed in a separate section. Layer two is specified as "surficial sediments."

Figure 3. Layer Sequences.

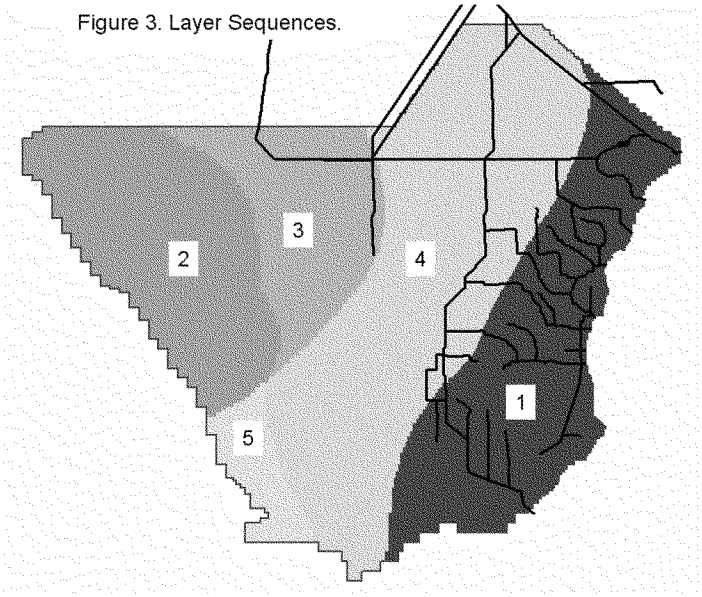


Table 1. Layers by Sequence					
Sequence #	*Direction of increasing depth →*				
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
1	Overland Flow	Surficial Sediments	Biscayne Aquifer		Lower Clastics of Tamiami
2			Gray Limestone		
3			Gray Limestone Confining Unit	Gray Limestone	
4			Biscayne Aquifer	Gray Limestone Confining Unit	Gray Limestone
5			Biscayne Aquifer		Gray Limestone

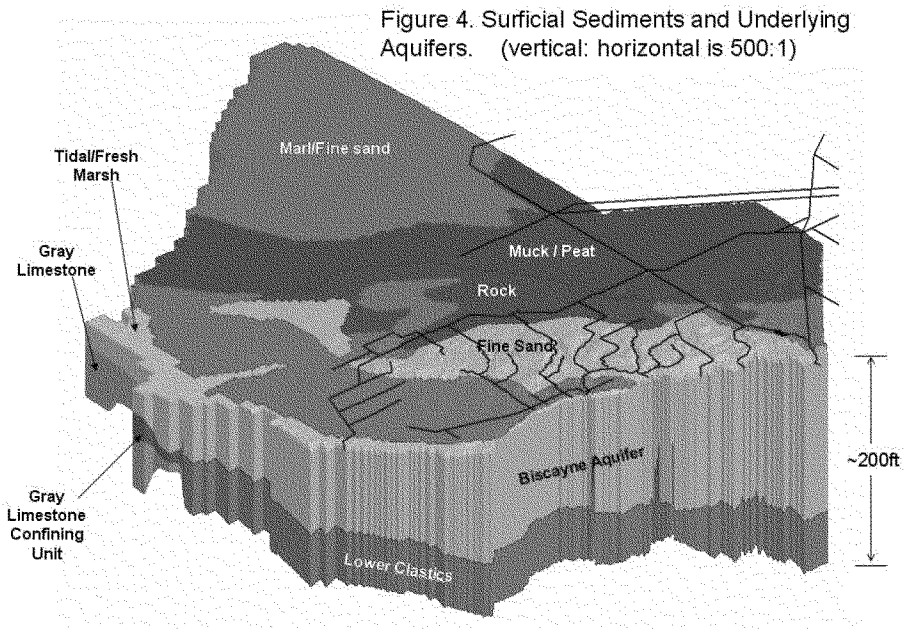


Figure 4. Surficial Sediments and Underlying Aquifers. (vertical: horizontal is 500:1)

Layers 2-5, which include the surficial sediments and the underlying aquifers, are shown in figure 4. The corresponding hydraulic conductivity of each sediment type is also listed in table 3. The thicknesses of each surficial sediment type are not generally available over the entire region. However, the thickness can be

inferred by taking the difference between the land surface elevation and the top of the surficial aquifer. This procedure was used for all the surficial sediment types with the exception of peat. When peat was present, a thickness based on figure 5 was used.

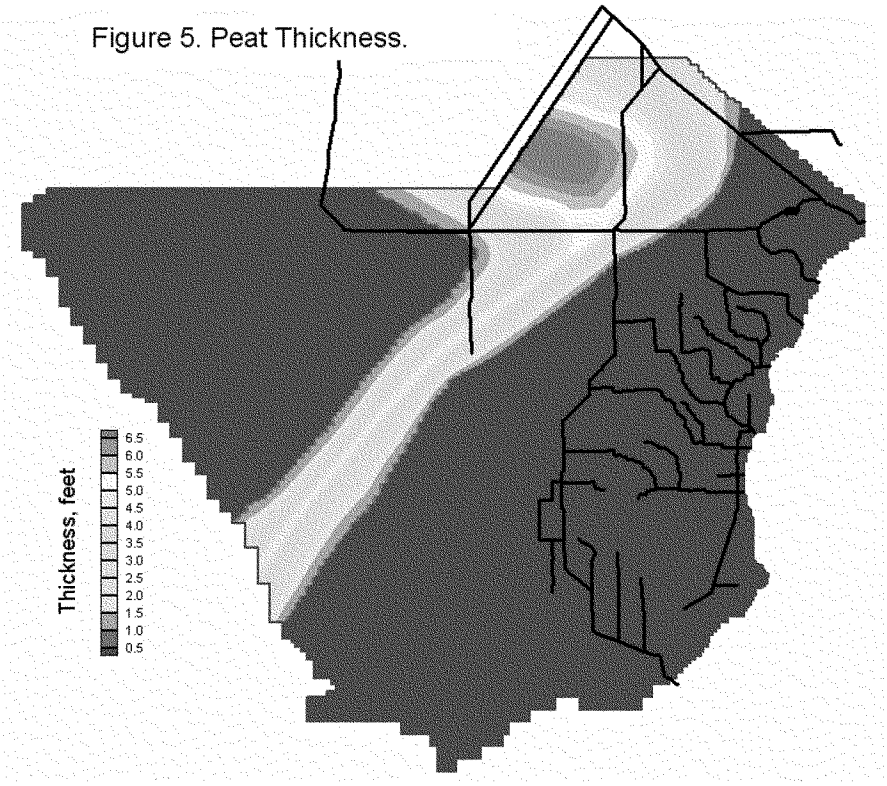


Figure 5. Peat Thickness.

The elevation of each subsequent layer was determined primarily by using the information found in the Fish and Stewart[2] (eastern part) and Reese and Cunningham[3] (western part).

TOPOGRAPHY

The topography used in this model (figure 6) was produced from a variety of sources which include LIDAR ("Light Detection and Ranging") data collected for the C-111, the CSOP, the WPA projects and USGS Helicopter data. The data collected were processed and the USACE Jacksonville GIS staff created a 100 foot topographic model of south Florida. This data set was sampled to a 200 foot model prior to being used to create the MB_2006 topographic data. Major roads, canals and levees were digitally removed from the data sets. Using the 200 foot

model, a median value for each MB_2006 cell was calculated and assigned to the cell. Figure 7 shows the domain of each data source. Figure 8 shows the standard deviation of the 200 ft values within each MB_2006 cell. Note that even with roads, canals and levees removed there are cells with very significant variation of topography.

Figure 6. MB_2006 Topography.

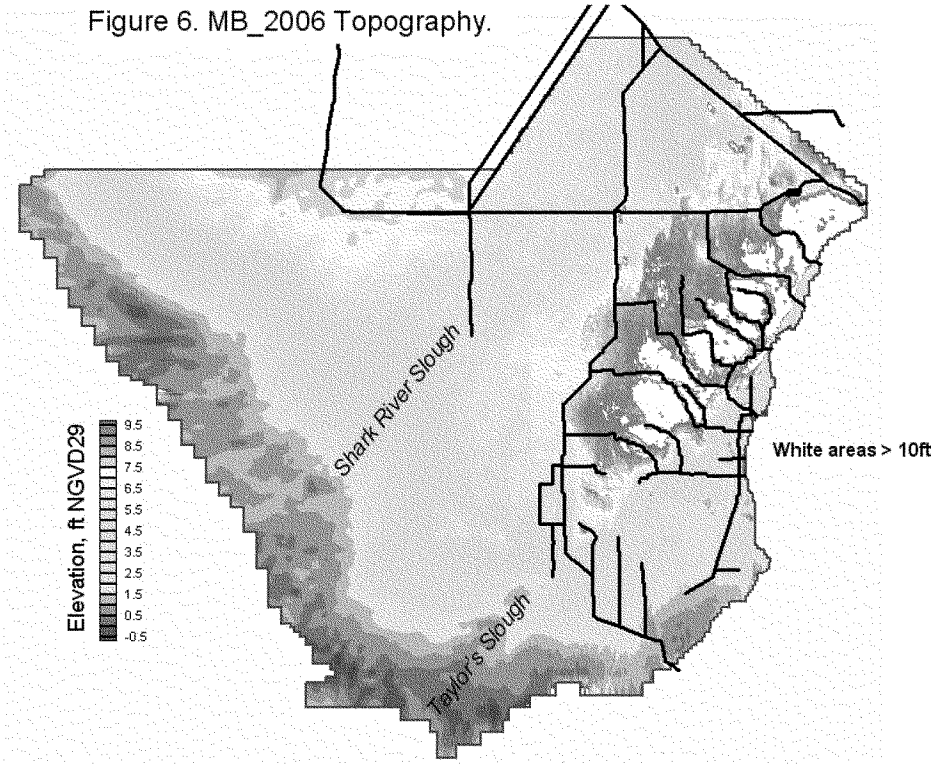


Figure 7. MB_2006 Topography Source.

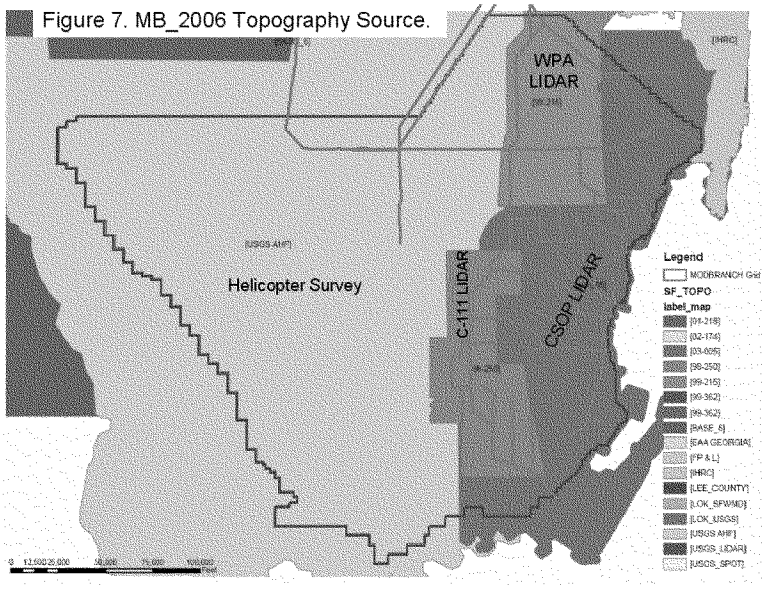
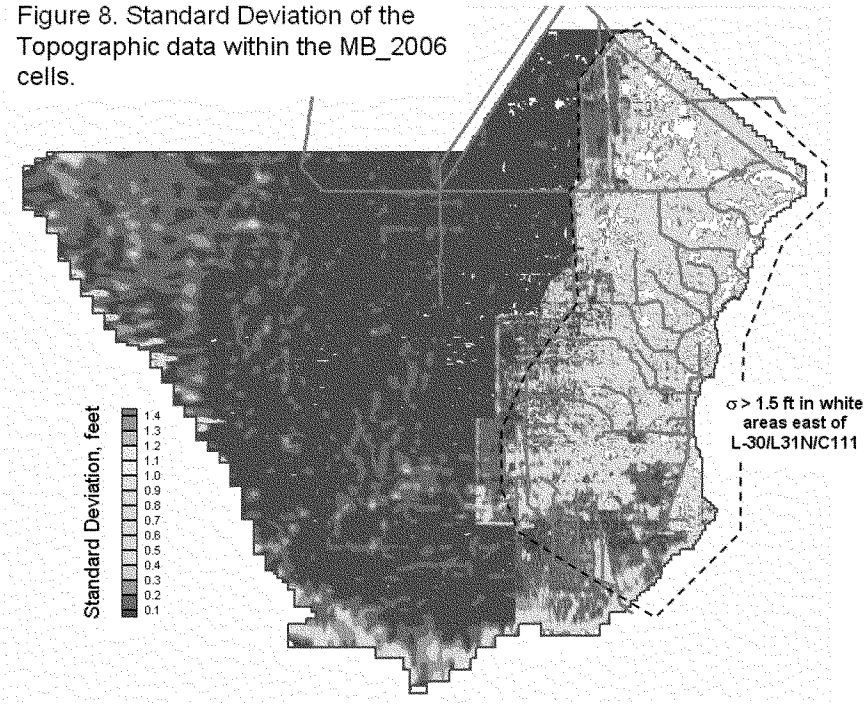


Figure 8. Standard Deviation of the Topographic data within the MB_2006 cells.



STORAGE COEFFICIENTS

The model requires the definition of the storage properties of the various aquifer materials. These are referred to as the primary (sf1) and secondary (sf2) storage coefficients. Table 2 lists the values used for the MB_2006 model simulations.

Table 2. Storage Coefficients of Geologic Materials

Material	Primary Storage Coefficient (sf1)	Secondary Storage Coefficient (sf2, specific yield)
Overland Flow	1.00	n/a
Muck/Peat	0.10	0.44
Fine Sand	0.20	0.23
Tidal/Fresh Marsh	0.10	0.08
Marl/Fine Sand	0.10	0.23
Rock/Caprock/ Oolite	0.10	0.14
Biscayne	0.20	0.12
Gray Limestone Confining Unit	0.05	0.01
Gray Limestone	0.10	0.12
Lower Clastics of Tamiami Formation	0.01	0.01

HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of each cell varied based on the material. For certain materials, such as the surficial sediments and the gray limestone confining unit, the hydraulic conductivity was assigned a constant value. The gray limestone and the Biscayne aquifers were given values that varied according to location. These values were derived using information from Fish and Stewart (1991) and Reese and Cunningham (2000). Table 3 gives the values, or range of values, used for hydraulic conductivity in the MB_2006 model.

Table 3. Hydraulic Conductivities of Geologic Materials

Material	Hydraulic Conductivity, feet per day	Source
Muck/Peat	1	Mark Wilsnack
Fine Sand	10	Domenico & Schwartz
Tidal/Fresh Marsh	1	
Marl/Fine Sand	1	
Rock/Caprock/ Oolite	1	Fish & Stewart
Biscayne	3,000 to 45,000	
Gray Limestone Confining Unit	10	
Gray Limestone	300 to 7,000	Reese & Cunningham
Lower Clastics of Tamiami Formation	1	Fish & Stewart

OVERLAND FLOW

One of the issues of concern of the previous MODBRANCH models (South Dade, PDM) is that overland flow equations were approximated through the use of extremely high conductivity values for the uppermost layer and by specifying the upper layer's bottom elevation as the land surface elevation. This concern has been addressed by implementing the Kadlec's "Rate Law" equation[7,8] for overland flow for the top layer. This is the method employed by the South Florida Water Management District (SFWMD) in its MODFLOW Wetland package. Appendix B discusses the Kadlec equation and the application to MODFLOW. The general form of the equation is

$$v = K_f * d^{\beta} * S_f^{\alpha}$$

where,
v is velocity,
K_f is the flow conductance,
d is the depth,
β is the depth exponent,
S_f is the friction slope, and
α is the slope exponent.

As applied by the SFWMD's wetland package, the value of α=1 and β =3. The MODBRANCH code was modified so that a value of K_f was input for the top layer instead of hydraulic conductivity.

The flow conductance (K_f) of the area will depend on vegetation and land use. Water flow through a dense stand of vegetation will be impeded much more than water flowing over a parking lot or a manicured lawn. Actual values of conductance are not available from field measurements in the area. However, values can be assigned using land use and the values used by the SFWMD in its Lower East Coast Sub-Regional (LECsR) MODFLOW model as a guide. Table 4 lists suggested values of the Kadlec "coefficient" with and associated land use types. Note that due to assignment of β =3, the Kadlec coefficients have units of $1/ft^2$-day which results in v having units of ft/day.

Table 4. Suggested Kadlec Coefficient Values and Land Use Types.

http://www.sfwmd.gov/org/pld/hsm/modflow/wtl_input_kdl.htm

Each land use or vegetation type category in the map has a value for the Kadlec coefficient, the suggested values did not come from field data as they were obtained during the calibration process. The suggested values ranges from 400,000 to 2,000,000, as seen in the following table.

Description	Suggested Kadlec coefficient		Description	Suggested Kadlec coefficient
Lakes	2,000,000		Borrow land	400,000
Reservoirs	2,000,000		Rock Quarries	992,000
Streams and waterways	2,000,000		Freshwater Marshes	992,000
Embayment opening	2,000,000		Freshwater Marshes - Sawgrass	992,000
Bay Swamps	2,000,000		Melaleuca	992,000
Mangrove Swamps	2,000,000		Row Crops	992,000
Channels	2,000,000		Wet Prairies - with Pine	710,000
Wet prairies	1,760,000		Spoil Areas	992,000
Tidal Flats	1,760,000		Roads and Highways	992,000
Mixed Wetland Hardwoods	1,760,000		Improved Pastures	992,000
Mixed Wetland Hardwoods - Willows	1,760,000		Wetland Forested Mixed	1,259,000
Mixed Wetland Hardwoods- Mixed Shrubs	1,760,000		Cypress-with Wet Prairies	1,514,000
Cypress	1,510,000		Light Industrial	710,000

Figure 9 shows the 2000 land use types found within the model domain. There are 31 second level landuse types within the model domain. Of particular interest is the fact that "vegetated non-forested wetlands" (primarily sawgrass), covers the majority of the model domain (>56%). The Kadlec values used in the model are shown in table 5, sorted according to most prevalent land use to least.

Figure 9. South Florida Land Use (2000).

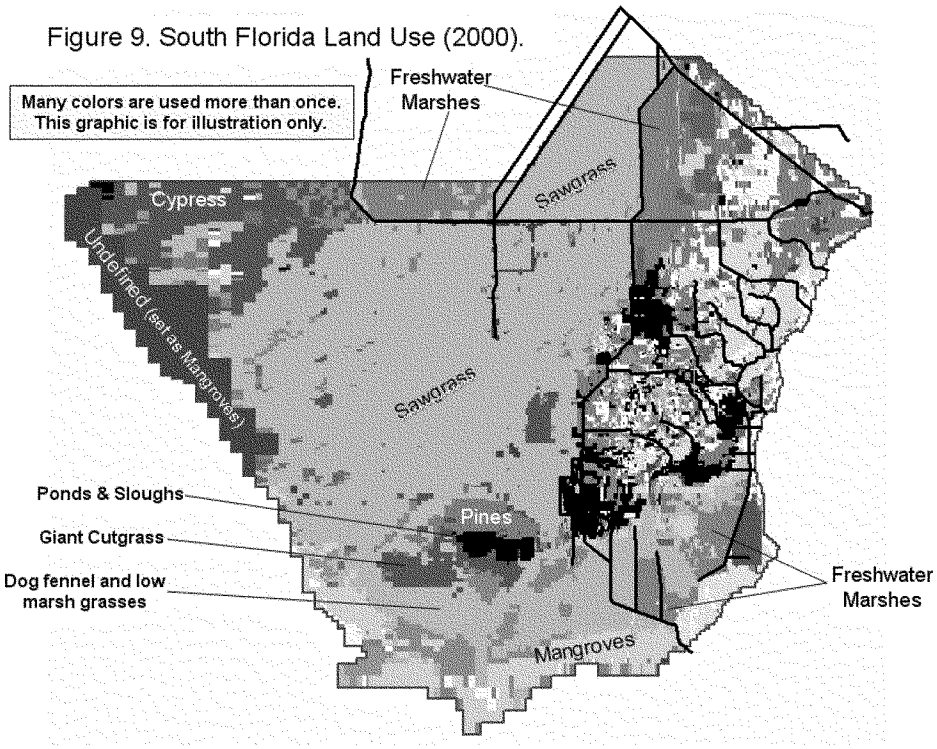


Table 5. Kadlec Coefficient based on 2000 Landuse and applied to MB_2006 grid.

Landuse Code	Landuse type	Number of MB_2006 cells	Area, acres	% of total area	Kadlec Coefficient, 1/ft^2-sec			
					Average	Median	Minimum	Maximum
640	Vegetated non-forested wetlands	23,155	723,177	56.5%	991,963	992,000	991,642	993,186
610	Wetland Hardwood Forest	4,292	188,049	14.7%	1,759,995	1,760,000	1,758,900	1,772,700
130	Single Family units (>6/acre)	2,901	64,445	5.0%	710,043	710,000	709,808	712,100
210	Crop & Pasture Land	5,491	52,907	4.1%	992,011	992,000	991,581	992,619
620	Cypress	425	45,166	3.5%	1,513,974	1,514,000	1,513,650	1,514,150
120	Single Family units (2-5/acre)	1,712	30,837	2.4%	710,033	710,000	710,000	710,936
650	Non-vegetated tidal flats	474	18,391	1.4%	1,759,983	1,760,000	1,759,240	1,760,240
140	Commercial & Services	645	15,748	1.2%	710,056	710,000	710,000	711,988
110	Low density residential	1,433	15,444	1.2%	710,058	710,018	709,877	710,802
220	Tree Crops	1,800	14,552	1.1%	899,989	900,000	899,795	900,561
240	Nurseries & Vineyards	1,275	13,550	1.1%	900,008	900,000	899,769	900,698
420	Upland Hardwood Forests	489	11,313	0.9%	992,016	992,000	991,617	993,034
810	Transportation Facilities	405	9,872	0.8%	991,961	992,000	991,600	992,578
160	Rock Quarries	283	9,812	0.8%	992,025	992,000	991,624	992,739
320	Shrubs & Brush	499	9,502	0.7%	900,024	900,000	899,818	900,848
830	Utilities	410	9,039	0.7%	992,068	992,000	991,699	992,634
410	Upland Coniferous Forests	157	7,206	0.6%	900,024	900,000	899,919	900,229
150	Industrial	195	6,923	0.5%	710,040	710,000	710,000	710,634
170	Institutional	356	6,156	0.5%	999,954	999,988	999,605	1,000,520
180	Recreational	263	5,696	0.4%	999,978	999,998	999,537	1,000,620
190	Open Land	375	5,656	0.4%	999,960	999,984	999,644	1,000,850
530	Reservoirs	225	5,227	0.4%	1,999,698	1,999,800	1,998,680	2,000,000
310	Herbaceous Dry Prairie	117	2,635	0.2%	900,108	900,007	899,877	901,651
540	Embayments	57	2,214	0.2%	1,999,933	1,999,980	1,999,290	2,000,000
260	Rural Open Land	208	1,876	0.1%	900,013	900,006	899,815	900,329
510	Streams & Waterways	54	1,412	0.1%	1,999,627	1,999,850	1,998,020	2,000,000
740	Disturbed Land	88	1,360	0.1%	400,320	400,284	400,000	401,164
630	Wetland Forested Mix	45	612	0.05%	1,258,977	1,259,000	1,258,770	1,259,270
430	Upland Hardwood Forests	37	469	0.04%	991,955	991,988	991,759	992,000
250	Specialty Farms	21	326	0.03%	900,004	900,000	899,922	900,079
330	Mixed Rangeland	22	269	0.02%	900,030	900,000	899,871	900,369

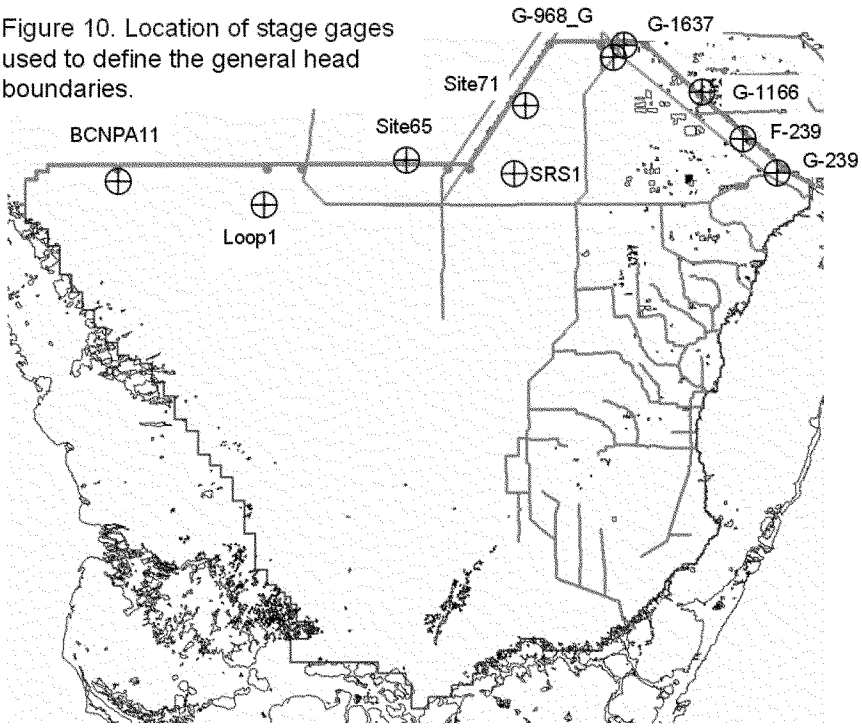
MODEL BOUNDARY CONDITIONS

The ground water portion of the model (MODFLOW) requires a number of input data sets as boundary conditions. These include the general head boundaries, the recharge (rainfall), evapo-transpiration, and production well withdrawal rates. Each of these is dependent on the specific time period simulated. For calibration and verification simulation the data used to create these boundary conditions was derived from field data when possible.

GENERAL HEAD BOUNDARIES

The general head boundaries were generated using field data from ground water gages and a constant stage of 0.25 feet at the coastal boundaries. The locations of the gages and stations are shown in figure 10. Generally, stages were interpolated between the locations. Some locations used the nearest daily stage as a constant (L-28 to L-67A and the top row of the grid).

Figure 10. Location of stage gages used to define the general head boundaries.



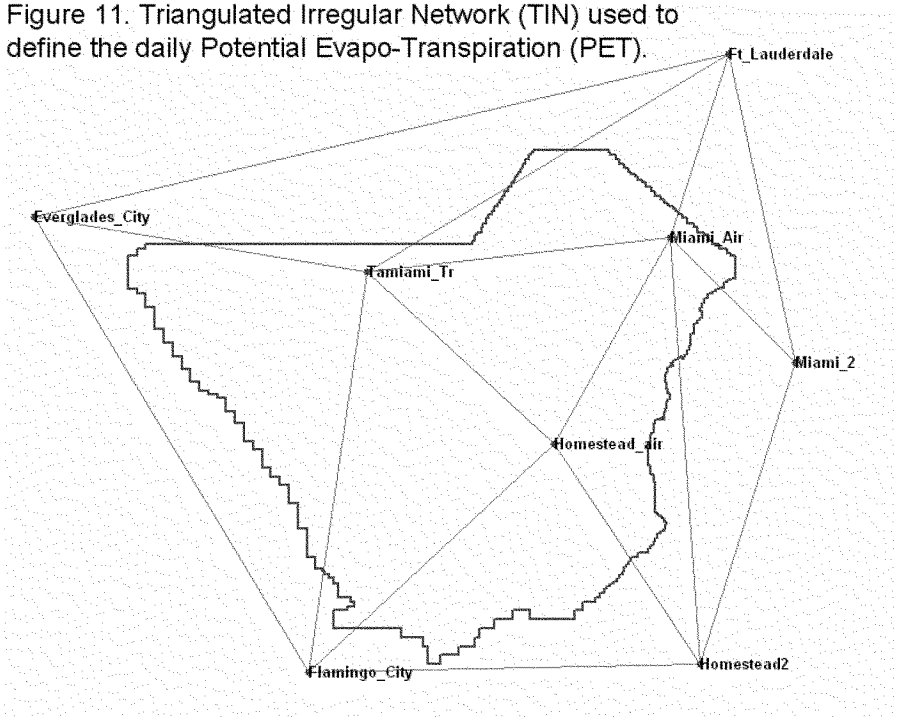
The general head boundary for the coastal areas was modified in order to include the density effects of salinity. A description of the adjustment procedure is found in Appendix A.

The general head boundary values along the northern edge of the model domain (indicated by the green and magenta lines in figure 10) are more complicated. The exact value at each cell is computed using a combination of field data and knowledge of both horizontal (levees and canals) barriers.

METEOROLOGY

The meteorological boundaries consist of rainfall (recharge) and evapo-transpiration (ET). The region lacks a complete rainfall record (both spatially and temporally) for the calibration and verification time periods. Rainfall was defined based on the values used by the South Florida Water Management 2x2 model (SFWMM2x2).

Figure 11. Triangulated Irregular Network (TIN) used to define the daily Potential Evapo-Transpiration (PET).



ET is computed by MODBRANCH using the MODFLOW evapo-transpiration package. This package requires that the user input the maximum potential evapo-transpiration (PET) and parameters that control the effective ET.
The maximum potential ET was defined on a daily basis by using the same data the SFWMD uses for the SFWMM2x2. Figure 11 shows a triangulated irregular network (TIN) with the vertices located at points with daily PET values. The MODBRANCH cells within each triangle were assigned daily PET values based on the equation of a plane through the three vertices. Figure 12 lists the monthly

total PET values at each of the nine locations for the average (1978), dry (1989) and wet (1995) years.

In order to compute ET the model requires several depth values. The first value is the depth below ground at which maximum ET can occur and is known as the "maximum ET depth". The second value is the "ET extinction depth" below which no ET can occur. The ET is computed using a simple equation:

$$ET(z) = PET * f(z).$$

The function f(z) ranges from 1 (at elevations greater than ground elevation – maximum ET depth) to 0 (at elevations less than ground elevation – ET extinction depth).

Good approximations for the maximum ET depth and the ET extinction depth are the "shallow root zone" and the "deep root zones," respectively. The values used in the MB_2006 model are modified from values used in the SFWMM2x2 and are shown in Table 6. The land use types used are those shown in figure 9.

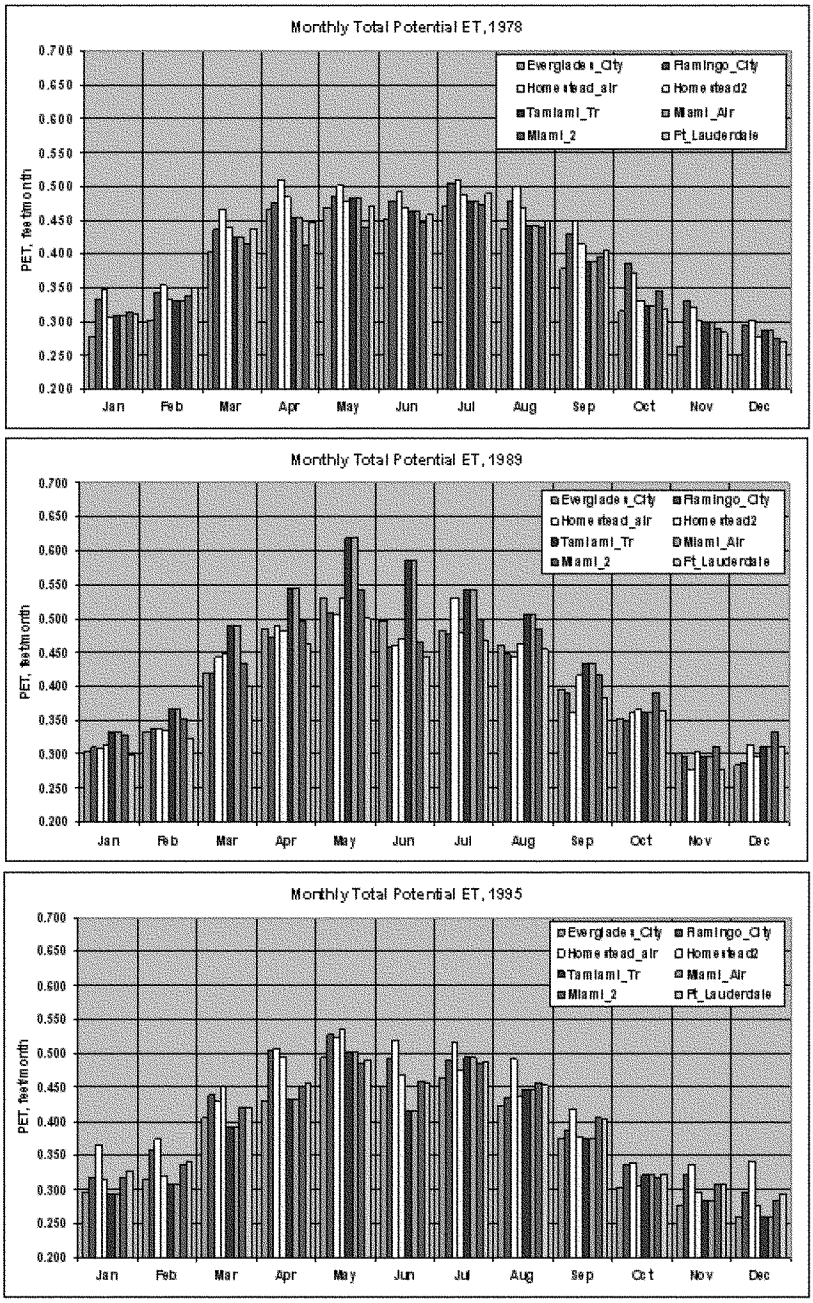


Figure 12. Monthly Total Potential Evapo-Transpiration (PET).

Table 6. Landuse codes and associated root zone depths.

Landuse Codes	Depth, feet	
	Shallow Root Zone (depth of maximum ET)	Deep Root Zone (ET extinction depth)
111-156	1.0	2.0
160-163	20.0	30.0
165	1.0	2.0
166	3.0	8.0
170-192	1.0	2.0
211-212	1.5	3.0
213	1.5	4.0
214-216	1.5	3.0
221-241	2.0	3.0
242-330	1.0	2.0
411-420	4.5	8.0
422-424	1.5	8.0
427-437	4.5	8.0
511-512	2.0	8.0
520-543	3.0	10.0
611-612	0.0	10.0
617-619	2.0	8.0
621-624	0.0	4.5
625-630	0.0	8.0
641-642	0.0	4.5
643-644	0.0	5.0
650-651	0.0	2.0
740-835	1.0	2.0

PRODUCTION WELLS

All significant sources and sinks must be input as a boundary condition. Municipal water production wells in the area are shown in figure 13. The daily rate at which each individual well in each well field was pumped was not available. The only data available were the monthly total volumes for each permitted well field (see Table 7). A computational cell may only have a single "well" assigned to it. Therefore, the actual pumping rate assigned to each MODBRANCH "well" depended on the number of wells located within a cell. The rates of each well were dependent on the number of wells covered by the permit and the total pumped volume. Only the wells in the north (permit # 13-00037-W) had information available indicating the distribution of pumping rates between the wells.

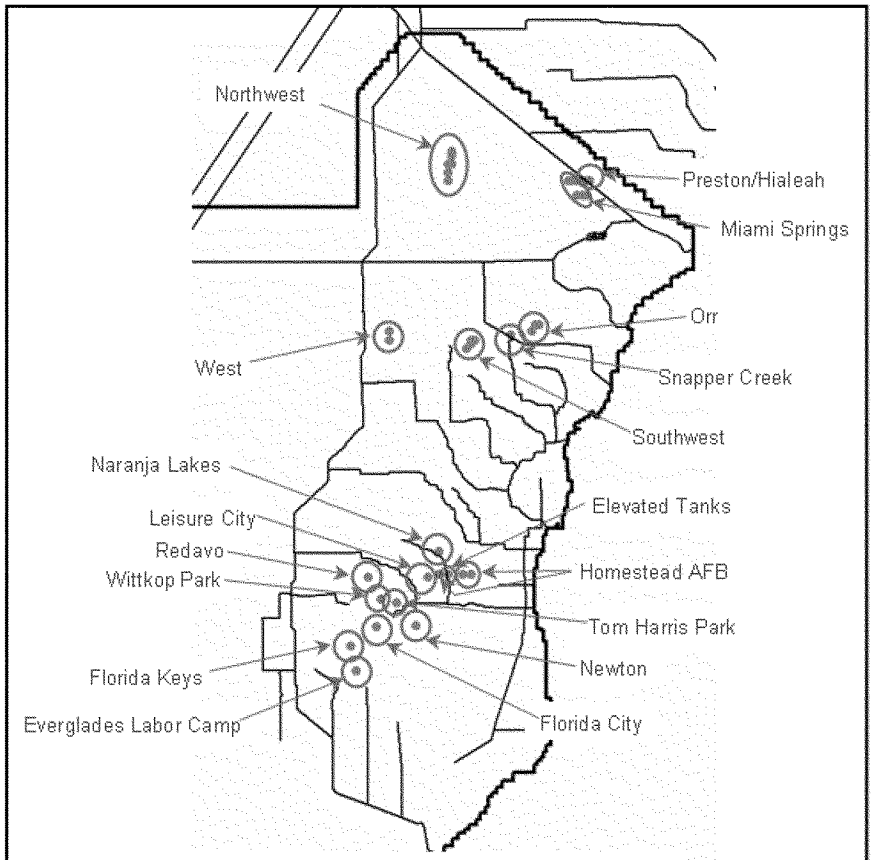


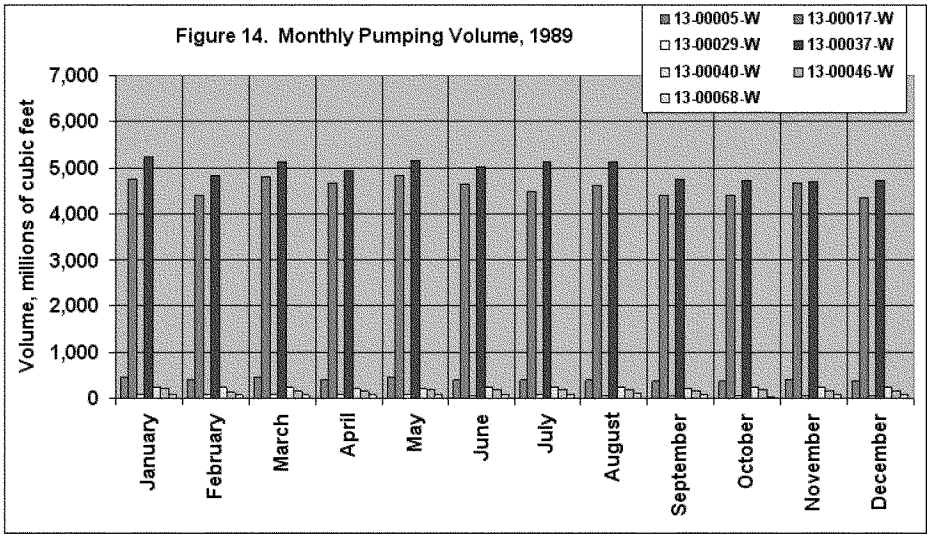
Figure 13. Production Well Locations.

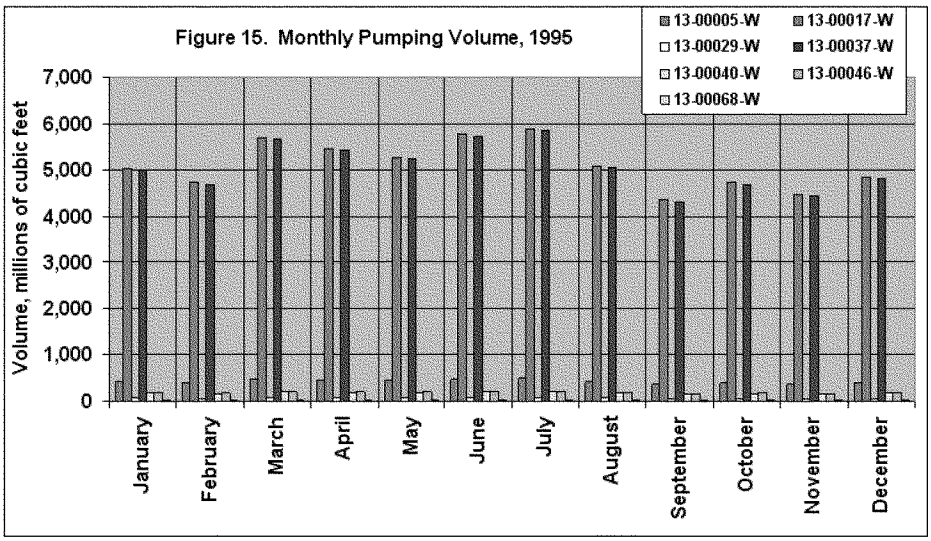
Table 7. Volumes Pumped, millions of cubic feet

1988							
Permit #	**13-00005-W**	**13-00017-W**	**13-00029-W**	**13-00037-W**	**13-00040-W**	**13-00046-W**	**13-00068-W**
Yearly Total	*4819.7*	*55758.0*	*803.2*	*59171.1*	*2542.3*	*2541.6*	*0.0*
January	413.0	4576.0	78.3	4866.0	205.3	206.3	0.0
February	393.1	4427.0	62.9	4535.6	191.7	193.7	0.0
March	434.1	4888.0	67.0	5043.0	211.3	214.6	0.0
April	436.2	4968.0	67.2	5310.1	235.6	219.8	0.0
May	392.8	4699.0	65.7	5000.7	213.6	208.1	0.0
June	359.3	4416.0	64.5	4730.0	204.9	204.6	0.0
July	389.6	4595.0	62.1	4871.3	211.9	210.5	0.0
August	391.8	4641.0	70.0	4883.9	217.8	217.1	0.0
September	367.0	4456.0	64.8	4881.1	204.7	215.6	0.0
October	404.4	4676.0	66.9	5105.6	216.7	220.8	0.0
November	409.0	4552.0	66.9	4918.0	207.3	210.3	0.0
December	429.5	4864.0	66.9	5025.8	221.5	220.1	0.0
1989							
Permit #	**13-00005-W**	**13-00017-W**	**13-00029-W**	**13-00037-W**	**13-00040-W**	**13-00046-W**	**13-00068-W**
Yearly Total	*4936.0*	*55056.0*	*759.5*	*59480.9*	*2772.8*	*2102.0*	*990.2*
January	455.6	4752.5	77.5	5232.9	238.2	221.4	87.1
February	413.2	4401.0	72.8	4836.7	227.3	142.6	80.5
March	445.9	4821.5	74.4	5130.6	245.8	157.8	91.6
April	410.1	4666.0	72.0	4936.5	219.0	165.9	85.4
May	446.6	4824.5	74.4	5151.5	224.6	183.1	82.6
June	412.6	4655.0	66.0	5009.8	227.2	183.0	82.0
July	408.5	4491.5	68.2	5142.3	229.6	181.8	91.8
August	413.5	4619.0	49.6	5121.5	232.5	182.3	117.1
September	383.0	4397.0	51.0	4751.2	226.9	170.6	84.9
October	383.5	4402.5	49.6	4742.1	237.4	174.4	26.6
November	388.8	4664.0	51.0	4705.7	231.1	168.5	78.2
December	374.6	4361.5	53.0	4720.1	233.1	170.6	82.5
1994							
Permit #	**13-00005-W**	**13-00017-W**	**13-00029-W**	**13-00037-W**	**13-00040-W**	**13-00046-W**	**13-00068-W**
Yearly Total	*5130.1*	*60927.5*	*701.6*	*61895.7*	*2907.6*	*2090.9*	*504.2*
January	420.7	4996.1	57.5	5075.4	238.4	171.5	41.3
February	395.0	4691.4	54.0	4766.0	223.9	161.0	38.8
March	477.1	5666.3	65.2	5756.3	270.4	194.5	46.9
April	456.6	5422.5	62.4	5508.7	258.8	186.1	44.9
May	441.2	5239.8	60.3	5323.0	250.1	179.8	43.4
June	482.2	5727.2	65.9	5818.2	273.3	196.5	47.4
July	492.5	5849.0	67.4	5942.0	279.1	200.7	48.4
August	425.8	5057.0	58.2	5137.3	241.3	173.5	41.8
September	364.2	4325.9	49.8	4394.6	206.4	148.5	35.8
October	395.0	4691.4	54.0	4766.0	223.9	161.0	38.8
November	374.5	4447.7	51.2	4518.4	212.3	152.6	36.8
December	405.3	4813.3	55.4	4889.8	229.7	165.2	39.8
1995							
Permit #	**13-00005-W**	**13-00017-W**	**13-00029-W**	**13-00037-W**	**13-00040-W**	**13-00046-W**	**13-00068-W**
Yearly Total	*5136.9*	*61375.5*	*838.0*	*60875.5*	*2209.8*	*2354.1*	*377.8*
January	421.2	5032.8	68.7	4991.8	181.2	193.0	31.0
February	395.5	4725.9	64.5	4687.4	170.2	181.3	29.1
March	477.7	5707.9	77.9	5661.4	205.5	218.9	35.1
April	457.2	5462.4	74.6	5417.9	196.7	209.5	33.6
May	441.8	5278.3	72.1	5235.3	190.0	202.5	32.5
June	482.9	5769.3	78.8	5722.3	207.7	221.3	35.5
July	493.1	5892.0	80.4	5844.0	212.1	226.0	36.3
August	426.4	5094.2	69.6	5052.7	183.4	195.4	31.4
September	364.7	4357.7	59.5	4322.2	156.9	167.1	26.8
October	395.5	4725.9	64.5	4687.4	170.2	181.3	29.1
November	375.0	4480.4	61.2	4443.9	161.3	171.8	27.6
December	405.8	4848.7	66.2	4809.2	174.6	186.0	29.8

Permit #	**Well fields included in permit**
13-00005-W	Florida Keys Aqueduct Authority
13-00017-W	West, Orr, Snapper Creek, and Southwest
13-00029-W	Florida City
13-00037-W	Northwest, Preston/Hialeah, and Miami Springs
13-00040-W	Everglades Labor Camp, Naranja Lakes, Leisure City, Redavo, Newton, and Elevated Tanks
13-00046-W	City of Homestead: Wittkop Park and Tom Harris Park
13-00068-W	Homestead Air Force Base

Figures 14 and 15 show the monthly total volumes pumped from the wells covered under each permit. Note that the majority of pumping is done in the well fields covered by permits 13-00017-W and 13-00037-W, both in the northern part of the model domain.





CANAL GEOMETRY AND LEAKAGE

Canal stage and flow rates are simulated by the BRANCH part of MODBRANCH. Canals are represented by a series of one-dimensional "branches" each of which are defined by a number of "cross-sections" or "segments" of defined length, depth, and area. Structures can be defined as pumps, culverts, or spillways. The canal network is comprised of 798 branches (~3000 cross-sections) and 52 structures of various types. The network represents over 360 miles of canals as illustrated in Figure 16. The model domain covers approximately 2,000 square miles.

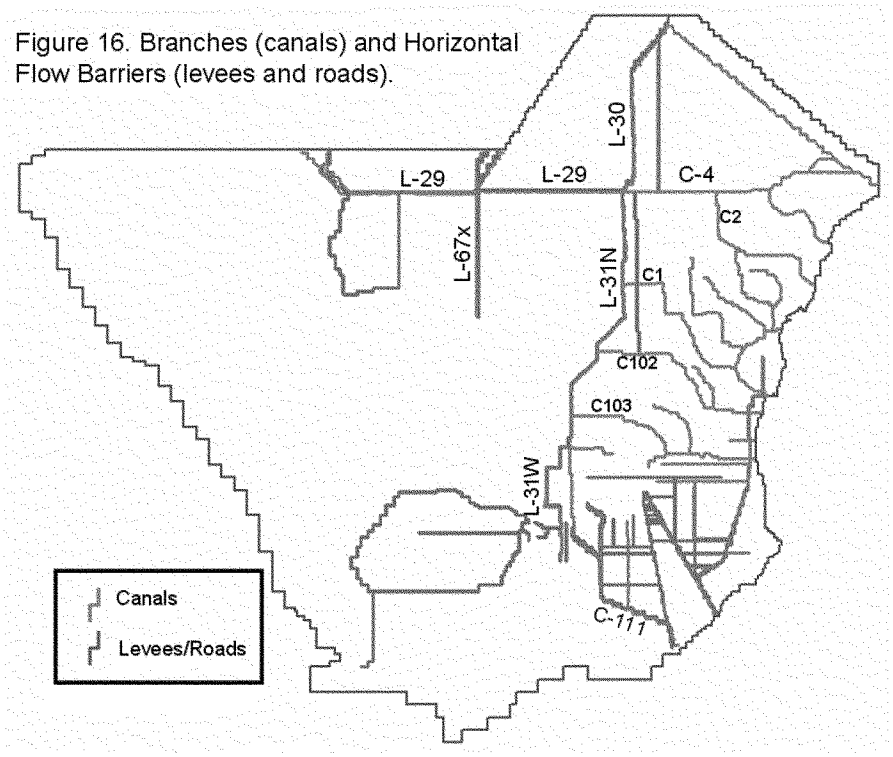


Figure 16. Branches (canals) and Horizontal Flow Barriers (levees and roads).

Each branch segment is assigned to a specific MODFLOW cell corresponding approximately to that segment's geographic location. Canal location accuracy is therefore limited to the local grid resolution. Each canal segment is assigned to the 3rd layer. It is important to note that the model does not simulate flow between the canals and the top (overland flow) layer directly. Water which moves overland (i.e., within the 1st layer) must first move down through the 2nd and 3rd layers and then into the canals. Conversely, water moving out of the canals into the 1st layer must first pass through the 2nd and 3rd layers. There is no direct hydraulic link between any canal segment and overland flow.

Movement between the 3rd layer and the canal segment is controlled by a "leakage coefficient," which is an input variable via the BRANCH portion of the code. An analysis of field data for a number of canal reaches was done in order to determine the range of values for the leakage coefficients. This analysis is found in Appendix C. Based on the analysis, the MB_2006 model used only two values of leakage coefficient: 0.00024/second and 0.00048/second. The lower value was applied only to C-4, L-30, and C-6 (Miami Canal). The value of 0.00048/second agrees with the value found by Genereux, et al[9].

The cross-sectional area of each canal was based on the "as built" specifications of the canals, if that information was available. If the information was not available, then the next approximation was the planned cross-sections. If that information was not available, then approximations were made using other means (aerial photography, personal communications, etc.) The last method was used mainly for non-project canals (Military canal, Card Sound Road canal, etc.).

There are fifty-one structures in the calibration branch network and fifty-two structures in the verification branch network (G-211 did not exist in 1989). These include pumps, gated culverts and gated spillways. The specific structures and types are listed in Table 8.

Table 8. Structures included in the MB_2006 Branch Network for Calibration and Verification Simulations

Pumps	Gated Culverts	Gated Spillways
S-331	***CulC4***	*G-114*
S-332	***CulML***	***G-93***
S-332D	***G-119***	S-118
	G-211	S-119
	S-120	S-123
	S-121	S-148
	S-122	S-165
	S-14	S-166
	S-149	S-167
	S-173	*S-174**
	S-175	S-176
	S-178	S-177
	S-194	S-179
	S-195	S-18C
	S-196	S-20
	S-197	S-20F
	S-25	S-20G
	S-25A	S-21
	S-336	S-21A
	S-338	S-22
	S-343A	S-25b
	S-343B	S-26
	S-346	***S-333***
	S-347	***S-334***
		S-335

Manually operated structues in **Bold Italics.**
Remotely operated structures in *Red, Bold Italics*
Uncontrolled in *Blue, Bold Italics*
Automatically operated structures are in plain font
**S-174 is both automatic and manually controlled.*

CANAL BOUNDARY CONDITIONS

The canals must have boundary conditions defined wherever a branch junction is not connected to another branch. There were two types of canal boundary

conditions used in the calibration and verification of the models. The first is a flow boundary. The flow boundaries were used when a canal had a terminal end within the model domain; in these cases the flow was specified as 0. Flow boundaries were also used to define the inflows of the S12 (A, B, C, D) structures.

There are sixteen canal junctions that require stage boundaries. Nine of the stage boundaries are tidal boundaries. These data are harmonic daily average stages. Six stage boundaries were obtained from field data at the nearest gauging stations. The last stage boundary is a constant and represents the stage in the Turkey Point cooling ponds. The stage boundary locations are shown in figure 17.

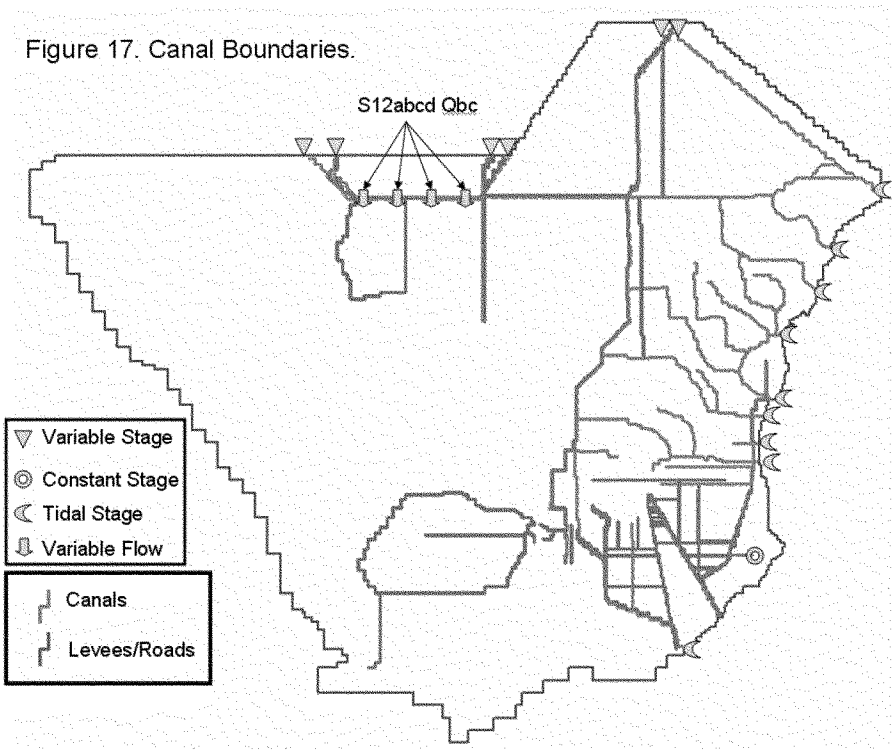


Figure 17. Canal Boundaries.

HORIZONTAL FLOW BARRIERS

Levees, and some roads, are designated as “horizontal flow barriers” in the model. The flow barriers were generally placed only in layers 1 and 2. The effectiveness of the horizontal flow barrier is determined by the hydraulic

characteristic (HYDCHR) assigned to the barrier. The majority of the barriers were assigned values of HYDCHR equal to –9.999. This value serves as a "flag" to the code and indicates that there is essentially no flow allowed through that segment of the barrier. The only exceptions to this were the barriers for L-28 and L-29. These barriers had HYDCHR values of 10 in order to increase the amount of seepage through the levees.

Most defined roads were included in both layers 1 and 2. However, a few roads were included as horizontal flow barriers only in layer 1. These include State Highway 27 (within the ENP) and Krome Avenue.

MODEL TIME STEPS

The computational time step used in both the BRANCH and MODFLOW portions of the model is 1 hour. Using the same time step increases model stability, although computation time is increased. The simulation time is 396 days, which covers an entire year and has an additional 31 days of "spin-up." The total number of time steps is 9504.

MODFLOW SOLVER

The solver used for the MODFLOW portion of the model is the Preconditioned Conjugate-Gradient Package 2 (PCG2). The modified, incomplete Cholesky method of preconditioning was used. The PCG2 package also requires that the user define two different iterations, an outer (Picard) iteration and an inner iteration.

The number of outer iterations required to reach a solution varies depending on whether a problem is linear or non-linear. In general a MODFLOW model is non-linear if the aquifers are unconfined or if certain packages are used. These packages include the River package, the Stream Package, the Evapo-transpiration package, and the Drain package. In the case of this study, the aquifers are unconfined and the Evapo-transpiration package is also used. Although neither the River nor Stream package is used, coupling the BRANCH model with the MODFLOW model can also be expected to introduce non-linearity.

The practical problem with non-linear simulations is that they require much more time than linear simulations. A linear problem generally requires 1 outer iteration and less than 50 inner iterations. A non-linear problem may require 100 outer iterations and 3-10 inner iterations.

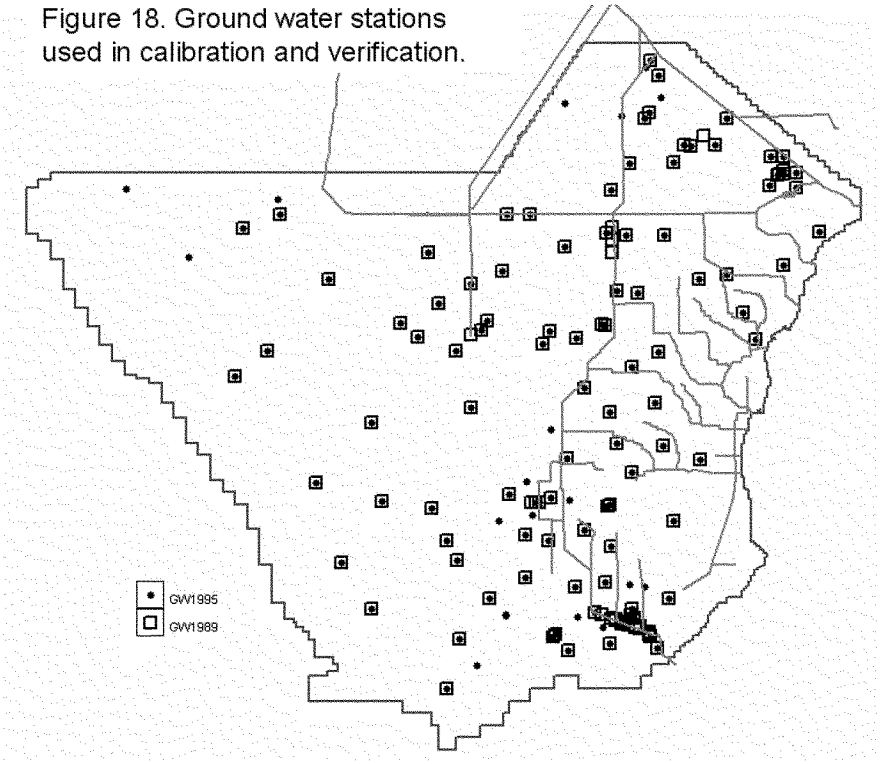
Test simulations were previously run with a variety of outer iterations and 4 inner iterations. Results of these tests are discussed in Appendix E. The final conclusion is that it is appropriate and justified to use 5 outer iterations and 4 inner iterations for this study.

The convergence criteria were set at 0.050 ft (head change) and 30,000 cf/d (residual change). The relaxation parameter is 0.98.

CALIBRATION AND VERIFICATION

The MB_2006 MODBRANCH model was *calibrated* to 1989 data. The model was *verified* to 1995 data. The locations of the data stations are shown in figure 18.

Figure 18. Ground water stations used in calibration and verification.



The canal inputs are based on fairly well known data (cross-section, leakage coefficient, Manning's n, maximum structure flow rates, etc.). As such, it was not justifiable that these values should be used as a "knob" in order to calibrate/verify the model.

Model simulations were generally performed for both years without using general structure operational rules. Structures were operated based on field data records, if available. This insured that the canal levels were representative of

actual field conditions and put the burden of calibration and verification on having correct hydrogeological and meteorological parameters. This is justifiable due to the fact that the latter parameters have a wide range of valid values that can be adjusted during the calibration and verification process. The canal parameters have a narrower range of valid values.

Time series plots of each station with both field data and model results can be found in appendix D.

CALIBRATION AND VERIFICATION STATISTICS

Many different statistics have been created and used to "prove" a model's worthiness.

Ten statistical measurements were used in order to determine the "goodness" of the model results versus field data. These are: Pearson's correlation coefficient[10] (r), average absolute difference, average difference, root mean squared error (RMSE), systematic root mean squared error ($RMSE_S$), unsystematic root mean squared error ($RMSE_U$), the ratio $RMSE_S$ / RMSE, the index of agreement (d), and the least square fit (slope and intercept)[11] of the field data versus model data. In order to insure that each measurement is understood a short description of each is included here.

Pearson's Correlation Coefficient, r

This is also known as the linear correlation coefficient and is defined as:

$$r = \frac{\sum_i (x_i - \underline{x})(y_i - \underline{y})}{\sqrt{\sum_i (x_i - \underline{x})^2}\sqrt{\sum_i (y_i - \underline{y})^2}}$$

where

x_i = individual field data points,
$\underline{x}$ = the average of the individual field data points,
y_i = individual model data points, and
$\underline{y}$ = the average of the individual model data points.

The correlation coefficient has a range between –1 and +1. When the value approaches +1, then the model and field are near "positive correlation." Complete positive correlation occurs when the model data versus the field data lie on a perfect straight line with positive slope. When the value approaches –1, the model and field data have "negative correlation." As r approaches a zero value, the data are uncorrelated. A good model should have r values approaching +1.

Average Absolute Difference

The average absolute difference is also known as the *mean absolute error*. The value indicates the amount of deviation between the model and field data. It is the average of the absolute difference between the model and field data:

$$\Delta_{abs} = \sum_{i}^{N} |m_i - f_i| \Big/ N$$

where

m_i = individual model data value,
f_i = individual field data value, and
N = number of model and field data pairs.

Average Difference, or "Bias"

The average difference is simply the average of the differences between model and field data. This is also known as the *mean bias error*. Its main value is that it will give an indication whether the model is over-predicting (> 0) or under-predicting (< 0).

$$\Delta = \sum_{i}^{N} (m_i - f_i) \Big/ N$$

Root Mean Square Error (RMSE)

The *root mean square error* is computed as:

$$RMSE = \sqrt{\sum_{i}^{N} (m_i - f_i)^2 \Big/ N}$$

The utility of the RMSE is limited, as are the previous error indicators, in that it contains errors associated with both the imperfections of the model and the inaccuracy of the field data. A better measure of model performance is the *Systematic Root Mean Square Error*. Since the RMSE is commonly used, it is included for comparison with other models.

Systematic Root Mean Square Error ($RMSE_S$)

The $RMSE_S$ is a measure of error that is associated with the model parameters. As such, it is a better indication of how the model is performing than the RMSE alone. The more accurate that a model is, the closer that $RMSE_S$ is to zero. The $RMSE_S$ is defined:

$$RMSE_S = \sqrt{\sum_i^N (\hat{m}_i - f_i)^2 \Big/ N}$$

where

$\hat{m}_i$ = the *expected value* of the model results derived from a linear least squares fit of the model and field data, evaluated at f_i.

Unsystematic Root Mean Square Error ($RMSE_U$)

The $RMSE_U$ is an indication of the amount of error that will always exist and which probably can not be removed from the system. As $RMSE_S$ approaches zero, $RMSE_U$ approaches RMSE. The $RMSE_U$ is defined:

$$RMSE_U = \sqrt{\sum_i^N (m_i - \hat{m}_i)^2 \Big/ N}$$

where the variables are defined above.

$RMSE_S$ / RMSE

The ratio of $RMSE_S$ to RMSE indicates the proportion of the error that arises from systematic error. Ideally, this should be small.

Index of Agreement (d)

The index of agreement is a measurement of average relative error. It ranges between 0 and 1, with 1 being considered "good." The index of agreement, d, is defined as:

$$d = 1 - \sum_i^N (m_i - f_i)^2 \Big/ \left(|m_i'| - |f_i'|\right)^2$$

$$where$$

$$m_i' = m_i - \underline{f}$$

$$f_i' = f_i - \underline{f}$$

Slope and Intercept

The final statistics used are the slope and intercept of a linear least squares fit between the field data and the model results. For a "perfect" fit, the slope would be 1 and the intercept would be 0.

Percent of time model is within 1 foot of field data

The SFWMD uses the percentage of the simulated period that the model is within +/- 1 foot of field data as an estimate of the "goodness" of the model. This is used in its discussion of calibration and verification of the LECsR model.

Statistical Analysis

Table 9 shows the MB_2006 results for both the calibration (1989) and verification (1995) periods. This table lists the Pearson's r (correlation coefficient), the average absolute error, the bias, the RMSE, and the systematic RMSE for all the groundwater stages used within the MB_2006 domain. Table 10 is a global summary of the results and includes other statistics. The two most commonly used statistics, Pearson's r and RMSE, indicate average values of ~0.79 and ~0.6 ft, respectively. It should be noted that the Systematic RMSE (that error associated with the model data) is about 0.1 ft less than the normal RMSE. Figures 19 and 20 show the RMSE of the stage plotted with color relative to the magnitude of the RMSE (red is "bad" and blue is "good"). The location of production wells is superimposed on each figure.

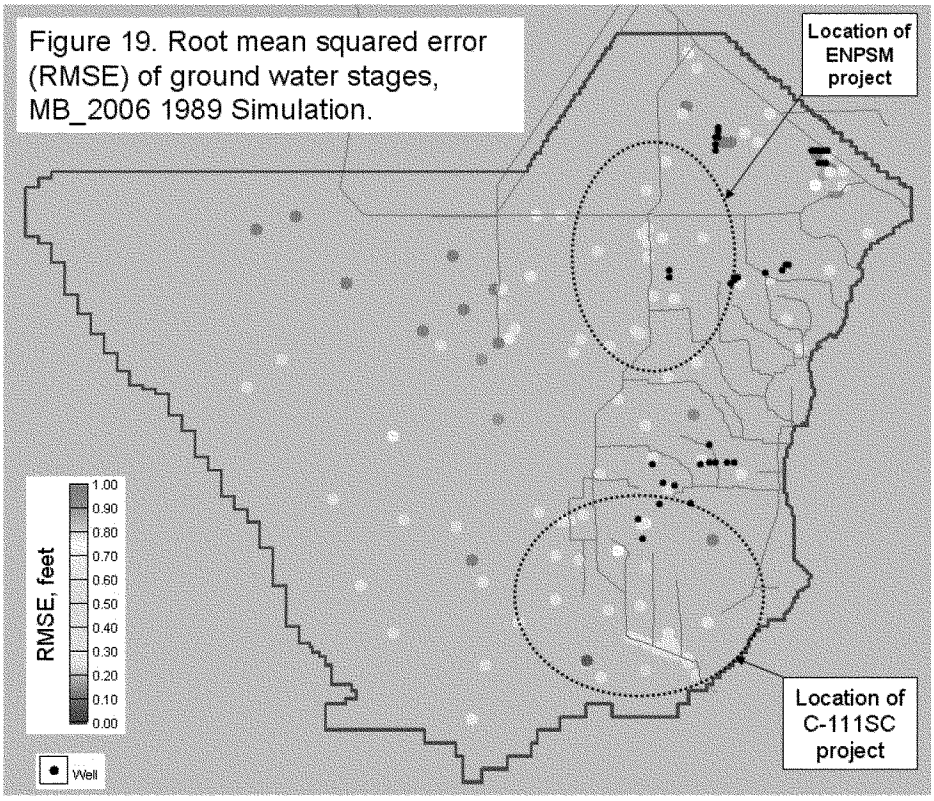


Figure 19. Root mean squared error (RMSE) of ground water stages, MB_2006 1989 Simulation.

For both simulation periods, some of the largest RMSE values are in the vicinity of the production wells that pump the largest values. As discussed above, the information on the pumping rates did not designate which wells pumped specific

volumes; only the volumes for each permit were provided. This could be a significant source of errors for locations near the production wells.

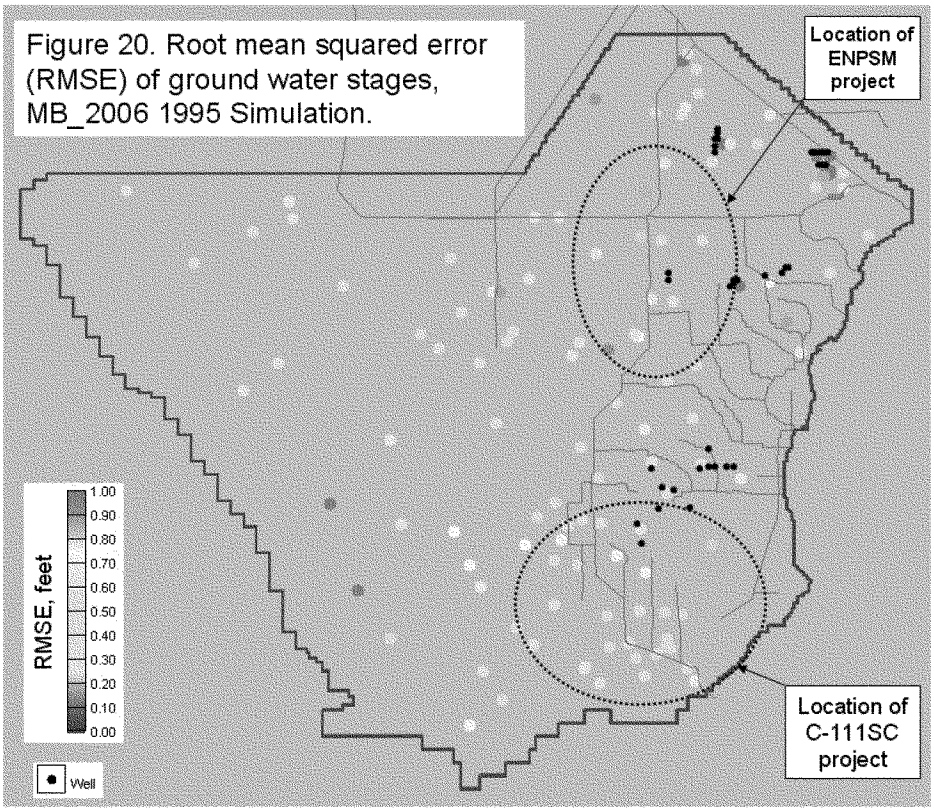


Figure 20. Root mean squared error (RMSE) of ground water stages, MB_2006 1995 Simulation.

The 1989 RMSE shows larger values in the north western part of the model domain than the 1995 RMSE. This may be indicative of dry year errors in boundary conditions, meteorological errors, or errors in geologic input. If the latter two reason are the source of the error, this indicates that the model is doing a fairly good job with the overland flow equations, which would dominate in the wet (1995) year.

The geologic parameters in the western part of the model are defined by the gray limestone and the gray limestone confining unit (figure 3 and table 1) and are based on the work of Reese and Cunningham[12]. Their work is fairly recent (2000) and represents fairly up to date data. If these data are inaccurate, it would require significant field work to correct.

The third possible cause is meteorological: rain and/or evapo-transpiration. This region is more isolated than the rest of the model domain and has the fewest rain gages for the creation of accurate rainfall boundary conditions.

Do the values shown in tables 9 and 10 indicate that the MB_2006 model is sufficiently calibrated and verified? There are many ways to answer that question. However, in order to be consistent, one of the best ways is to compare with other hydrologic models in the region. The south Florida area is blessed to have a plethora of modeling work and two of the most scrutinized models are from the SFWMD. The first is the venerable South Florida Water Management Model (SFWMM), also referred to as the "2x2"; the second is the SFWMD Lower East Coast sub-Regional (LECsR) MODFLOW model. These models have been reviewed by numerous individuals and agencies and have been found to be useful tools to understand the hydrology of the area. Therefore, it behooves us to compare the MB_2006 results with these models.

Table 11 shows the SFWMM2x2 summary values of correlation coefficient, RMSE, and Bias for 79 locations which are within the domain of the MB_2006 model. These are from the SFWMM v5.4 calibration and verification report (April 2004, http://www.sfwmd.gov/org/pld/hsm/models/sfwmm/index.html). The calibration period is a 12 year period covering 1984-1995; the verification periods are from 1981-1993 and 1996-2000, a total of 18 years. The correlation coefficient for calibration and verification is 0.87, the RMSE is ~0.4 ft, and the absolute average bias <0.1 ft. These values correspond fairly well with the MB_2006 values of 0.79, 0.6 ft, and <0.1 ft, respectively. There can be many reasons for the discrepancy, including the choice of gages and the periods and length of the simulations. Note that two gages that are included in the MB_2006 statistics (G-3355 and G-3356) are not included in the SFWMM2x2 analysis. These two locations are potentially bad data stations; the inclusion of these locations could reduce the estimated accuracy of the MB_2006 model.

The SFWMD LECsR model has much finer resolution than the SFWMM2x2 and is a MODFLOW based model. Since the MODBRANCH model is also MODFLOW based and has fine resolution, the LECsR model results should be comparable to the MB_2006 results. Table 12 reports the bias, the mean absolute error, and the RMSE for the calibration and verification periods, as reported by the SFWMD[13]. Note that the upper part of the table reports all 195 locations used in the LECsR model calibration and verification. The lower part reports the values only for the 85 locations that are within the MB_2006 domain. The calibration period is 1986-1999, approximately 14 years. The verification period is 1999-2000, a period of 2 years.

The 85 locations within the MB_2006 domain indicate better values of mean absolute error and RMSE than the values for all 195 locations. The bias for the 195 locations is slightly less than that of the 85 locations, although the difference is really insignificant. The absolute value of the bias for both the MB_2006 and LECsR are both on the order of ~0.1 ft, the mean absolute errors are both ~0.5 ft

and the RMSE values are in the range of 0.5 to 0.7 ft. Based on these statistics, the MB_2006 model compares well with the LECsR model.

Another measure of "goodness" used by the SFWMD is the percent of simulation time that model results are within a specified range of field data. The SFWMD uses this in its discussion of calibration and verification of the LECsR model. The standard of the SFWMD is to determine how often the model stages are within +/-1 foot of the field data. Tables 13 and 14 show this "statistic" for the MB_2006 and LECsR models, respectively. At the end of each table is a summary with the number of locations with percentages greater than 90%, 80% and 70%, and the global average percentage. The same results are shown graphically in figures 21 and 22, with the red dots indicative of poor agreement and the blue dots indicative of good agreement.

Figure 21. Percent of Time MB_2006 stage is within 1 foot of ground water stages, 1989 Simulation.

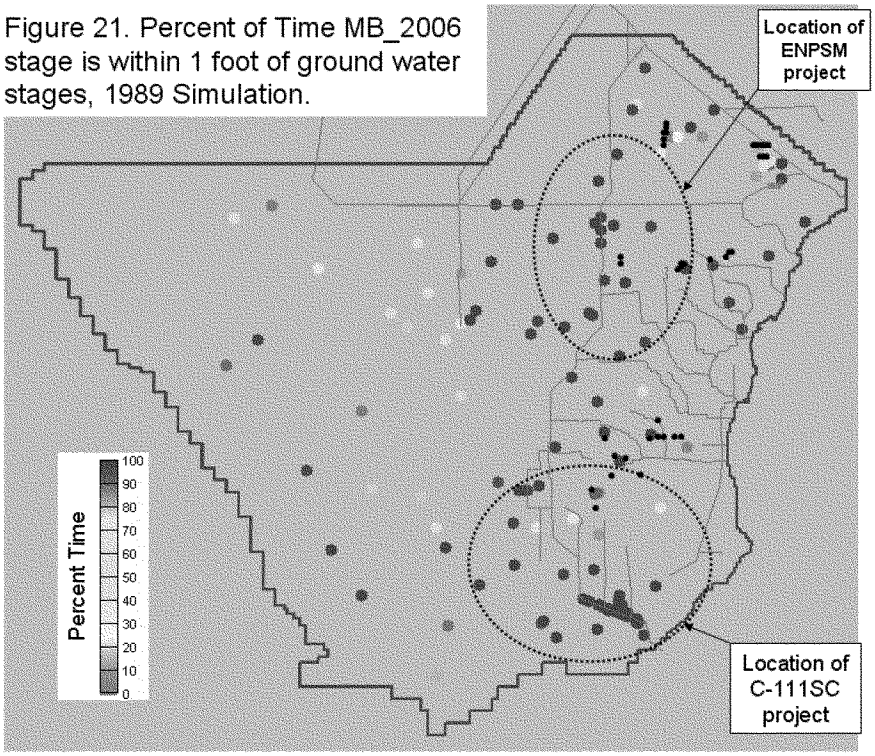
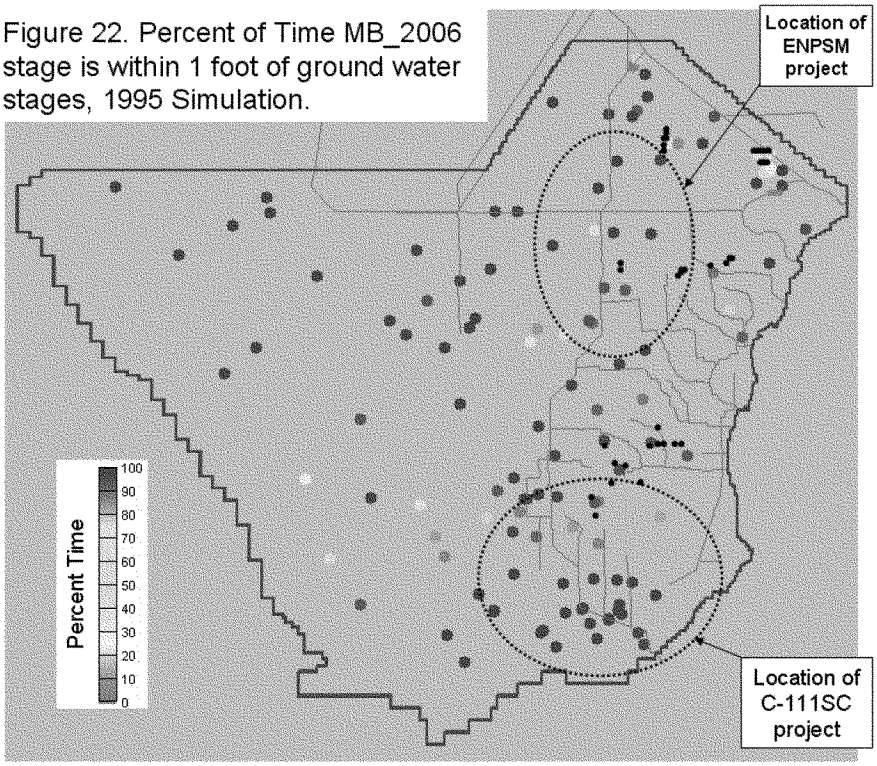


Figure 22. Percent of Time MB_2006 stage is within 1 foot of ground water stages, 1995 Simulation.



The MB_2006 shows the average percent of time the model is within 1 ft of the field measurements to be 87% (1989) and 90% (1995). The LECsR model reports values of ~87% for both its calibration and verification periods.

Based on the general agreement between the three models discussed above, it is evident that the MB_2006 model is calibrated and verified at least to the level of the SFWMD LECsR and SFWMM2x2 models.

Table 9. MB_2006 Statistics for Calibration (1989) and Verification (1995) Stations.

Station	1989					1995				
	Pearson's r	Average Absolute Difference, feet	Bias (model - field), feet	RMS Error, feet	Systematic RMSE, feet	Pearson's r	Average Absolute Difference, feet	Bias (model - field), feet	RMS Error, feet	Systematic RMSE, feet
2287497						0.76	0.32	0.23	0.38	0.29
2289096						0.92	1.34	1.34	1.35	1.35
3-34						0.96	0.41	-0.41	0.49	0.45
3-71						0.99	0.15	-0.15	0.17	0.15
3B-SE_B	0.77	0.28	0.16	0.38	0.23	0.96	0.15	-0.04	0.20	0.05
ANGELS	0.87	0.31	0.20	0.40	0.25	0.93	0.85	-0.85	0.91	0.86
BCNPA10						0.82	0.34	0.31	0.38	0.31
BCNPA11						0.95	0.34	-0.34	0.35	0.34
BCNPA9						0.88	0.64	0.64	0.66	0.65
EVER8						0.69	0.42	-0.15	0.49	0.15
F-179	0.83	0.18	-0.09	0.28	0.21	0.87	0.43	-0.41	0.54	0.50
F-319	0.87	0.26	0.02	0.33	0.13	0.70	0.25	0.00	0.36	0.10
F-358	0.84	0.37	-0.30	0.45	0.30	0.76	0.46	-0.18	0.59	0.18
Fpond	0.85	0.28	0.12	0.35	0.18	0.87	0.28	-0.03	0.39	0.05
G-1183	0.79	0.73	-0.73	0.78	0.73	0.52	0.54	-0.10	0.66	0.13
G-1362	0.90	0.56	0.56	0.60	0.56	0.72	0.46	-0.08	0.52	0.20
G-1363	0.89	0.53	0.52	0.58	0.53	0.76	0.52	0.20	0.66	0.20
G-1368A	0.69	0.59	-0.15	0.79	0.63	0.57	1.99	1.85	3.13	3.11
G-1486	0.86	0.30	0.04	0.35	0.11	0.72	0.46	0.18	0.58	0.21
G-1487	0.83	0.31	-0.27	0.38	0.33	0.83	0.56	-0.52	0.63	0.57
G-1488	0.84	0.30	-0.13	0.37	0.25	0.95	0.20	-0.16	0.26	0.22
G-1502	0.88	0.44	0.04	0.50	0.06	0.89	0.60	-0.55	0.78	0.67
G-3	0.71	2.09	-2.09	2.22	2.10	0.77	1.10	1.09	1.26	1.12
G-3073	0.93	0.19	-0.02	0.26	0.08	0.51	0.58	-0.47	0.71	0.59
G-3253	0.80	3.89	3.88	4.07	4.04	0.83	0.83	-0.33	1.04	0.94
G-3259A	0.92	1.48	1.46	1.62	1.59	0.85	0.60	-0.58	0.78	0.67
G-3264A	0.88	0.43	0.21	0.58	0.26	0.98	0.36	0.26	0.39	0.36
G-3273	0.86	0.44	0.18	0.53	0.19	0.90	0.49	-0.37	0.62	0.50
G-3328	0.84	0.26	-0.13	0.32	0.15	0.69	0.21	-0.06	0.28	0.20
G-3329	0.83	0.64	-0.53	0.75	0.56	0.65	0.38	0.12	0.47	0.14
G-3354	0.88	0.25	-0.21	0.30	0.21	0.73	0.36	0.09	0.44	0.13
G-3355	0.45	0.64	-0.56	0.81	0.70	0.55	0.57	-0.44	0.71	0.45
G-3356	0.72	0.95	-0.95	1.00	0.97	0.53	0.65	-0.57	0.80	0.60
G-3439	0.69	0.31	-0.06	0.43	0.18	0.92	0.28	-0.06	0.35	0.06
G-3465	0.84	0.77	-0.73	0.89	0.74	0.84	0.75	0.72	0.85	0.76
G-3466	0.80	0.55	-0.42	0.64	0.42	0.85	1.24	1.26	1.36	1.33
G-3467	0.89	0.24	-0.15	0.31	0.15	0.89	0.35	0.26	0.40	0.35
G-551	0.88	0.36	-0.18	0.45	0.18	0.78	1.56	1.43	1.68	1.55
G-553	0.90	0.40	-0.34	0.50	0.36	0.73	0.66	-0.92	0.86	0.57
G-594	0.78	1.16	-1.16	1.24	1.20	0.89	0.58	-0.44	0.66	0.59
G-596	0.85	0.34	0.24	0.40	0.36	0.89	0.65	-0.64	0.73	0.66
G-596_B	0.87	0.31	0.23	0.38	0.34	0.87	0.52	-0.50	0.62	0.51
G-613	0.50	0.60	0.55	0.75	0.56	0.68	0.63	0.58	0.72	0.54
G-614	0.91	0.90	0.90	0.93	0.90	0.88	0.47	0.82	0.59	0.47
G-618_B	0.92	0.37	0.30	0.40	0.31	0.90	0.28	0.25	0.30	0.28
G-620_B	0.36	1.11	-0.93	1.35	1.08	0.77	0.39	0.32	0.47	0.46
G-757A	0.92	0.40	0.40	0.44	0.41	0.82	0.40	-0.27	0.54	0.38
G-789	0.82	0.39	0.33	0.45	0.37	0.78	0.34	0.06	0.47	0.19
G-855	0.86	0.22	0.12	0.27	0.14	0.75	0.46	-0.37	0.59	0.37
G-860	0.90	0.22	-0.10	0.27	0.11	0.35	0.50	-0.04	0.67	0.27
G-864	0.75	0.58	-0.56	0.69	0.56	0.65	0.61	-0.43	0.84	0.52
G-864A	0.74	0.55	-0.50	0.66	0.51	0.64	0.53	-0.26	0.78	0.39
G-968	0.90	0.53	0.46	0.68	0.65	0.93	0.72	-0.72	0.79	0.79
G-972	0.85	0.30	-0.24	0.40	0.33	0.82	0.39	0.37	0.42	0.38
G-973	0.93	0.22	0.03	0.27	0.11	0.74	0.58	0.58	0.64	0.56
G-975	0.77	0.39	-0.10	0.49	0.39	0.85	0.30	0.18	0.38	0.21
G-976	0.81	0.75	0.63	0.83	0.74	0.86	0.27	-0.13	0.37	0.13
HUMBLE	0.94	0.36	0.35	0.40	0.37	0.83	0.33	-0.13	0.40	0.13
KROME	0.82	0.23	-0.12	0.28	0.22	0.93	0.45	-0.45	0.53	0.48
L29	0.94	0.20	0.02	0.25	0.09	0.68	0.24	0.19	0.27	0.19
L31.EXT1	0.86	0.26	0.12	0.34	0.27					
L31.EXT2	0.73	0.26	0.34	0.35	0.32					
L31.EXT3	0.84	0.20	0.24	0.29	0.25					
L67E	0.66	0.63	0.61	0.81	0.78					
L67E.S	0.65	1.17	1.17	1.30	1.26					
L67EXE_B	0.42	0.50	0.45	0.61	0.56	0.89	0.15	0.11	0.18	0.11
L67EXW	0.36	1.54	1.32	1.76	1.67	0.86	0.50	0.49	0.64	0.63
Loop1	0.47	2.69	-2.70	2.82	2.73	0.86	0.24	0.24	0.28	0.24
Loop2	0.64	2.17	-2.17	2.37	2.30	0.81	0.34	-0.33	0.38	0.34
NESRS1	0.39	0.52	-0.28	0.63	0.45	0.88	0.25	0.23	0.28	0.23
NESRS2	0.54	0.40	-0.32	0.49	0.26	0.83	0.23	0.15	0.27	0.16
NESRS3_B	0.66	0.24	0.01	0.32	0.15	0.87	0.71	-0.71	0.80	0.75
NESRS4_B	0.87	0.27	-0.08	0.35	0.27	0.89	0.37	0.37	0.39	0.37
NESRS5_B	0.31	0.60	-0.62	0.68	0.52	0.89	0.40	0.40	0.42	0.40

Table 9 (continued). MB_2006 Statistics for Calibration (1989) and Verification (1995) Stations.

Station	1989					1995				
	Pearson's r	Average Absolute Difference, feet	Bias (model - field), feet	RMS Error, feet	Systematic RMSE, feet	Pearson's r	Average Absolute Difference, feet	Bias (model - field), feet	RMS Error, feet	Systematic RMSE, feet
NP-112						0.83	0.60	-0.10	0.71	0.23
NP-127	0.87	0.27	0.10	0.35	0.16	0.85	0.22	0.13	0.30	0.14
NP-146						0.53	0.30	-0.18	0.39	0.26
NP-158	0.83	0.71	0.70	0.79	0.70	0.89	0.44	0.36	0.55	0.40
NP-201	-0.07	1.26	-1.27	1.57	1.39	0.86	0.47	0.21	0.55	0.54
NP-202	0.22	0.75	-0.65	1.00	0.76	0.84	0.45	0.43	0.58	0.57
NP-203	0.40	0.62	-0.51	0.79	0.57	0.81	0.50	0.50	0.58	0.57
NP-205	0.56	1.20	-0.57	1.38	1.27	0.55	0.35	-0.01	0.38	0.36
NP-206	0.80	0.65	-0.37	0.90	0.53	0.90	0.32	0.07	0.35	0.20
NP-311	0.92	0.44	0.02	0.55	0.43	0.86	0.46	-0.19	0.55	0.18
NP-31W	0.86	0.28	0.11	0.34	0.17	0.89	0.32	0.10	0.39	0.13
NP-C27	0.93	0.22	-0.30	0.25	0.22	0.74	0.48	0.22	0.55	0.25
NP-C50						0.76	0.50	0.26	0.57	0.31
NP-CHP	0.27	0.53	-0.64	0.66	0.63	0.59	0.65	-0.69	0.73	0.69
NP-CT3R	0.88	0.24	-0.02	0.29	0.12					
NP-CV1N	0.91	0.24	-0.07	0.28	0.15					
NP-CV1S	0.85	0.27	-0.09	0.31	0.12					
NP-CV2N	0.89	0.26	0.09	0.31	0.18					
NP-CV2S	0.85	0.29	0.00	0.35	0.24					
NP-CV3N	0.89	0.27	0.09	0.31	0.19					
NP-CV3S	0.86	0.29	0.10	0.33	0.18					
NP-CV4N	0.88	0.27	0.10	0.32	0.18					
NP-CV4S	0.86	0.29	0.10	0.33	0.17					
NP-CV5N	0.93	0.23	-0.07	0.27	0.16	0.76	0.43	0.23	0.49	0.21
NP-CV5S	0.85	0.32	0.05	0.35	0.26					
NP-CV6N	0.88	0.27	0.07	0.32	0.19					
NP-CV6S	0.85	0.28	0.10	0.32	0.17					
NP-CV7N	0.85	0.25	0.11	0.30	0.16					
NP-CV7S	0.84	0.26	0.14	0.30	0.14					
NP-CV8N	0.87	0.26	0.13	0.32	0.16					
NP-CV8S	0.85	0.29	0.13	0.34	0.16					
NP-CV9N	0.90	0.25	0.00	0.30	0.15	0.76	0.45	0.17	0.52	0.24
NP-CV9S	0.88	0.28	-0.03	0.33	0.15					
NP-DO1	0.97	0.27	-0.63	0.30	0.27	0.79	0.57	0.53	0.67	0.55
NP-EP1	0.92	0.21	-0.12	0.27	0.21	0.76	0.28	-0.06	0.37	0.13
NP-EP12R	0.81	0.48	-0.48	0.51	0.50	0.75	0.75	-0.75	0.77	0.75
NP-EP9R	0.81	0.32	-0.31	0.35	0.32	0.70	0.23	0.10	0.30	0.12
NP-EPS	0.87	0.19	-0.16	0.23	0.16	0.72	0.28	-0.06	0.34	0.12
NP-EV6						0.76	0.38	-0.10	0.46	0.20
NP-EV7						0.76	0.39	-0.31	0.46	0.27
NP-EV8						0.70	0.39	0.04	0.49	0.09
NP-N10						0.92	0.38	-0.25	0.46	0.25
NP-N14						0.55	0.62	-0.44	0.74	0.27
NP-NTS1	0.87	0.28	0.01	0.34	0.19	0.93	0.33	-0.28	0.42	0.28
NP-NTS3	0.90	0.28	0.10	0.36	0.21					
NP-OT3	0.54	0.44	-0.27	0.55	0.44	0.64	0.45	0.45	0.63	0.50
NP-P33	0.62	0.76	-0.78	0.90	0.79	0.83	0.54	0.54	0.59	0.58
NP-P34	0.84	0.42	0.29	0.48	0.39	0.86	0.23	0.25	0.29	0.20
NP-P35	0.36	0.49	-0.42	0.57	0.46	0.77	1.06	1.06	1.11	1.06
NP-P36	0.46	0.62	-0.34	0.76	0.57	0.85	0.63	0.62	0.66	0.65
NP-P37	0.89	0.35	0.23	0.55	0.52	0.71	0.26	0.10	0.30	0.16
NP-P38	0.85	0.25	-0.06	0.31	0.27	0.71	0.88	0.83	0.98	0.87
NP-P44	0.95	0.71	0.12	0.79	0.73	0.77	0.61	0.45	0.75	0.53
NP-P46	0.86	0.35	-0.04	0.40	0.38	0.72	0.37	0.25	0.47	0.25
NP-P62	0.84	0.58	0.29	0.79	0.72	0.96	0.61	0.53	0.63	0.61
NP-P67	0.91	0.22	-0.05	0.30	0.18	0.78	0.29	0.20	0.35	0.24
NP-P72	0.85	0.94	-0.92	1.10	0.96	0.78	0.62	0.47	0.73	0.54
NP-ROB						0.72	0.43	0.16	0.57	0.31
NP-TSB	0.94	0.47	0.35	0.55	0.47	0.87	0.36	0.00	0.47	0.03
NP-TSH						0.78	0.25	0.11	0.33	0.12
RUTZKE_G						0.91	0.30	-0.15	0.38	0.18
S-19	0.83	0.74	-0.68	0.87	0.70	0.84	1.06	1.09	1.16	1.09
S-196A	0.89	0.55	0.55	0.60	0.56	0.69	0.50	0.16	0.63	0.17
S-68	0.78	0.95	-0.94	1.07	0.94	0.82	1.45	1.40	1.67	1.62
SNAPPERN	0.86	0.28	0.72	0.31	0.28					
SWEVER1	0.84	0.23	-0.18	0.27	0.23	0.90	0.16	0.08	0.21	0.13
SWEVER2A	0.88	0.21	-0.06	0.27	0.20	0.71	0.36	0.05	0.45	0.09
SWEVER2B	0.86	0.24	-0.19	0.29	0.19	0.71	0.38	0.09	0.46	0.12
SWEVER3	0.65	0.30	0.03	0.36	0.09	0.80	0.25	0.32	0.31	0.10
SWEVER4	0.65	0.38	0.31	0.49	0.35	0.87	0.41	0.35	0.52	0.41
SWEVER5A	0.72	0.28	0.20	0.44	0.41	0.79	0.20	0.09	0.28	0.09
SWEVER5B	0.78	0.05	-0.31	0.07	0.02	0.67	0.25	0.03	0.35	0.23
TSHilton						0.78	0.22	0.02	0.30	0.02

Table 10. MODBRANCH MB_2006 Statistical Summary for Calibration (1989) and Verification (1995)

	Pearson's r	Average Absolute Difference, feet	Bias (model-field), feet	RMSE, feet	Systematic RMSE, feet	Unsystematic RMSE, feet	Sys RMSE/ RMSE	Index of Agreement	slope	Intercept	Average Number of Points
1989 (127 locations)											
All Data											
Average	0.78	0.52	-0.06	0.61	0.49	0.31	0.56	0.77	0.82	0.66	309
Median	0.85	0.35	-0.02	0.40	0.32	0.28	0.59	0.83	0.78	0.56	365
Standard Deviation	0.18	0.50	0.67	0.53	0.54	0.15	0.27	0.16	0.38	1.47	108
Minimum	-0.07	0.05	-2.70	0.07	0.02	0.06	0.01	0.26	-0.07	-2.90	38
Maximum	0.97	3.89	3.88	4.07	4.04	0.81	0.99	0.97	2.47	5.96	365
Best 90% (re: RMSE)											
Average	0.80	0.40	-0.05	0.48	0.36	0.29	0.53	0.79	0.86	0.50	305
Median	0.85	0.31	0.00	0.40	0.27	0.27	0.56	0.84	0.82	0.41	365
Standard Deviation	0.15	0.20	0.38	0.23	0.24	0.12	0.26	0.14	0.36	1.22	111
Minimum	0.22	0.05	-1.16	0.07	0.02	0.06	0.01	0.26	0.13	-2.44	38
Maximum	0.97	1.16	0.90	1.24	1.20	0.73	0.97	0.97	2.47	4.84	365
1995 (123 locations)											
Average	0.79	0.49	0.09	0.59	0.42	0.34	0.51	0.75	0.92	0.40	347
Median	0.81	0.43	0.09	0.52	0.31	0.34	0.49	0.77	0.89	0.32	365
Standard Deviation	0.12	0.29	0.49	0.36	0.39	0.16	0.33	0.13	0.37	2.11	33
Minimum	0.35	0.15	-0.92	0.17	0.02	0.06	0.00	0.35	0.09	-6.95	206
Maximum	0.99	1.99	1.85	3.13	3.11	0.69	0.99	0.98	1.90	6.96	365
Best 90% (re: RMSE)											
Average	0.79	0.42	0.02	0.50	0.33	0.33	0.47	0.77	0.95	0.32	348
Median	0.81	0.40	0.07	0.49	0.27	0.32	0.44	0.78	0.97	0.24	365
Standard Deviation	0.12	0.15	0.35	0.17	0.20	0.16	0.32	0.12	0.36	2.17	32
Minimum	0.35	0.15	-0.75	0.17	0.02	0.06	0.00	0.35	0.20	-6.95	206
Maximum	0.99	0.75	0.82	0.85	0.79	0.69	0.99	0.98	1.90	6.96	365

Table 11. SFWMM v5.4 Calibration (1984-1995) and Verification (1981-1993,1996-2000) Statistics for Stage Locations

Based on 79 locations within the MB_2006 Domain

	R^2		r		RMSE (ft)		Bias (ft)	
	Calibration	Verification	Calibration	Verification	Calibration	Verification	Calibration	Verification
Average	0.77	0.76	0.87	0.87	0.42	0.38	0.04	-0.03
Median	0.80	0.79	0.89	0.89	0.39	0.39	0.06	-0.02
Standard Deviation	0.09	0.11	0.06	0.06	0.14	0.14	0.20	0.18
Mimimum	0.50	0.52	0.71	0.72	0.15	0.16	-0.41	-0.55
Maximum	0.91	0.93	0.96	0.96	0.92	0.79	0.65	0.59

Table 12. SFWMD Lower East Coast sub-Regional (LECsR) MODFLOW Model Statistics for Stage Locations

Source: Lower East Coast Subregional MODFLOW Model Documentation, March 2006 (DRAFT), South Florida Water Management District. Calibration Period: 1986-1999; Verification Period: 1999-2000.

Based on 195 locations						
	Bias (ft)		Mean Absolute Error (ft)		RMSE (ft)	
	Calibration	Verification	Calibration	Verification	Calibration	Verification
Average	-0.01	-0.11	0.55	0.54	0.70	0.67
Median	-0.05	-0.12	0.41	0.40	0.57	0.57
Standard Deviation	0.59	0.69	0.53	0.57	0.59	0.59
Mimimum	-3.26	-5.32	0.08	0.09	0.12	0.12
Maximum	4.77	4.45	5.10	5.09	5.71	5.09

Based on 85 locations within MB_2006 Domain						
	Bias (ft)		Mean Absolute Error (ft)		RMSE (ft)	
	Calibration	Verification	Calibration	Verification	Calibration	Verification
Average	-0.04	-0.15	0.43	0.40	0.55	0.53
Median	-0.05	-0.16	0.37	0.35	0.50	0.50
Standard Deviation	0.23	0.30	0.29	0.22	0.32	0.26
Mimimum	-0.53	-0.79	0.08	0.11	0.12	0.14
Maximum	0.72	0.88	2.25	1.19	2.50	1.42

Table 13. MB_2006 Results, % of Time Model Stage is within 1 foot of Field Data.

			1989		1995	
Station	X-coord	Y-coord	# field points	Percent of Time Absolute Stage Difference < 1 ft	# field points	Percent of Time Absolute Stage Difference < 1 ft
2289096	835378	578905			365	4.4%
2287497	841274	566512			365	100.0%
3-34	825303	559313			365	98.9%
3-71	801994	564175			365	100.0%
3B-SE_B	820851	529008	365	99.5%	365	100.0%
ANGELS	806957	468810	365	99.5%	365	65.2%
BCNPA10	649101	501843			365	100.0%
BCNPA11	623422	529314			365	100.0%
BCNPA9	685212	525374			365	99.7%
EVER8	834860	367666			327	100.0%
F-179	905899	512154	365	98.6%	365	94.5%
F-319	891160	498320	365	97.8%	324	98.1%
F-358	829313	413952	365	99.5%	365	95.3%
Fpond	796565	403850	365	99.5%	365	97.5%
G-1183	857277	419462	365	86.0%	365	92.1%
G-1362	840325	462941	365	96.2%	303	98.7%
G-1363	820479	438390	365	98.4%	365	90.7%
G-1368A	891249	542725	365	77.5%	365	41.4%
G-1486	842298	425090	365	98.4%	360	93.6%
G-1487	823366	488133	365	98.6%	337	93.2%
G-1488	828485	539825	365	99.7%	355	100.0%
G-1502	793261	466320	365	98.4%	365	74.0%
G-3	885986	542697	365	14.5%	362	44.8%
G-3073	868018	494567	365	99.7%	303	88.1%
G-3253	850493	547187	365	4.4%	330	69.4%
G-3259A	853344	547139	365	28.5%	365	85.2%
G-3264A	863595	547248	365	84.1%	317	100.0%
G-3273	795899	471579	360	97.2%	365	83.6%
G-3328	896308	530092	365	100.0%	365	100.0%
G-3329	885665	530700	365	82.2%	343	97.7%
G-3354	830481	354958	363	100.0%	365	100.0%
G-3355	820958	383815	335	83.3%	332	86.1%
G-3356	846444	394457	354	69.8%	365	81.6%
G-3439	842593	510443	365	96.2%	365	98.9%
G-3465	889097	535020	365	64.4%	362	69.3%
G-3466	891068	535697	365	91.5%	348	33.3%
G-3467	896166	536028	365	99.5%	365	99.7%
G-551	856774	492878	365	98.1%	339	18.9%
G-553	874737	479153	365	97.5%	231	77.1%
G-594	836567	560636	365	46.0%	273	91.9%
G-596	818479	473697	365	98.4%	350	89.7%
G-596_B	817030	474579	365	98.9%	365	94.5%
G-613	810206	390419	365	74.5%	341	83.0%
G-614	839129	442461	365	57.0%	259	87.6%
G-618_B	787975	519305	365	100.0%	331	100.0%
G-620_B	735304	474960	365	51.2%	320	100.0%
G-757A	829529	456839	365	99.5%	309	97.7%

Table 13 (continued). MB_2006 Results, % of Time Model Stage is within 1 foot of Field Data.

			1989		1995	
Station	X-coord	Y-coord	# field points	Percent of Time Absolute Stage Difference < 1 ft	# field points	Percent of Time Absolute Stage Difference < 1 ft
G-789	803285	419854	365	99.5%	294	96.6%
G-855	831713	487197	365	100.0%	363	92.0%
G-860	880065	468034	365	99.5%	365	91.5%
G-864	820785	400774	365	88.8%	365	87.1%
G-864A	819411	400527	365	91.0%	319	92.8%
G-968	836917	581839	365	80.5%	365	77.0%
G-972	840229	575796	365	96.7%	362	100.0%
G-973	868365	558296	365	99.5%	357	93.8%
G-975	834824	558084	365	96.7%	365	99.5%
G-976	846246	540565	365	74.5%	365	97.5%
HUMBLE	810090	448375	365	99.7%	365	99.5%
KROME	826974	510620	365	100.0%	365	100.0%
L29	778650	519278	365	100.0%	365	100.0%
L31.EXT1	821639	514070	241	100.0%		
L31.EXT2	821659	508719	216	100.0%		
L31.EXT3	821680	503369	167	100.0%		
L67E	763909	490972	354	74.6%		
L67E.S	764235	470277	365	40.0%		
L67EX.E_B	764092	490972	365	83.0%	365	100.0%
L67EX.W	763909	490972	365	32.6%	365	84.7%
Loop1	686496	518914	365	0.0%	365	100.0%
Loop2	671322	513556	365	21.4%	365	100.0%
NESRS1	776611	496053	365	98.6%	365	100.0%
NESRS2	802191	505722	312	100.0%	365	100.0%
NESRS3_B	819270	511739	365	99.7%	365	63.8%
NESRS4_B	770627	475644	115	100.0%	365	100.0%
NESRS5_B	768349	472105	186	100.0%	365	100.0%
NP-112	788804	396448			358	86.6%
NP-127	786310	371405	365	100.0%	362	100.0%
NP-146	766402	335312			365	100.0%
NP-158	795528	386475	365	69.9%	348	90.5%
NP-201	746593	503552	332	43.7%	365	97.8%
NP-202	751028	482866	365	62.7%	365	93.2%
NP-203	742179	469219	365	77.8%	365	99.2%
NP-205	705999	492886	365	35.9%	365	100.0%
NP-206	764216	440698	365	76.7%	365	100.0%
NP-311	779611	405204	353	94.3%	358	92.5%
NP-31W	791629	401908	365	100.0%	364	99.5%
NP-C27	825094	352557	103	100.0%	312	97.4%
NP-C50	814433	356859			326	95.4%
NP-CHP	754121	325795	258	80.2%	332	78.9%
NP-CT3R	836491	348362	345	100.0%		
NP-CV1N	836764	348868	336	100.0%		
NP-CV1S	836582	348665	351	100.0%		
NP-CV2N	832812	350265	39	100.0%		
NP-CV2S	832807	351578	39	100.0%		
NP-CV3N	830790	350964	39	100.0%		
NP-CV3S	830699	350863	39	100.0%		

Table 13 (continued). MB_2006 Results, % of Time Model Stage is within 1 foot of Field Data.

			1989		1995	
Station	X-coord	Y-coord	# field points	Percent of Time Absolute Stage Difference < 1 ft	# field points	Percent of Time Absolute Stage Difference < 1 ft
NP-CV4N	828125	351963	39	100.0%		
NP-CV4S	828033	351862	39	100.0%		
NP-CV5N	825459	353164	333	100.0%	323	100.0%
NP-CV5S	825643	352963	210	100.0%		
NP-CV6N	822978	354064	38	100.0%		
NP-CV6S	822886	353962	39	100.0%		
NP-CV7N	821231	354764	38	100.0%		
NP-CV7S	821140	354662	38	100.0%		
NP-CV8N	817188	356263	39	100.0%		
NP-CV8S	817097	356162	39	100.0%		
NP-CV9N	814523	357263	358	100.0%	365	99.7%
NP-CV9S	814524	357162	343	100.0%		
NP-DO1	758215	378155	110	100.0%	365	85.8%
NP-EP1	837046	347355	165	100.0%	365	100.0%
NP-EP12R	839636	342419	365	100.0%	365	97.0%
NP-EP9R	803564	341578	365	100.0%	313	100.0%
NP-EPS	820443	344565	365	100.0%	365	100.0%
NP-EV6	817574	351116			362	99.7%
NP-EV7	807372	355320			293	100.0%
NP-EV8	828427	368621			327	100.0%
NP-N10	786562	410474			364	97.8%
NP-N14	775331	394289			209	77.0%
NP-NTS1	790621	401804	321	100.0%	365	98.1%
NP-NTS3	788329	401797	353	99.4%		
NP-OT3	667863	453186	334	89.8%	357	100.0%
NP-P33	757935	463700	358	57.3%	365	100.0%
NP-P34	681042	463589	365	97.5%	332	100.0%
NP-P35	700840	409940	337	96.7%	365	29.6%
NP-P36	723652	434560	324	87.3%	331	93.7%
NP-P37	759215	346399	365	88.8%	365	100.0%
NP-P38	711266	377204	365	100.0%	342	57.3%
NP-P44	748091	399272	346	78.0%	339	72.3%
NP-P46	723676	358647	365	100.0%	365	93.2%
NP-P62	727918	402263	344	77.6%	292	99.3%
NP-P67	771747	362784	365	99.5%	365	100.0%
NP-P72	754262	386465	365	48.5%	365	83.0%
NP-ROB	804093	402857			365	96.4%
NP-TSB	786076	388566	365	97.5%	365	96.4%
NP-TSH	778280	356139			362	100.0%
RUTZKE_G	796485	431502			365	99.2%
S-19	889204	535566	365	65.2%	359	47.6%
S-196A	823494	426044	365	100.0%	363	96.1%
S-68	891334	537092	365	47.9%	358	29.6%
SNAPPERN	858864	551078	81	100.0%		
SWEVER1	844599	362630	261	100.0%	206	100.0%
SWEVER2A	829384	358530	224	100.0%	365	100.0%
SWEVER2B	829026	356106	365	100.0%	365	100.0%
SWEVER3	818792	369191	365	100.0%	233	100.0%
SWEVER4	806413	367431	365	96.4%	365	100.0%
SWEVER5A	797579	347313	365	92.3%	365	100.0%
SWEVER5B	798219	348122	365	100.0%	279	100.0%
TSHilton	778073	355816			362	100.0%
		Total number of stations with data		129		125
		Number of stations> 90%		88		91
		Number of stations > 80%		99		104
		Number of stations > 70%		107		110
		Average		87.6%		90.0%

Table 14. SFWMD LECsR MODFLOW Results, % of Time Model Stage is within 1 foot of Field Data.

Station	Calibration	Verification	Station	Calibration	Verification	Station	Calibration	Verification
1-7	90.6%	98.6%	G3549	99.4%	100.0%	NESRS5	87.9%	97.4%
1-9	93.9%	100.0%	G3550	99.6%	100.0%	NP112	88.2%	98.2%
2A-17	78.0%	90.9%	G3551	99.5%	98.1%	NP127	96.4%	100.0%
2B-Y	71.0%	98.8%	G3552	96.3%	97.0%	NP146	99.7%	100.0%
ANGEL	91.3%	79.5%	G3553	81.6%	88.1%	NP158	99.1%	84.2%
EVER1	99.7%	100.0%	G3554	60.0%	67.4%	NP-201	96.5%	100.0%
EVER2A	99.9%	100.0%	G3555	89.5%	89.8%	NP-202	93.8%	98.6%
EVER2B	100.0%	100.0%	G3556	85.1%	90.1%	NP-203	92.2%	100.0%
EVER3	99.8%	100.0%	G3557	99.6%	97.4%	NP-205	81.1%	87.7%
EVER4	99.6%	100.0%	G3558	97.6%	100.0%	NP-206	72.4%	65.6%
F239	76.1%	79.8%	G3559	99.7%	98.4%	NP311	80.2%	100.0%
F291	96.3%	94.1%	G3560	93.0%	92.9%	NP-33	86.4%	97.0%
F319	98.3%	97.7%	G3561	75.0%	87.9%	NP-35	100.0%	99.1%
F358	92.5%	90.2%	G3563	94.6%	100.0%	NP-36	86.2%	77.7%
F45	91.2%	80.9%	G3564	95.1%	100.0%	NP-38	99.4%	99.7%
FROGP	99.1%	98.8%	G3565	91.5%	95.2%	NP-44	58.6%	91.3%
G1074B	9.3%	6.4%	G3566	78.3%	52.4%	NP-46	96.3%	98.7%
G1166	98.1%	97.2%	G3567	95.9%	100.0%	NP-62	91.6%	95.8%
G1183	96.9%	96.0%	G3568	97.0%	100.0%	NP-67	96.0%	98.4%
G1213	81.8%	80.6%	G3570	76.5%	85.7%	NPA13	90.7%	100.0%
G1220	97.4%	98.0%	G3572	96.8%	99.5%	NPCHP	96.5%	100.0%
G1221	96.5%	91.2%	G3576	99.7%	98.8%	NPCR2	94.3%	100.0%
G1223	91.6%	95.5%	G3619	99.3%	99.8%	NPCR3	86.3%	100.0%
G1224	98.4%	96.7%	G3620	99.3%	99.5%	NPCY2	94.4%	100.0%
G1225	82.0%	87.7%	G3621	99.8%	99.3%	NPCY3	87.7%	100.0%
G1226	97.4%	95.8%	G3622	98.0%	95.4%	NPD01	83.7%	100.0%
G1260	29.4%	28.6%	G3626	79.4%	77.9%	NPD02	77.6%	100.0%
G1315	98.4%	97.0%	G3627	98.3%	97.4%	NPEP1	100.0%	100.0%
G1316	93.6%	97.7%	G3628	97.3%	92.6%	NPEPS	99.9%	100.0%
G1362	95.8%	95.4%	G3676	99.3%	100.0%	NPEV6	99.7%	100.0%
G1363	95.8%	95.8%	G3A	45.0%	19.1%	NPEV7	99.5%	100.0%
G1473	95.9%	94.0%	G551	67.7%	41.3%	NPEV8	99.6%	100.0%
G1486	98.4%	97.7%	G553	90.8%	95.1%	NPN10	94.7%	94.7%
G1487	98.4%	98.4%	G561	94.4%	96.6%	NPN14	69.0%	89.4%
G1488	99.4%	100.0%	G580A	97.0%	95.6%	NPNTS1	98.3%	96.5%
G1636	98.2%	97.2%	G614	96.2%	96.2%	NPP37	94.5%	100.0%
G1637	98.6%	94.7%	G617	90.9%	80.0%	NPROB	96.6%	96.5%
G2031	95.9%	97.2%	G620	86.5%	100.0%	NP-TSB	93.6%	89.1%
G2032	94.3%	81.6%	G757 A	97.2%	96.3%	NPTSH	99.4%	100.0%
G2033	89.6%	93.0%	G789	97.2%	96.1%	PB1491	18.4%	-34.9%
G2034	91.3%	86.5%	G852	95.9%	90.2%	PB1639	54.3%	33.0%
G2035	97.0%	95.8%	G853	40.5%	62.4%	PB1642	76.0%	88.5%
G2147	48.9%	72.7%	G855	94.2%	93.3%	PB1661	92.9%	95.4%
G2395	35.8%	10.0%	G860	98.7%	98.6%	PB1662	87.7%	68.8%
G2739	81.1%	85.7%	G864	92.5%	90.7%	PB1680	87.9%	89.5%
G2852	54.6%	60.1%	G864A	94.0%	85.7%	PB1684	92.3%	96.3%
G2866	2.0%	0.0%	G968	94.6%	97.0%	PB445	95.3%	94.9%
G3074	66.8%	54.2%	G970	99.1%	97.6%	PB561	59.9%	63.7%
G3253	13.7%	47.2%	G973	98.9%	98.0%	PB565	51.4%	77.4%
G3259A	47.9%	72.4%	G975	98.1%	99.5%	PB683	77.5%	72.6%
G3264A	98.0%	99.7%	G976	81.2%	99.5%	PB685	95.2%	93.7%
G3272	98.8%	91.8%	HUMBLE	98.6%	97.4%	PB689	96.1%	89.1%
G3273	88.0%	85.1%	JD12	96.0%	95.8%	PB732	81.0%	92.1%
G3327	97.9%	96.9%	JD26	89.5%	68.8%	PB809	54.9%	26.7%
G3328	99.3%	97.9%	JD6	47.9%	17.9%	PB831	79.4%	89.8%
G3329	92.6%	96.1%	JDMW1	57.7%	52.2%	S18	98.4%	96.0%
G3353	97.8%	100.0%	JDMW3	54.9%	61.3%	S182	96.9%	98.1%
G3355	93.0%	94.3%	KROME	94.2%	86.5%	S19	74.7%	89.7%
G3356	93.0%	90.9%	L30L67A	99.8%	100.0%	S196A	97.5%	96.1%
G3437	85.0%	68.6%	L67A	99.6%	100.0%	S329	78.6%	82.1%
G3439	93.6%	90.4%	M1024	31.0%	100.0%	S68	51.7%	62.4%
G3465	84.3%	93.3%	M1234	69.4%	14.3%	SWEV5A	95.4%	100.0%
G3466	64.2%	100.0%	NESRS1	93.0%	99.8%	SYLVA	82.6%	82.1%
G3467	97.8%	100.0%	NESRS2	99.3%	100.0%	WCA363	88.1%	88.7%
G3473	96.6%	100.0%	NESRS4	93.3%	97.7%	WPBCA	93.1%	93.5%

Summary		
Total number of stations is	195	
	Calibration	Verification
Number of stations> 90%	127	136
Number of stations > 80%	154	161
Number of stations > 70%	168	170
Average % of Time Model Stage is within 1 ft of Field Data	86.6%	87.8%

Source: Lower East Coast Subregional MODFLOW Model Documentation, March 2006 (DRAFT), South Florida Water Management District, Table 13 (Calibration) and Table 16 (Verification).

SOURCES OF ERROR

There are seven primary sources of error resulting from inputs to the MODBRANCH model. These are (not necessarily in order of importance):

1- Approximation of overland flow with linear version of the Kadlec equation,
2- Meteorological boundary conditions,
3- General head boundary conditions,
4- Geologic parameters,
5- Structure operations and implementation,
6- Topography, and
7- Field data.

OVERLAND FLOW

As discussed above, the Kadlec equation requires the user define a number of flow coefficients. These include flow conductance (K_f), depth exponent (β), and slope exponent (α). The latter two values are set to 3 and 1, respectively, which follows the usage of the SFWMD. The flow conductance values are assigned based on land use and also uses the values determined by the SFWMD. In reality, these values could vary depending on vegetation type and season. However, a more accurate determination of these values is beyond the time and budget of this study.

METEOROLOGICAL CONDITIONS

The rainfall is an important parameter, especially in the region of south Florida. The amount and timing of rainfall greatly affects the increase or decrease in stage (ground water and canal) and flows within the system. The rainfall boundary conditions used for this study were the same that are used as inputs for the SFWMM 2x2, as mentioned above. The spatial resolution is 2 miles x 2 miles and the temporal resolution is 1 day. The MODBRANCH model could give better results if finer resolution rainfall information were available. This is especially important for simulating ground water stages. Unfortunately, these data are not presently available. Future studies could include rainfall derived from NEXRAD or other methods, which would give rainfall at fine resolutions in both temporal and spatial terms. However, these data would be limited to the time periods in which NEXRAD data were actually recorded; this would exclude the calibration period of 1989.

GENERAL HEAD BOUNDARY CONDITIONS

The general head boundaries, as mentioned above, were generated as a hybrid of ground water observation well data and daily average tide stages. Unfortunately there is not a complete set of observation wells or tide gages that would more accurately define the head boundaries. In addition, the head

boundary may vary with depth. The variation in depth occurs for two reasons. First, there are saline density effects at the coastal head boundaries. The approximation used in the present study is explained in Appendix A. The second depth variation is a result of some regions being in a confined or semi-confined condition at depth. In order to have these data set, stage gages would need to be co-located and screened at different depths. There are few gages of that description in this area.

GEOLOGIC PARAMETERS

South Florida's geology is extremely heterogeneous. Measurements and tests performed at one location can give distinctly different values when done a relatively short distance away. It is important to keep this in mind when reviewing the model results. The model considers the hydrogeologic parameters input to be homogenous within each grid cell. While hydraulic conductivity and transmissivity vary from cell to cell, each is isotropic within the cell. Additionally, the parameters do not vary significantly between adjacent cells, increasing the degree of homogeneity of the model. The real world is not homogenous. There are indications that there are preferential flow paths within the surficial aquifer. These preferential flow paths are not represented by the model inputs. For this reason, the model results should be considered primarily on an areal basis, secondarily on a site-specific basis.

STRUCTURE OPERATIONS AND IMPLEMENTATION

Future refinement of structure operation routines, especially in opening and closing could result in better replication of field stages and flows. However, there is still a problem in determining exactly how each structure was operated during the calibration and verification periods.

TOPOGRAPHY

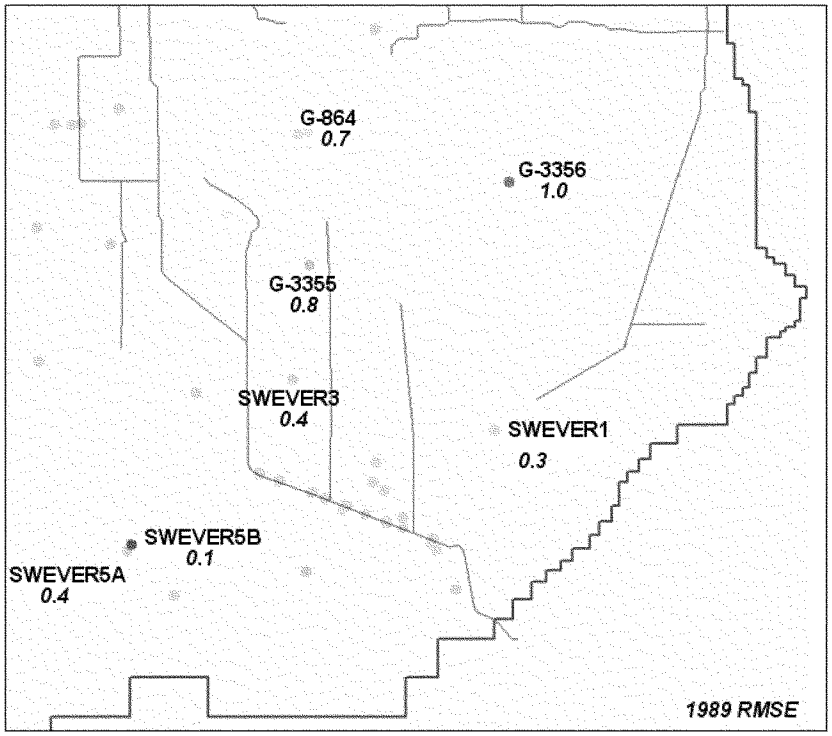
The topographic data used in the model were described above. The accuracy of these data (on the order of 0.5 feet) can significantly affect both the results of the MODBRANCH model and the interpretation of the results. The results can be affected by slight variations in elevations, since this would change the local land slope. A small change in topography could cause a significant change in flow direction due to the small water gradients found in the area. Comparison between model stages and observation well stages could have consistent errors based on the error in the observation well reference point. The average errors found between model and field data are approximately within the accuracy of the topography.

FIELD DATA

Field data are generally considered to be accurate. However, there is always some error and is occasionally significant. Figures 23 and 24 show the RMSE in

the C-111 Spreader Canal area of interest for the dry (1989) and wet (1995) years.

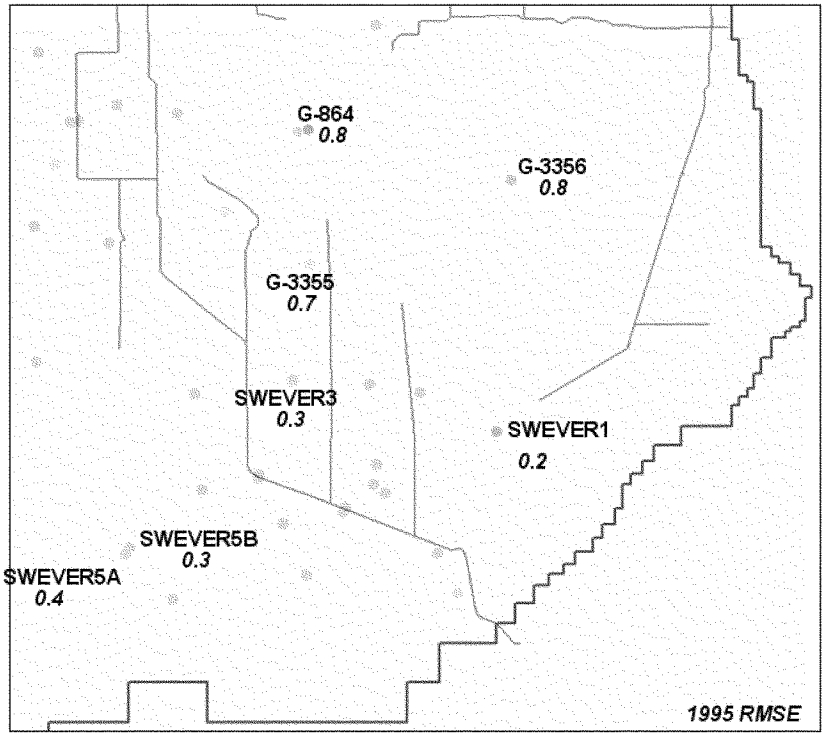
Figure 23. RMSE in vicinity of C-111SC Project, 1989 Simulation.



The 1989 RMSE for SWEVER5A is 0.4 foot; the value for SWEVER5B is 0.1 foot. This is surprising given the fact that they are nearly co-located and supports the position that field data can have significant error, in this case ~0.3 foot.

During both years, G-3356 has a RMSE of more than 0.8 foot and G-3355 has values greater than 0.7 foot. Other gages in the area range from 0.2 to less than 0.5 foot. The concern is whether or not the model is more inaccurate than the data show.

Figure 24. RMSE in vicinity of C-111SC Project, 1995 Simulation.

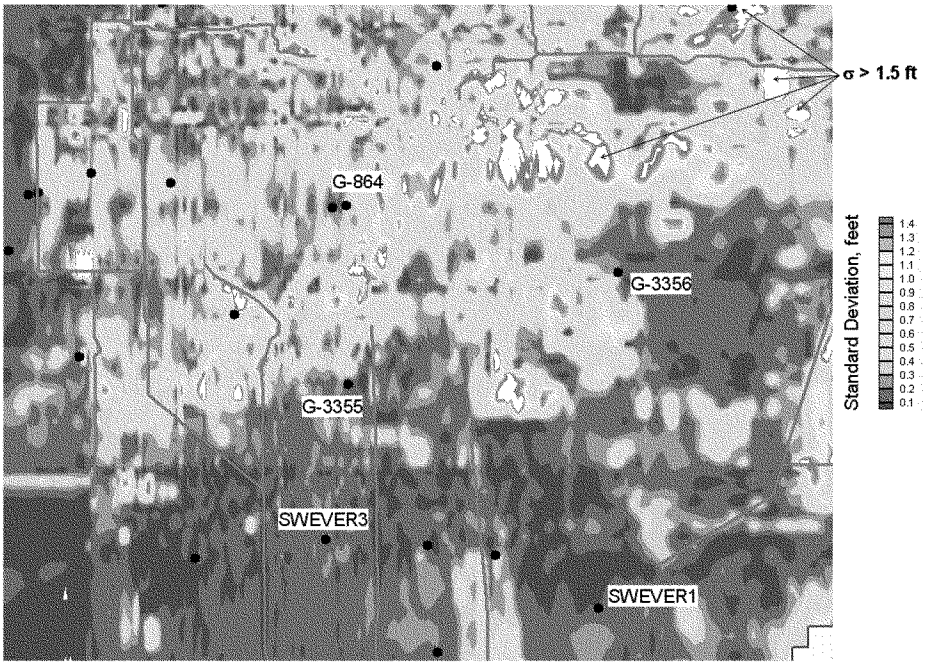


The variability in topography is described above and shown for the entire model domain in figure 8. Figure 25 shows the variability in the vicinity of the C-111SC project. Note that the gages showing the largest RMSE (G-864, G-3355, and G-3356) are in areas with large topographic variability.

Many of these stations are USGS gages and, in addition to water level data, have local ground elevations. Both the water level data and the ground elevations are referenced to a common datum. The local ground elevations reported for many of these gages is significantly different from the elevation used in the MODBRANCH model which is derived from LIDAR data. Table 15 lists twenty-six locations (figure 26) with both USGS reported ground elevations and the corresponding MODBRANCH ground elevations, both referenced to NGVD29. The average and median differences are -0.5 and -0.9 feet, respectively. These values indicate that the MODBRANCH topographic data is lower than the USGS data. This does not mean that the USGS reported ground elevation is erroneous. The MODBRANCH topographic data is an average of LIDAR data that has been processed to represent the entire MODBRANCH cell. The USGS data is a “spot-elevation” and represents only that specific location. However, the trend is clear that the USGS ground elevations tend to be higher

than the MODBRANCH elevations and that it is not beyond the realm of possibility that the field water levels are referenced to an erroneous datum.

Figure 25. MB_2006 Standard Deviation of Topographic Data within cells



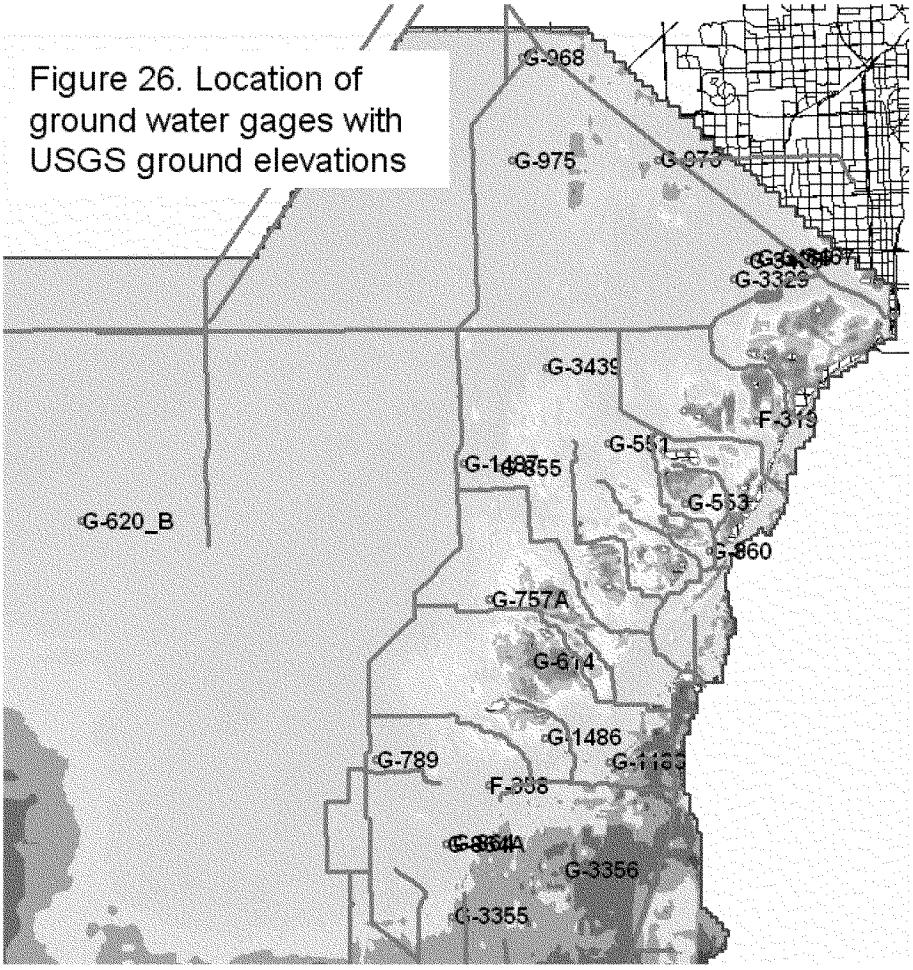


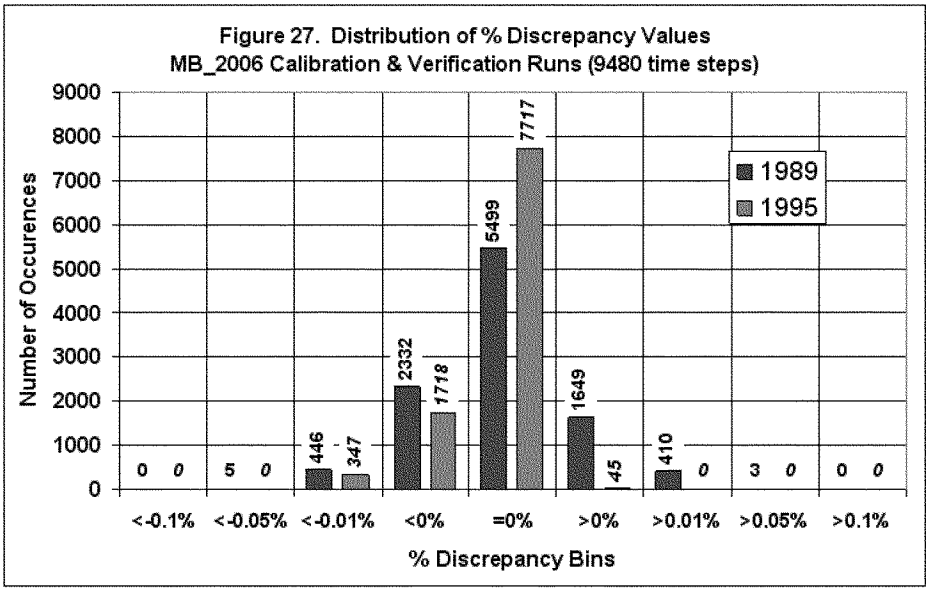
Figure 26. Location of ground water gages with USGS ground elevations

Table 15. Ground Elevation Differences, MB_2006 and USGS			
Observation Well	ground elevation, ft NGVD29		
	MODBRANCH	USGS	MODBRANCH - USGS
F-319	10.4	12.2	-1.8
F-358	7.2	8.3	-1.1
G-1183	4.2	6.2	-2.0
G-1486	9.4	10.4	-1.0
G-1487	7.7	6.8	0.9
G-3329	10.0	6.6	3.4
G-3355	**2.8**	**5.6**	**-2.8**
G-3356	**2.0**	**3.3**	**-1.3**
G-3439	6.5	5.9	0.6
G-3465	8.2	8.2	0.0
G-3466	8.3	8.3	0.0
G-3467	6.6	4.3	2.3
G-551	8.9	8.7	0.2
G-553	11.0	12.3	-1.3
G-613	7.5	7.1	0.4
G-614	12.4	11.1	1.3
G-620	5.3	6.8	-1.5
G-757A	9.1	9.9	-0.8
G-789	6.3	7.6	-1.3
G-855	7.5	7.9	-0.4
G-860	9.4	11.0	-1.6
G-864	**7.7**	**8.9**	**-1.2**
G-864a	8.0	8.3	-0.3
G-968	5.5	5.2	0.3
G-973	5.7	6.9	-1.2
G-975	5.1	7.4	-2.3
Average, feet			**-0.5**
Median, feet			**-0.9**
Standard Deviation, feet			**1.4**

VOLUME FLOWS AND MASS CONSERVATION

The MODBRANCH model prints the mass volume balance at each time step for the entire model domain. This global report is broken into input and output of canal leakage, recharge (rain), evapo-transpiration, well pumping, general head boundaries, and storage. The output totals the cumulative and instantaneous time step volumes and computes the mass balance (input – output). The

"percent discrepancy" (PD) is computed (100* (IN-OUT)/((IN+OUT)/2) and also printed for each time step. On a global basis the model should have very small PD values. Figure 27 shows the frequency of occurrence of PD for both the dry and wet years. It is obvious that, on a global basis, the MODBRANCH model has very little mass discrepancy or mass imbalance.



The mass balance for specified sub-regions is not an output of the MODBRANCH model. However, certain utilities can extract water movement from one area to the next. The types of volumes (recharge, evapotranspiration, horizontal flow, and storage) that can be extracted depend on the output controls implemented when the model is run. Due to disk space limitations, the model is generally run with the horizontal and vertical flows output. When this is done only a partial mass balance can be computed by delineating transects that enclose a specified area. This balance computes only the horizontal flow volumes and does not include the volume changes in storage, rainfall (recharge) or evapo-transpiration.

Figure 28 shows a sub-region of Taylor's Slough with arrows indicating the direction of positive flow. To get the flow volume balance, it is only necessary to compute the difference between the inflows and the outflows. In this case the inflow volumes are through the sections labeled "Taylor's Slough North Side" and "Taylor's Slough West Side." The other two sections are the outflow. Note that the west side was defined along Ingraham Highway. The Taylor's Slough region is an area of high interest and is why it was chosen as an example of flow volume balance.

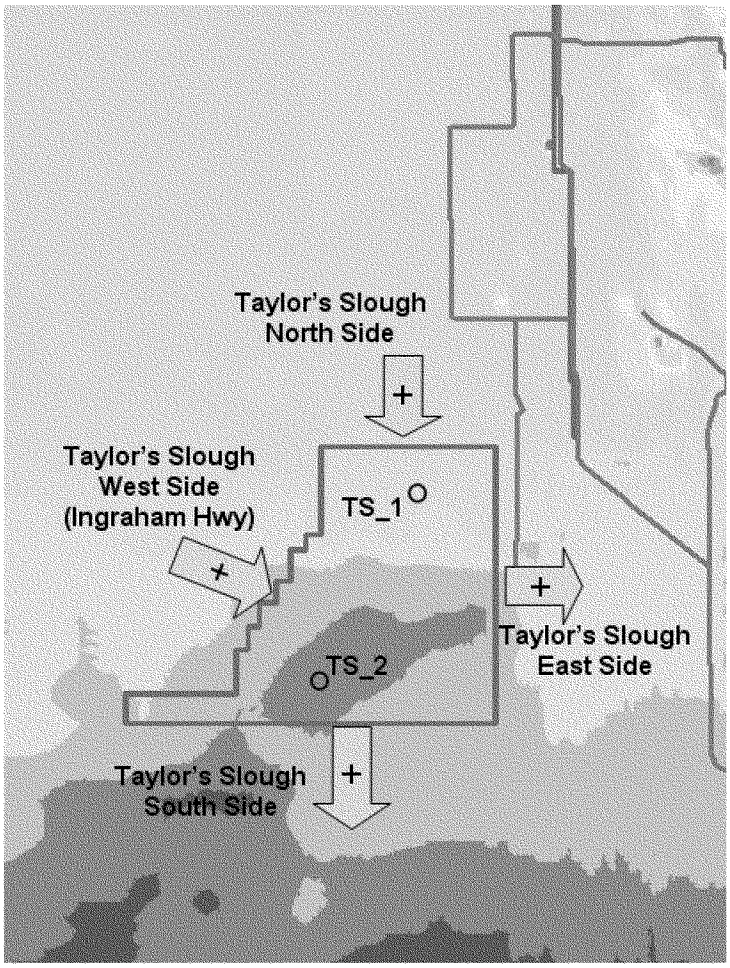


Figure 28. Taylor's Slough Sub-region.
Arrows indicate direction of positive flows.

The volume flows through the sections is shown on a monthly basis in table 16. An estimate of expected head change is computed by dividing the volumes (acre-feet) by the area enclosed by the sections (9,979 acres). These computations result in estimated head changes *due to horizontal flow differences* of +0.87 foot for 1989 and -0.47 foot for 1995.

Table 16. Mass Balance of Horizontal Flows, Taylor's Slough Subregion.

Area = 9,979 acres

Volumes in acre-feet

1989

Month	West Side	North Side	East Side	South Side	Net In - Net Out	Average Head Change (net Volume/area), feet
Jan	-251	626	-557	517	415	0.04
Feb	-223	513	-664	341	613	0.06
Mar	-391	691	-823	184	939	0.09
Apr	-363	471	-636	154	590	0.06
May	-402	644	-950	37	1,155	0.12
Jun	-353	657	-976	22	1,257	0.13
Jul	432	612	-752	512	1,284	0.13
Aug	535	687	-488	785	925	0.09
Sep	718	774	-391	951	932	0.09
Oct	487	735	-413	1,218	417	0.04
Nov	-26	665	-447	1,106	-20	0.00
Dec	-99	554	-667	906	216	0.02
Total	**64**	**7,629**	**-7,762**	**6,733**	**8,723**	**0.87**

1995

Month	West Side	North Side	East Side	South Side	Net In - Net Out	Average Head Change (net Volume/area), feet
Jan	899	934	272	1,652	-91	-0.01
Feb	777	616	367	1,310	-284	-0.03
Mar	906	348	483	1,364	-593	-0.06
Apr	442	250	557	1,144	-1,009	-0.10
May	281	279	65	810	-314	-0.03
Jun	616	497	-192	896	409	0.04
Jul	928	734	-666	1,408	920	0.09
Aug	959	744	-560	1,943	320	0.03
Sep	1,438	743	-1,083	3,377	-114	-0.01
Oct	1,868	1,035	-1,482	6,016	-1,631	-0.16
Nov	2,026	1,135	-1,033	5,466	-1,272	-0.13
Dec	1,506	831	-97	3,451	-1,017	-0.10
Total	**12,646**	**8,146**	**-3,369**	**28,835**	**-4,675**	**-0.47**

If the only water moving into and out of the area were the horizontal flows, the differences would be closer to the values shown in table 16: +0.87 and -0.47 ft for the dry and wet years. However, there are other volumes that are not represented in these tables: rainfall, evapo-transpiration and change in storage. These volumes are obviously significant.

Table 17 gives monthly totals of rainfall, evapo-transpiration (ET) and storage for the Taylor's Slough sub-region. These values are obtained through the use of the USGS utility program ZONEBUDGET.

Figure 17. Volume of Water moving in and out of Taylor's Slough Subregion

Area = 9979 acres

Volumes are in acre-feet

1989

Month	Rainfall	Evapo-Transpiration	Storage IN	Storage OUT	Net In - Net Out	Average Head Change, (Net In - Net Out) / Area, feet
Jan	715	2,542	2,000	584	-411	-0.04
Feb	8	2,252	1,629	0	-615	-0.06
Mar	209	1,893	877	131	-938	-0.09
Apr	2,512	2,845	1,632	1,887	-589	-0.06
May	1,943	2,821	1,236	1,533	-1,174	-0.12
Jun	2,931	2,633	918	2,471	-1,253	-0.13
Jul	7,595	4,733	2,523	6,620	-1,236	-0.12
Aug	7,074	4,485	2,573	6,076	-914	-0.09
Sep	4,271	4,022	2,079	3,292	-964	-0.10
Oct	1,446	3,609	2,728	1,002	-436	-0.04
Nov	350	2,889	2,674	122	13	0.00
Dec	982	2,827	2,367	735	-213	-0.02
Total	**30,037**	**37,552**	**23,237**	**24,452**	**-8,730**	**-0.87**

1995

Month	Rainfall	Evapo-Transpiration	Storage IN	Storage OUT	Net In - Net Out	Average Head Change, (Net In - Net Out) / Area, feet
Jan	2,133	3,287	2,674	1,421	99	0.01
Feb	859	3,303	3,287	517	327	0.03
Mar	1,618	4,305	4,259	954	618	0.06
Apr	2,261	4,642	4,767	1,363	1,023	0.10
May	5,220	5,101	3,978	3,748	350	0.04
Jun	12,492	4,732	2,605	10,798	-434	-0.04
Jul	5,202	4,935	2,339	3,539	-933	-0.09
Aug	9,250	4,556	1,847	6,904	-364	-0.04
Sep	7,401	3,892	1,568	5,042	35	0.00
Oct	9,237	3,229	2,674	6,961	1,722	0.17
Nov	780	3,060	3,745	311	1,154	0.12
Dec	522	3,009	3,446	82	877	0.09
Total	**56,976**	**48,051**	**37,189**	**41,640**	**4,475**	**0.45**

Note that the volume shown in table 17 complements the volumes in table 16 and that the average head change balances. The output from ZONEBUDGET includes the percent discrepancy for the subregion for each stress period (1 day). The percent discrepancy is 0.00% which indicates that the model is conserving mass, not only globally but also locally.

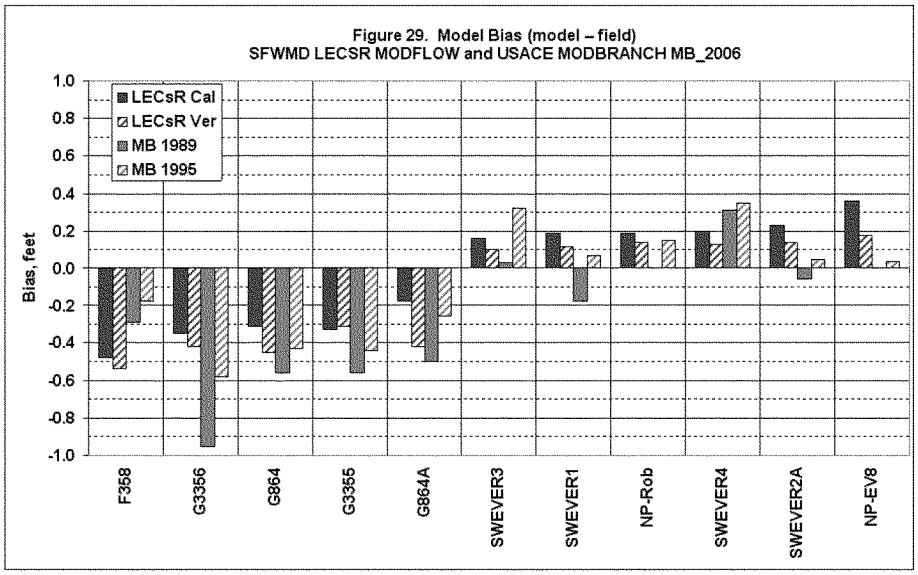
MODEL APPLICABILITY

The most reliable use of numerical models is in relative comparisons between two or more simulations. The use of any model in absolute terms is fraught with issues regarding the accuracy of the models. In the discussion above, three distinct models (MB_2006, SFWMM2x2 v5.4, and SFWMD LECsR) all have similar calibration and verification statistics, in spite of having different grid sizes, boundary conditions, and simulation periods. If the RMSE can be used as a reliable estimate of the accuracy a model, it appears that the best accuracy within the model domain that one could hope for with stage is about 0.5 ft.

The MB_2006 model was developed to be used for two projects: the C-111 Spreader Canal (C-111SC) and the ENP Seepage Management (ENPSM) projects.

The C-111SC project area (figure 21) has a number of gages in its periphery but only few in the interior. Possible errors at these gages have been discussed above. Unfortunately, without other gages nearby, the potential errors can not be isolated and corrected. The facts that (a) the SFWMD LECsR model shows the same trends (figure 29) as the MODBRANCH MB_2006 and (b) the topographic data shows large discrepancies, indicates that the field data may have errors that can't be replicated by the model.

The results in the vicinity of the ENPSM project (figure 21) show good agreement between the model and the field data sets (see figures 19-22 and supporting tables). In addition to good agreement for the dry and wet years, the model source code has been modified to have time-varying horizontal flow barriers. This will be useful when simulating the ENPSM barrier plans, which are supposed to test seasonal operations.



CONCLUSIONS

The MODBRANCH MB_2006 has been tested using dry (1989) and wet (1995) years. The results indicate that the model is adequate for testing scenarios within the model domain. The accuracy of the model, as is the case for any model, depends primarily on the accuracy of the inputs. The MB_2006 model is shown to be as accurate as both the SFWMD LECsR model and the SFWMM2x2 v5.4 model.

The primary drawback is that the model requires long computation times in order to simulate a 13-month period while both of the SFWMD models run many years is just a few hours. Obviously the MB_2006 model is not to be used for long-term simulations.

The strengths of the MB_2006 model are:

- Structure operation rules are very flexible,
- the canals are located more precisely than either the SFWMM2x2 or the LECsR models due to finer grid resolution,
- operational "triggers" are located with more precision than the SFWMM2x2,
- features (such as detention areas) which are below the scale of the SFWMM2x2 can be adequately simulated,
- near field effects of canal/structure operations can be more accurately simulated than with the SFWMM2x2, and
- canal stages and flows are a function of operational rules and local ground water stages.

The results of the model, at the level of accuracy produced, can be used with confidence in determining the relative differences between different alternatives. However, the users of the model should be careful when comparing absolute values. Model results are an indication of what may happen under certain conditions, but not necessarily what will happen.

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C.3.1 Attachment 1A: Appendix A; Fresh Water Equivalent Heads of Saline Water General Head Boundaries (GHB) for MODFLOW/MODBRANCH

Appendix A

Fresh Water Equivalent Heads of Saline Water General Head Boundaries (GHB) for MODFLOW/MODBRANCH

The General Head Boundary (GHB) package of MODFLOW/MODBRANCH requires that the *Head* at the center of each boundary cell be specified. This head value is usually expressed as a distance above some common reference point. This is straightforward when using fresh water, but is not when the water is saline and the model is not density driven.

Using ρ_s = density of salt water and ρ_f = density of fresh water, an equation expressing the **mass** balance between a column of saline water and an equivalent column of fresh water is derived as follows:

Mass of saline column = $\rho_s A (Z_s-Z)$
Mass of fresh column = $\rho_f A (Z_f-Z)$

where

Z_s = elevation of the saline water surface (known),
Z_f = elevation of the fresh water surface (unknown),
Z = common reference point (known),
A = area of the base of each column (will cancel).

Since the masses of the column should be equal, we get the following:

$$\rho_s A (Z_s-Z) = \rho_f A (Z_f-Z), \text{ or}$$

$$\rho_s (Z_s-Z) = \rho_f (Z_f-Z).$$

Using a value of fresh water density (ρ) of 1.0 g/cc and for ocean water, a density (ρ_s) of approximately 1.025 g/cc, the equivalent fresh water head Z_f is:

$$Z_f = 1.025 (Z_s-Z) + Z.$$

If we do not take into account salinity, then the head throughout the water column (i.e., for each layer) is constant because the $(\rho_s/\rho_f) = 1$. However, since the density of the ocean water is not equal to the fresh water, the *head* is not constant with depth and must be adjusted.

Example:

Assume we have a 3 layer model. At one specific location (x,y), the elevations of the cell centers are 0., -20., -50 feet. The ocean water elevation is 1.2 feet. If this were fresh water, then the head would be 1.2 (=Z_s) feet at each cell. However, for ocean water ($\rho_s = 1.025$) there will be a different value of head at each depth.

Layer 1: Z_s-Z = 1.2 – 0.0 = 1.2
Z_f = (1.025)(1.2) + 0.0 = **1.23** feet (2.5% increase)

Layer 2: Z_s-Z = 1.2 – (-20) = 21.2
Z_f = (1.025)(21.2) + (-20) = **1.73** feet (44% increase)

Layer 3: Z_s-Z = 1.2 – (-50) = 51.2
Z_f = (1.025)(51.2) + (-50) = **2.48** feet (107% increase)

For this simple example, the difference in general head boundary specification between the top and bottom layers is over 100%. A problem remains in that, if we specify these general head boundary (ghb) values, the groundwater model will attempt to move water vertically upward instead of horizontally. In order to avoid this, the vertical leakage in the boundary cells is set close to 0.

C.3.2 Attachment 1B: Appendix B; Overland Flow Simulation in MODBRANCH: Implementation of the Kadlec Equation

Appendix B

Overland Flow Simulation in MODBRANCH: Implementation of the Kadlec Equation

The applicability of MODBRANCH to problems with a significant amount of overland flow has been debated since the model was first applied to areas in south Florida. In normal surface water models, the flow is computed using empirical equations that rely on the use of a roughness factor, such as Manning's n or the Chezy coefficient. Unfortunately, these options were not available for the MODBRANCH model.

In previous studies[1,2] the overland flow in MODBRANCH was simulated by assigning extremely high hydraulic conductivity (K) values to the uppermost layer. Initially, these values were assigned based on an earlier study by Swain, et al[3]. Using an equation that states the relationship between equivalent Manning's n and Darcy's K, Swain obtained values of 3,000,000 and 100,000,000 feet per day for K in order to simulate overland flow. The values used for the Pennsuco-Dade-Monroe (P-D-M) model are discussed in Appendix B of "Calibration and Verification of the MODBRANCH Numerical Model of the Pennsuco-Dade-Monroe (P-D-M) Area of South Florida."[2]

The MODBRANCH model used in the current study implements a version of Kadlec's "Rate Law"[4] to compute overland flow. Kadlec's Rate Law has the form

$$v = K_f * d^{\beta} * S_f^{\alpha} \quad \text{(eq. B-1)}$$

where

v is velocity,
K_f is the flow conductance,
D is the depth,
β is the depth exponent,
S_f is the friction slope, and
α is the slope exponent.

The MODBRANCH model uses the empirical Darcy equation to compute flow in the three-dimensional grid cells. The Darcy equation is

$$u = -K \frac{dh}{dl}$$

or

$$u = -KS \quad \text{(eq. B-2)}$$

where

u = Darcian velocity, in feet per second,
h = hydraulic head, in feet,
l = length over which the head change occurs,
S = hydraulic slope, in feet/feet, and
K = Hydraulic conductivity, in feet per second.

Obviously, the trick in implementing the Kadlec Rate Law (or "Kadlec Equation") is to get equation B-1 in the form of B-2.

The South Florida Water Management District (SFWMD) has implemented the Kadlec Equation in its wetland package (a function of the MODFLOW model). According to its documentation[5] the friction slope exponent (α) is set to 1. This reduces equation B-1 to

$$v = K_f * d^{\beta} * S_f \quad \text{(eq. B-3).}$$

By defining $K_{eff} = K_f * d^{\beta}$, the equations becomes

$$v = K_{eff} * S_f \quad \text{(eq. B-4).}$$

Equation B-4 is in the exact form as Darcy's equation (B-2) with a time varying "effective" hydraulic flow coefficient instead of a constant. By modifying the MODBRANCH code such that the "K" value varies based on depth, $K_{eff} = K_f * d^{\beta}$, we can implement the Kadlec equation. The value of K_{eff} will vary for each time step based on the input value of K_f (Kadlec coefficient) the depth (d) and the exponent (β).

According to Kadlec (1990), the values of β are a function of vegetation type and water depth and ranges between 2.0 and 4.0. In its implementation of the Kadlec equation to the Lower East Coast sub-Regional (LECsR) MODFLOW model, the SFWMD uses a value of $\beta = 3$.

Table B-1 shows suggested Kadlec coefficients and the associated land use. Figure B-1 shows the MB_2006 grid with the value of the Kadlec coefficients used based on 2000 landuse. When using a value of $\beta = 3$, the units for the coefficient are $1/ft^2$-day.

Appendix B

Table B-1. Landuse and Suggested Kadlec Coefficients.			
source: http://www.sfwmd.gov/org/pld/hsm/modflow/wtl_input_kdl.htm			
Description	**Kadlec Coefficient**	**Description**	**Kadlec Coefficient**
Lakes	2,000,000	Borrow Land	400,000
Reservoirs	2,000,000	Rock Quarries	992,000
Streams and Waterways	2,000,000	Freshwater Marshes	992,000
Embayment Opening	2,000,000	Freshwater Marshes - Sawgrass	992,000
Bay Swamps	2,000,000	Melaleuca	992,000
Mangrove Swamps	2,000,000	Row Crops	992,000
Channels	2,000,000	Wet Prairies with Pines	710,000
Wet Prairies	1,760,000	Spoil Areas	992,000
Tidal Flats	1,760,000	Roads and Highways	992,000
Mixed Wetland Hardwoods	1,760,000	Improved Pastures	992,000
Mixed Wetland Hardwoods - Willows	1,760,000	Wetland Forested Mixed	1,259,000
Mixed Wetland Hardwoods - Mixed Shrubs	1,760,000	Cypress with Wet Prairies	1,514,000
Cypress	1,510,000	Light Industrial	710,000

Appendix B

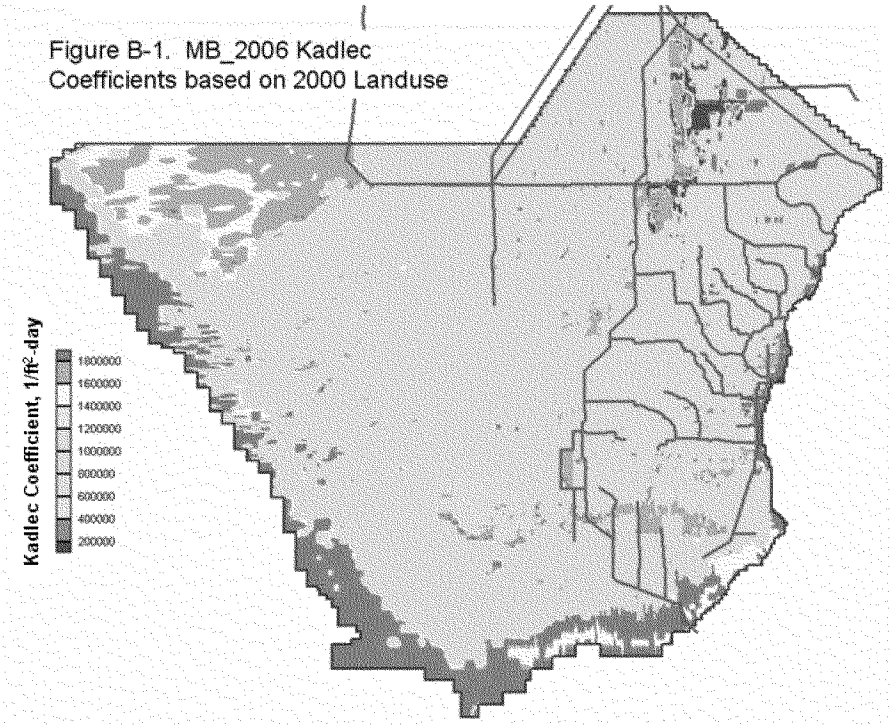
Figure B-1. MB_2006 Kadlec
Coefficients based on 2000 Landuse
Kadlec Coefficient, 1/ft²-day
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000

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C.3.3 Attachment 1C: Appendix C; Estimation of the Canal Leakance Value for MODBRANCH

Appendix C

Estimation of the Canal Leakance Value for MODBRANCH

The movement of water between canal "branches" and aquifer "cells" in the MODBRANCH model is a function of the difference in the canal and ground water stages, the canal geometry and the associated canal "leakance" value. Extremely high leakance values allow too much flow between the aquifer and canal; extremely low leakance values do not allow sufficient flow. The use of an appropriate value of leakance is important in the calibration and verification of the MODBRANCH model.

The leakance is defined as the hydraulic conductivity of the sediment layer lining the canal divided by the thickness of that sediment layer.

$$l_c = K_s / d_s \qquad \text{(eq. C-1)}$$

where

K_s = Hydraulic Conductivity of the sediment layer lining the canal (units of length/time)
and
d_s = the thickness of the sediment layer (units of length).

The value of leakance, l_c, has units of 1/time.

At any given location in a channel the hydraulic conductivity and/or the sediment thickness can be different from any other location in the same channel. In addition, the values may well change at the same spot over time. This is because the sediment layer can be scoured or deposited based on storm events, the sediment can compact over time, if left undisturbed and the material that makes up the sediment can vary with time.

The MODBRANCH model does not allow a time varying value of l_c. It does allow spatially varying values, if they can be determined. However, the data required to specify exactly the leakance at each point of the canal branches is not available. The available data is sufficient to get approximate values.

The method used in determining the approximate values of l_c over specific reaches of the south Florida canal system is described in this appendix. The values found are useful as guides and as an indication of where future studies on leakance should be performed.

The value of leakance can be written, along with equation C-1, as

$$l_c = Q_l / (L_r \times \Delta z \times P_w) \quad \text{(eq. C-2)}$$

where

Q_l = the leakage rate (length^3/time) into or out of the canal,
L_r = the length of the channel reach,
Δz = the head difference between the canal and ground water (length), and
P_w = the wetted perimeter (length).

The only value that is not directly measurable in the field is the leakage rate, Q_l.

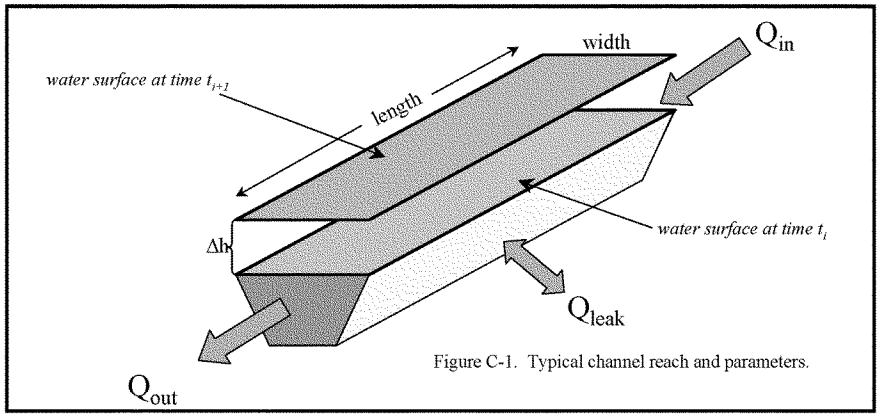


Figure C-1. Typical channel reach and parameters.

However, Q_l can be estimated from field measurements. Figure C-1 shows a typical channel reach and illustrates some of the variables needed to estimate leakance. If the inflow, outflow and channel stages are known, then the leakage rate, Q_l, can be estimated:

$$Q_l = Q_{store} + Q_{out} - Q_{in} \quad \text{(eq. C-3)}$$

where,

$$Q_{store} = \Delta h \times A_{surf} / (t_{i+1} - t_i) = storage$$
$$A_{surf} = length \times width = Surface\ Area$$
$$\Delta h = change\ in\ canal\ stage\ \ from\ t_i\ to\ t_{i+1}.$$

The data necessary to estimate leakance is available in a number of the canal reaches found within the model domain. Using field data an analysis of ten reaches of the SDCS was performed to determine the range and magnitude of leakance values.

Using the daily stages (canal and nearest ground water gage) and flows, the value of leakance was computed. In many cases, the value was nonsensical (it was < 0). This occurred when either the ground water stage exceeded the canal stage at the same time the computed leakage rate was out of the canal, or the reverse situation. In these cases, the value of leakance was not used in the analysis. Table C-1 shows the final results of the analysis.

Table C-1. Computed Leakances for Canal Reaches.

Canal Reach	Leakance, 1/seconds				Number of points	Period of Record	
	Average	Median	Mode	Std. Dev.		Start	Stop
L31N S335 to G211	4.41E-04	2.34E-04	1.95E-04	1.15E-03	1210	10/8/1991	12/30/1996
L31N G211 to S331	5.22E-04	7.23E-05	5.93E-05	1.97E-03	1240	10/8/1991	6/9/1997
L31N S331 to S176	1.06E-04	5.69E-05	2.69E-05	3.75E-04	369	1/1/1995	9/29/1996
C111 S176 to S177	2.20E-04	6.79E-05	7.40E-06	7.37E-04	704	12/28/1988	5/2/1995
L31W S174 to S175	2.85E-04	1.87E-04	1.41E-04	8.26E-04	1700	1/1/1989	10/27/1996
C1 S338 to S148	5.72E-05	4.78E-05	7.00E-07	7.05E-05	447	1/1/1995	12/30/1996
C102 S194 to S165	3.05E-05	7.00E-07	6.00E-07	5.91E-05	258	8/9/1995	11/2/1997
C103 S196 to S167	1.79E-04	1.31E-04	4.40E-06	4.18E-04	139	1/1/1996	9/29/1996
L-29 S333 to S334	1.40E-04	1.10E-04	2.10E-06	2.06E-04	3436	12/2/1984	10/30/1997
L-30 S32a to S335	6.42E-05	2.60E-06	4.50E-06	4.49E-04	1707	9/2/1985	10/28/1997
Minimum	3.05E-05	7.00E-07	6.00E-07				
Maximum	5.22E-04	2.34E-04	1.95E-04				
Range	4.92E-04	2.33E-04	1.95E-04				

Table C-2 lists the various data sources and other parameters used in the computation of leakance. Note that the distances from the canal to the ground water stage gage is generally greater than 1,000 feet. These large distances are not considered optimum for this analysis. Gages immediately adjacent to the canal would be preferred.

Figure C-1 shows the average, median, and mode values of the leakance for each reach, sorted in order of lowest (left) to highest (right) median value. Figure C-2 shows the distribution of the median values within the model domain and the associated surface sediment types.

Table C-2. Data sources for Leakance Analysis

Reach	Reach Length, feet	Inflow Structures	Outflow Structures	Canal Stages (tw=tail water, hw=head water)	Ground Water Stages	Minimum distance from GW well to canal, feet
L31N S335 to G211	37,500	S335 and S334	G211 and S338	average of S335tw, S334tw, S338hw, & G211hw	G1487	500
L31N G211 to S331	19,800	G211	S331 and S173	average of G211tw and S331hw	G596	5,000
L31N S331 to S176	53,900	S331 and S173	S194, S196, S174/S332D, and S176	average of S331tw and S174hw	average of Humble and G3437	Humble = 2,000, G3437 = 5,900
C111 S176 to S177	32,000	S176	S177	average of S176tw and S177 hw	HA11	1,400
L31W S174 to S175	37,700	S174 (S332D)	S332 and S175	average of S174tw, S332hw, and S175hw	average of NTS1 and L31W	NTS1 = 160 L31W < 100
C1 S338 to S148	59,560	S338	S148	average of S338tw and S148hw	G1362	7,000
C102 S194 to S165	38,460	S194	S165	average of S194tw and S165hw	G757a	1,640
C103 S196 to S167	21,360	S196	S167	average of S196tw and S167hw	S196a	2,500
L29 S333 to S334	57,900	S333	S334	average of S333tw and S334hw	G618	<100
L30 S337 to S335	65,200	S337	S335	S335hw	average of G968 and G1488	both < 100

The analysis shown in this appendix illustrates the range of values that can be found for leakance. Unfortunately, the values only indicate the approximate range. The data is neither sufficiently accurate nor collected under controlled conditions. Figures C-3 through C-7 show the variations in leakance over time. These figures further illustrate the need for controlled measurements.

Genereux (1998) performed a controlled study to determine various aquifer parameters using canal drawdown along L-31W. The value reported for leakance was 35.2/day or 0.00041/second. This value is about half of the median value computed for that reach (0.00019/second) using historical field data, but is well within the range of computed values.

The values used in the MODBRANCH P-D-M model were either 0.00024 or 0.00048. The lower value was used along the C-4, L-30, and C-6 canals. All other canals used the higher value.

The model is fairly insensitive to the exact value of leakance. This is primarily due to the effect of grid size on the leakage. The leakage coefficients are extremely sensitive to the head gradient between the canal and the ground water cell. Grid cells that are much larger than the canal size will minimize the effect of varying leakance values. The ideal situation would be one where the canal width is the same as the cell size; this is numerically unrealistic. The values used for the present application are reasonable and sufficiently accurate.

Appendix C

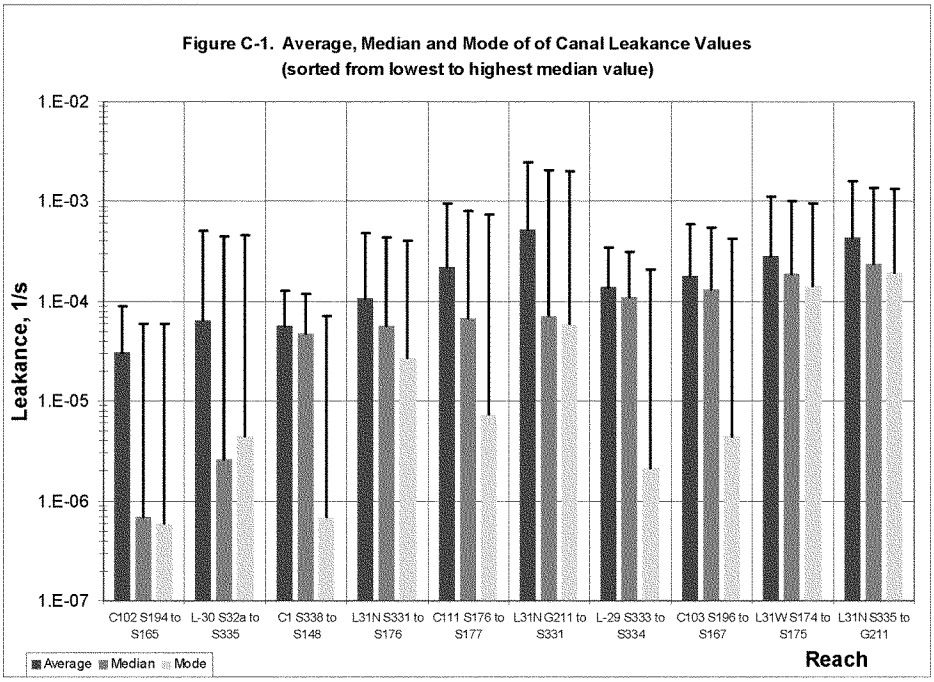


Figure C-1. Average, Median and Mode of of Canal Leakance Values
(sorted from lowest to highest median value)
Leakance, 1/s
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
C102 S194 to S165
L-30 S32a to S335
C1 S338 to S148
L31N S331 to S176
C111 S176 to S177
L31N G211 to S331
L-29 S333 to S334
C103 S196 to S167
L31W S174 to S175
L31N S335 to G211
Average
Median
Mode
Reach

Appendix C

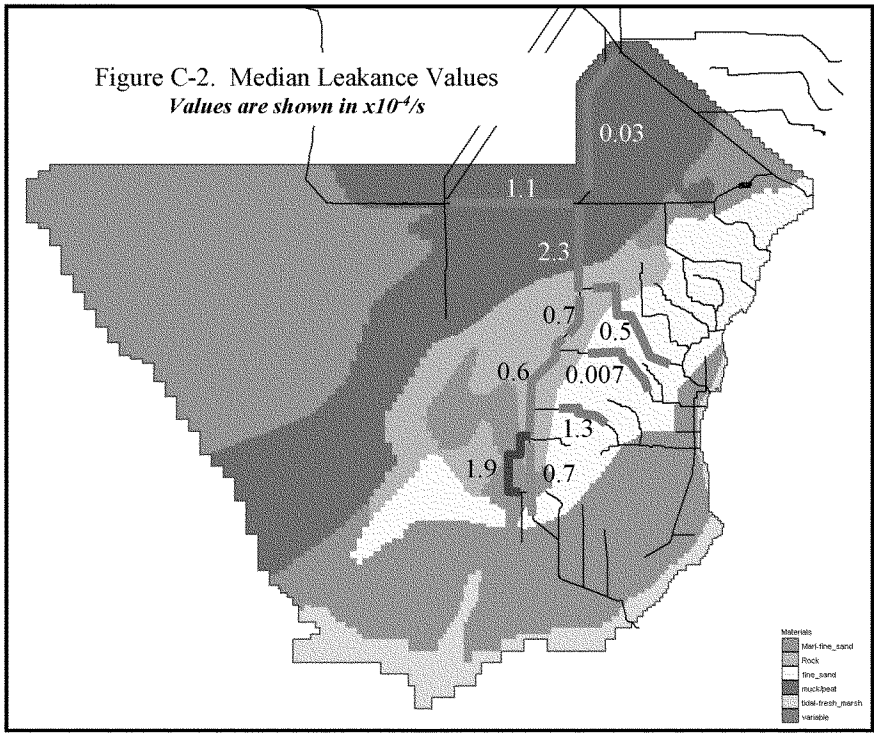
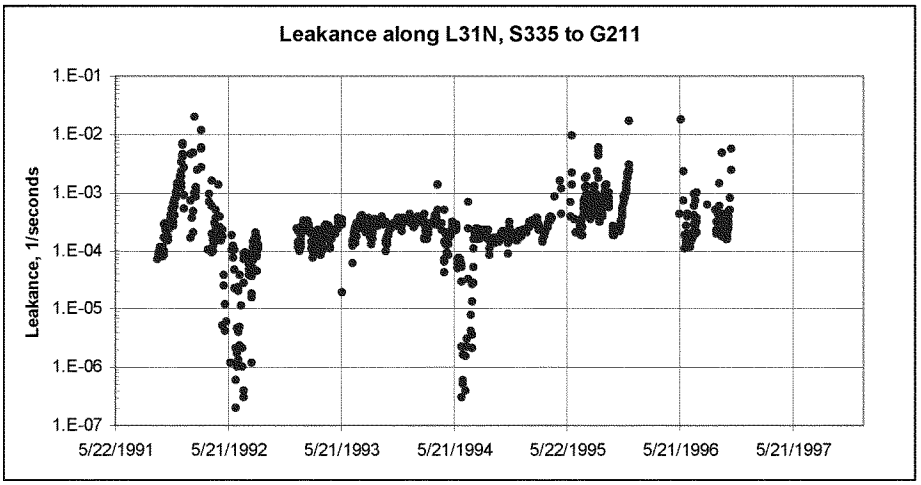


Figure C-2. Median Leakance Values
Values are shown in x10-4/s
0.03
1.1
2.3
0.7
0.5
0.6
0.007
1.3
1.9
0.7
Materials
Marl-fine_sand
Rock
fine_sand
muck/peat
tidal-fresh_marsh
variable

Appendix C



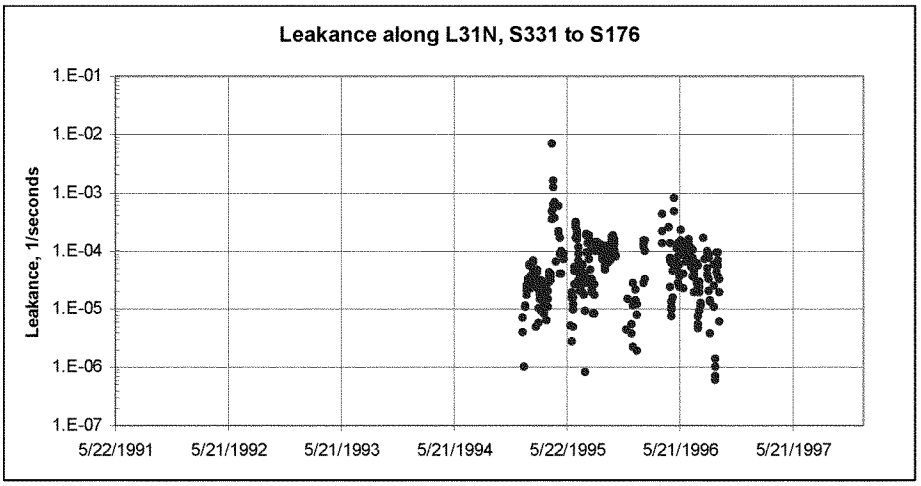
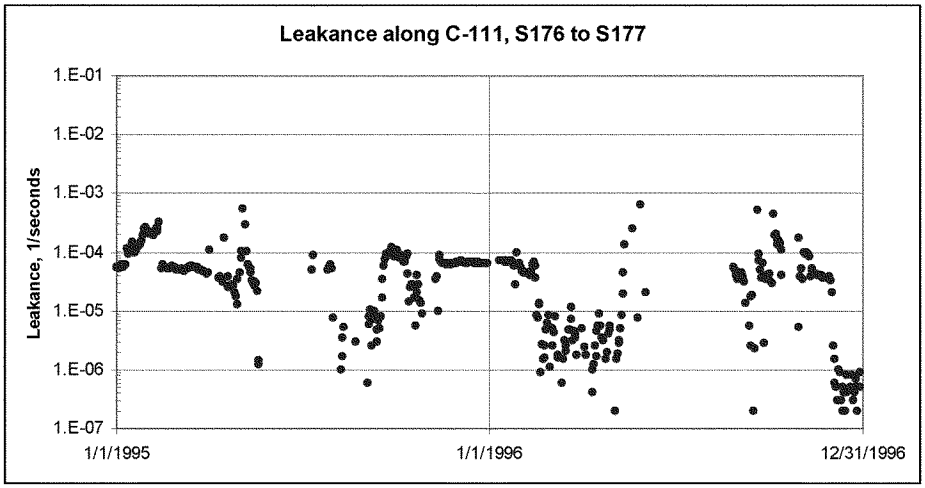


Figure C-3. Computed Leakance over time, L31N (S335 to G211) and L31N (S331 to S176).

Appendix C



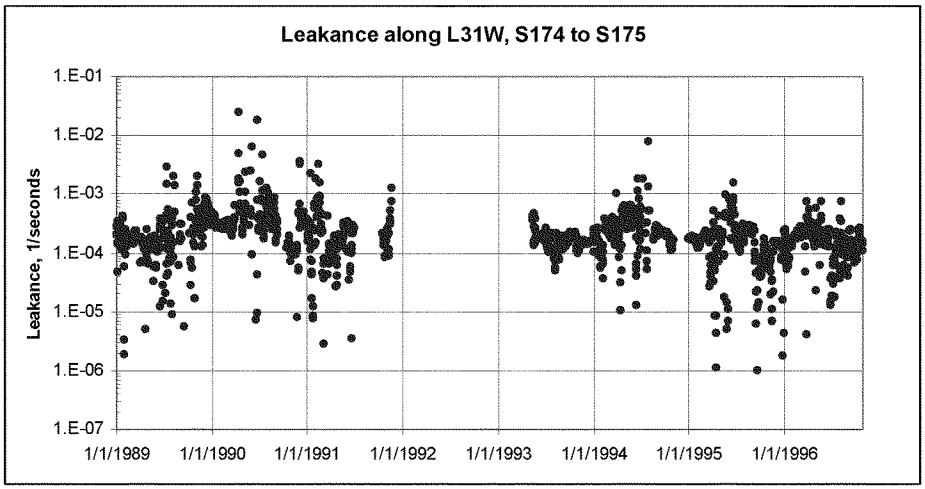
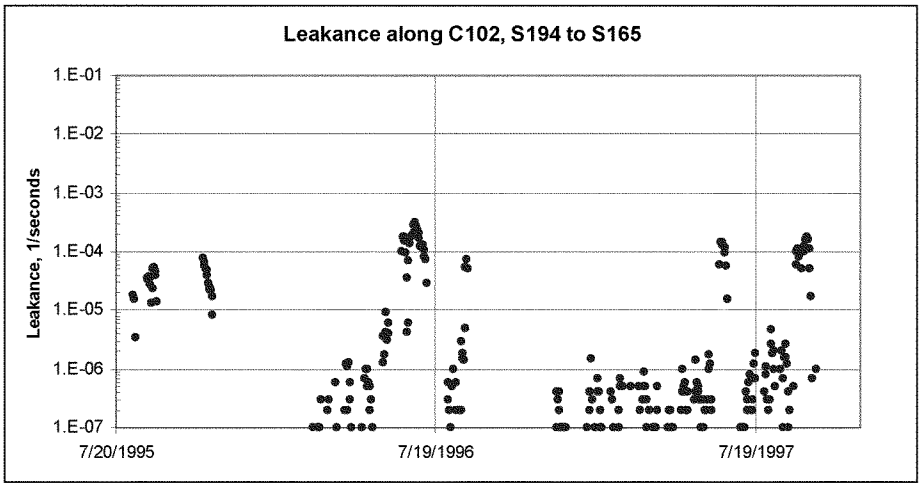


Figure C-4. Computed Leakance over time, C-111 (S176 to S177) and L31W (S174 to S175).

Appendix C



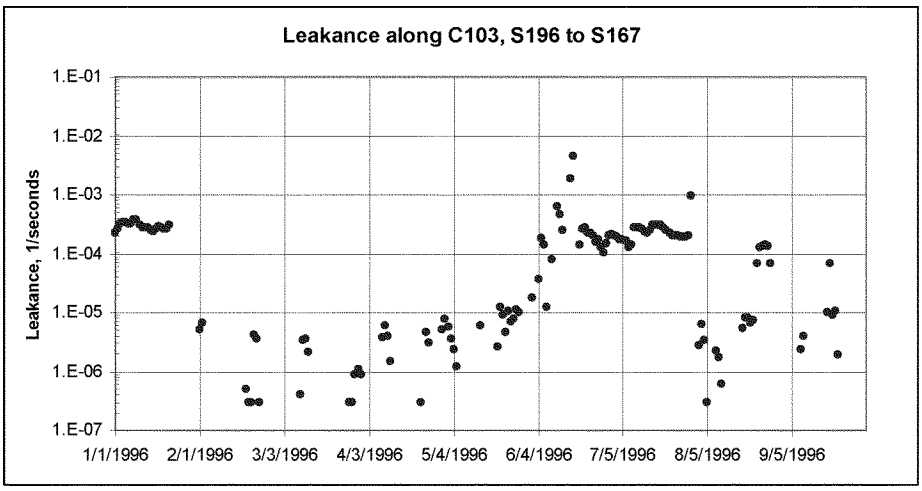
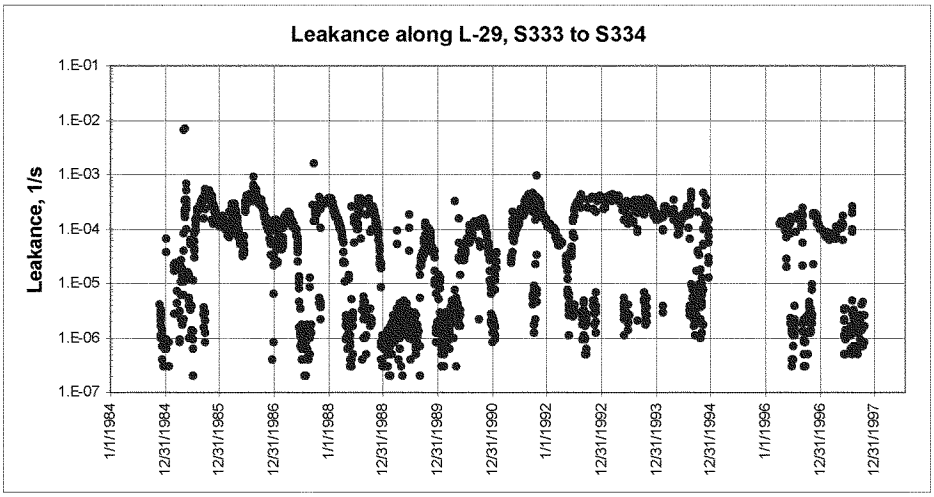


Figure C-5. Computed Leakance over time, C-102 (S194 to S165) and C-103 (S196 to S167).

Appendix C



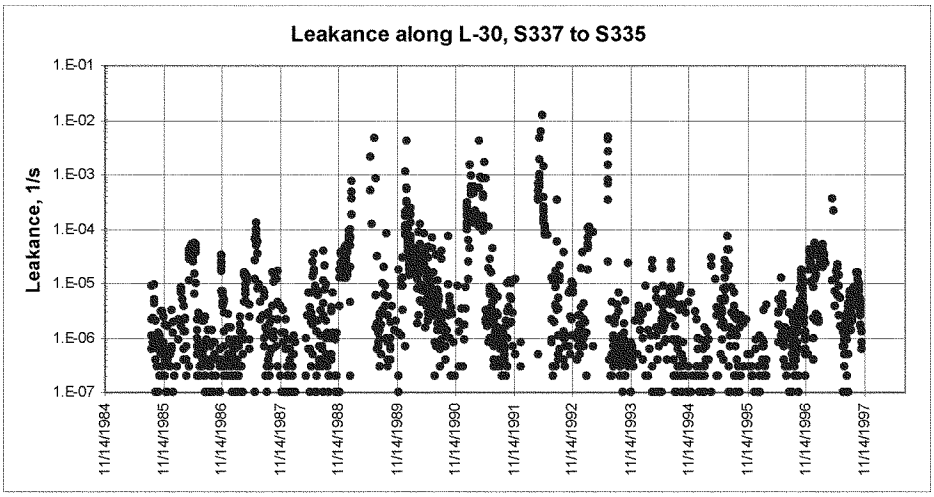
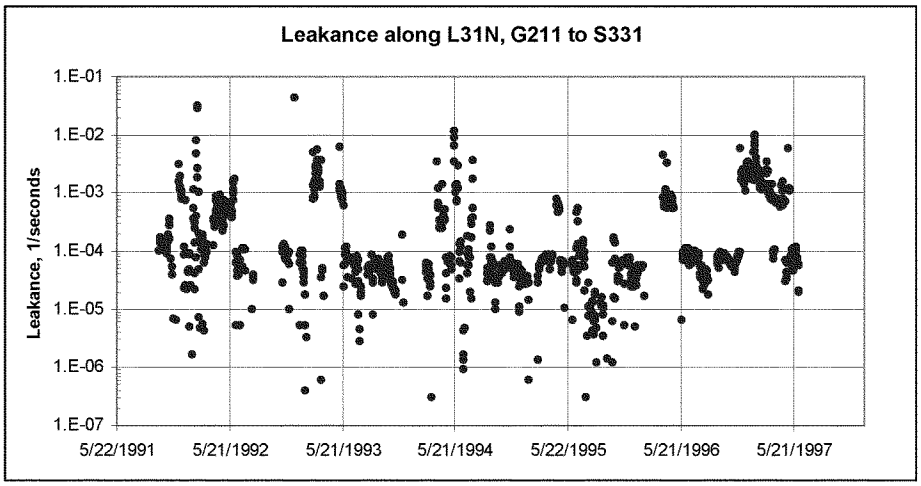


Figure C-6. Computed Leakance over time, L-29 (S333 to S334) and L-30 (S337 to S335).



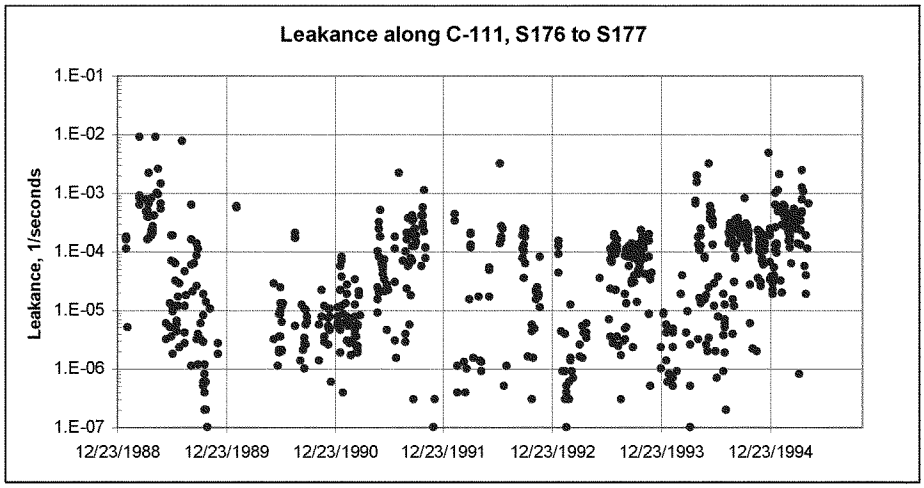


Figure C-7. Computed Leakance over time, L-31N (G211 to S331) and C-111 (S176 to S177).

References

Genereux, D., et al, "A Canal Drawdown Experiment for Determination of Aquifer Parameters," Journal of Hydrologic Engineering, Vol 3, No. 4, October 1998.

Swain, E.D., Howie, B., and Dixon, J., 1995, "Description and Field Analysis of a Coupled Ground-Water/Surface-Water Flow Model (MODFLOW/BRANCH) with Modifications for Structures and Wetlands in Southern Dade County, Florida," USGS Water-Resources Investigations Report 96-4118.

C.3.4 Attachment 1D: Appendix D; MODBRANCH MB_2006 Ground Water Stage Results Dry (1989) and Wet (1995) Years

Appendix D

MODBRANCH MB_2006 Ground Water Stage Results
Dry (1989) and Wet (1995) Years

The MODBRANCH MB_2006 model was calibrated and verified using 1989 and 1995 field data. The stations are listed in Table D-1 and shown in figures D-1A through D-1G. Most locations are found in both years but a number are found only in one or the other year. The 1989 locations are represented by black dots; the 1995 locations are represented by orange circles.

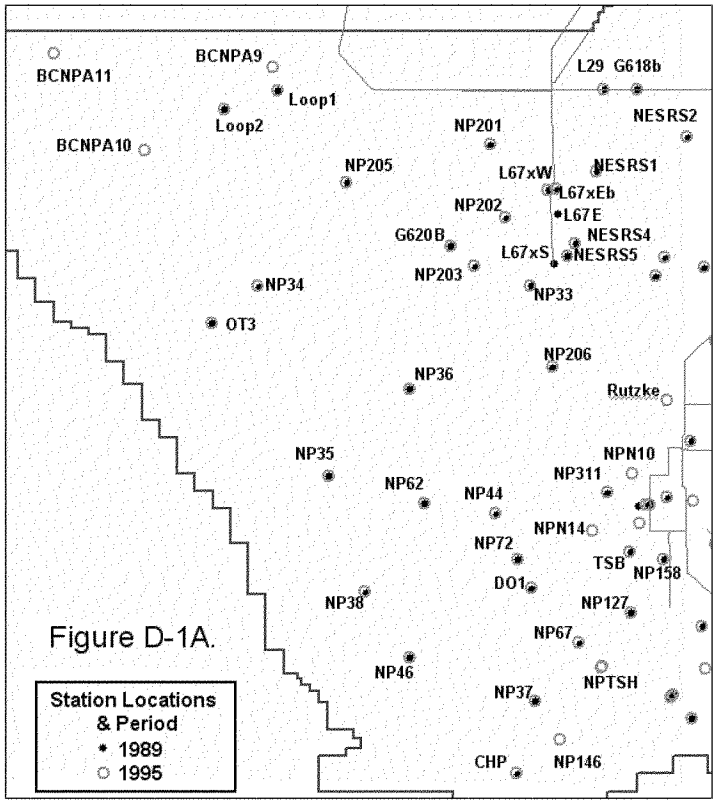

BCNPA11
BCNPA9
Loop1
Loop2
BCNPA10
L29
G618b
NESRS2
NP201
NP205
L67xW
NESRS1
L67xEb
NP202
L67E
G620B
NESRS4
L67xS
NESRS5
NP203
NP34
NP33
OT3
NP206
NP36
Rutzke
NP35
NPN10
NP311
NP62
NP44
NPN14
NP72
TSB
NP158
DO1
NP38
NP127
NP67
NP46
NPTSH
NP37
CHP
NP146
Station Locations
& Period
1989
1995

Figure D-1A.

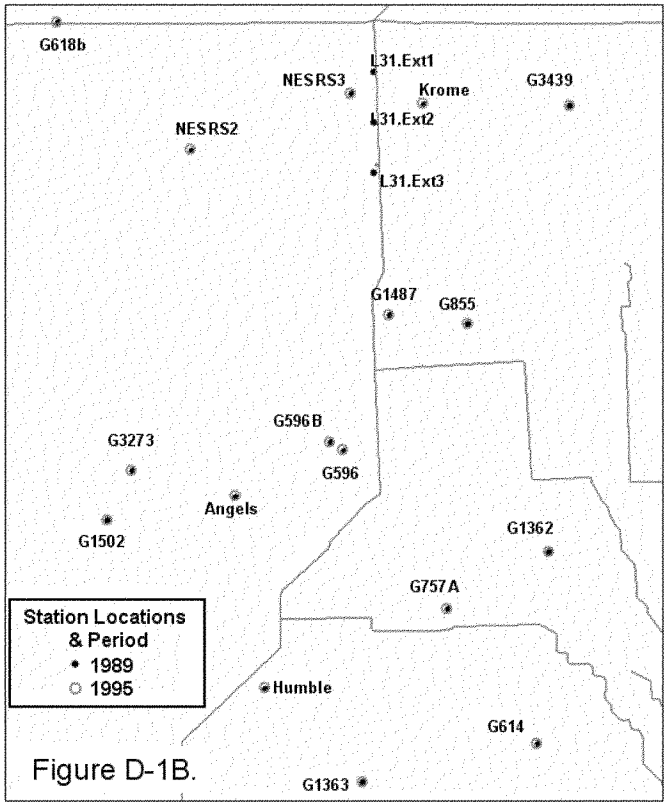

G618b
L31.Ext1
NESRS3
Krome
G3439
L31.Ext2
NESRS2
L31.Ext3
G1487
G855
G596B
G3273
G596
Angels
G1502
G1362
G757A
Station Locations
& Period
1989
1995
Humble
G614
G1363

Figure D-1B.

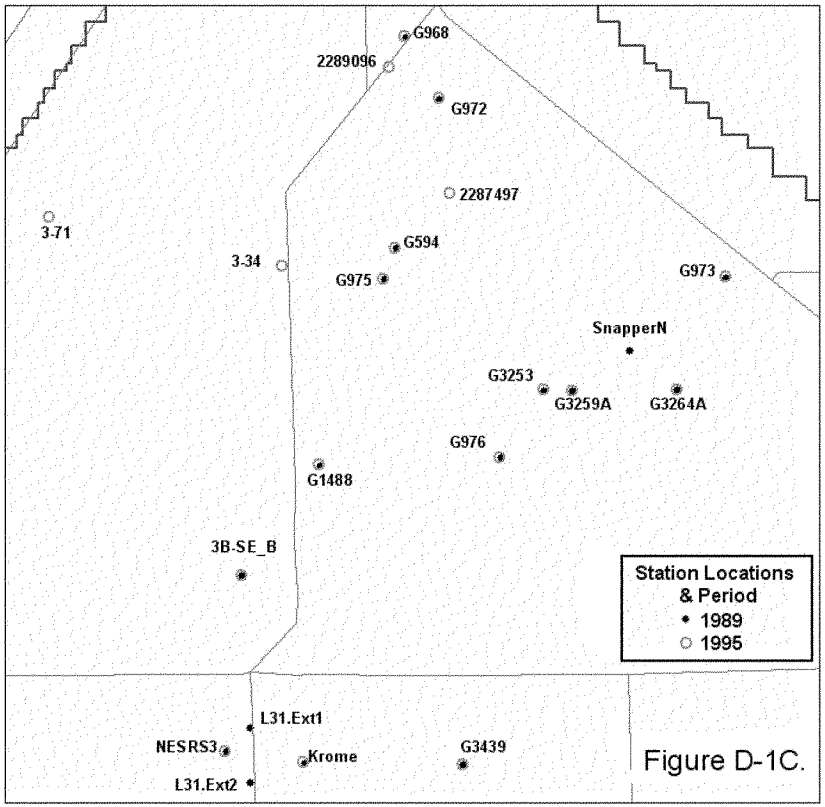

G968
2289096
G972
2287497
3-71
G594
3-34
G975
G973
SnapperN
G3253
G3259A
G3264A
G976
G1488
3B-SE_B
Station Locations
& Period
1989
1995
L31.Ext1
NESRS3
Krome
G3439
L31.Ext2

Figure D-1C.

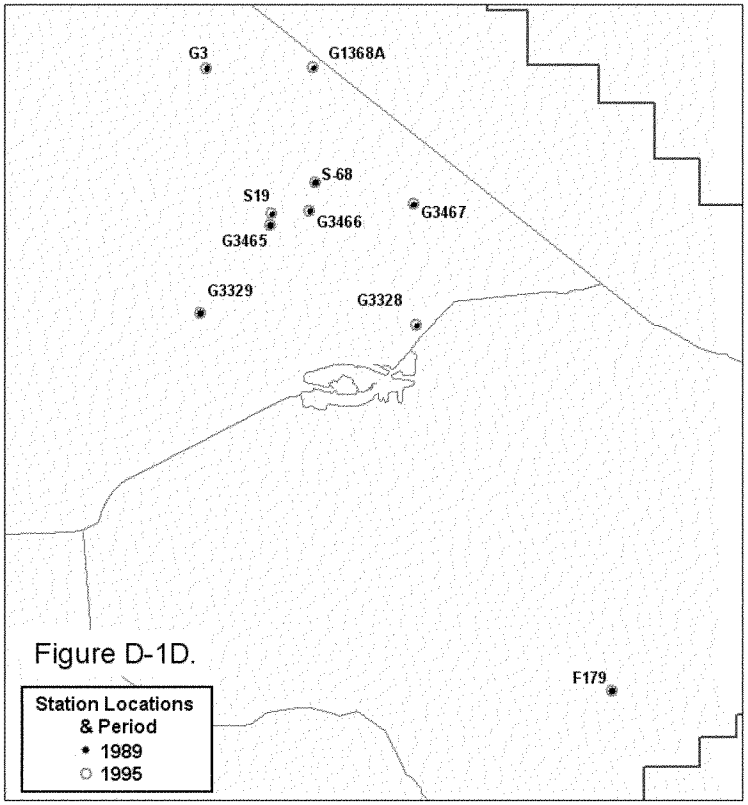

G3
G1368A
S-68
S19
G3466
G3467
G3465
G3329
G3328
F179
Station Locations
& Period
1989
1995

Figure D-1D.

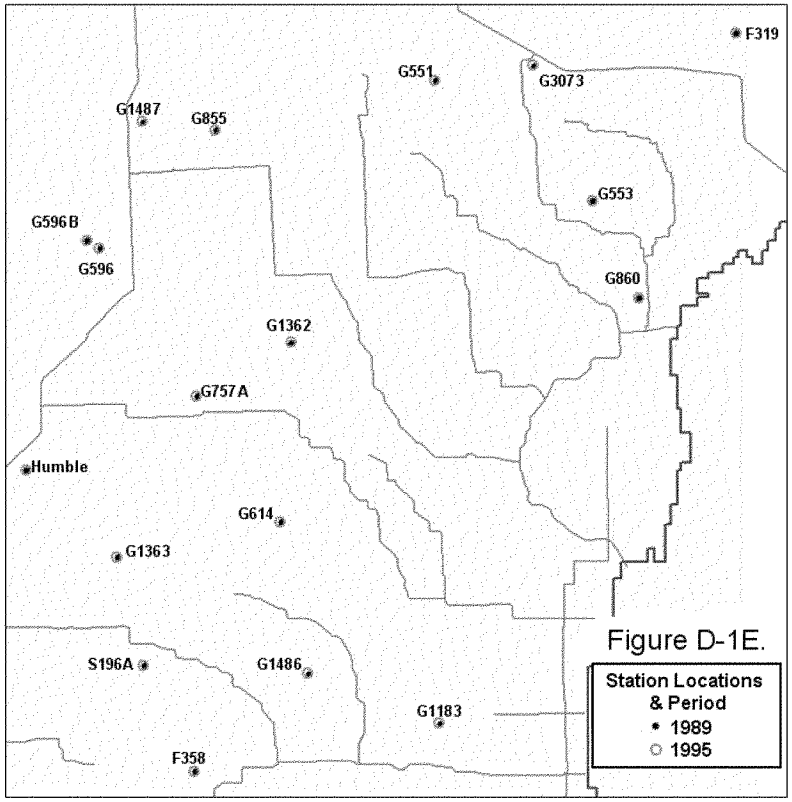
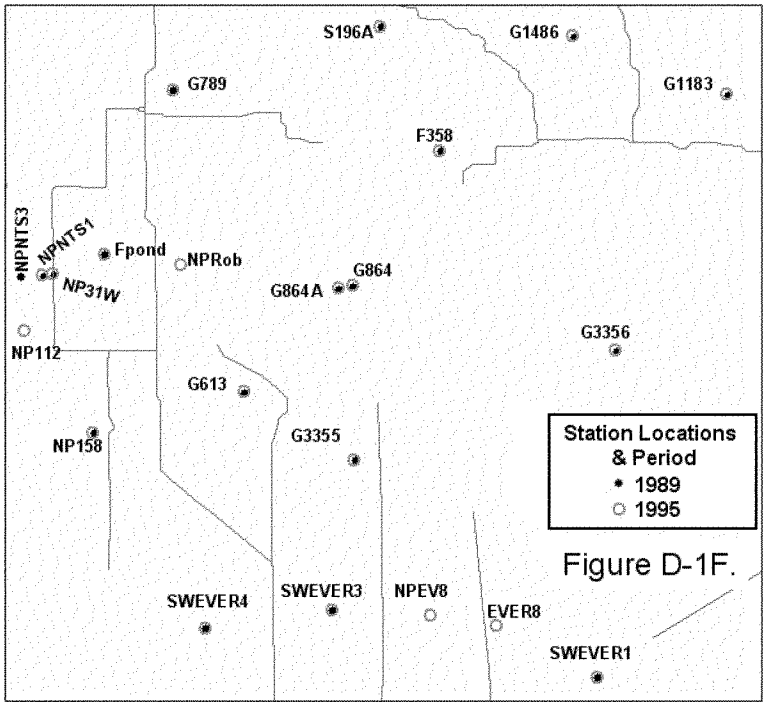

F319
G551
G3073
G1487
G855
G553
G596B
G596
G860
G1362
G757A
Humble
G614
G1363
S196A
G1486
G1183
F358
Station Locations
& Period
1989
1995

Figure D-1E.


S196A
G1486
G789
G1183
F358
NPNTS3
NPNTS1
Fpond
NPRob
NP31W
G864
G864A
G3356
NP112
G613
NP158
G3355
Station Locations
& Period
1989
1995
Figure D-1F.
SWEVER4
SWEVER3
NPEV8
EVER8
SWEVER1

Appendix D

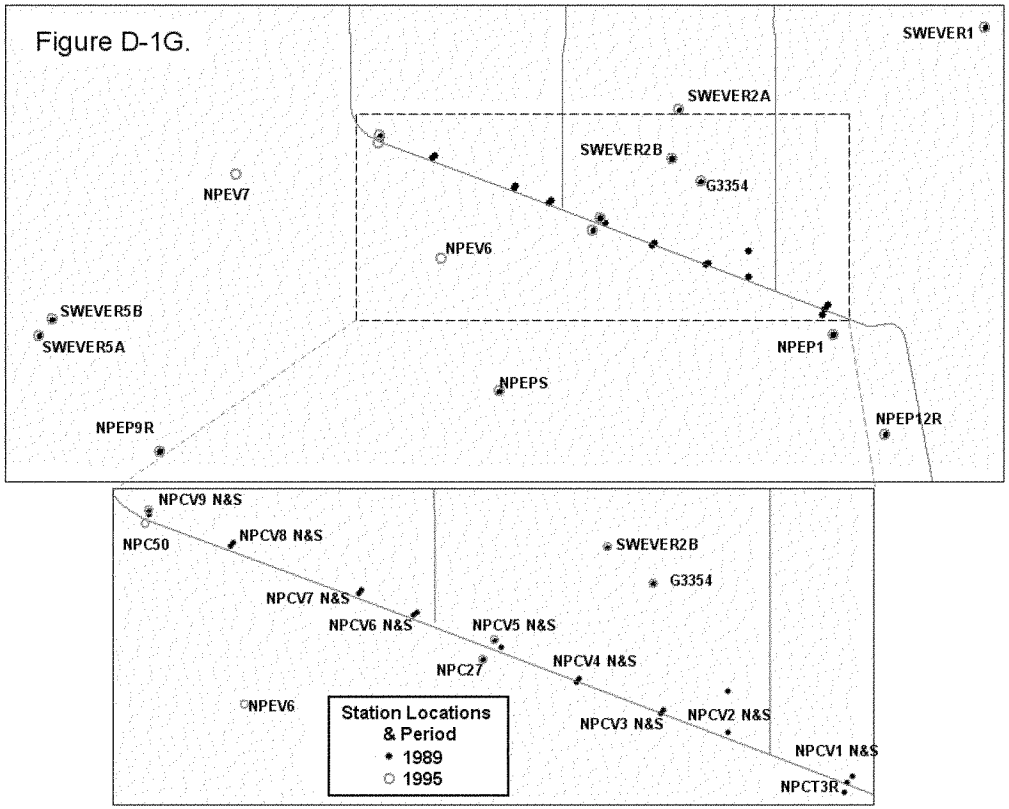


Figure D-1G.
SWEVER1
SWEVER2A
SWEVER2B
G3354
NPEV7
NPEV6
SWEVER5B
SWEVER5A
NPEP1
NPEPS
NPEP12R
NPEP9R
NPCV9 N&S
NPC50
NPCV8 N&S
SWEVER2B
G3354
NPCV7 N&S
NPCV6 N&S
NPCV5 N&S
NPCV4 N&S
NPC27
NPEV6
Station Locations
& Period
1989
1995
NPCV3 N&S
NPCV2 N&S
NPCV1 N&S
NPCT3R

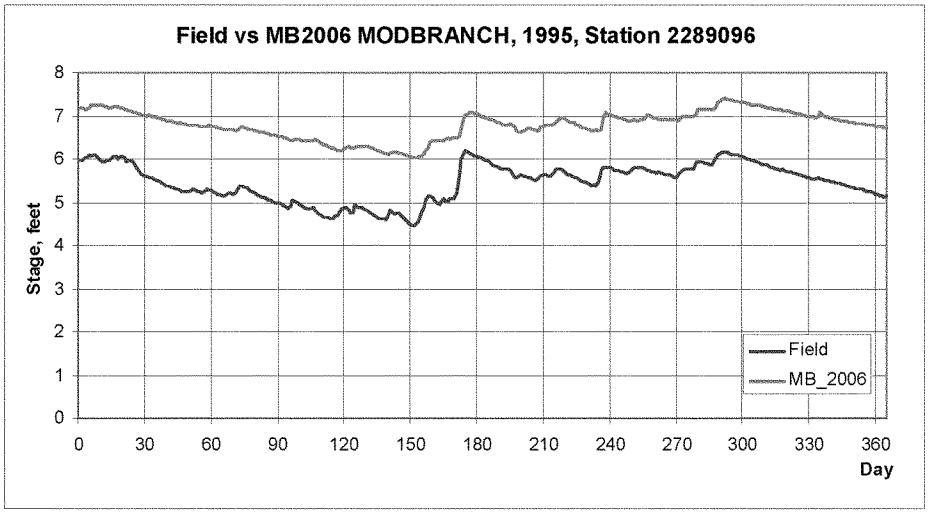
Appendix D

Table D-1. Ground Water Stations, Locations, MB_2006 Ground Elevations, and Number of Daily Values.

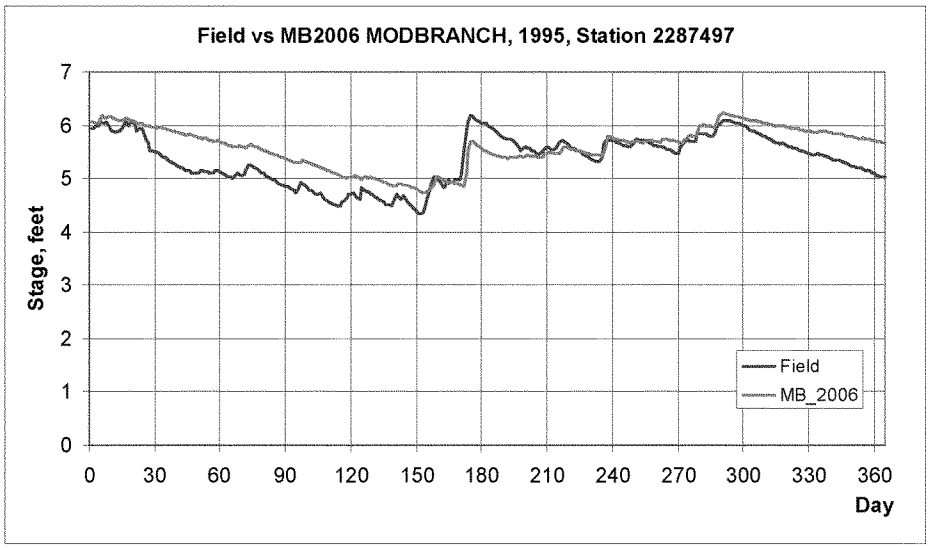
Station ID	X-coord	Y-Coord	Ground Elevation, ft NGVD29	# of Field Values (daily) 1989	1995
2289096	835378	578905	7.09		365
2287497	841274	568512	4.69		365
3-34	825303	559313	6.80		365
3-71	801994	564175	6.09		365
3B-SE_B	820851	529008	5.59	365	365
ANGELS	806957	468810	7.00	365	365
BCNPA10	649101	501843	4.30		365
BCNPA11	623422	529314	4.19		365
BCNPA9	685212	525374	7.90		365
EVER8	834860	367666	2.09		327
F-179	905899	512154	9.89	365	365
F-319	891160	498320	10.30	365	324
F-358	829313	413952	7.00	365	365
Fpond	796565	403850	5.80	365	365
G-1183	857277	419462	4.30	365	365
G-1362	840325	462941	10.39	365	303
G-1363	820479	438390	9.60	365	365
G-1368A	891249	542725	6.69	365	365
G-1486	842298	425090	9.39	365	360
G-1487	823366	488133	7.50	365	337
G-1488	828485	539625	6.09	365	355
G-1502	793261	466320	6.69	365	365
G-3	885986	542697	6.50	365	362
G-3073	868018	494567	8.80	365	303
G-3253	850493	547187	3.50	365	330
G-3259A	853344	547139	4.90	365	365
G-3264A	863595	547248	4.19	365	317
G-3273	795899	471579	6.80	360	365
G-3328	896308	530092	6.09	365	365
G-3329	885665	530700	10.19	365	343
G-3354	830481	354958	1.60	363	365
G-3355	820958	383815	3.00	335	332
G-3356	846444	394457	2.00	354	365
G-3439	842593	510443	6.50	365	365
G-3465	889097	535020	8.10	365	362
G-3466	891068	535697	8.30	365	348
G-3467	896166	536028	6.59	365	365
G-551	856774	492878	9.30	365	339
G-553	874737	479153	11.10	365	231
G-594	836567	560636	4.90	365	273
G-596	818479	473697	8.00	365	350
G-596_B	817030	474579	7.90	365	365
G-613	810206	390419	7.50	365	341
G-614	839129	442461	12.39	365	259
G-618_B	787975	519305	5.90	365	331
G-620_B	735304	474960	5.30	365	320
G-757A	829529	456839	9.30	365	309
G-789	803285	419854	6.30	365	294
G-855	831713	487197	7.40	365	363
G-860	880065	468034	10.50	365	365
G-864	820785	400774	7.59	365	365
G-864A	819411	400527	7.90	365	319
G-968	836917	581839	5.50	365	365
G-972	840229	575796	5.00	365	362
G-973	868365	558296	5.80	365	357
G-975	834824	558084	5.09	365	365
G-976	846246	540565	5.40	365	365
HUMBLE	810090	448375	7.80	365	365
KROME	826974	510620	7.09	365	365
L29	778650	519278	6.19	365	365
L31.EXT1	821639	514070	8.00	241	
L31.EXT2	821659	508719	8.10	216	
L31.EXT3	821680	503369	7.40	167	
L67E	763909	490972	5.80	354	
L67E.S	764235	470277	5.90	365	
L67EX.E_B	764092	490972	5.80	365	365
L67EX.W	763909	490972	5.80	365	365
Loop1	686496	518914	7.40	365	365
Loop2	671322	513556	6.30	365	365
NESRS1	776611	496053	5.80	365	365
NESRS2	802191	505722	5.80	312	365
NESRS3_B	819270	511739	6.19	365	365
NESRS4_B	770627	475644	5.50	115	365
NESRS5_B	768349	472105	5.50	186	365

Station ID	X-coord	Y-Coord	Ground Elevation, ft NGVD29	# of Field Values (daily) 1989	1995
NP-112	788804	396448	5.50		358
NP-127	786310	371405	1.79	365	362
NP-146	766402	335312	0.80		365
NP-158	795528	386475	4.59	365	348
NP-201	746593	503552	7.00	332	365
NP-202	751028	482866	5.80	365	365
NP-203	742179	469219	5.30	365	365
NP-205	705999	492886	6.19	365	365
NP-206	764216	440698	5.90	365	365
NP-311	779611	405204	6.09	353	358
NP-31W	791629	401908	5.30	365	364
NP-C27	825094	352557	2.09	103	312
NP-C50	814433	356859	2.29		326
NP-CHP	754121	325795	0.10	258	332
NP-CT3R	836491	348362	1.50	345	
NP-CV1N	836764	348868	1.50	336	
NP-CV1S	836582	348665	1.50	351	
NP-CV2N	832812	350265	1.79	39	
NP-CV2S	832807	351578	1.60	39	
NP-CV3N	830790	350964	1.89	39	
NP-CV3S	830699	350863	1.89	39	
NP-CV4N	828125	351963	2.00	39	
NP-CV4S	828033	351862	2.00	39	
NP-CV5N	825459	353164	2.00	333	323
NP-CV5S	825643	352963	2.00	210	
NP-CV6N	822978	354064	2.29	38	
NP-CV6S	822886	353962	2.00	39	
NP-CV7N	821231	354764	2.40	38	
NP-CV7S	821140	354662	2.40	38	
NP-CV8N	817188	356263	2.29	39	
NP-CV8S	817097	356162	2.29	39	
NP-CV9N	814523	357263	2.29	358	365
NP-CV9S	814524	357162	2.29	343	
NP-DO1	758215	378155	3.29	110	365
NP-EP1	837046	347355	1.29	165	365
NP-EP12R	839636	342419	1.20	365	365
NP-EP9R	803564	341578	1.29	365	313
NP-EPS	820443	344565	1.50	365	365
NP-EV6	817574	351116	2.29		362
NP-EV7	807372	355320	1.89		293
NP-EV8	828427	368621	2.29		327
NP-N10	786562	410474	6.19		364
NP-N14	775331	394289	5.00		209
NP-NTS1	790621	401804	6.00	321	365
NP-NTS3	788329	401797	5.69	353	
NP-OT3	667863	453186	1.00	334	357
NP-P33	757935	463700	5.50	358	365
NP-P34	681042	463589	2.79	365	332
NP-P35	700840	409940	0.69	337	365
NP-P36	723652	434560	3.50	324	331
NP-P37	759215	346399	1.10	365	365
NP-P38	711266	377204	1.10	365	342
NP-P44	748091	399272	4.89	346	339
NP-P46	723676	358647	1.50	365	365
NP-P62	727918	402263	2.09	344	292
NP-P67	771747	362784	2.09	365	365
NP-P72	754262	386465	5.09	365	365
NP-ROB	804093	402857	4.90		365
NP-TSB	786076	388566	4.69	365	365
NP-TSH	778280	356139	1.60		362
RUTZKE_G	796485	431502	6.50		365
S-19	889204	535566	8.10	365	359
S-196A	823494	426044	9.80	365	363
S-68	891334	537092	7.59	365	358
SNAPPERN	858864	551078	4.30	81	
SWEVER1	844599	362630	1.39	261	206
SWEVER2A	829384	358530	1.89	224	365
SWEVER2B	829026	356106	1.79	365	365
SWEVER3	818792	369191	2.50	365	233
SWEVER4	806413	367431	2.79	365	365
SWEVER5A	797579	347313	1.39	365	365
SWEVER5B	798219	348122	1.60	365	279
TSHilton	778073	355816	1.50		362

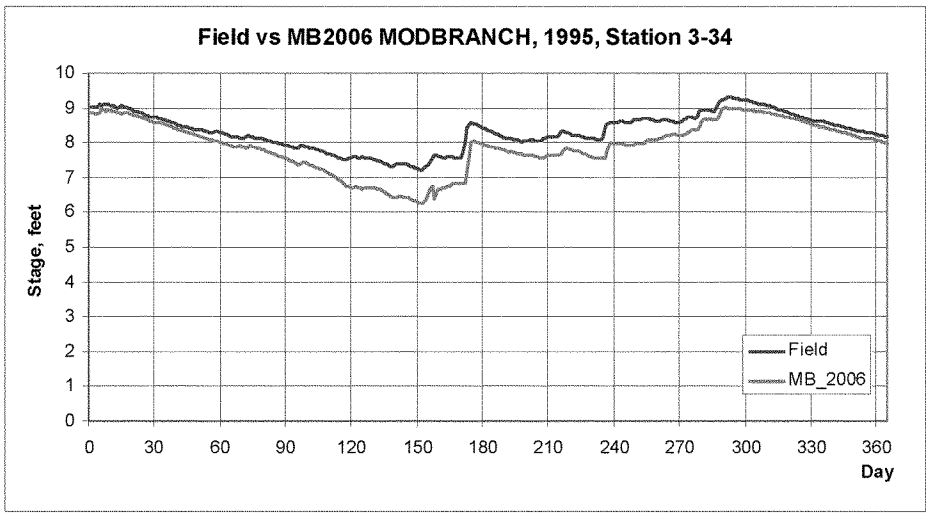
Appendix D


Field vs MB2006 MODBRANCH, 1995, Station 2289096
Stage, feet
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

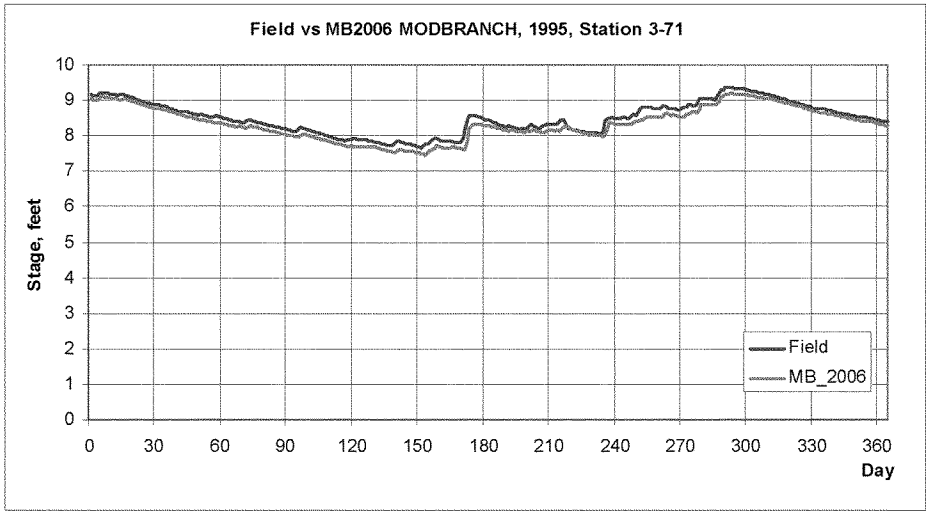
Appendix D


Field vs MB2006 MODBRANCH, 1995, Station 2287497
Stage, feet
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

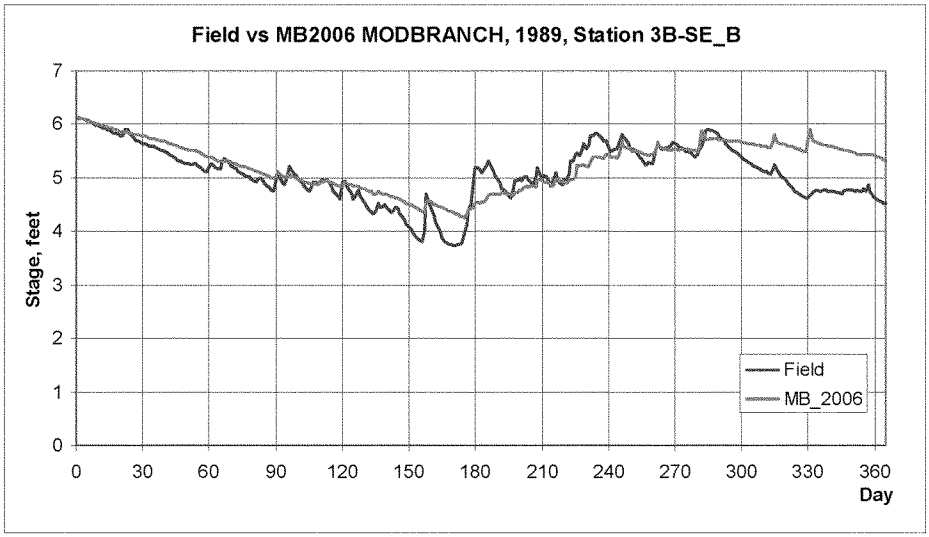
Appendix D


Field vs MB2006 MODBRANCH, 1995, Station 3-34
Stage, feet
10
9
8
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station 3-71
Stage, feet
10
9
8
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station 3B-SE_B
Stage, feet
0
1
2
3
4
5
6
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60
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120
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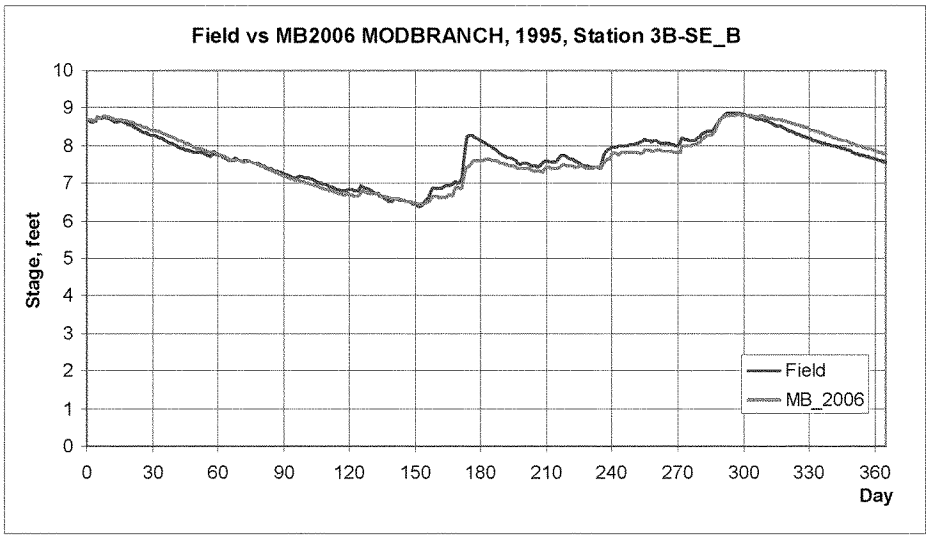
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station 3B-SE_B
Stage, feet
0
1
2
3
4
5
6
7
8
9
10
0
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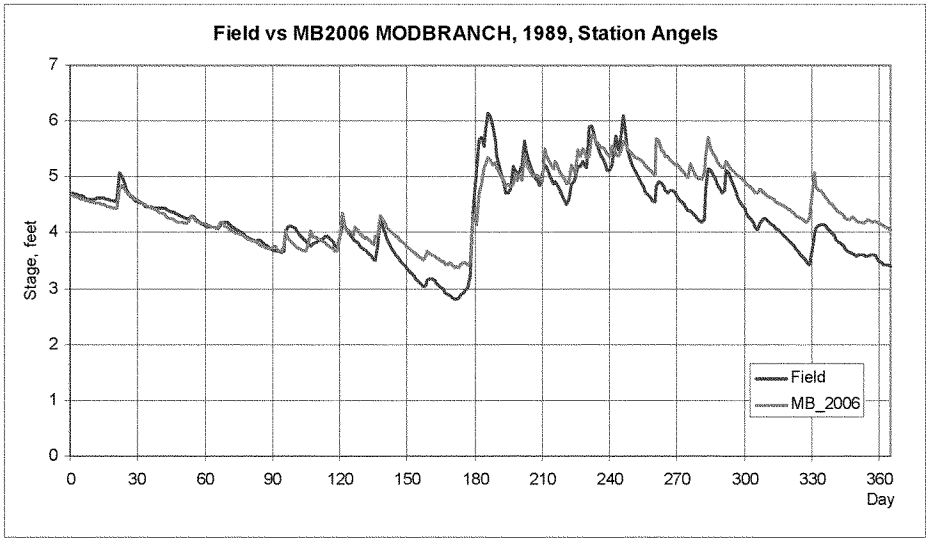
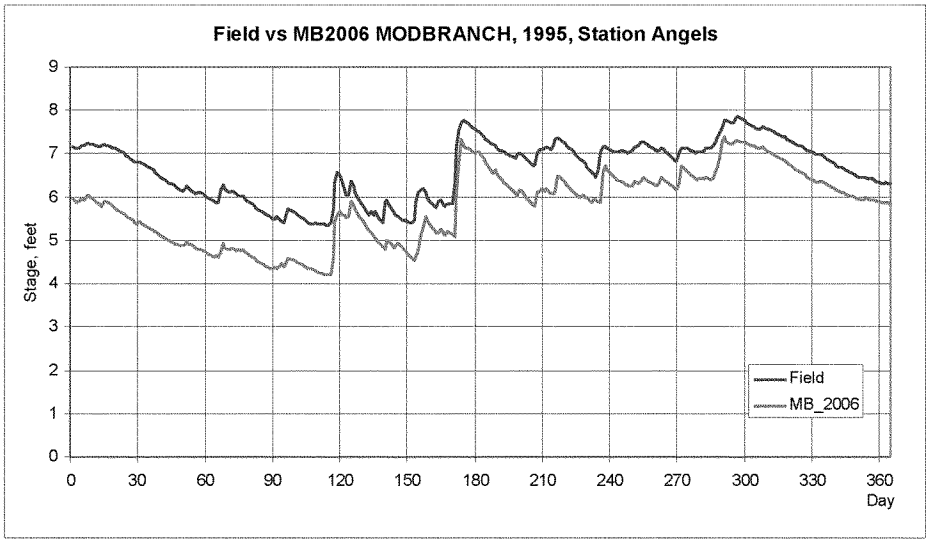
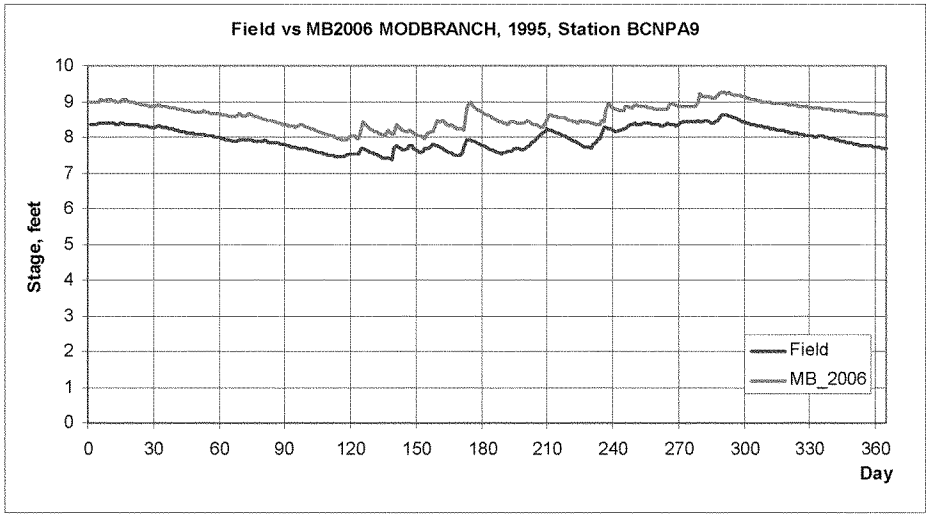
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D

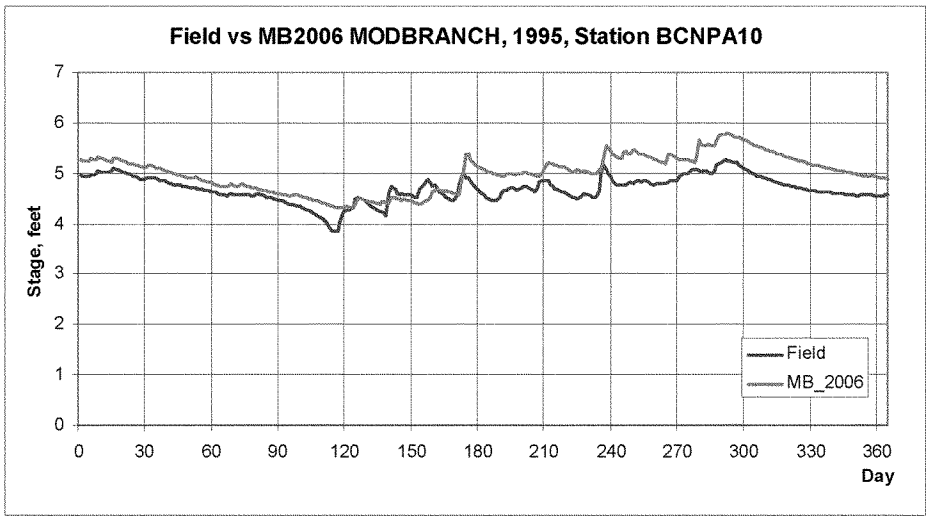

Field vs MB2006 MODBRANCH, 1989, Station Angels
Stage, feet
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station Angels
Stage, feet
0
1
2
3
4
5
6
7
8
9
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station BCNPA9
Stage, feet
10
9
8
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station BCNPA10
Stage, feet
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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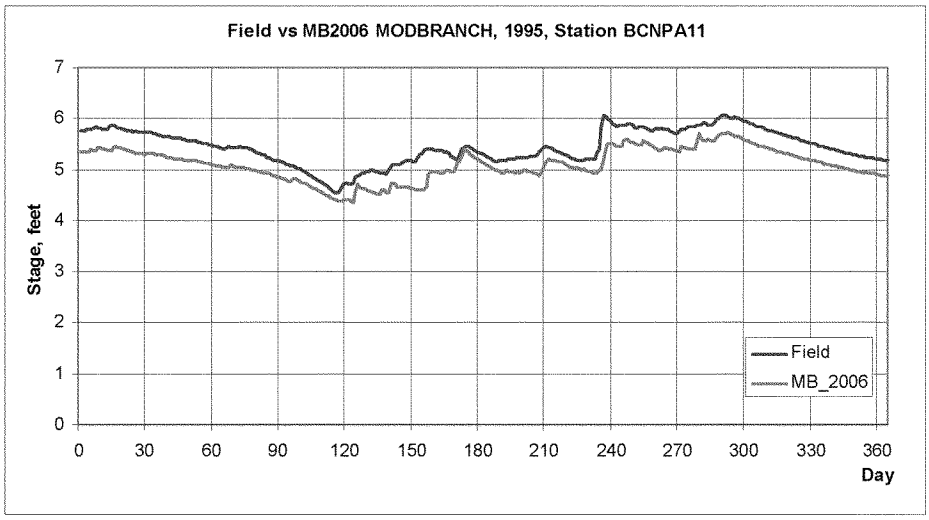
Field vs MB2006 MODBRANCH, 1995, Station BCNPA11
Stage, feet
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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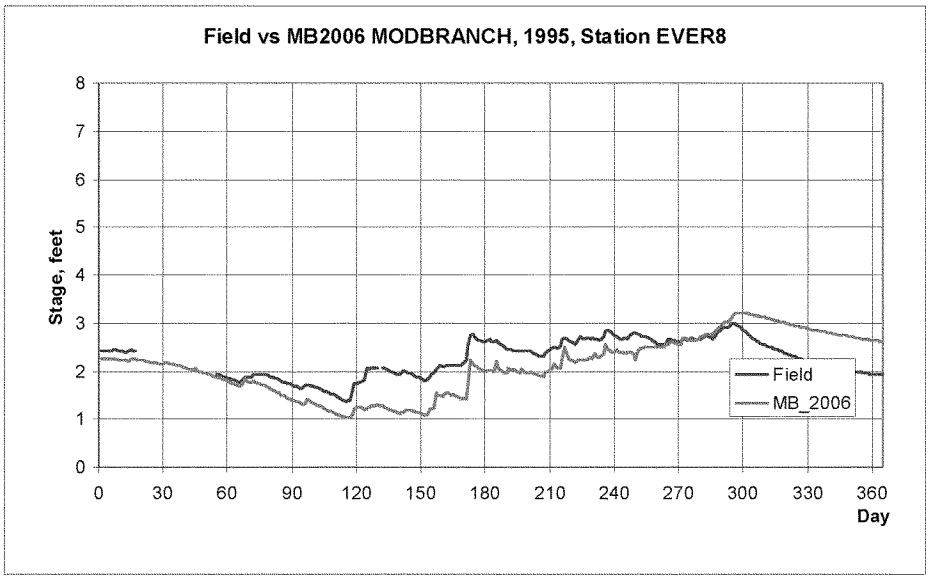
Field vs MB2006 MODBRANCH, 1995, Station EVER8
Stage, feet
8
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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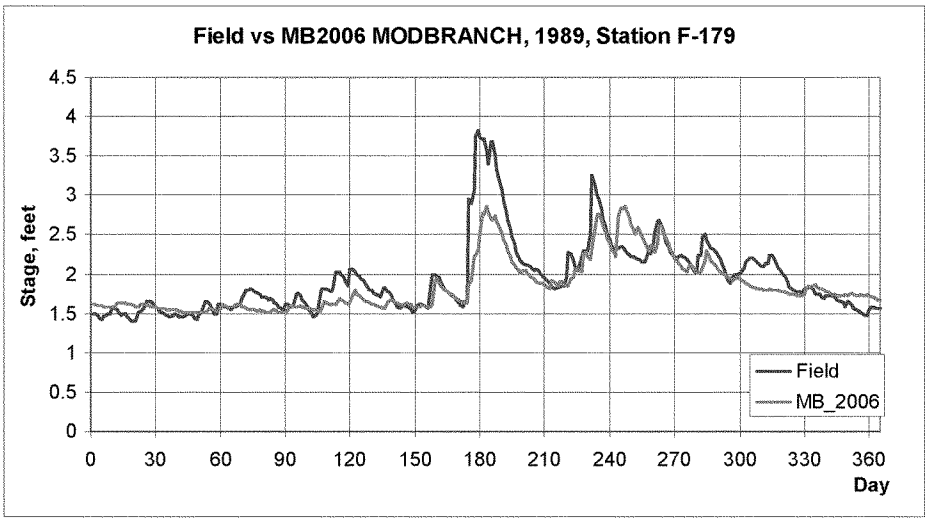
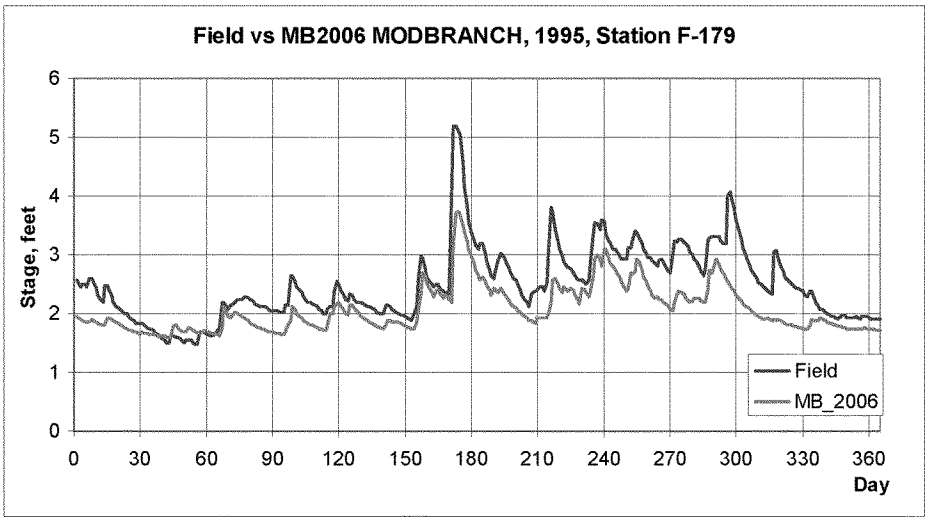
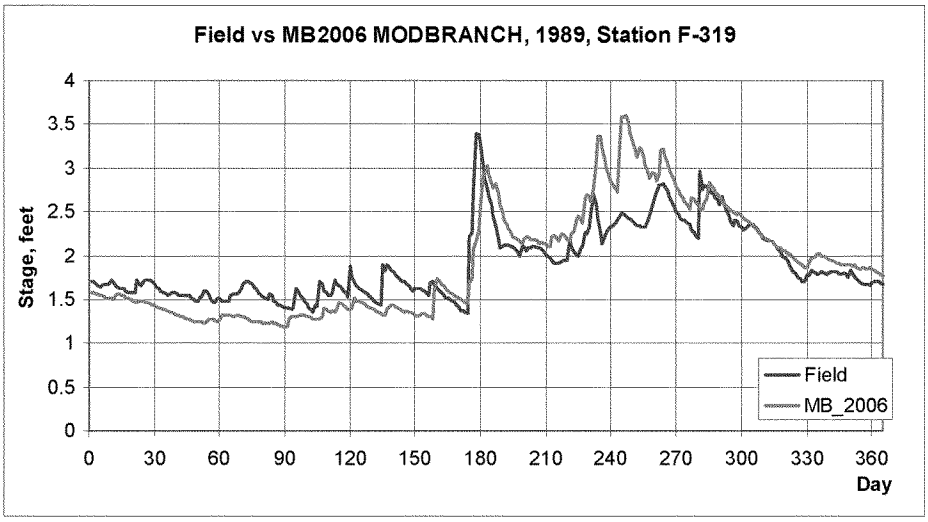
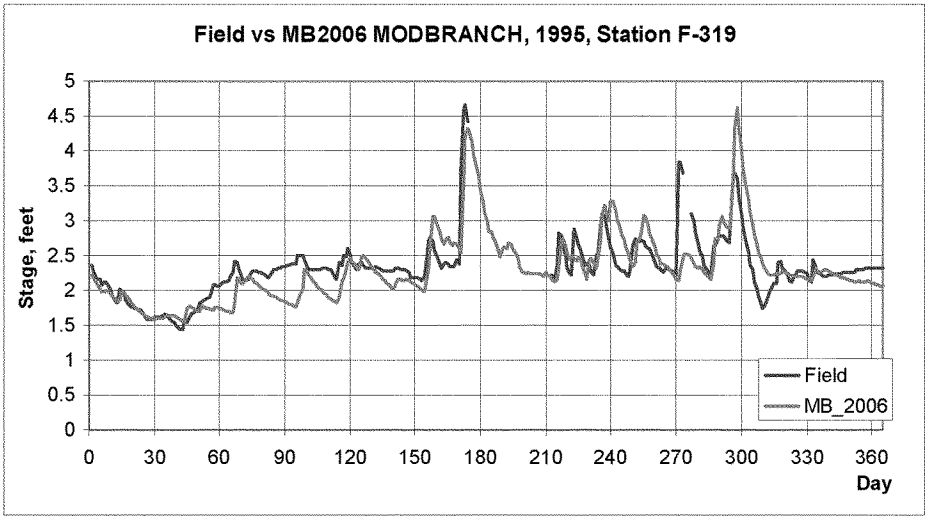

Field vs MB2006 MODBRANCH, 1989, Station F-179
Stage, feet
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

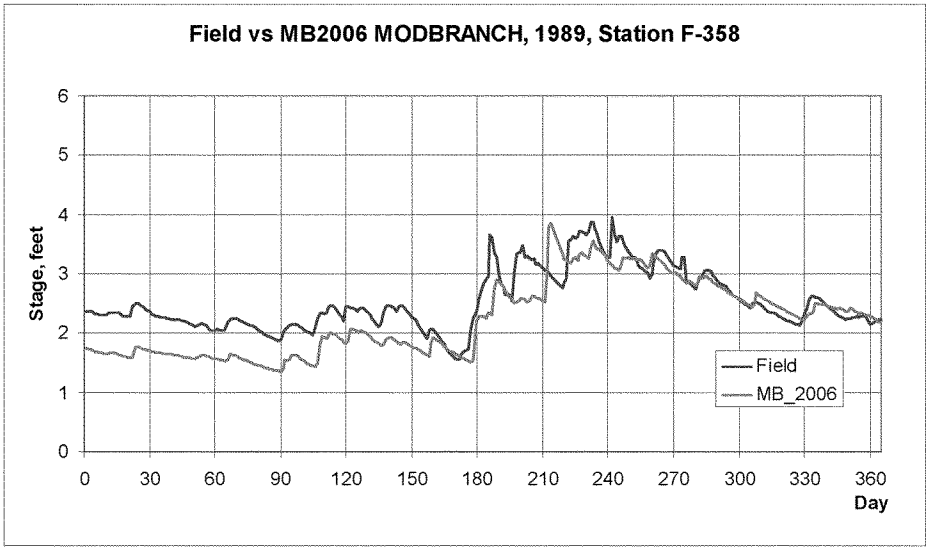

Field vs MB2006 MODBRANCH, 1995, Station F-179
Stage, feet
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

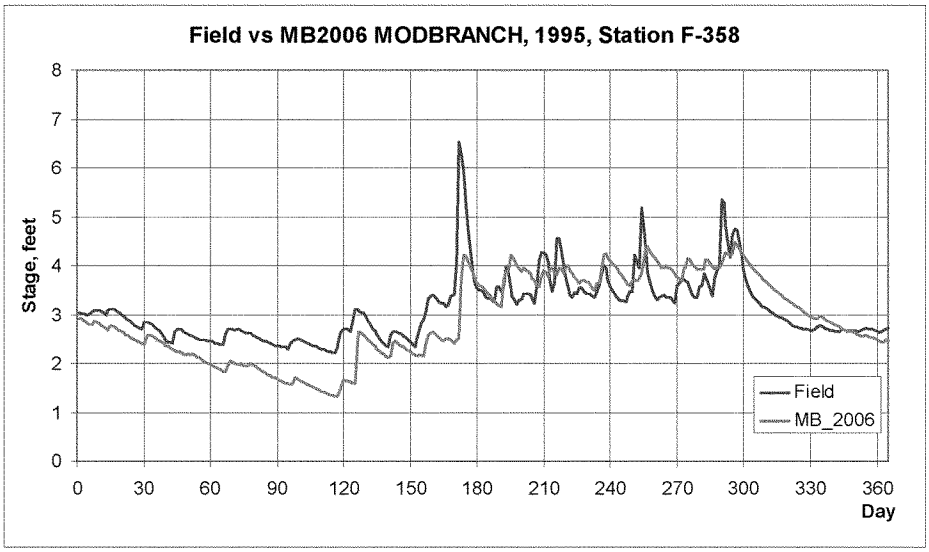
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station F-319
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station F-319
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station F-358
Stage, feet
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station F-358
Stage, feet
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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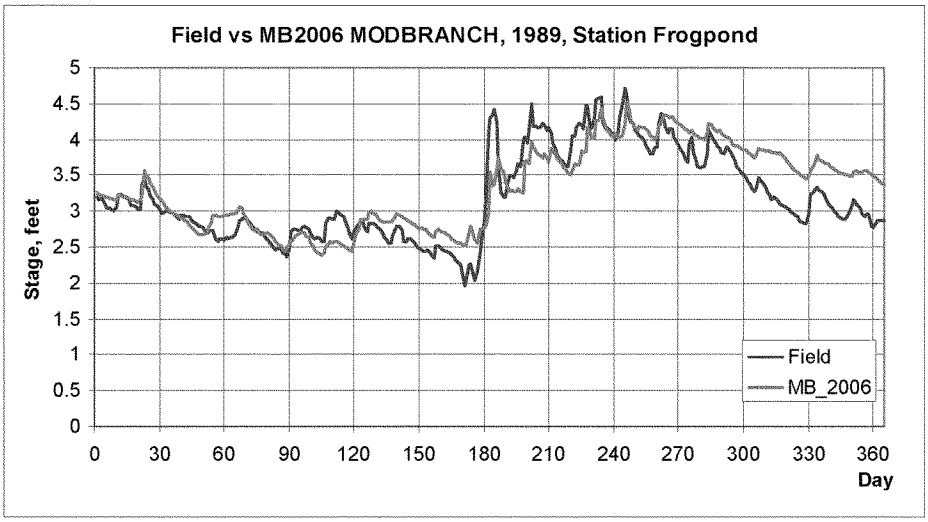
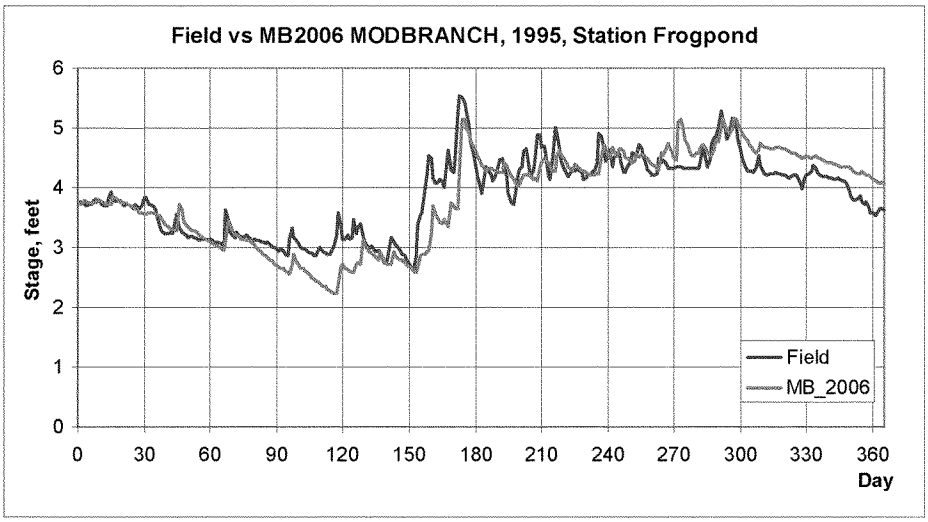
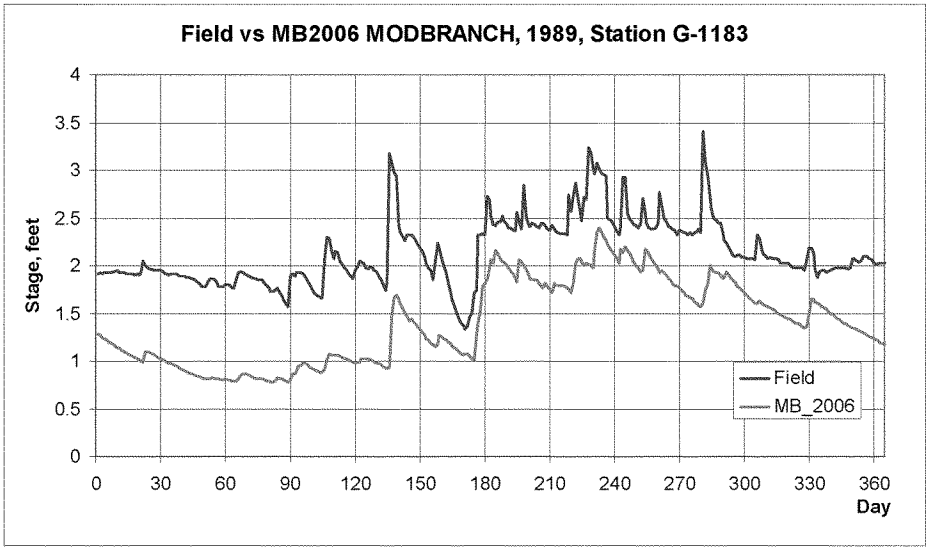
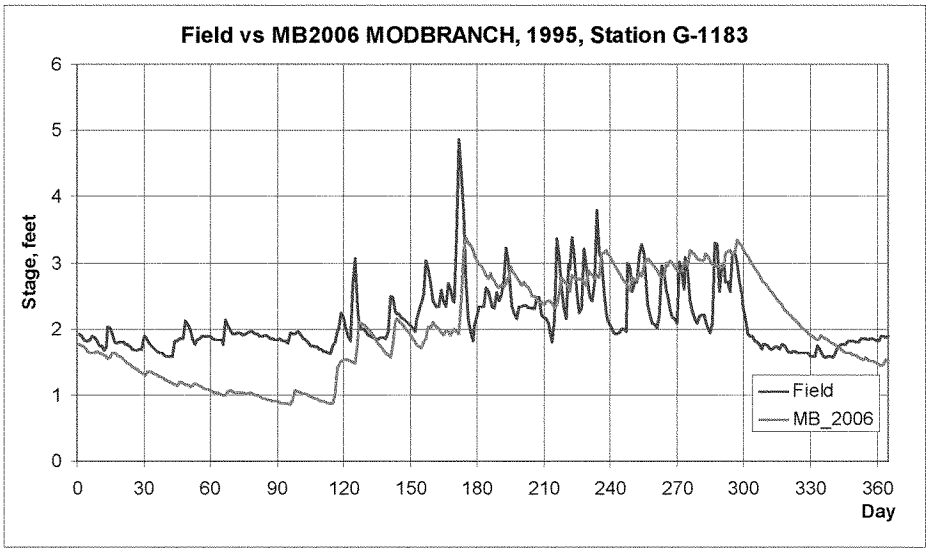

Field vs MB2006 MODBRANCH, 1989, Station Frogpond
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
30
60
90
120
150
180
210
240
270
300
330
360

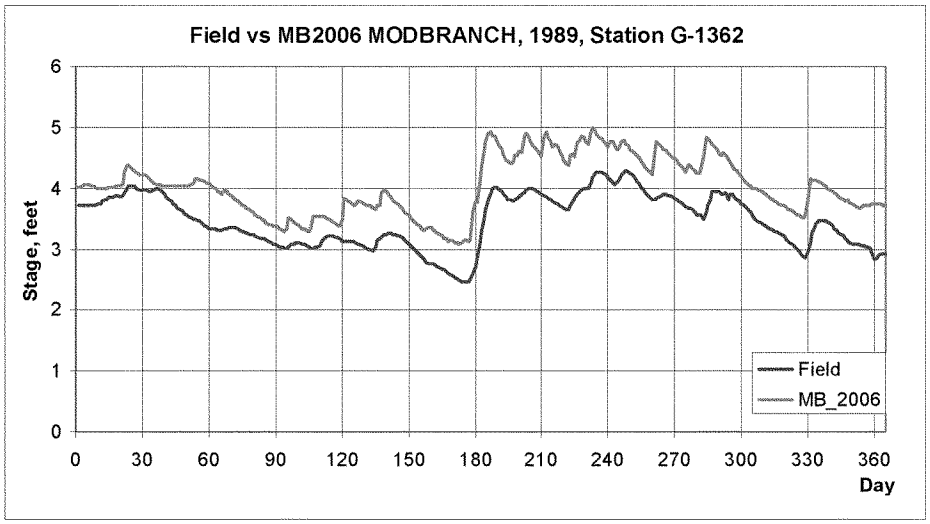

Field vs MB2006 MODBRANCH, 1995, Station Frogpond
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360

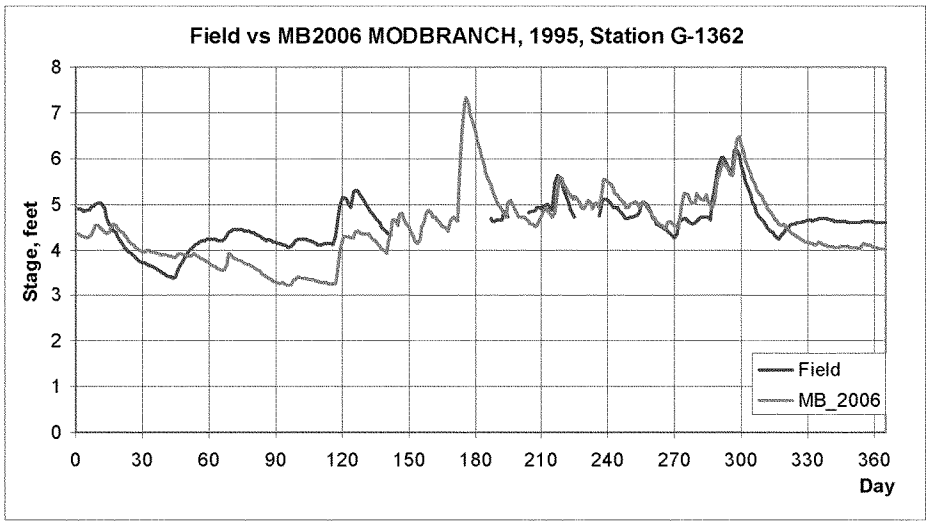
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-1183
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
0
30
60
90
120
150
180
210
240
270
300
330
360

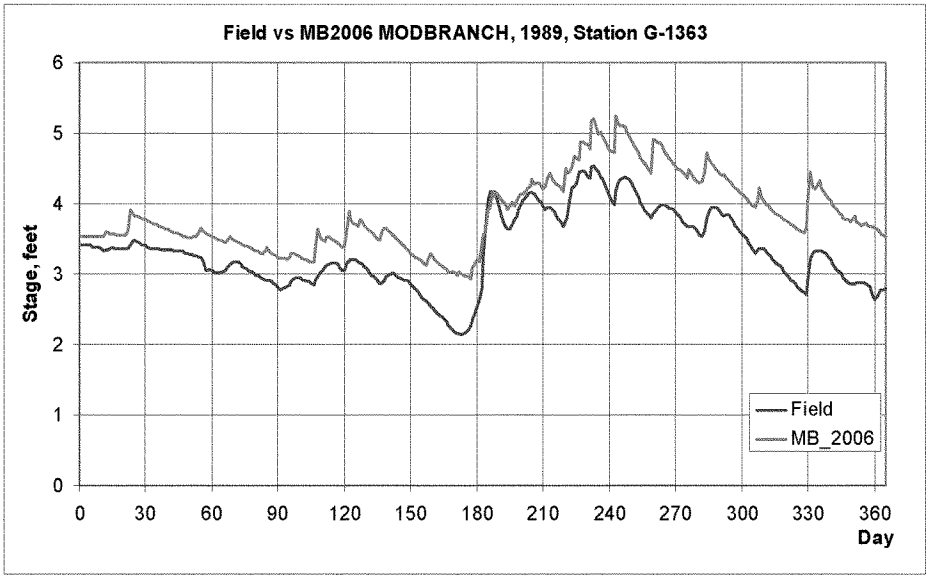

Field vs MB2006 MODBRANCH, 1995, Station G-1183
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360

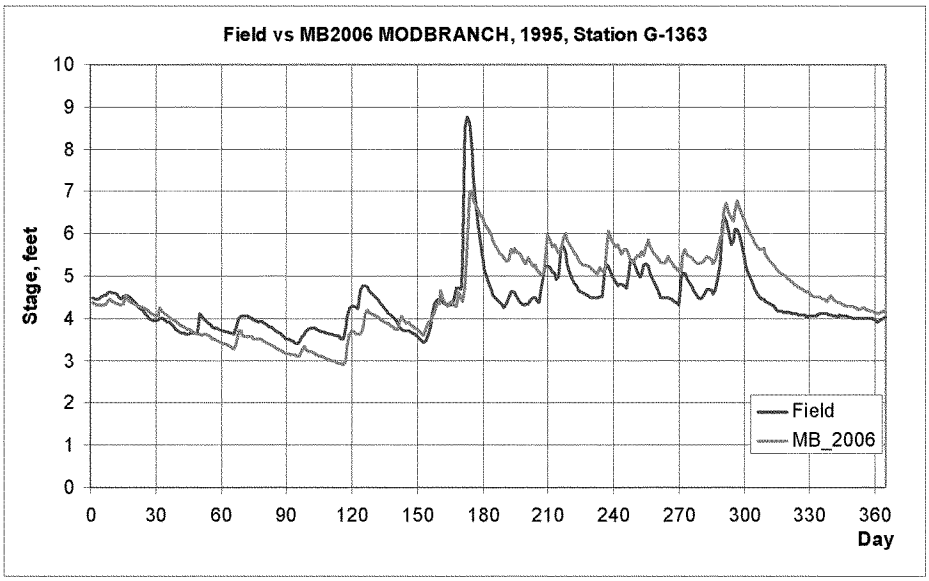
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-1362
Stage, feet
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

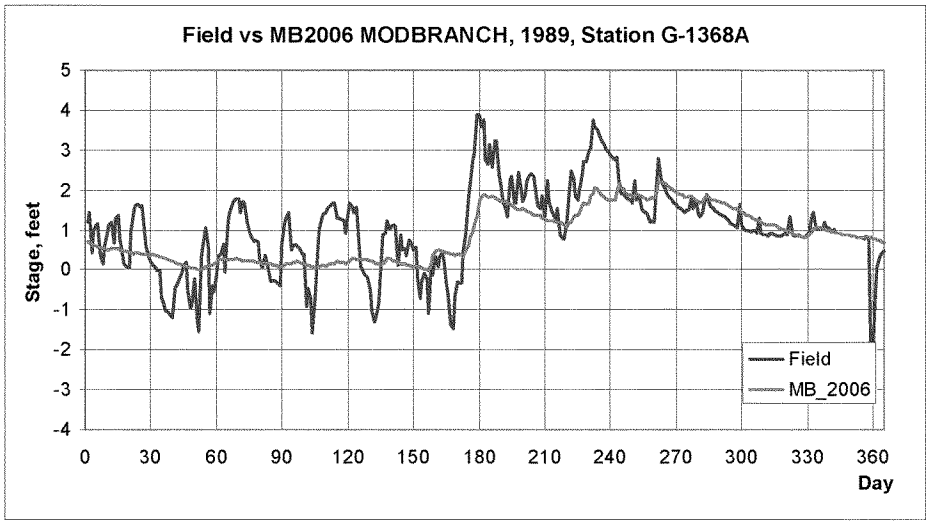

Field vs MB2006 MODBRANCH, 1995, Station G-1362
Stage, feet
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

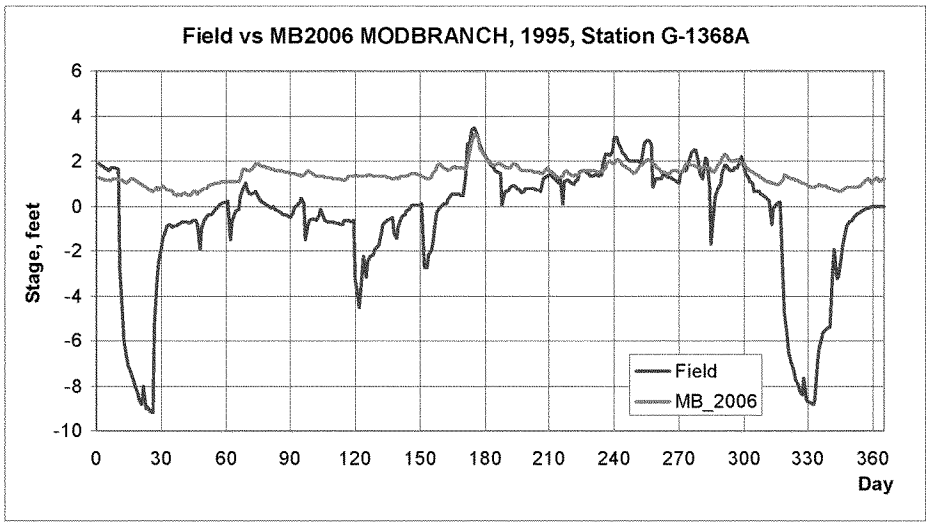
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-1363
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-1363
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
9
10
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-1368A
Stage, feet
5
4
3
2
1
0
-1
-2
-3
-4
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-1368A
Stage, feet
6
4
2
0
-2
-4
-6
-8
-10
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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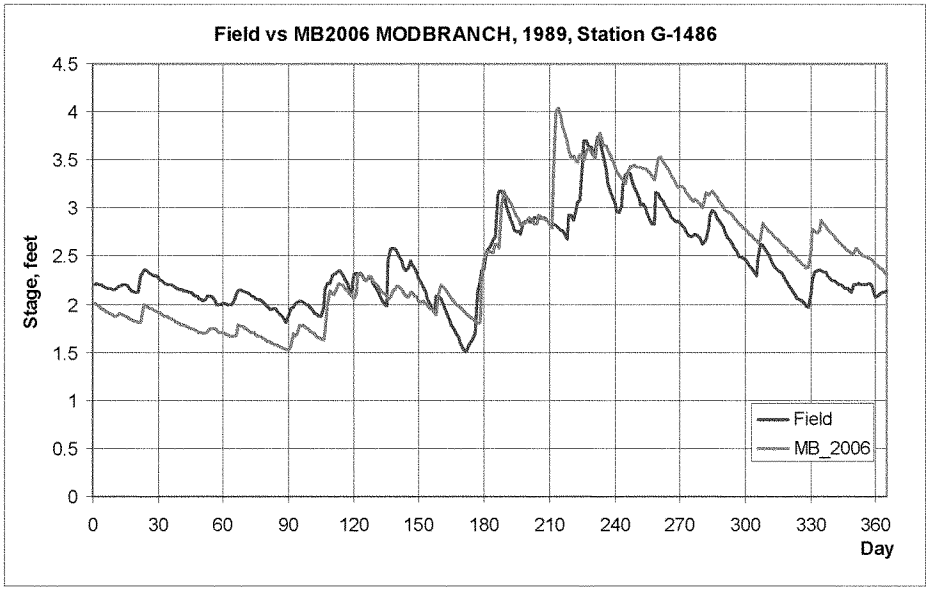
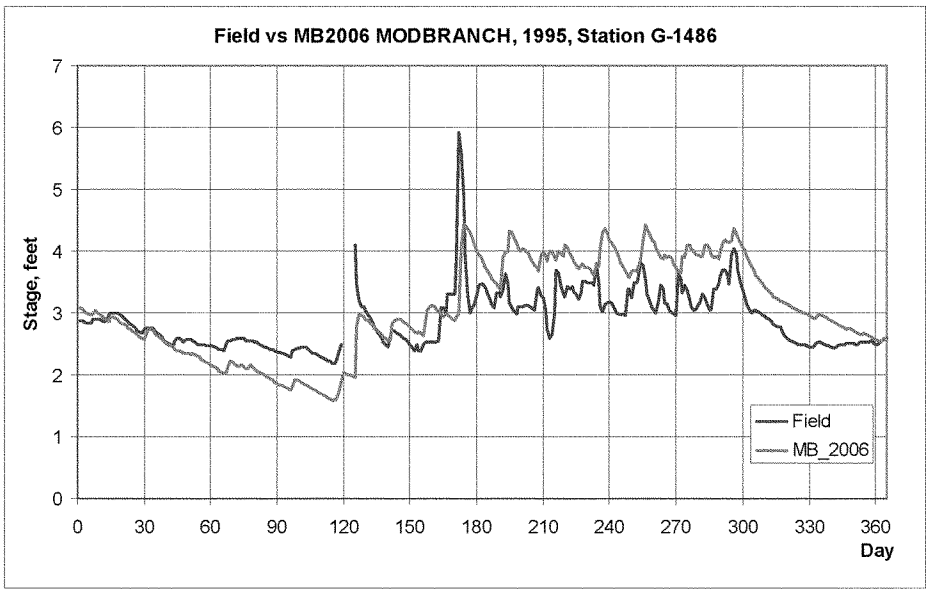

Field vs MB2006 MODBRANCH, 1989, Station G-1486
Stage, feet
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-1486
Stage, feet
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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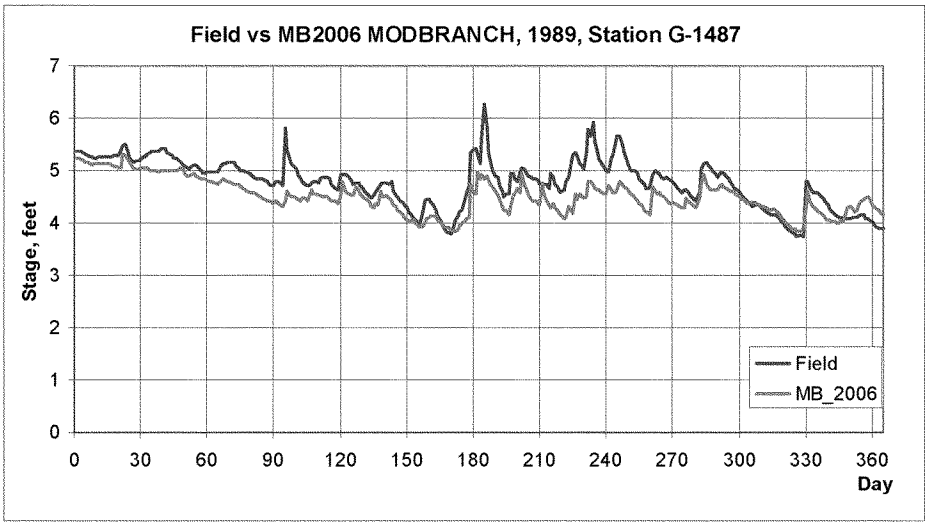
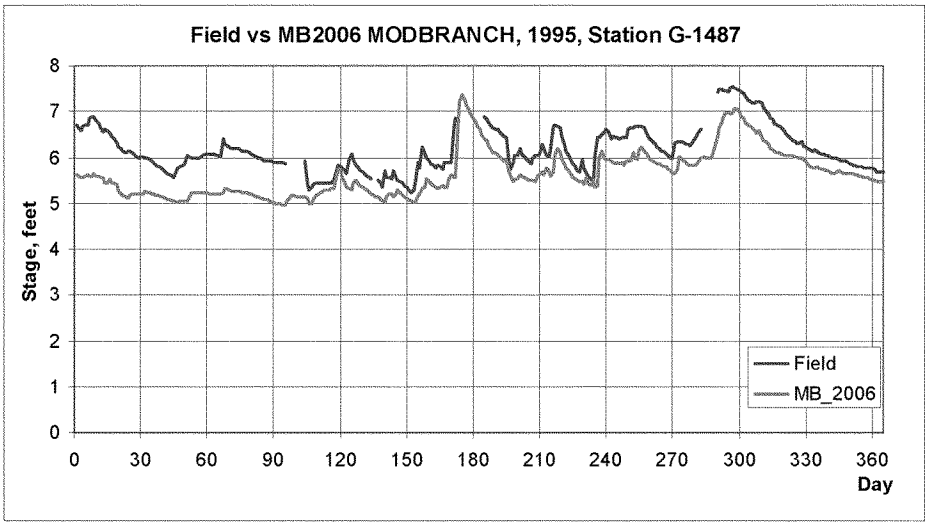

Field vs MB2006 MODBRANCH, 1989, Station G-1487
Stage, feet
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-1487
Stage, feet
0
1
2
3
4
5
6
7
8
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90
120
150
180
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240
270
300
330
360
Day
Field
MB_2006

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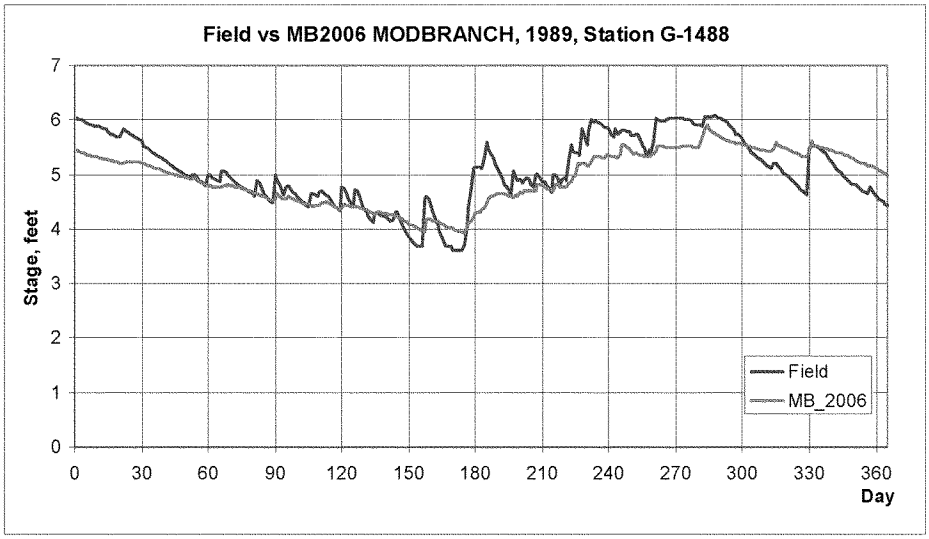
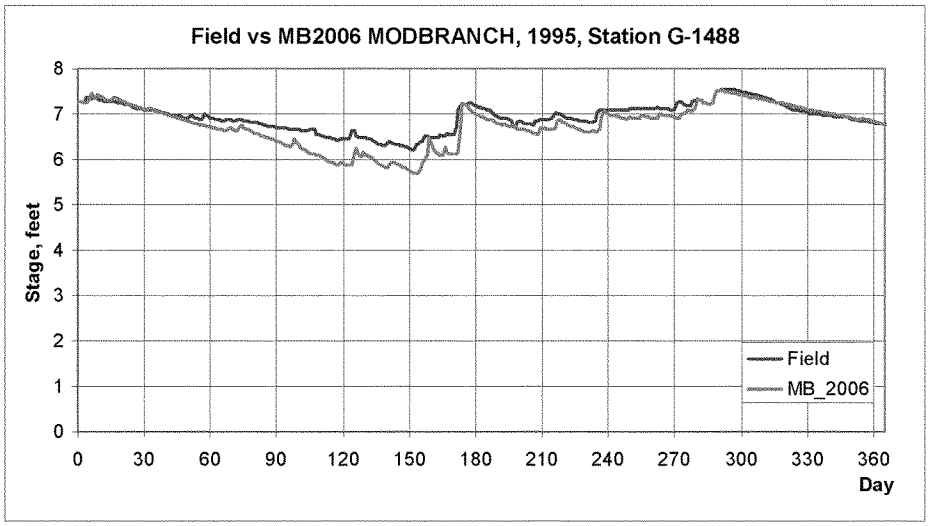

Field vs MB2006 MODBRANCH, 1989, Station G-1488
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-1488
Stage, feet
Day
Field
MB_2006
0
1
2
3
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5
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300
330
360

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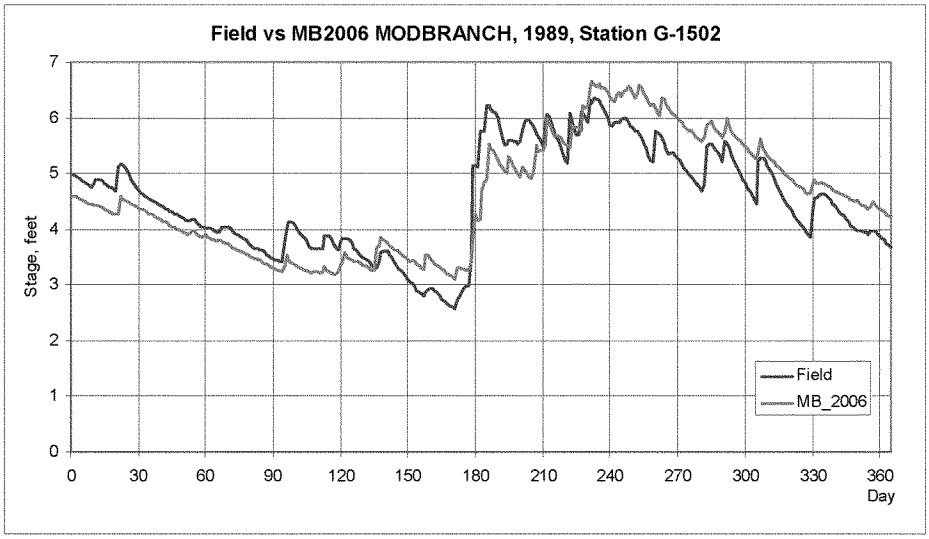
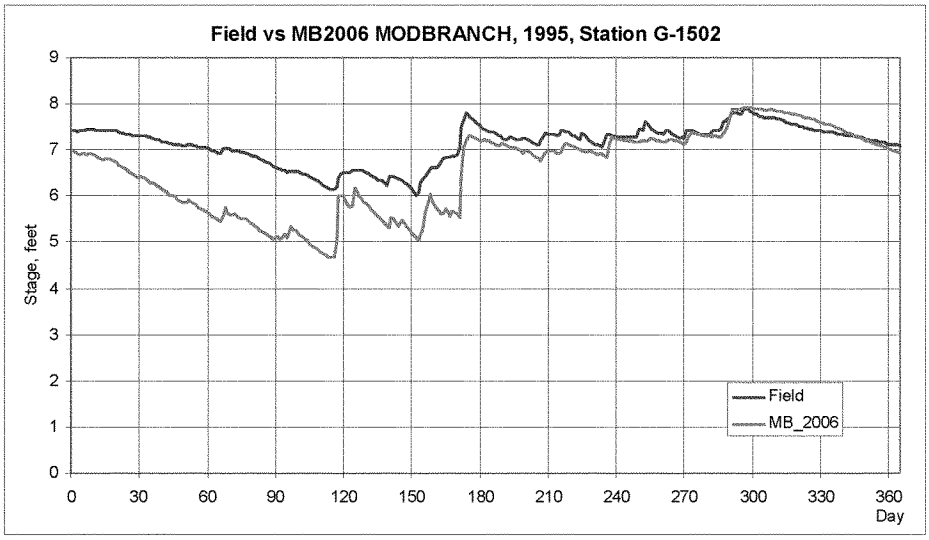

Field vs MB2006 MODBRANCH, 1989, Station G-1502
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-1502
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
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60
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120
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180
210
240
270
300
330
360

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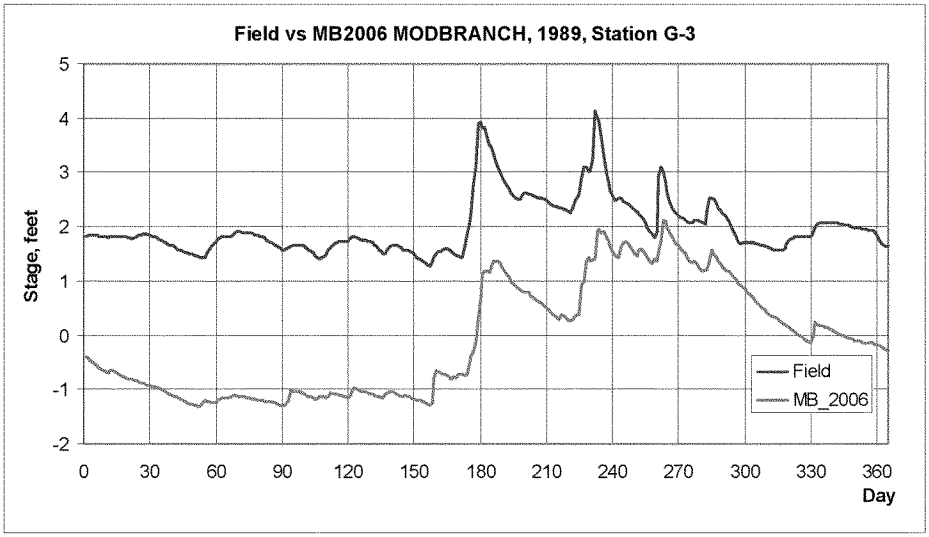
Field vs MB2006 MODBRANCH, 1989, Station G-3
Stage, feet
5
4
3
2
1
0
-1
-2
0
30
60
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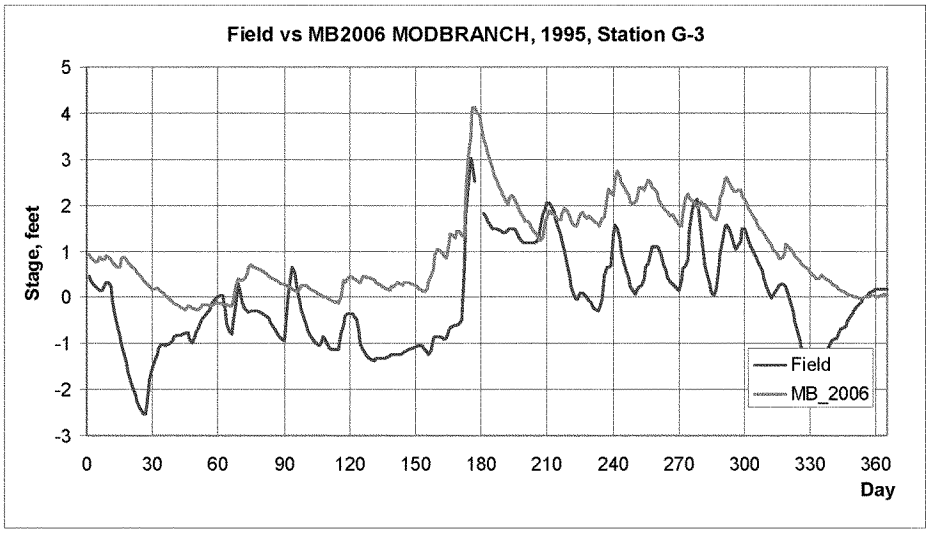
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-3
Stage, feet
5
4
3
2
1
0
-1
-2
-3
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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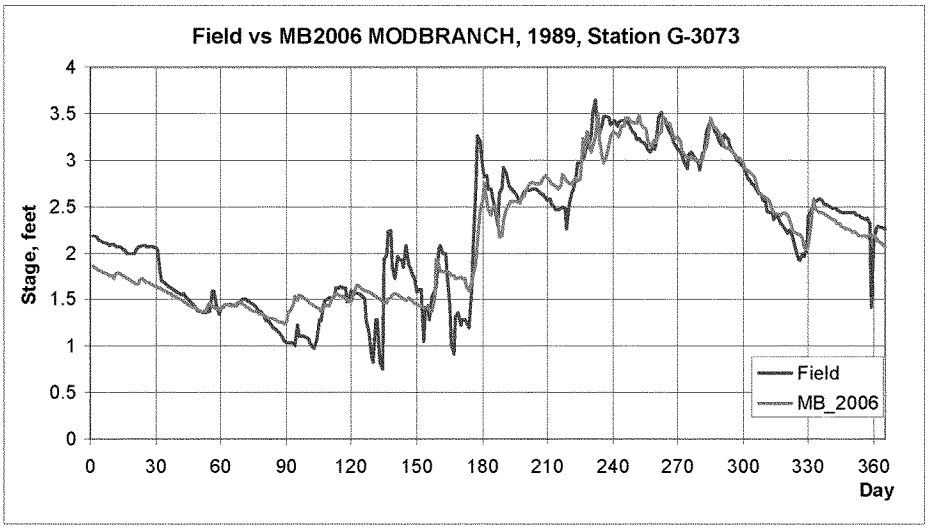
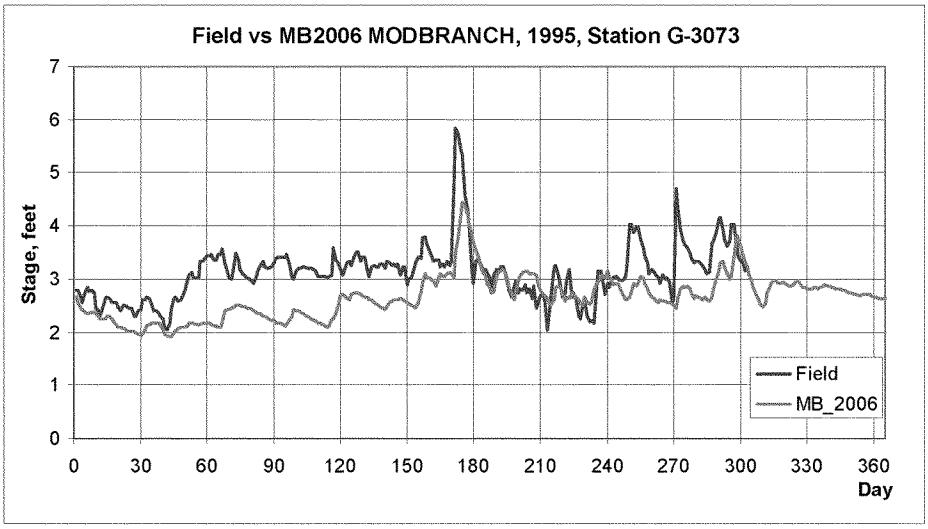
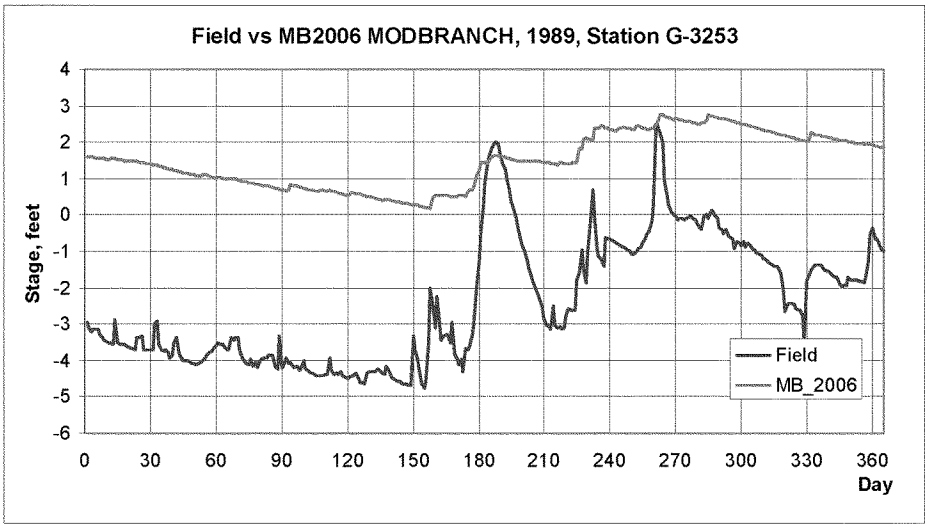
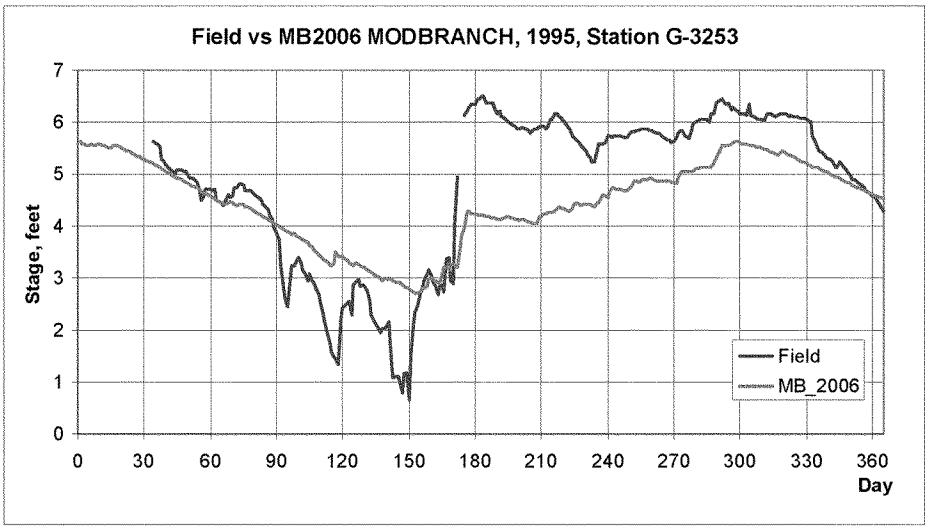

Field vs MB2006 MODBRANCH, 1989, Station G-3073
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
0
30
60
90
120
150
180
210
240
270
300
330
360

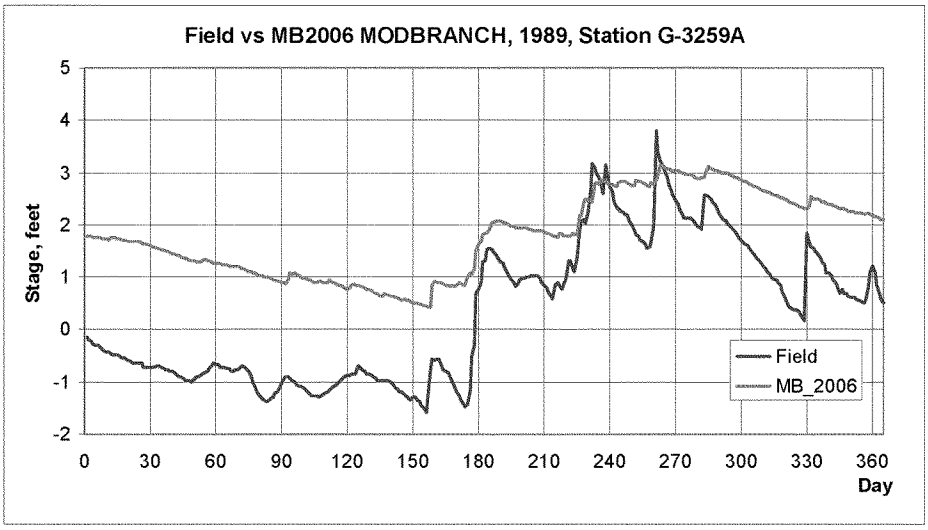

Field vs MB2006 MODBRANCH, 1995, Station G-3073
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360

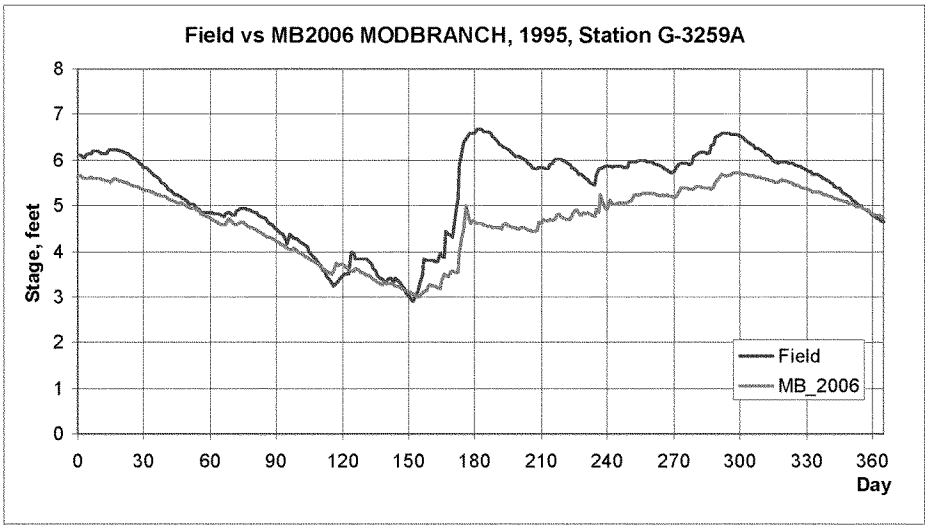
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3253
Stage, feet
4
3
2
1
0
-1
-2
-3
-4
-5
-6
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-3253
Stage, feet
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3259A
Stage, feet
5
4
3
2
1
0
-1
-2
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-3259A
Stage, feet
8
7
6
5
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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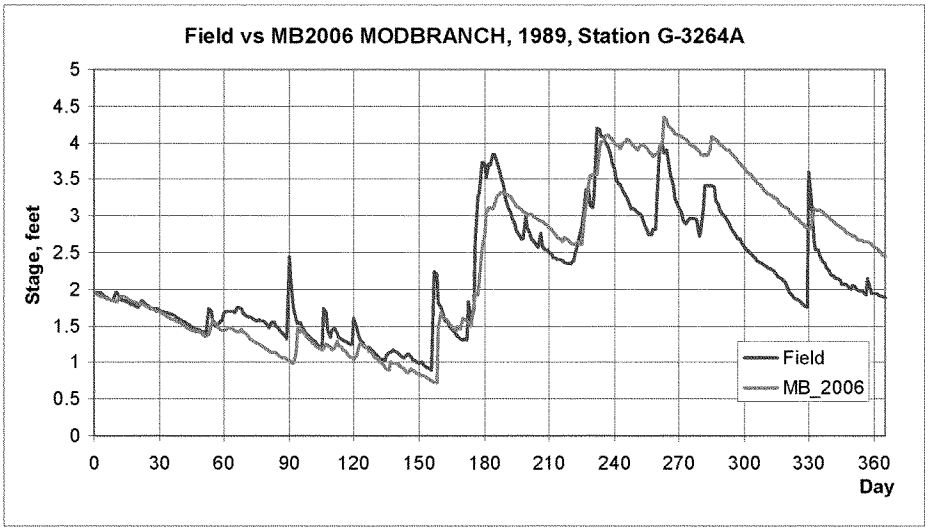
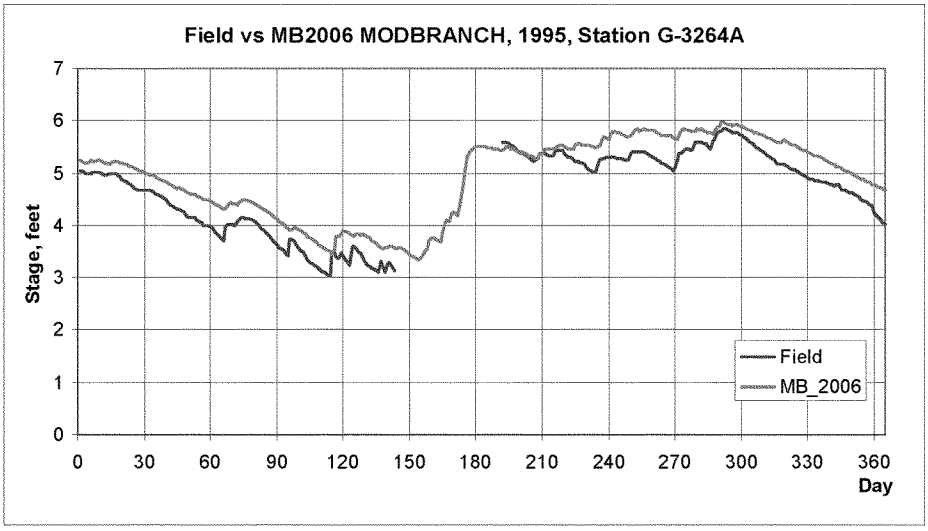
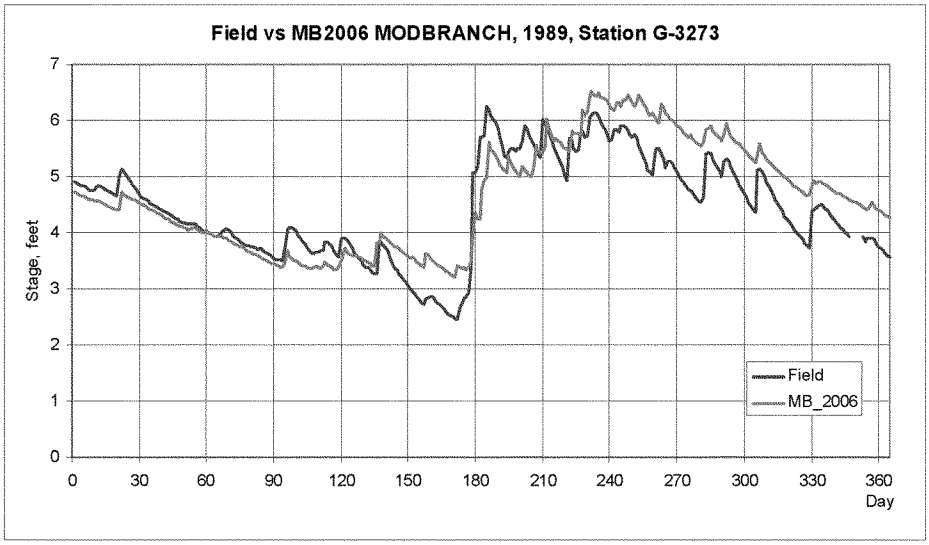
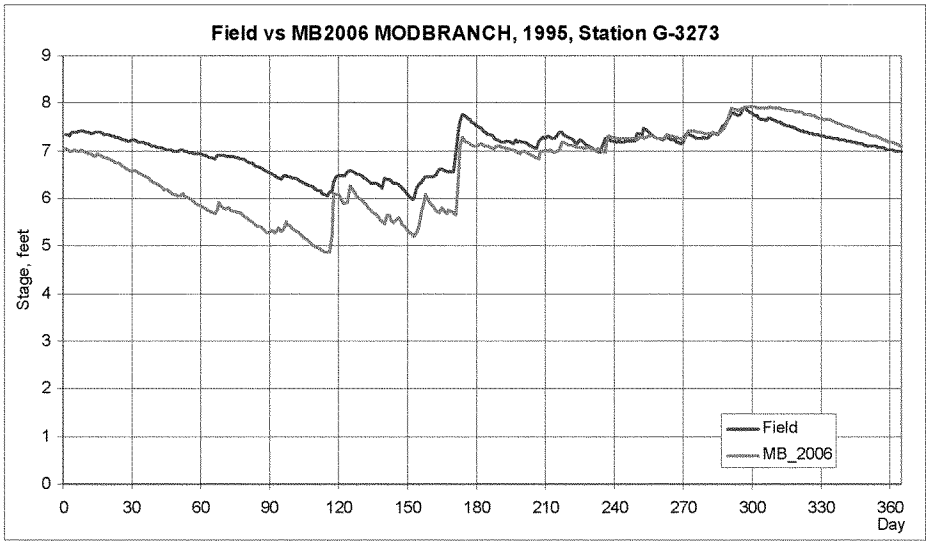

Field vs MB2006 MODBRANCH, 1989, Station G-3264A
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
30
60
90
120
150
180
210
240
270
300
330
360

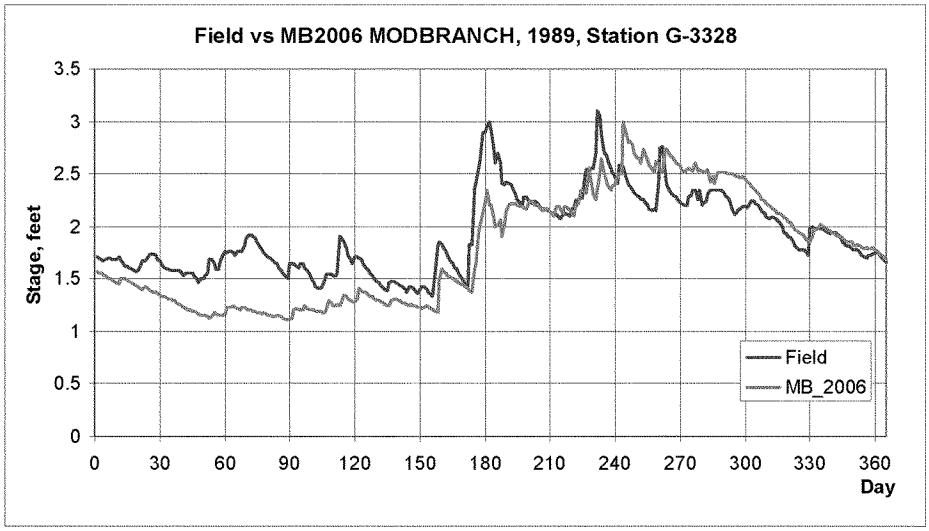

Field vs MB2006 MODBRANCH, 1995, Station G-3264A
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360

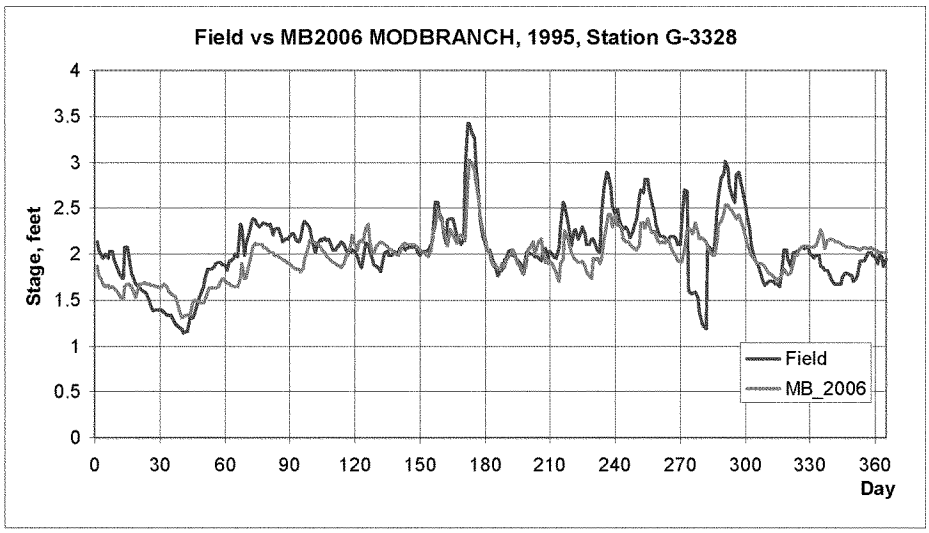
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3273
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360

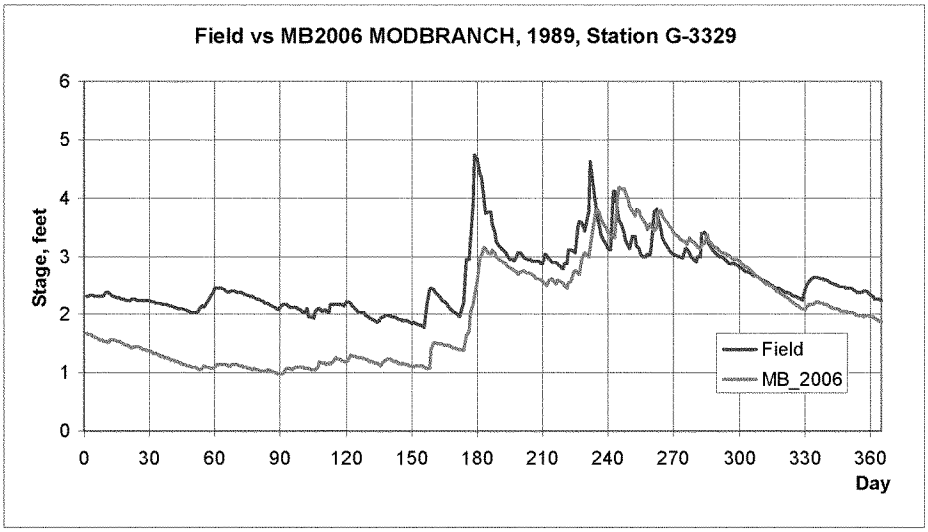

Field vs MB2006 MODBRANCH, 1995, Station G-3273
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
9
0
30
60
90
120
150
180
210
240
270
300
330
360

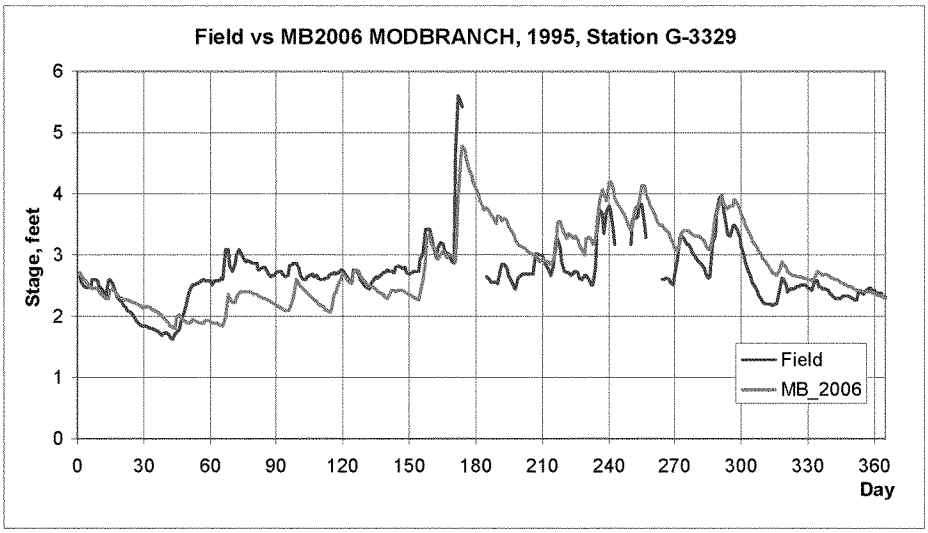
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3328
Stage, feet
3.5
3
2.5
2
1.5
1
0.5
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-3328
Stage, feet
4
3.5
3
2.5
2
1.5
1
0.5
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3329
Stage, feet
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-3329
Stage, feet
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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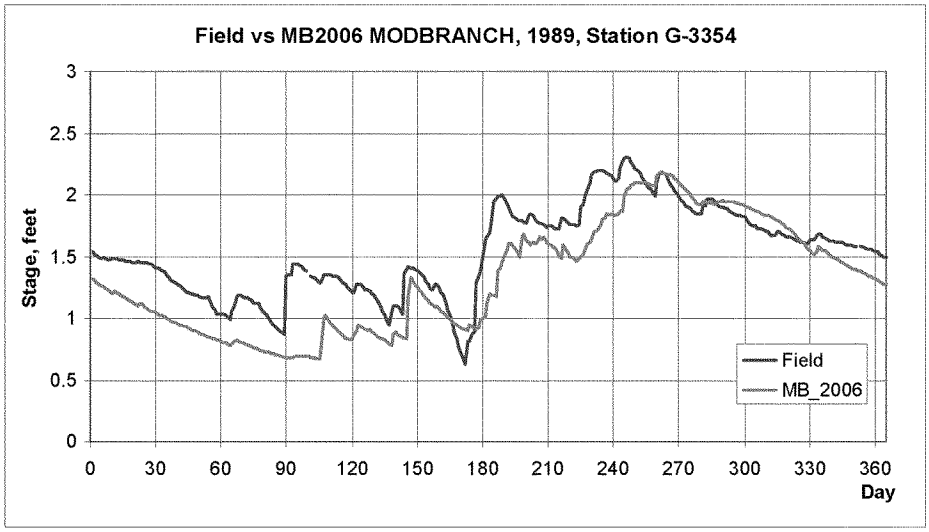
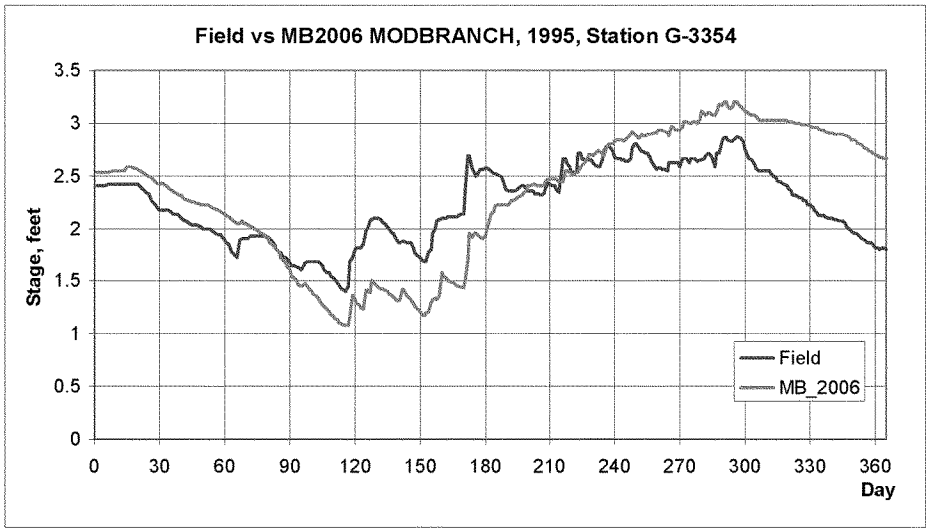

Field vs MB2006 MODBRANCH, 1989, Station G-3354
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-3354
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
0
30
60
90
120
150
180
210
240
270
300
330
360

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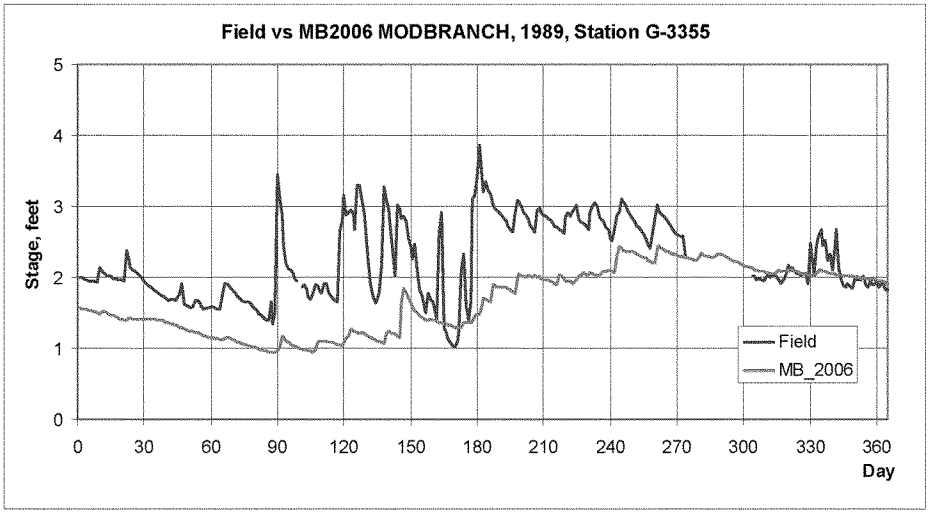
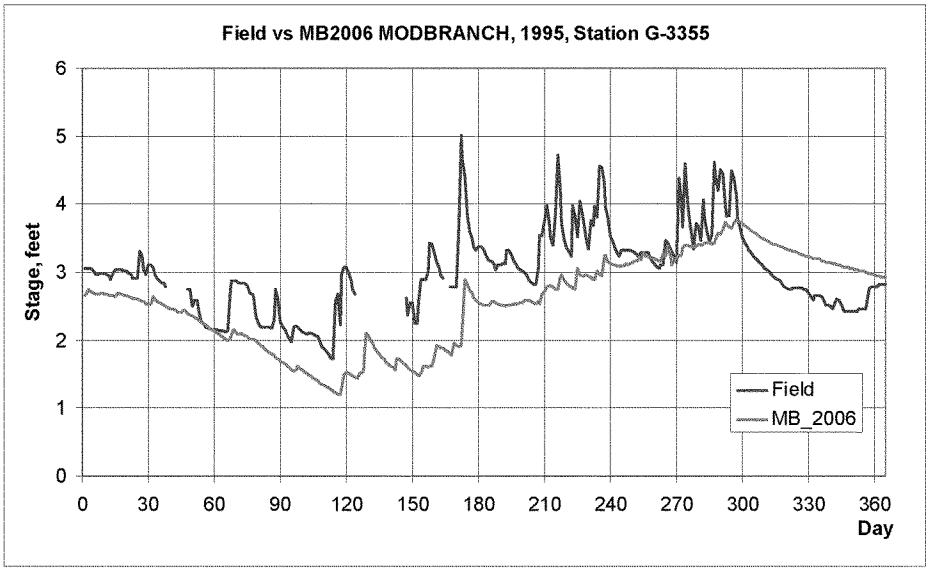
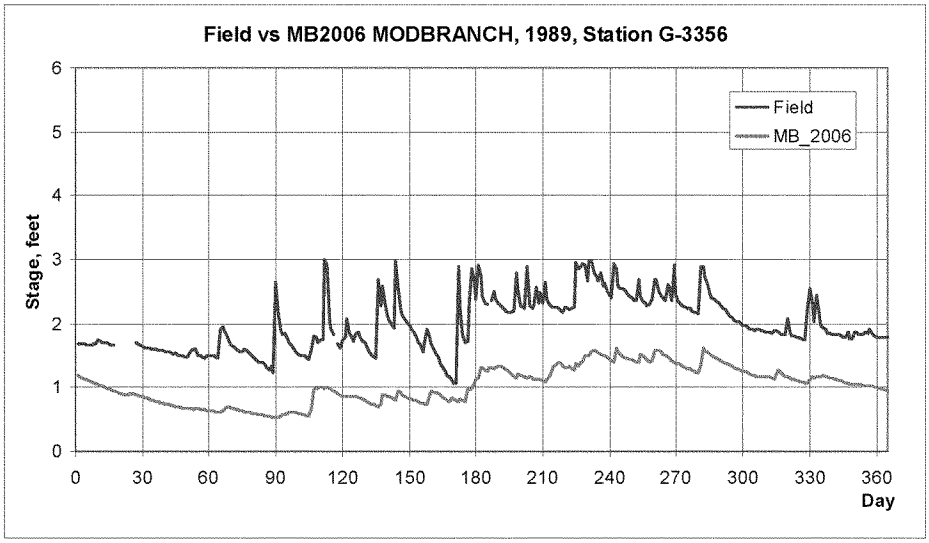
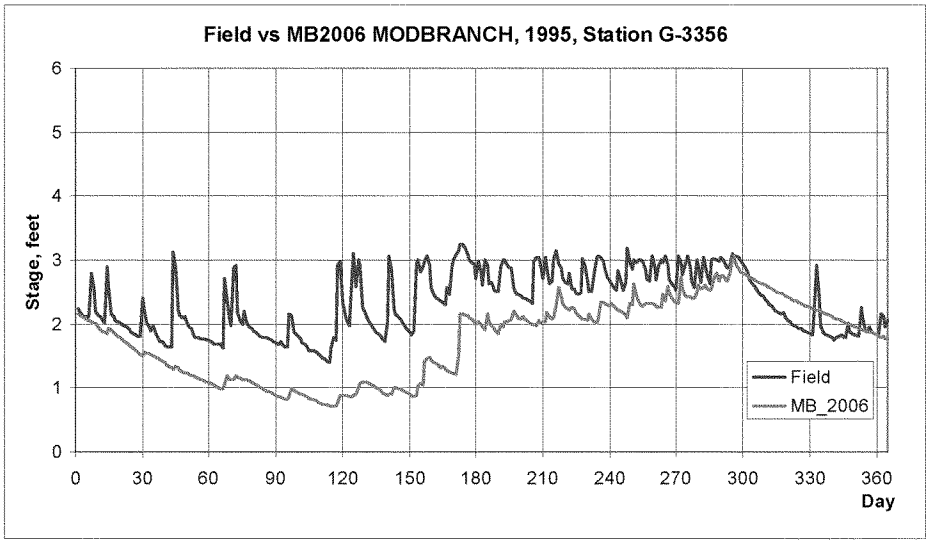

Field vs MB2006 MODBRANCH, 1989, Station G-3355
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-3355
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3356
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-3356
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360

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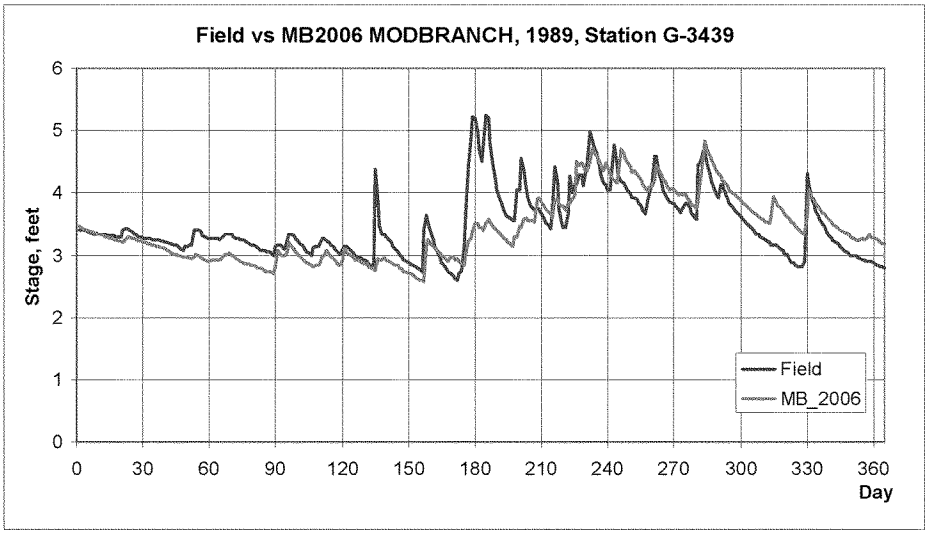
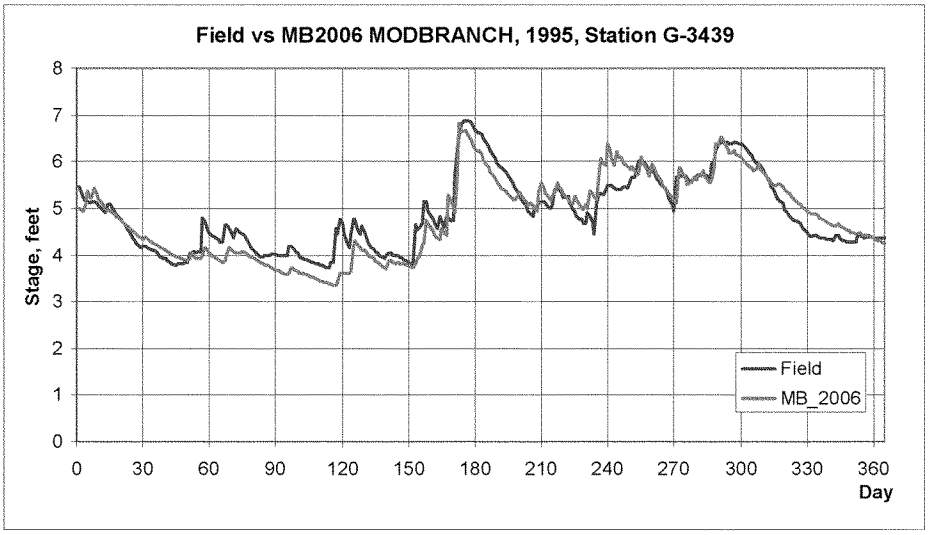
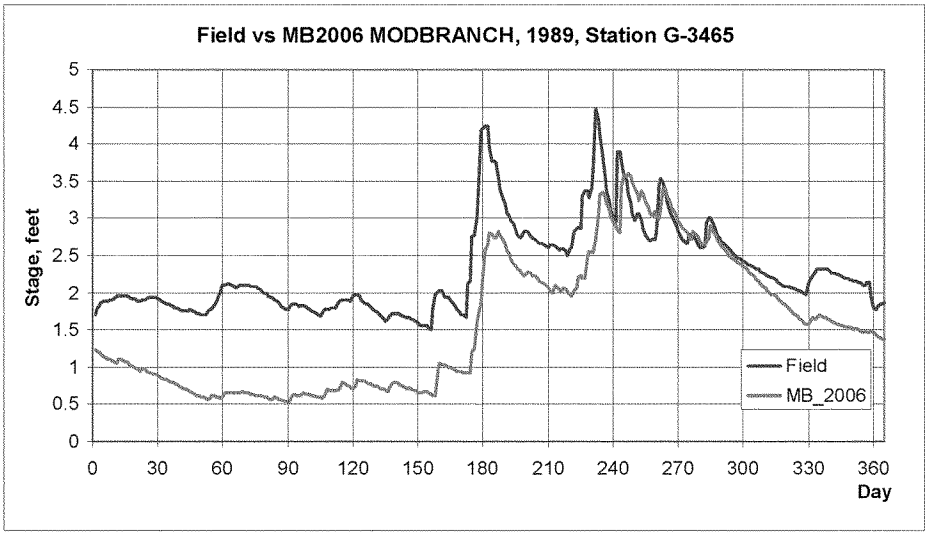
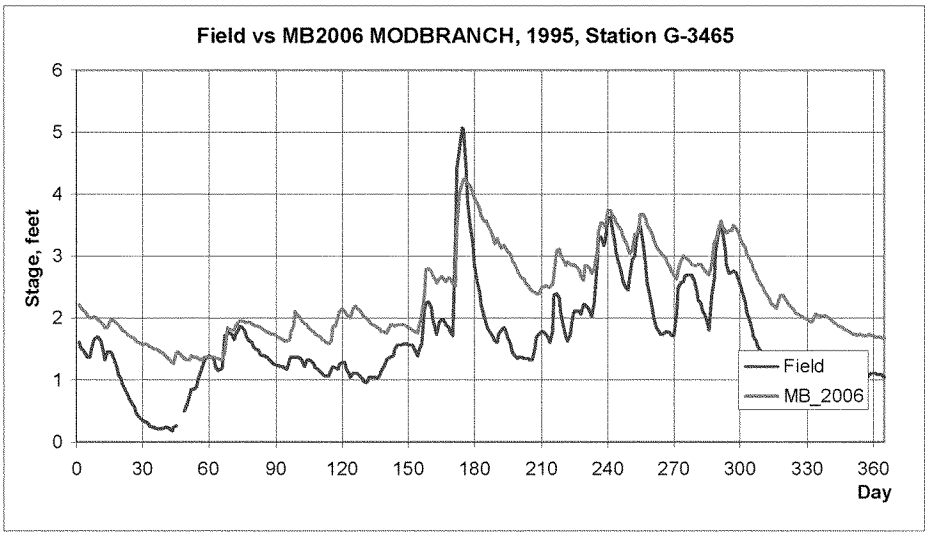

Field vs MB2006 MODBRANCH, 1989, Station G-3439
Stage, feet
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

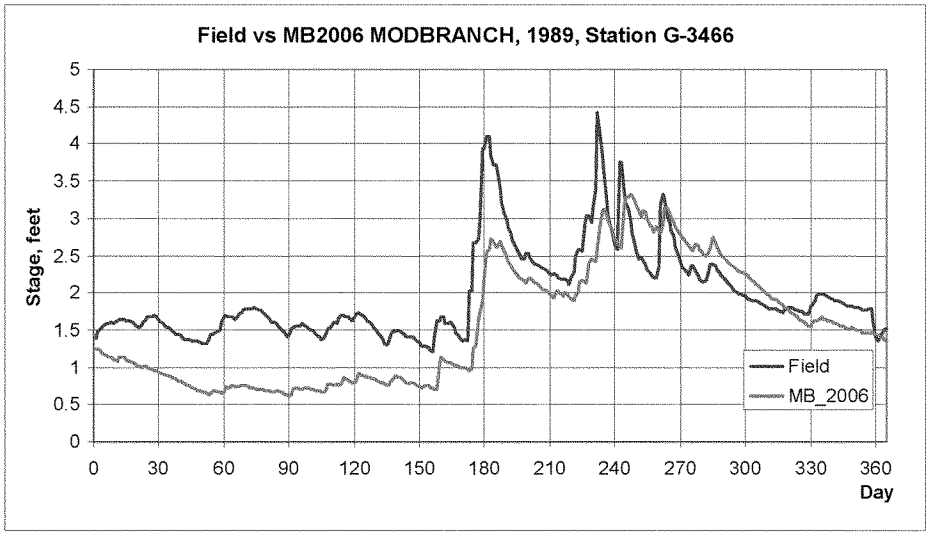

Field vs MB2006 MODBRANCH, 1995, Station G-3439
Stage, feet
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

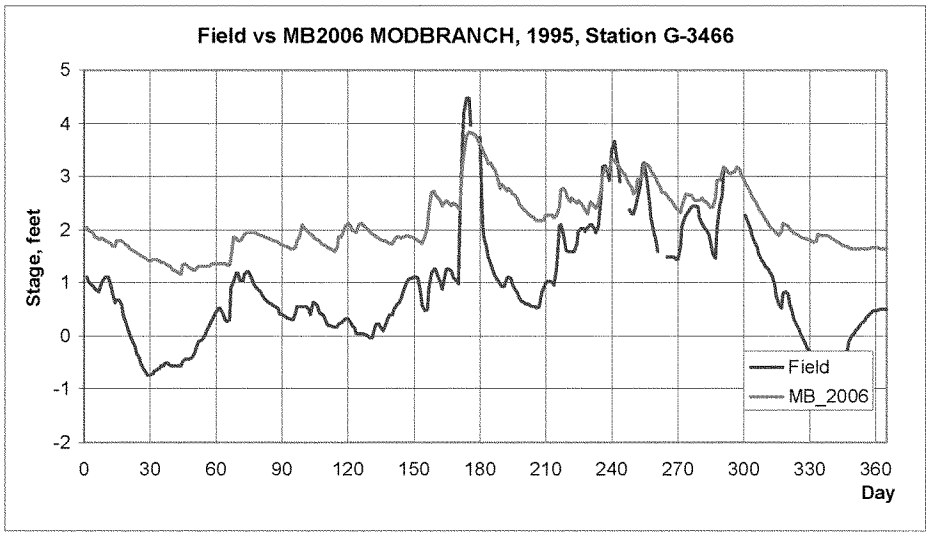
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3465
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-3465
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-3466
Stage, feet
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-3466
Stage, feet
5
4
3
2
1
0
-1
-2
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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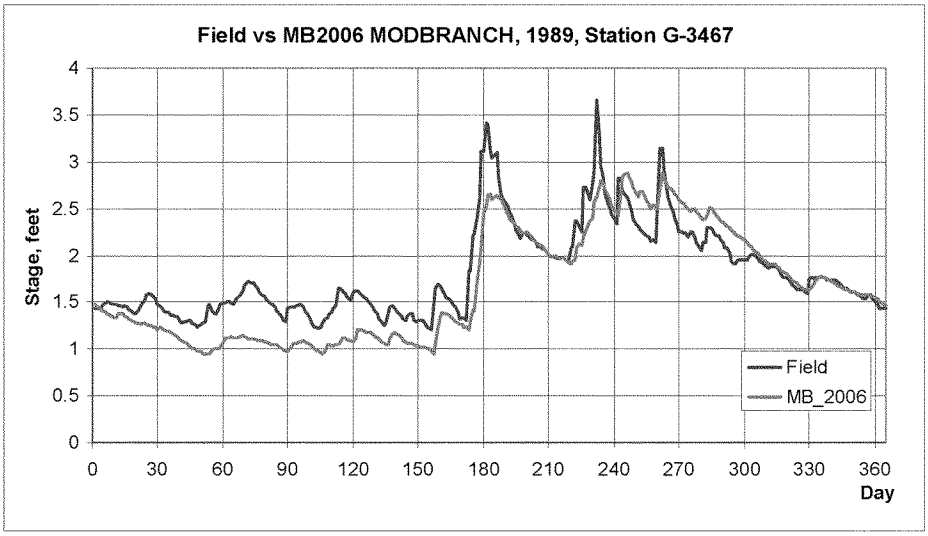
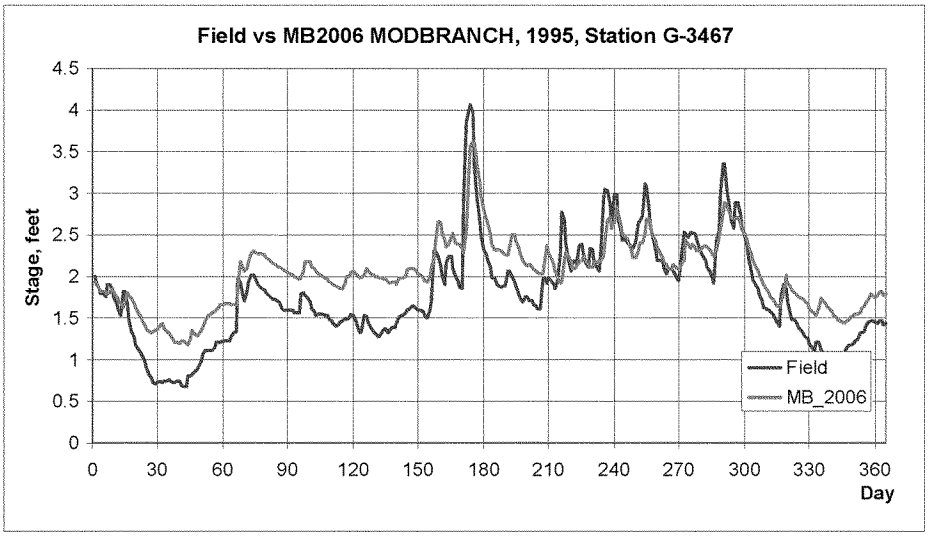
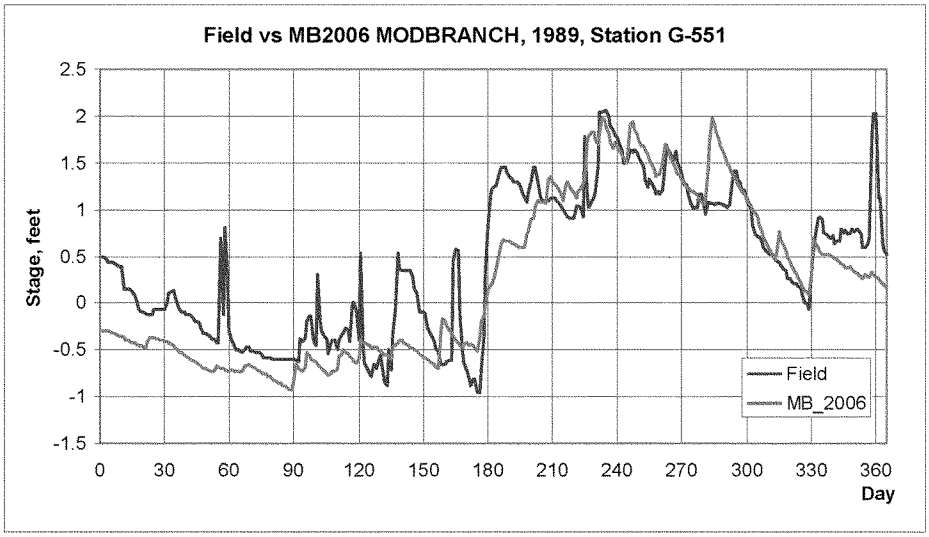
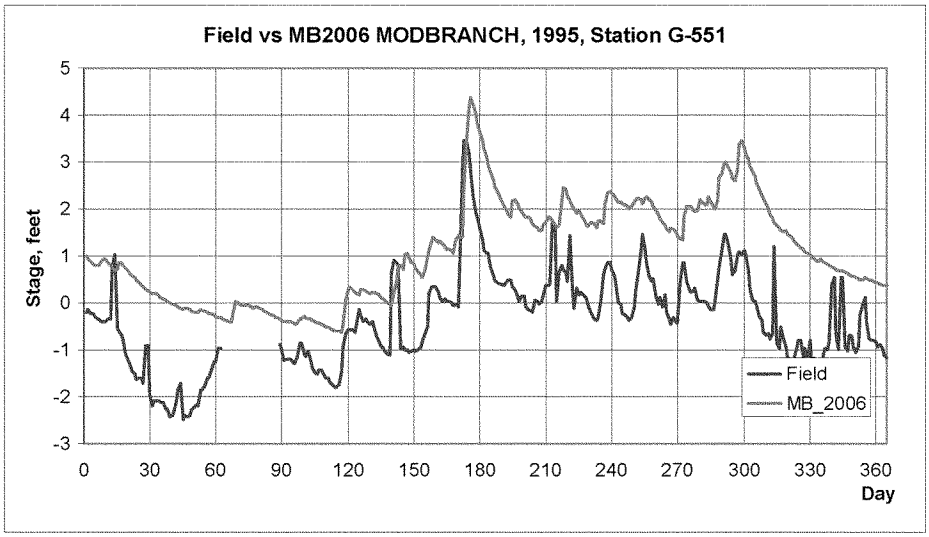

Field vs MB2006 MODBRANCH, 1989, Station G-3467
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-3467
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-551
Stage, feet
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-551
Stage, feet
5
4
3
2
1
0
-1
-2
-3
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

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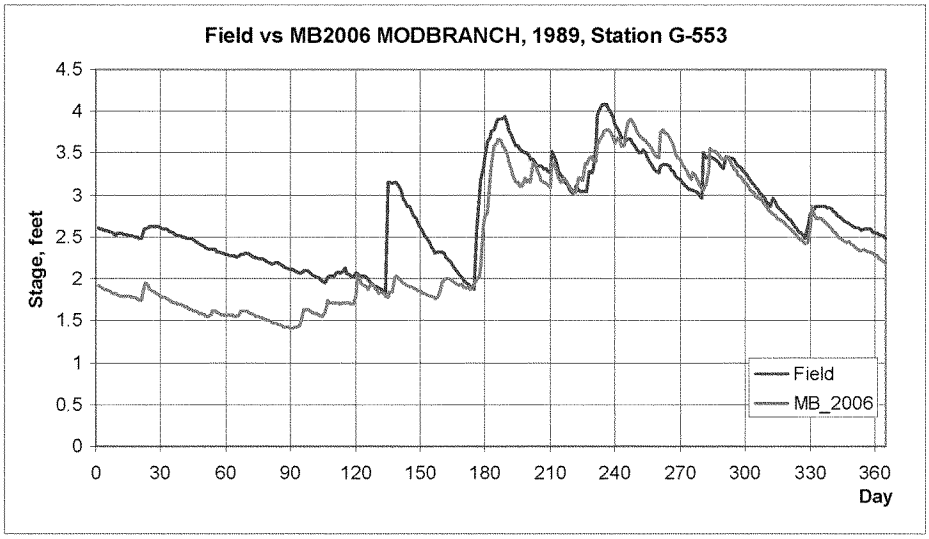
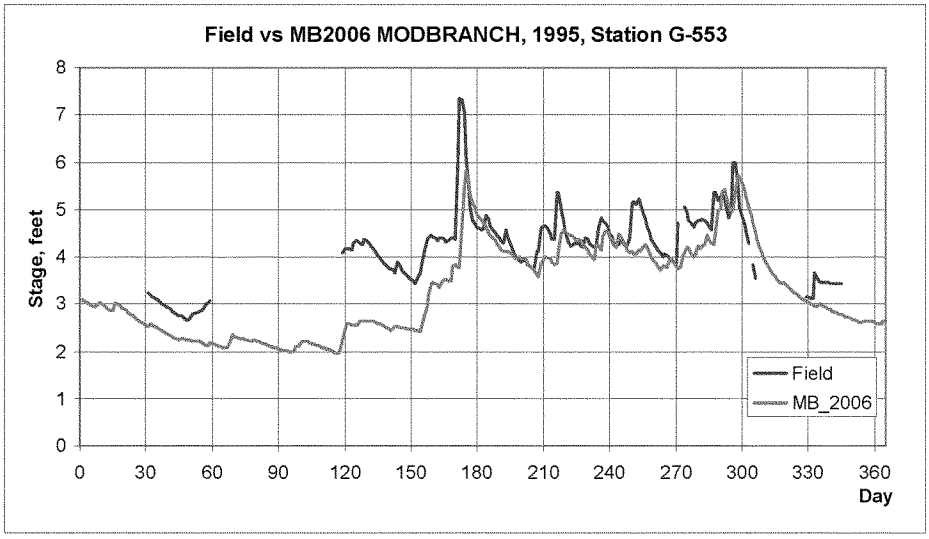
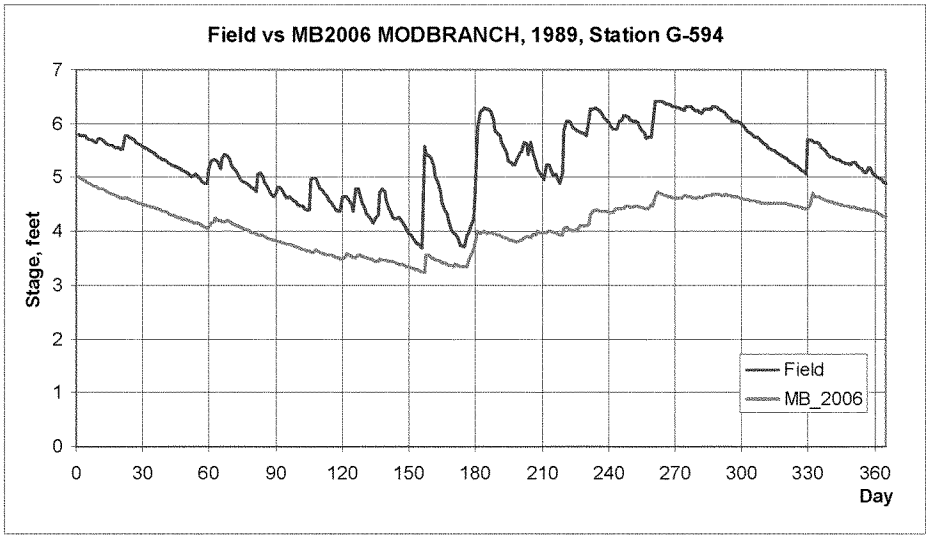
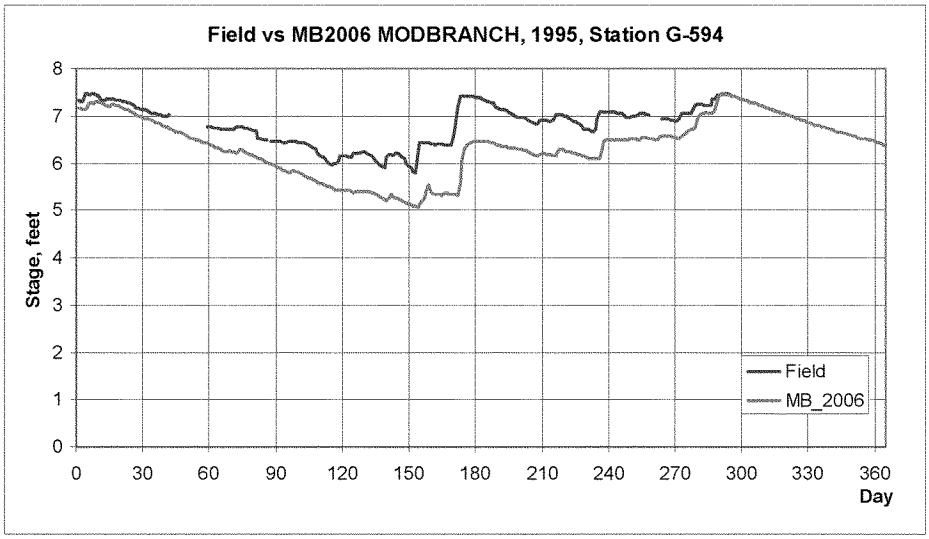

Field vs MB2006 MODBRANCH, 1989, Station G-553
Stage, feet
Day
Field
MB_2006
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-553
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-594
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-594
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
0
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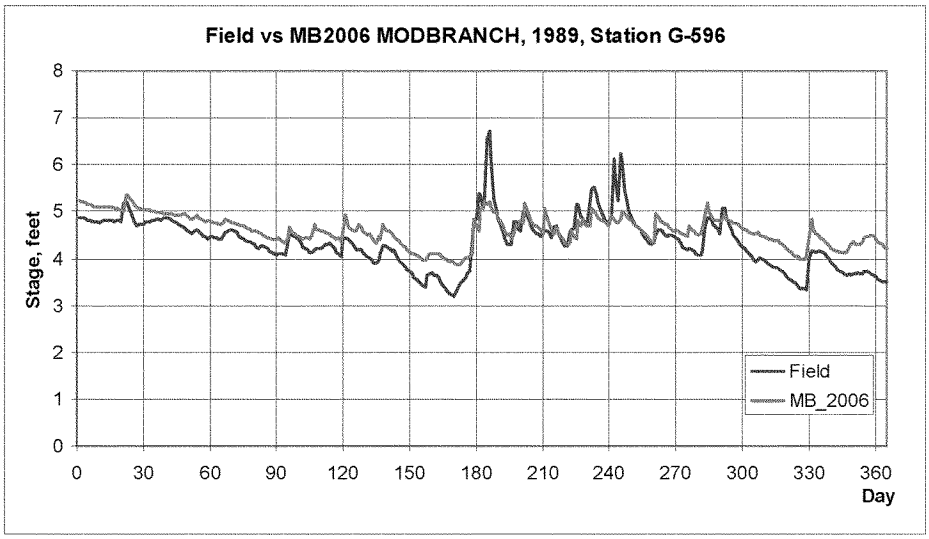
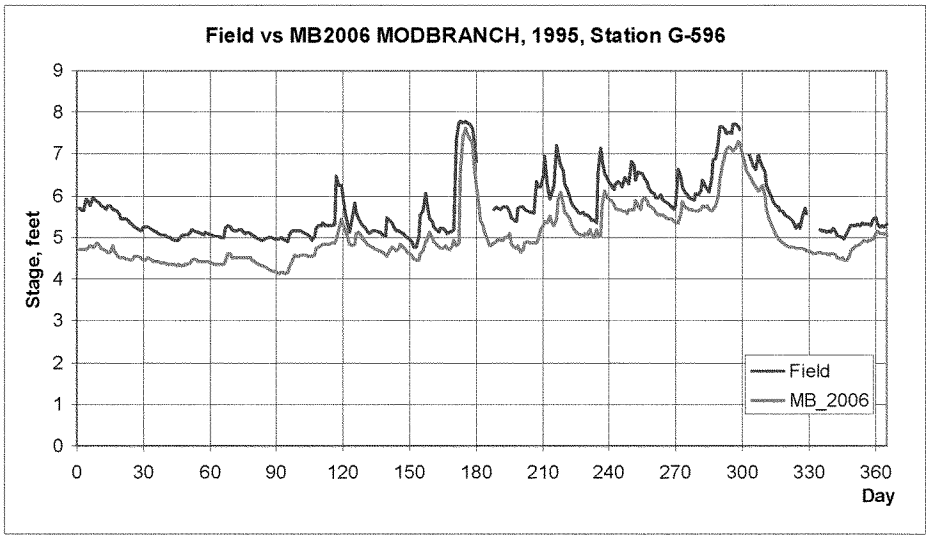
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-596
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-596
Stage, feet
Day
Field
MB_2006
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2
3
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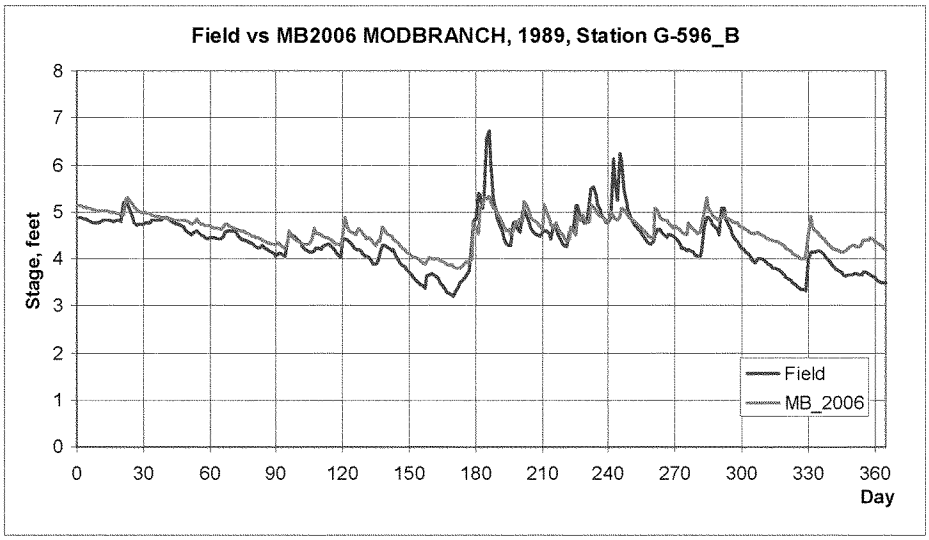
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-596_B
Stage, feet
Day
Field
MB_2006
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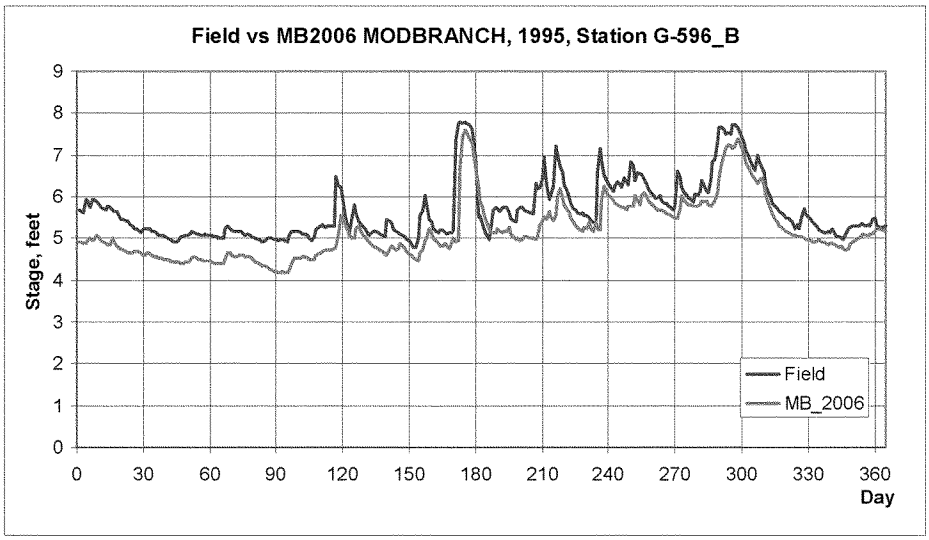
Field vs MB2006 MODBRANCH, 1995, Station G-596_B
Stage, feet
Day
Field
MB_2006
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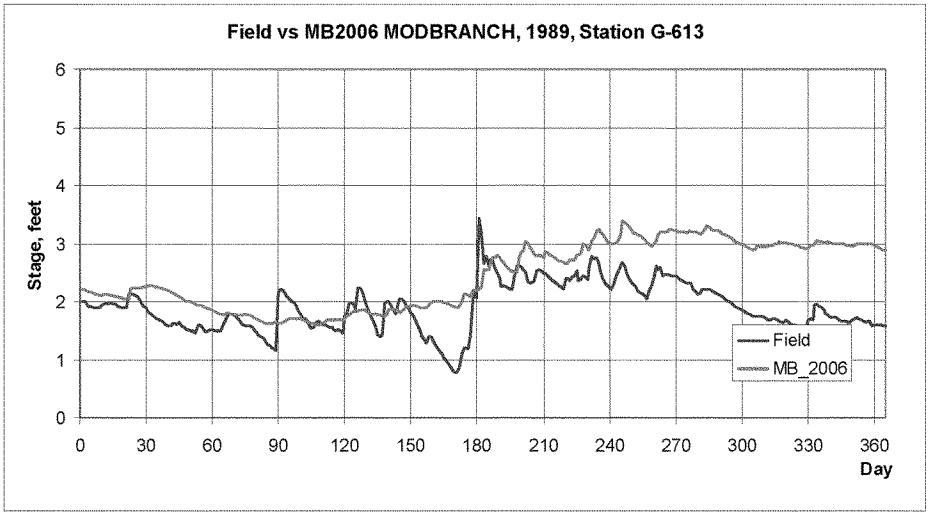
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-613
Stage, feet
Day
Field
MB_2006
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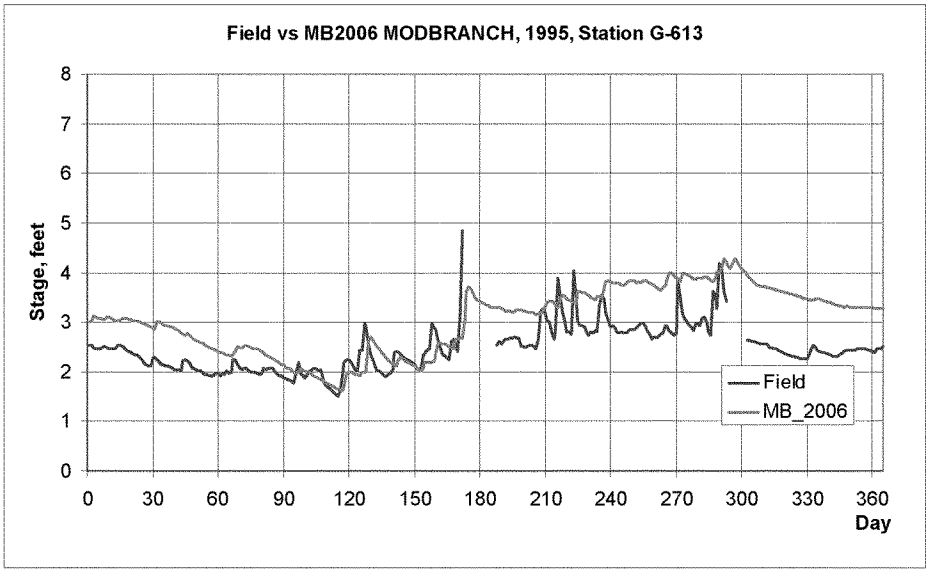
Field vs MB2006 MODBRANCH, 1995, Station G-613
Stage, feet
Day
Field
MB_2006
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2
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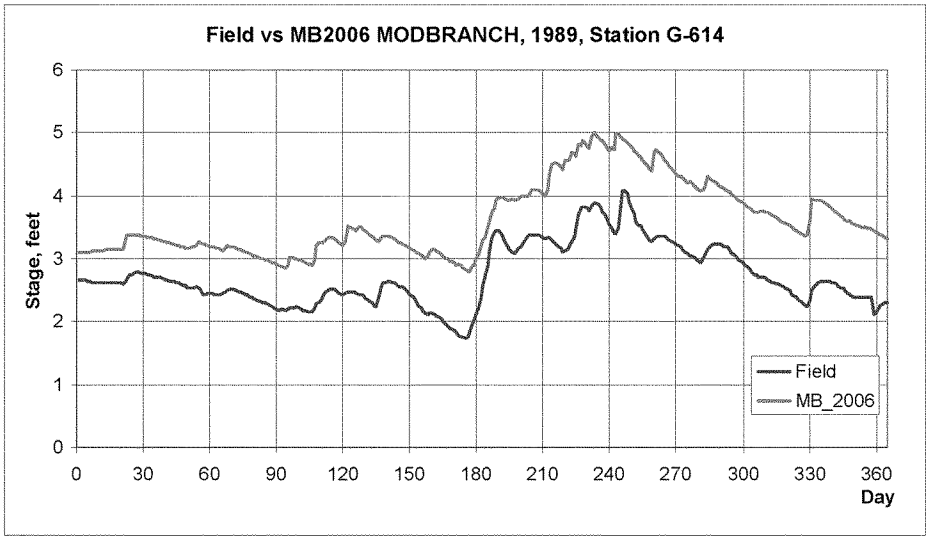
Field vs MB2006 MODBRANCH, 1989, Station G-614
Stage, feet
Day
Field
MB_2006
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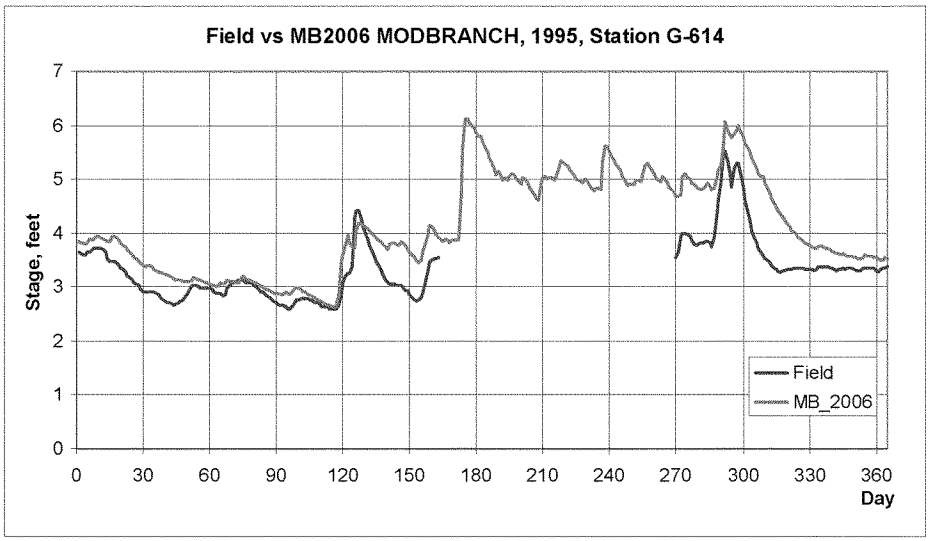
Field vs MB2006 MODBRANCH, 1995, Station G-614
Stage, feet
Day
Field
MB_2006
0
1
2
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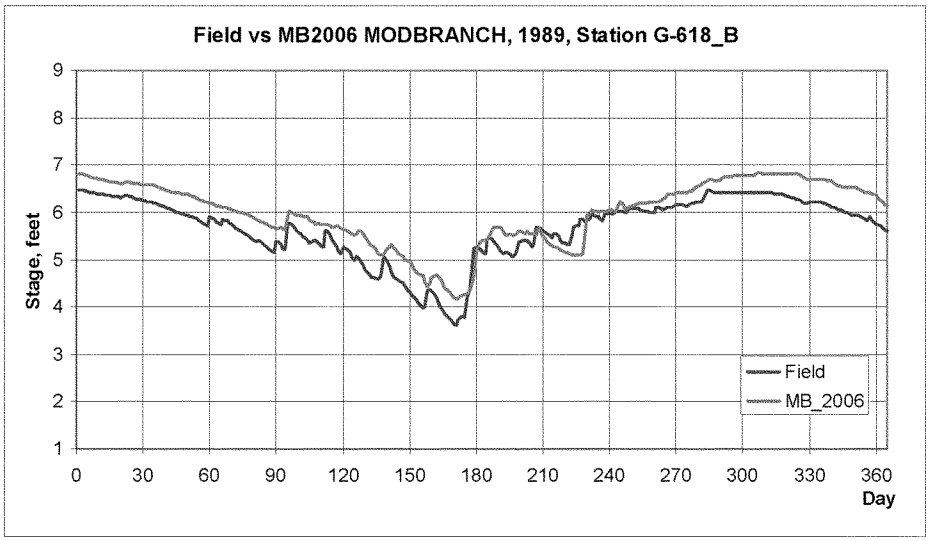
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-618_B
Stage, feet
9
8
7
6
5
4
3
2
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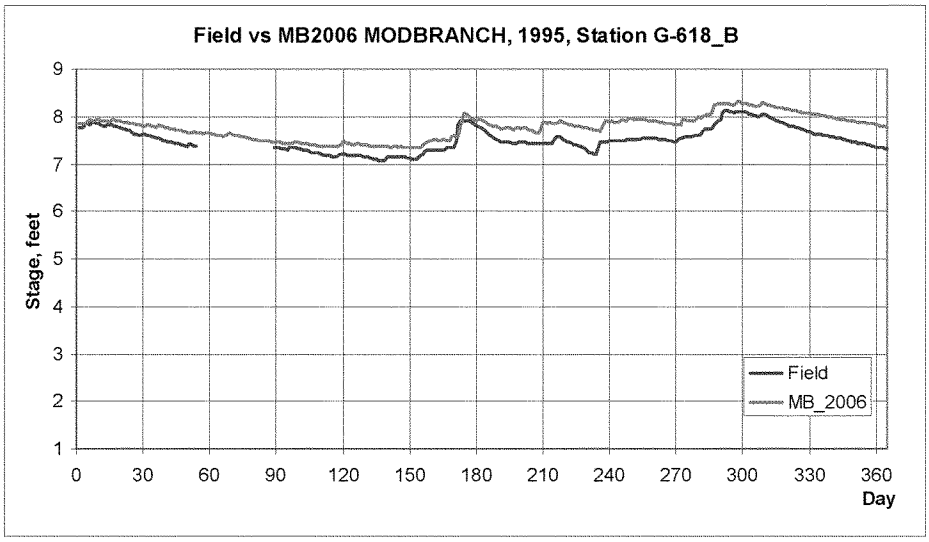
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-618_B
Stage, feet
9
8
7
6
5
4
3
2
1
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150
180
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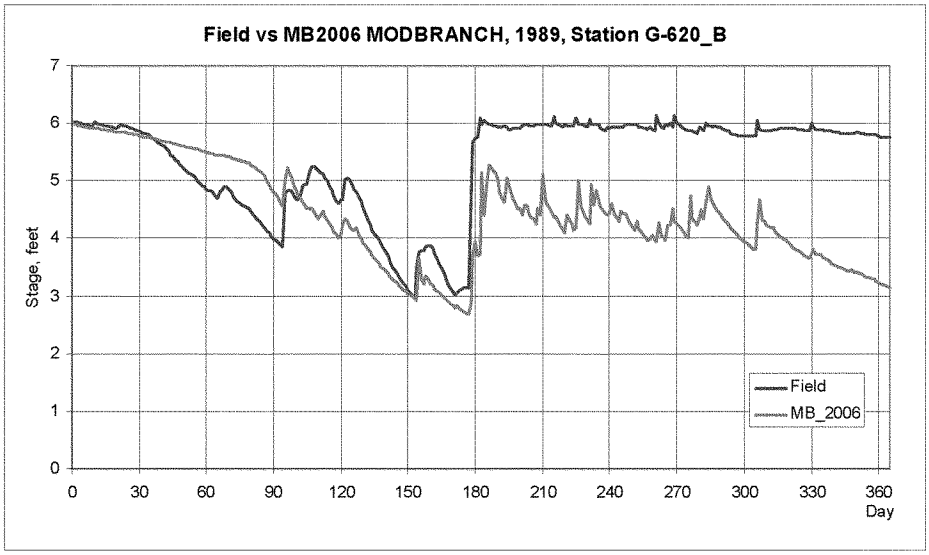
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-620_B
Stage, feet
Day
Field
MB_2006
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5
6
7
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150
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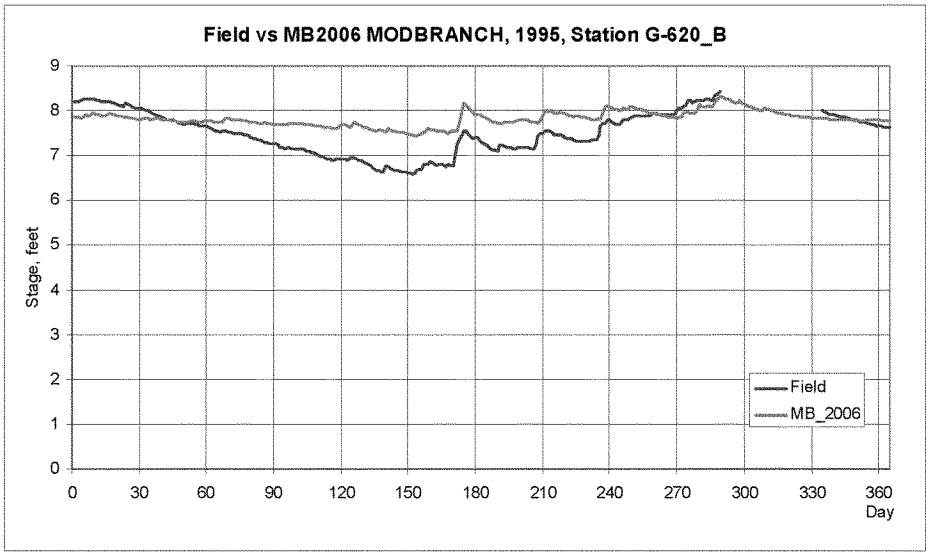
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-620_B
Stage, feet
Day
Field
MB_2006
0
1
2
3
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0
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60
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120
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180
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240
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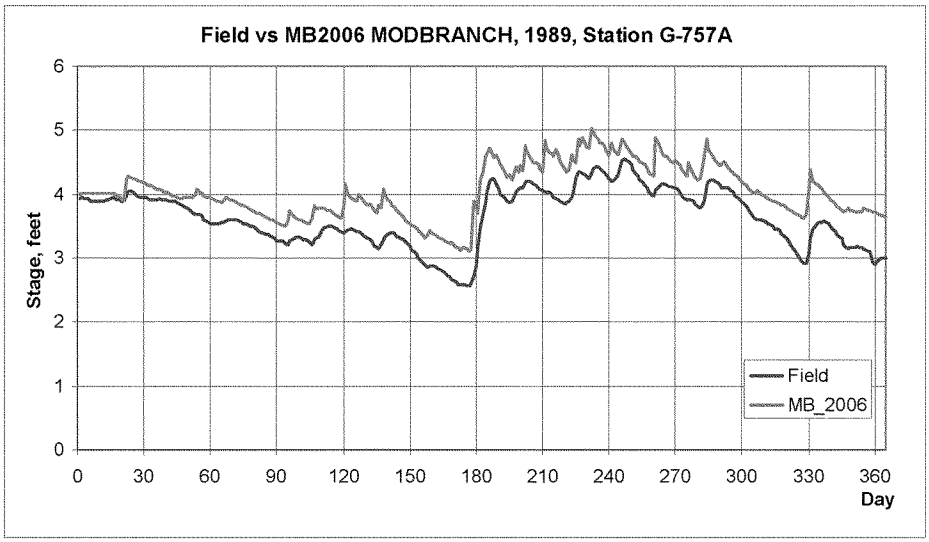
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-757A
Stage, feet
Day
Field
MB_2006
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1
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5
6
0
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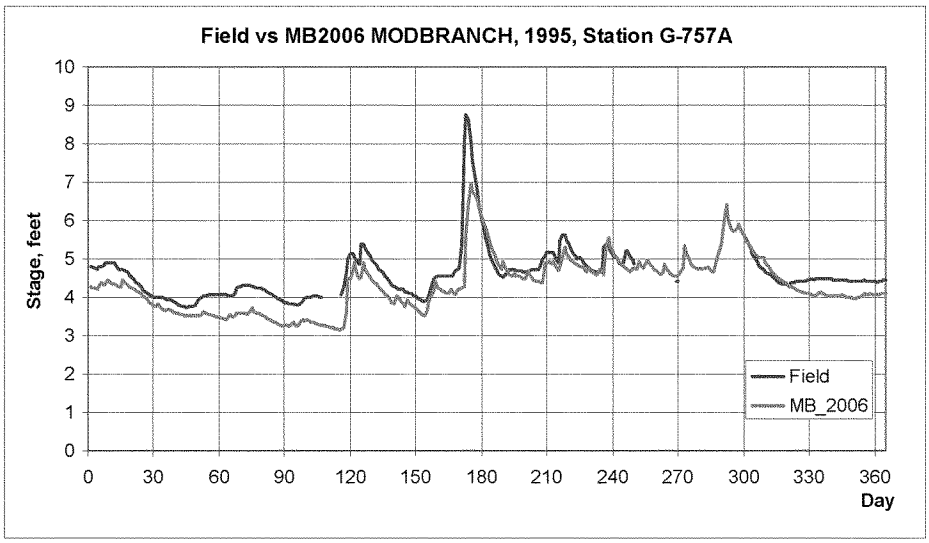
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-757A
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
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60
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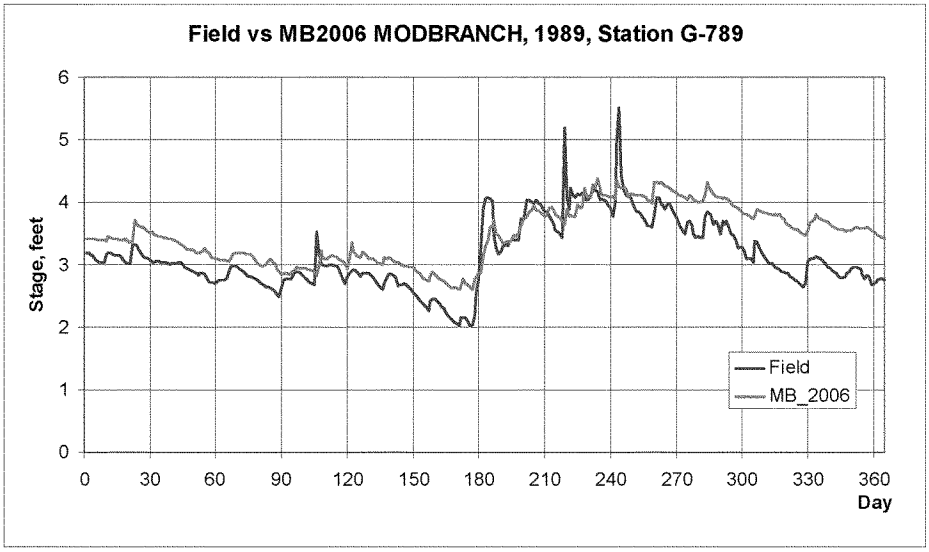
Field vs MB2006 MODBRANCH, 1989, Station G-789
Stage, feet
Day
Field
MB_2006
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1
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3
4
5
6
0
30
60
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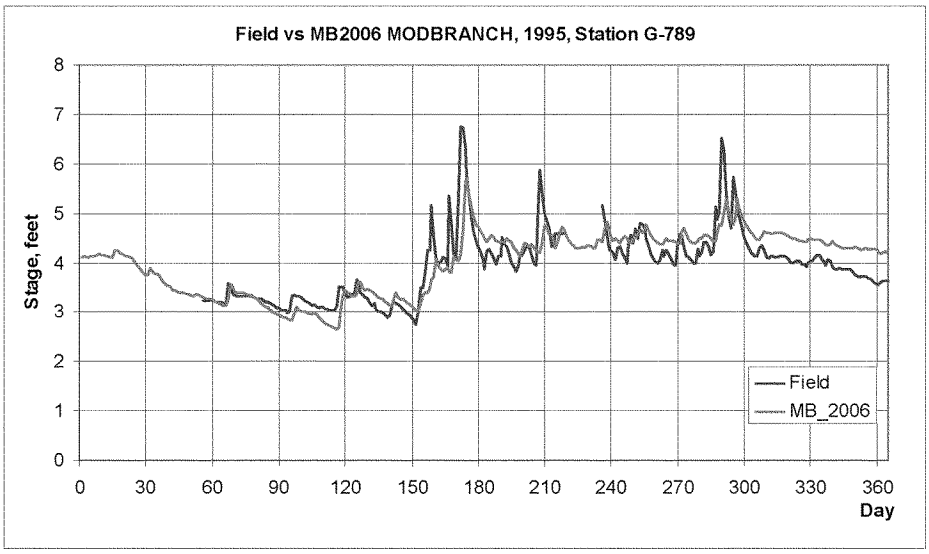
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-789
Stage, feet
Day
Field
MB_2006
0
1
2
3
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5
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8
0
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60
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120
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210
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300
330
360

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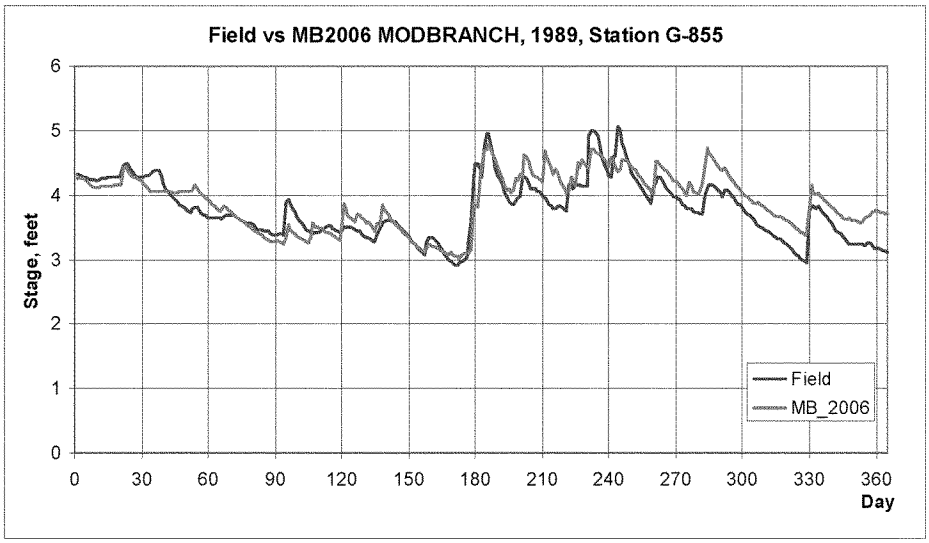
Field vs MB2006 MODBRANCH, 1989, Station G-855
Stage, feet
Day
Field
MB_2006
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3
4
5
6
0
30
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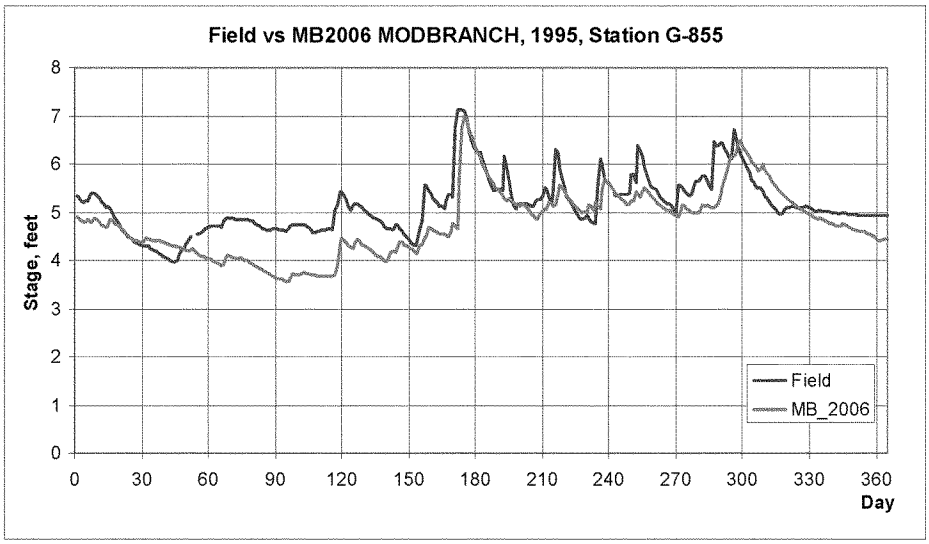
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-855
Stage, feet
Day
Field
MB_2006
0
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2
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0
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120
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240
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300
330
360

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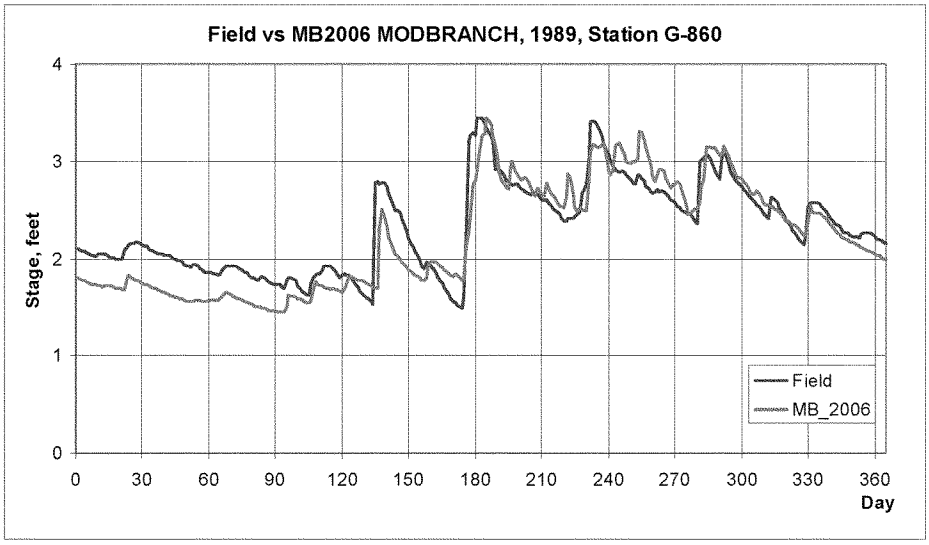
Field vs MB2006 MODBRANCH, 1989, Station G-860
Stage, feet
Day
Field
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3
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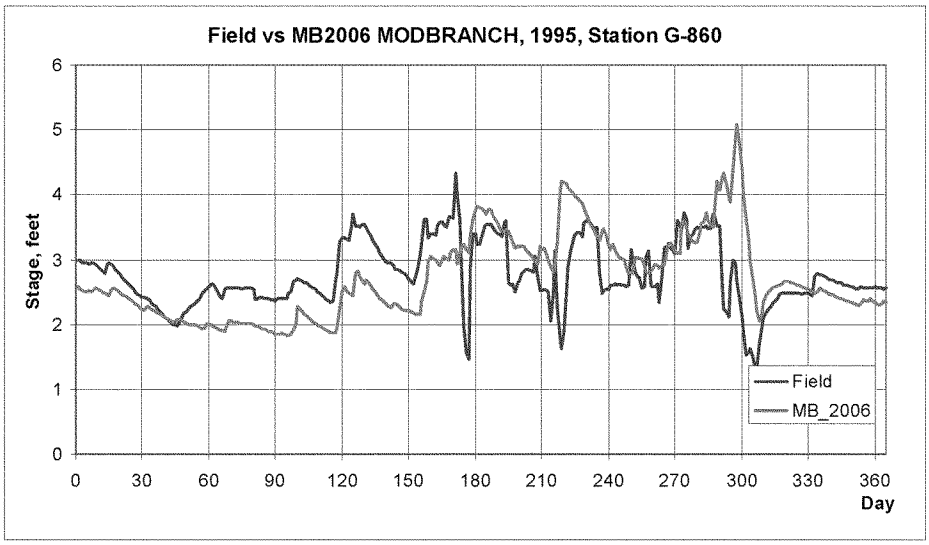
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station G-860
Stage, feet
Day
Field
MB_2006
0
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60
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120
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240
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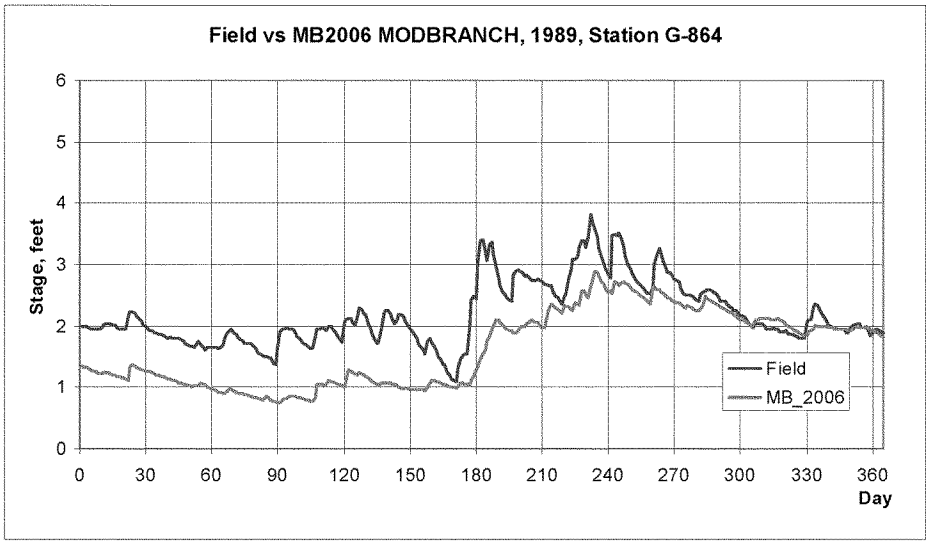
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station G-864
Stage, feet
0
1
2
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60
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240
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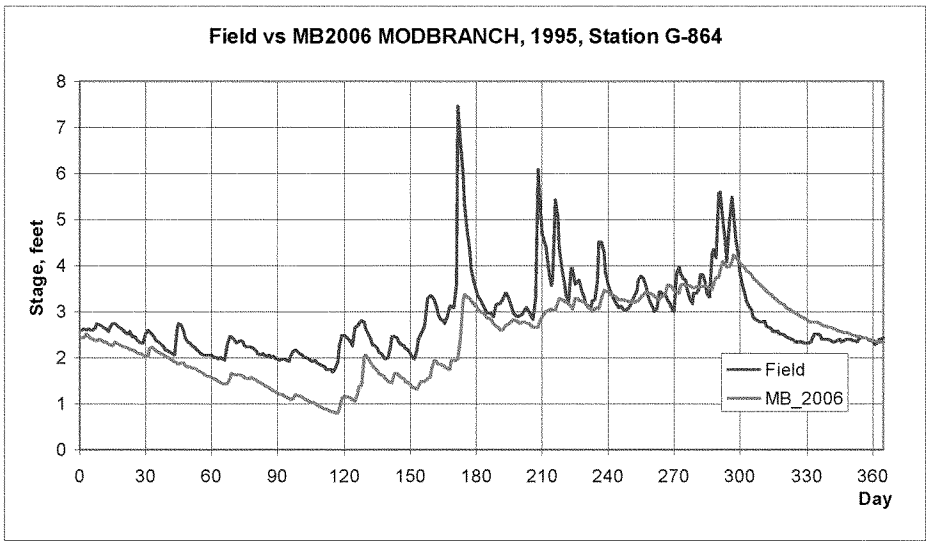
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-864
Stage, feet
0
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2
3
4
5
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300
330
360
Day
Field
MB_2006

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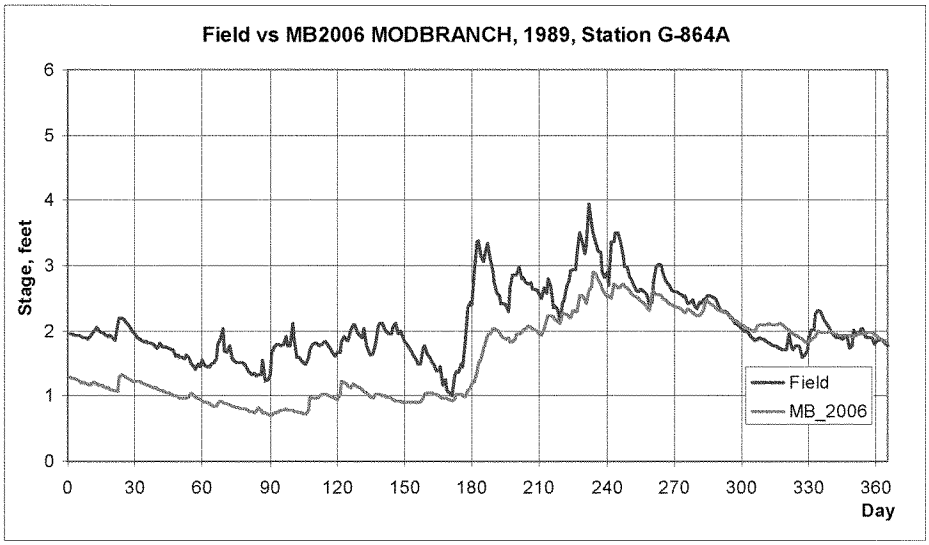
Field vs MB2006 MODBRANCH, 1989, Station G-864A
Stage, feet
Day
Field
MB_2006
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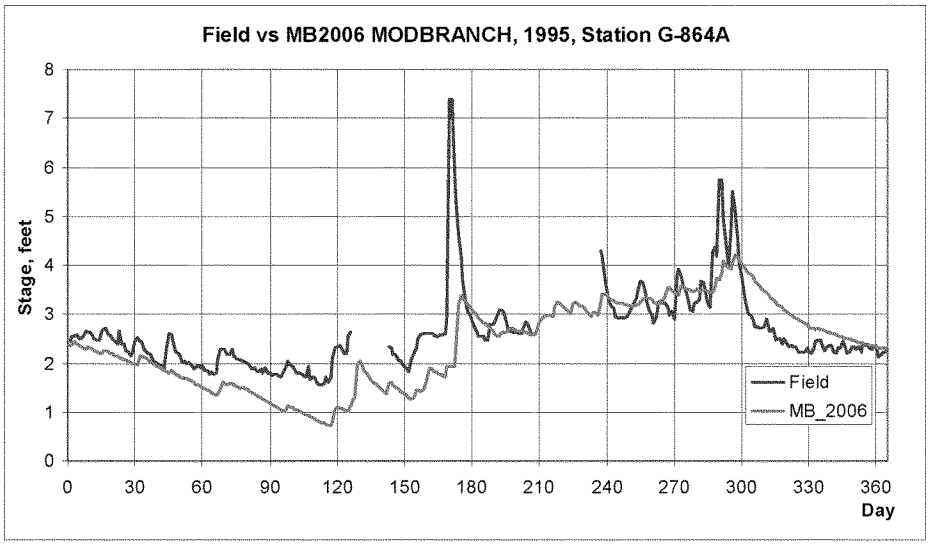
360


Field vs MB2006 MODBRANCH, 1995, Station G-864A
Stage, feet
Day
Field
MB_2006
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360

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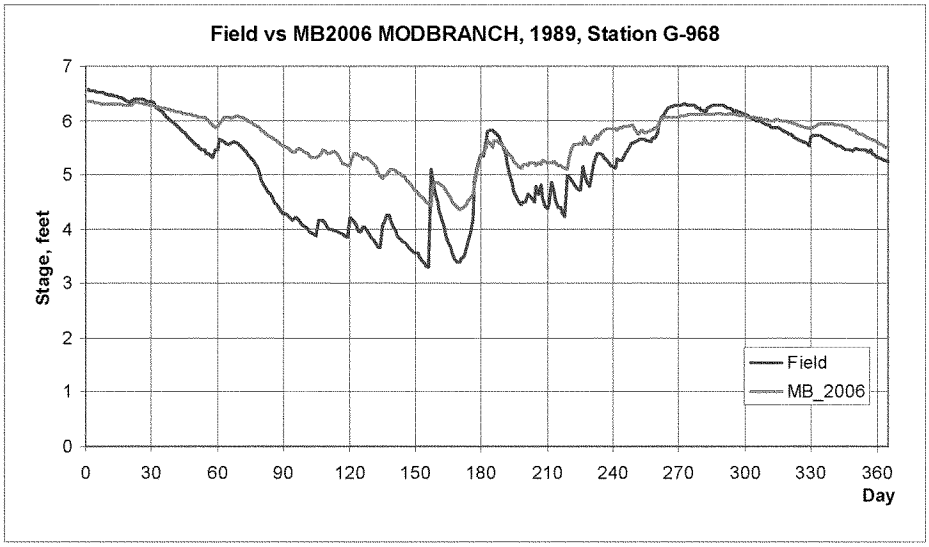
Field vs MB2006 MODBRANCH, 1989, Station G-968
Stage, feet
Day
Field
MB_2006
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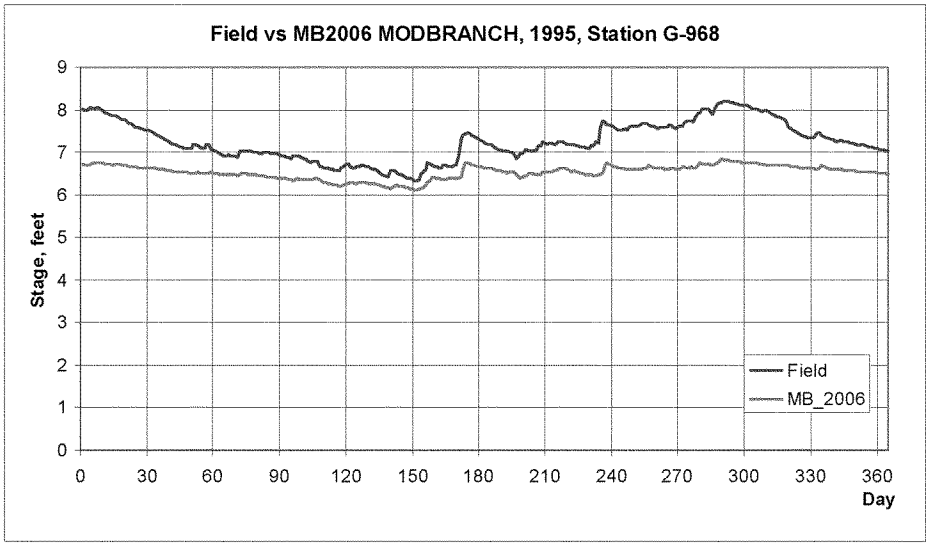
Field vs MB2006 MODBRANCH, 1995, Station G-968
Stage, feet
Day
Field
MB_2006
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3
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330
360

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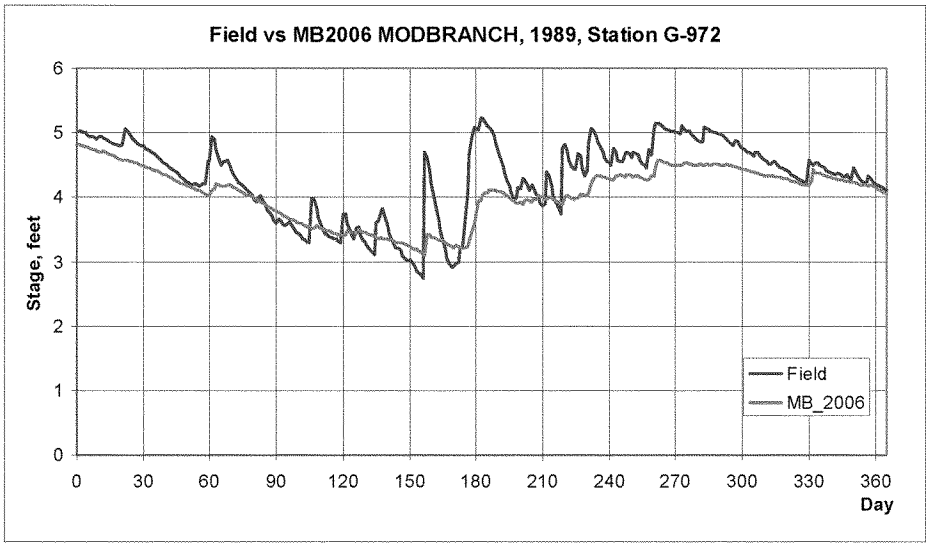
Field vs MB2006 MODBRANCH, 1989, Station G-972
Stage, feet
0
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2
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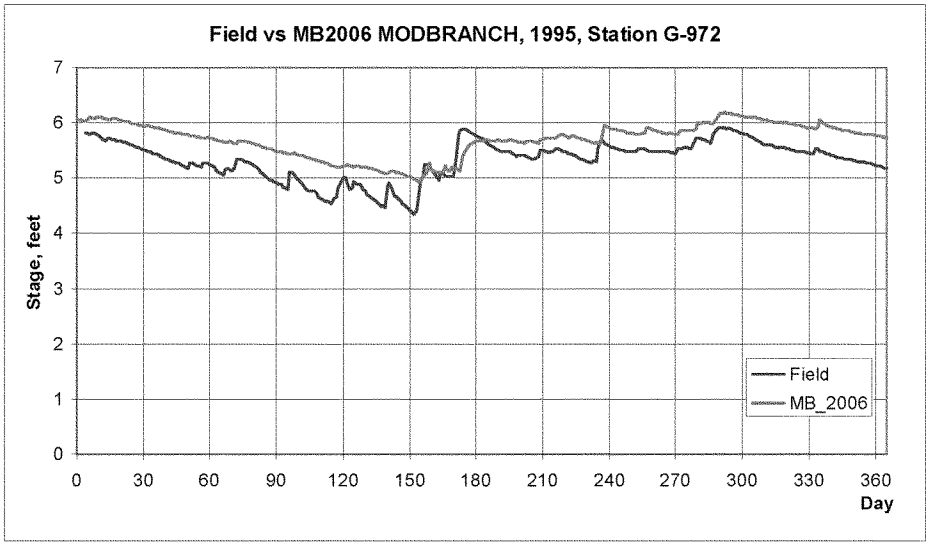
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station G-972
Stage, feet
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330
360
Day
Field
MB_2006

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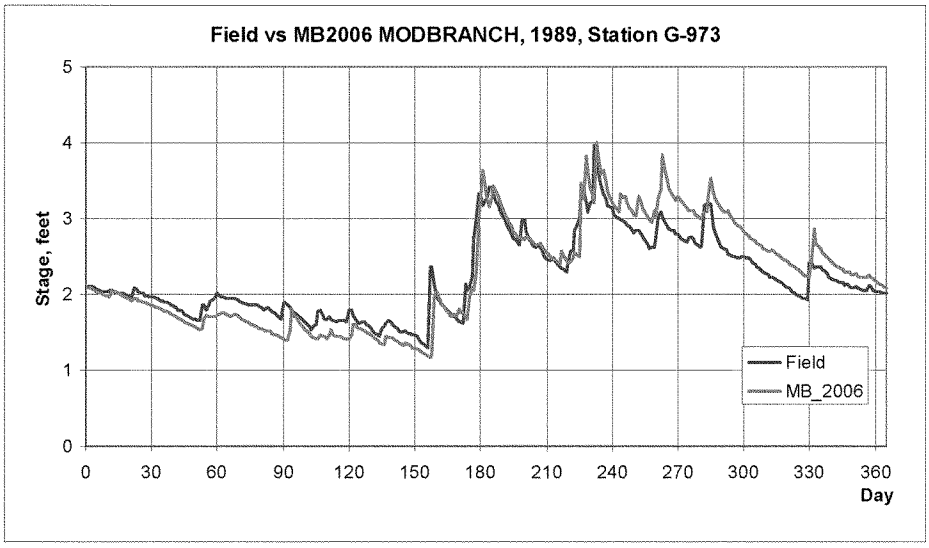
Field vs MB2006 MODBRANCH, 1989, Station G-973
Stage, feet
Day
Field
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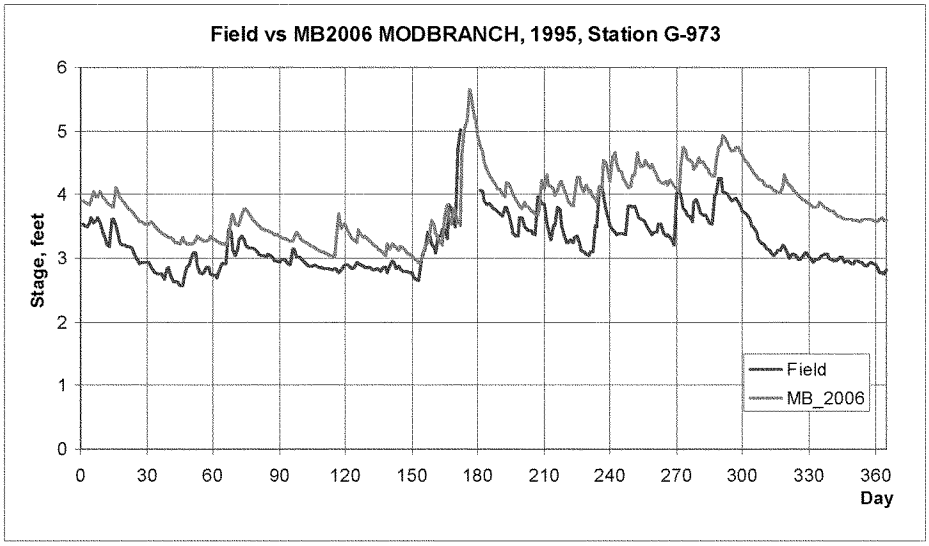
Field vs MB2006 MODBRANCH, 1995, Station G-973
Stage, feet
Day
Field
MB_2006
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360

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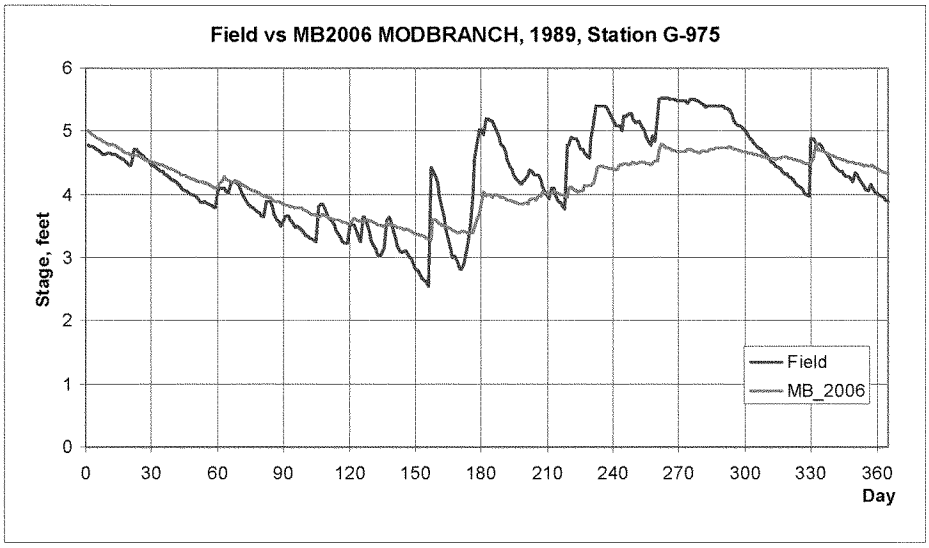
Field vs MB2006 MODBRANCH, 1989, Station G-975
Stage, feet
Day
Field
MB_2006
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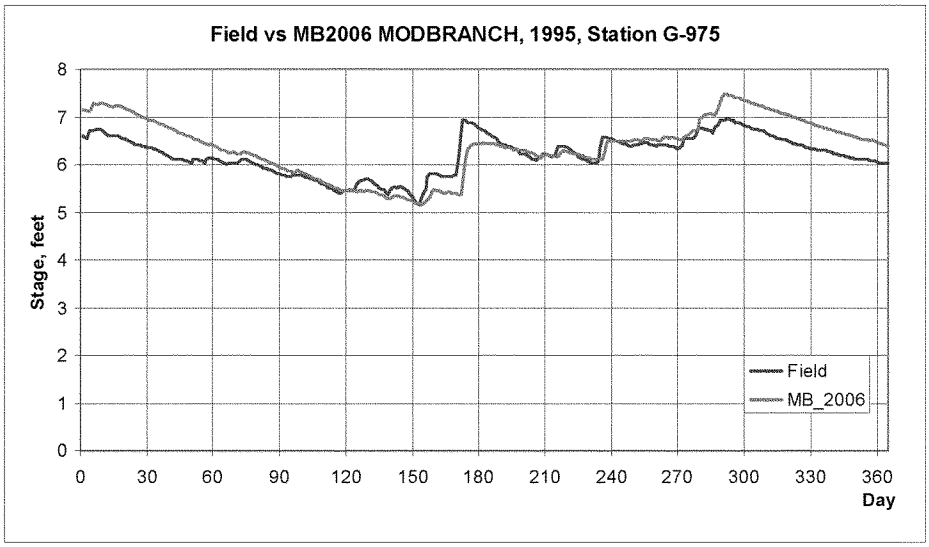
Field vs MB2006 MODBRANCH, 1995, Station G-975
Stage, feet
Day
Field
MB_2006
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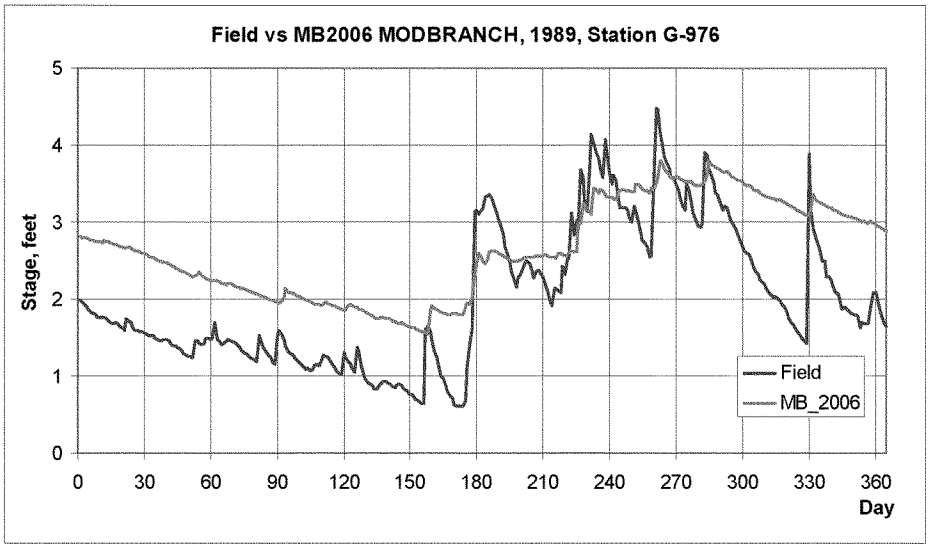
Field vs MB2006 MODBRANCH, 1989, Station G-976
Stage, feet
Day
Field
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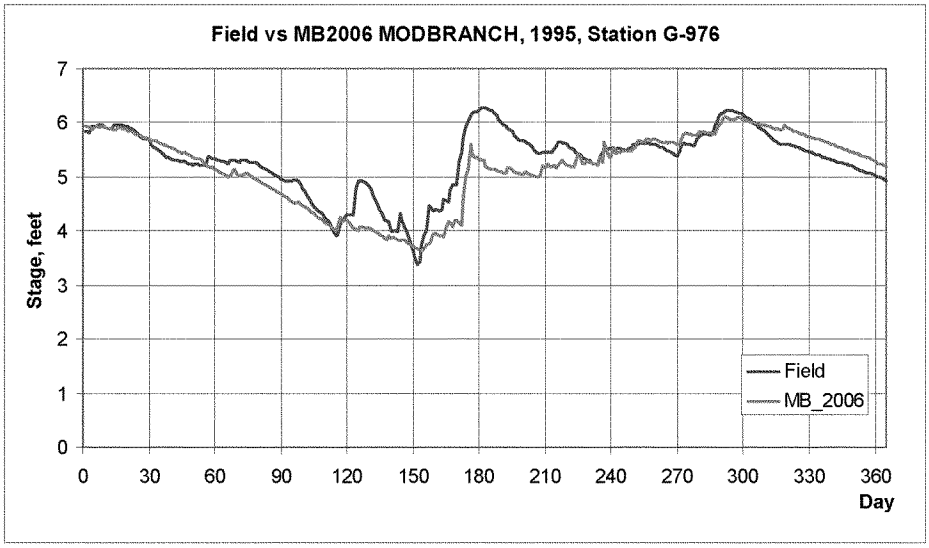
360


Field vs MB2006 MODBRANCH, 1995, Station G-976
Stage, feet
Day
Field
MB_2006
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360

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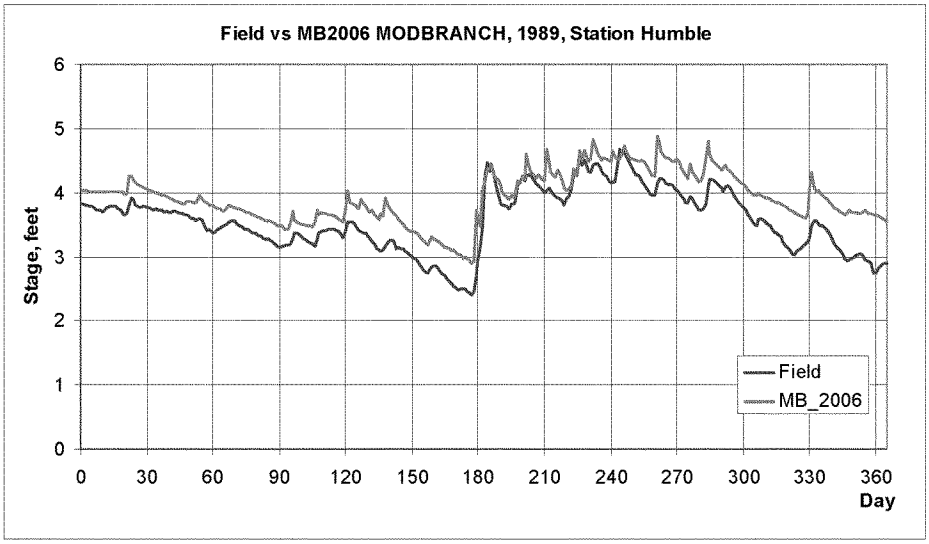
Field vs MB2006 MODBRANCH, 1989, Station Humble
Stage, feet
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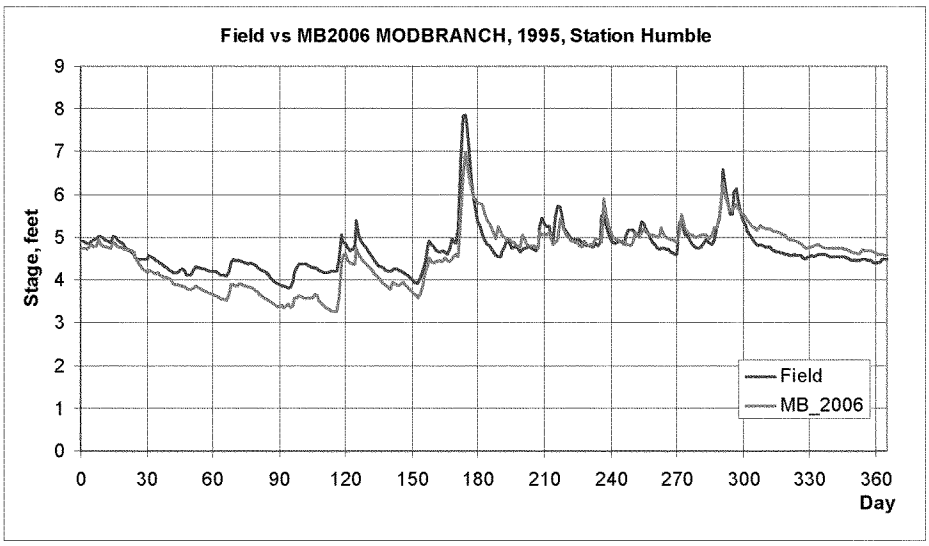
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station Humble
Stage, feet
0
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2
3
4
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6
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240
270
300
330
360
Day
Field
MB_2006

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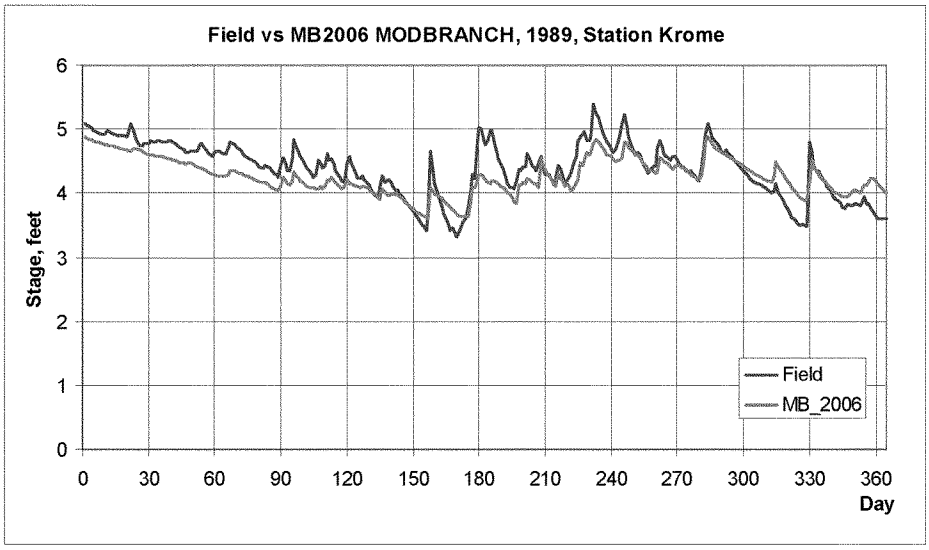
Field vs MB2006 MODBRANCH, 1989, Station Krome
Stage, feet
Day
Field
MB_2006
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3
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6
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90
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150
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210
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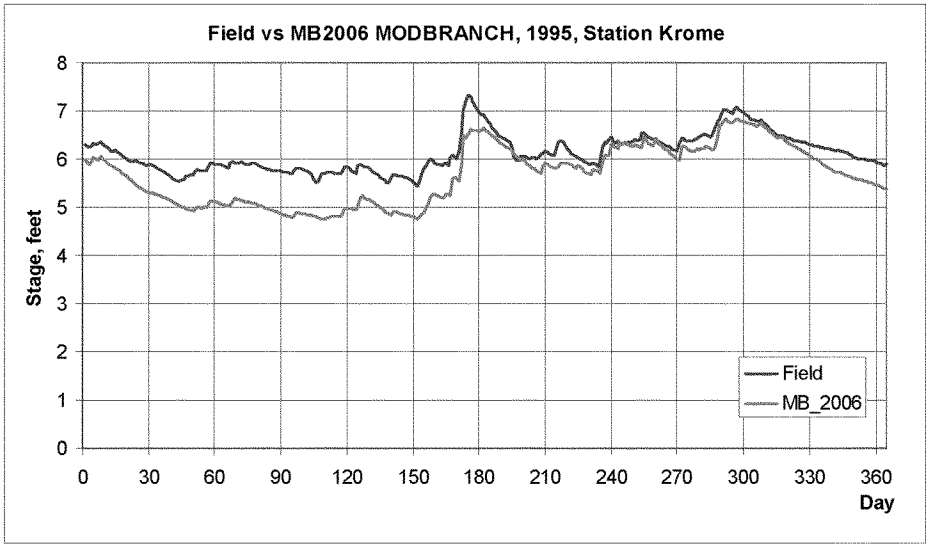
Field vs MB2006 MODBRANCH, 1995, Station Krome
Stage, feet
Day
Field
MB_2006
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1
2
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7
8
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330
360

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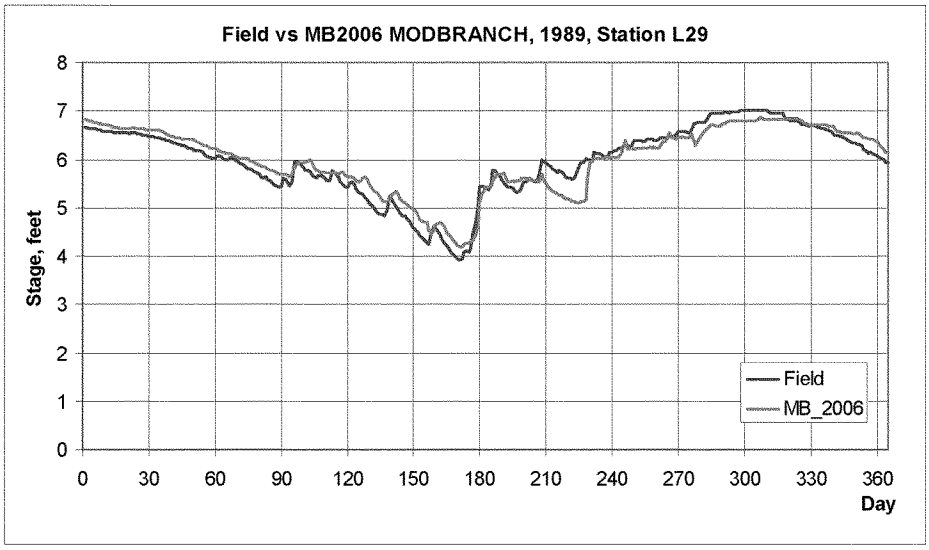
Field vs MB2006 MODBRANCH, 1989, Station L29
Stage, feet
Day
Field
MB_2006
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7
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330
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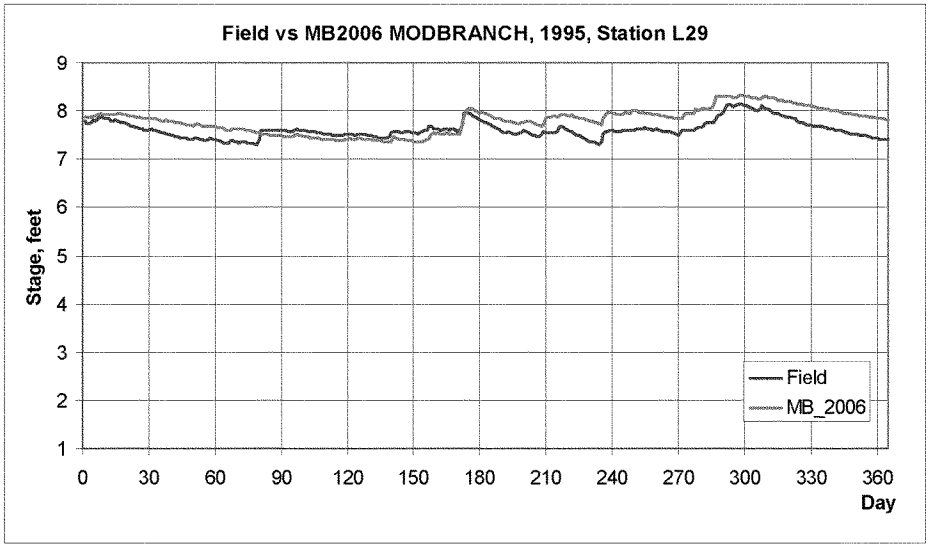
Field vs MB2006 MODBRANCH, 1995, Station L29
Stage, feet
Day
Field
MB_2006
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2
3
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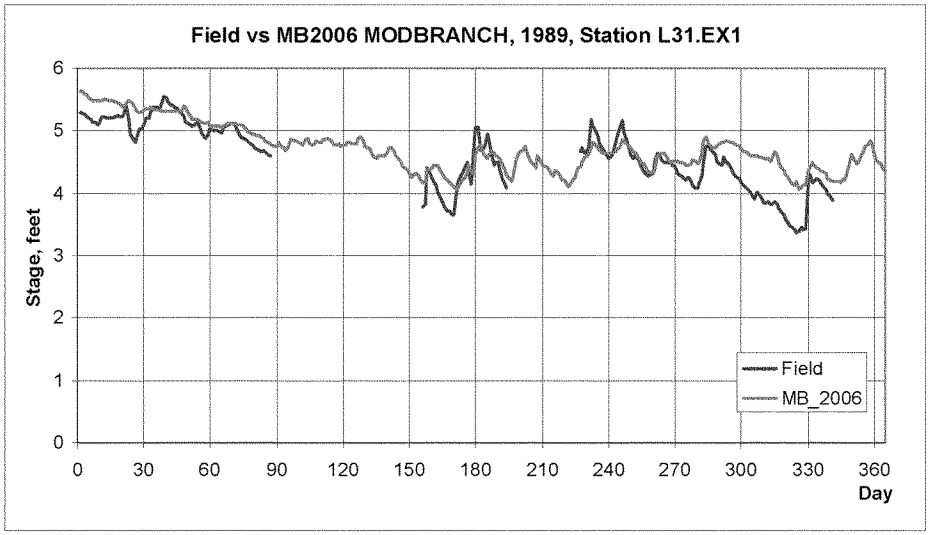
Field vs MB2006 MODBRANCH, 1989, Station L31.EX1
Stage, feet
6
5
4
3
2
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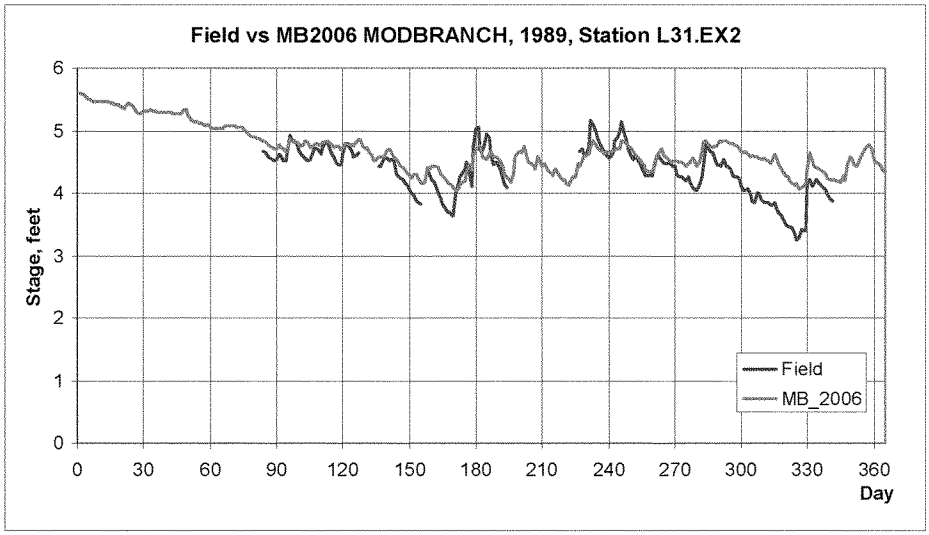
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station L31.EX2
Stage, feet
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4
3
2
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150
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210
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270
300
330
360
Day
Field
MB_2006

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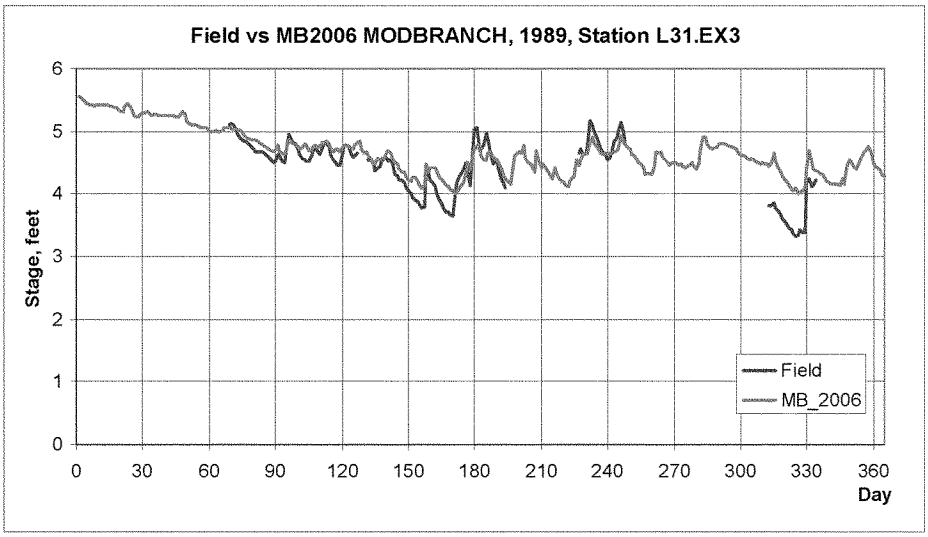
Field vs MB2006 MODBRANCH, 1989, Station L31.EX3
Stage, feet
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3
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270
300
330
360
Day
Field
MB_2006

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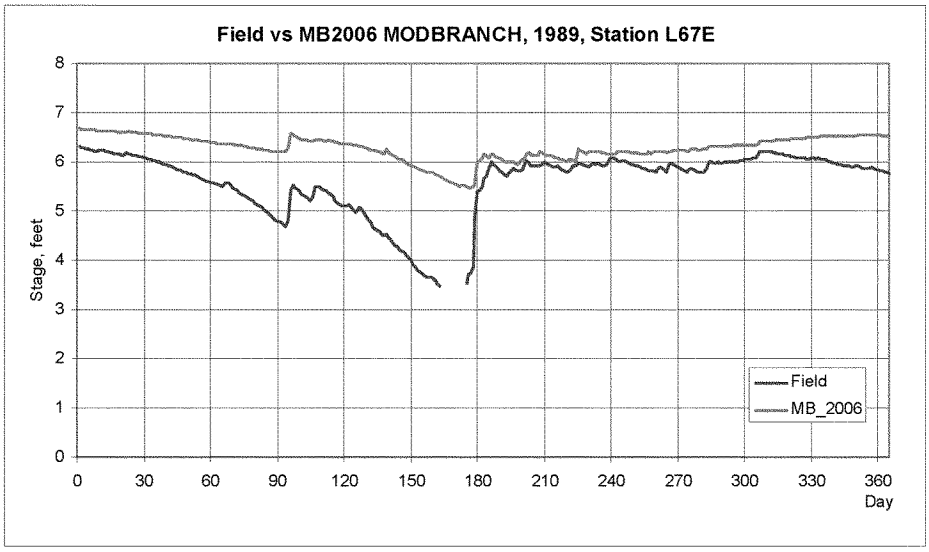
Field vs MB2006 MODBRANCH, 1989, Station L67E
Stage, feet
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2
3
4
5
6
7
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120
150
180
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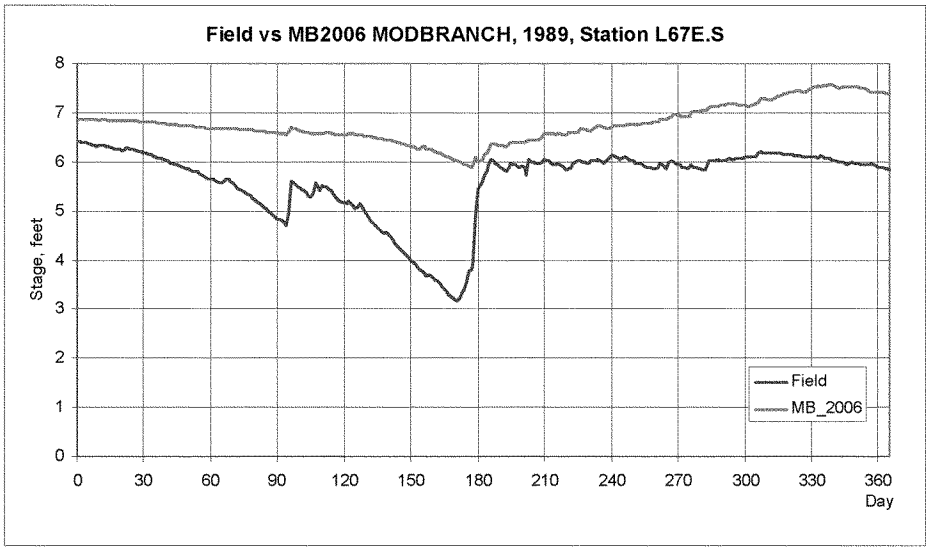
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station L67E.S
Stage, feet
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7
6
5
4
3
2
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0
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90
120
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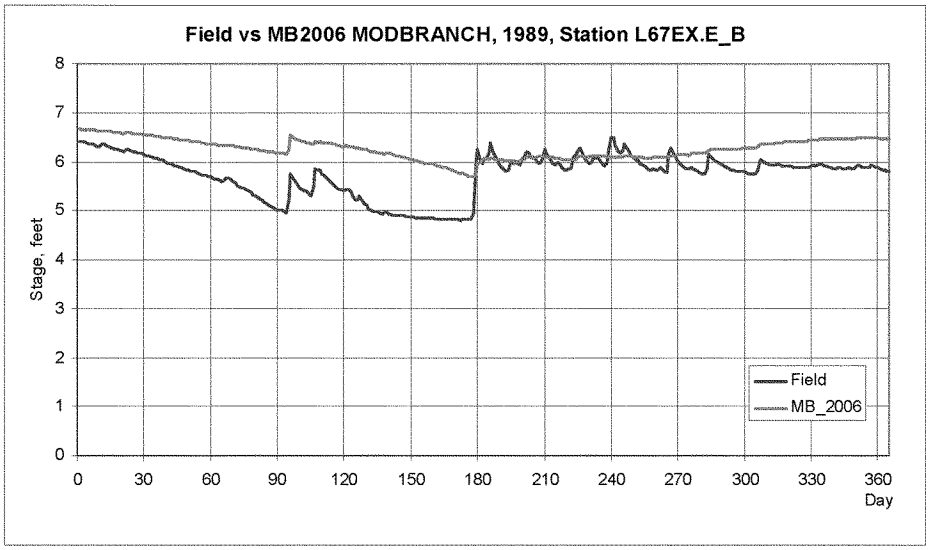
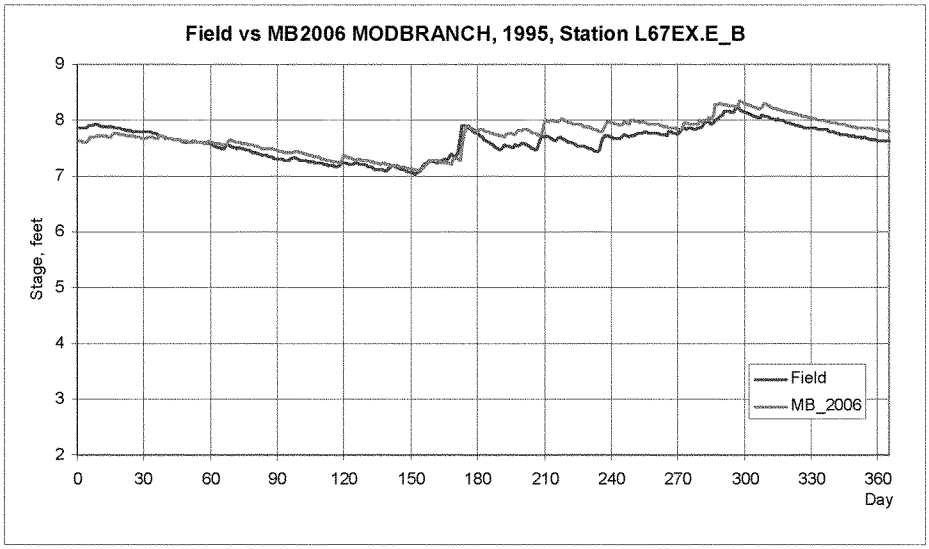
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station L67EX.E_B
Stage, feet
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station L67EX.E_B
Stage, feet
Day
Field
MB_2006

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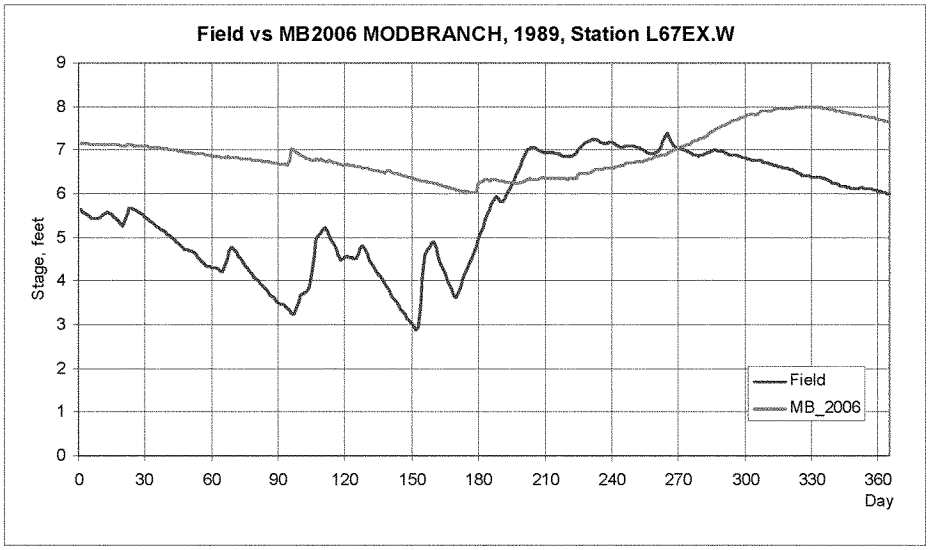
Field vs MB2006 MODBRANCH, 1989, Station L67EX.W
Stage, feet
Day
Field
MB_2006
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0
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270
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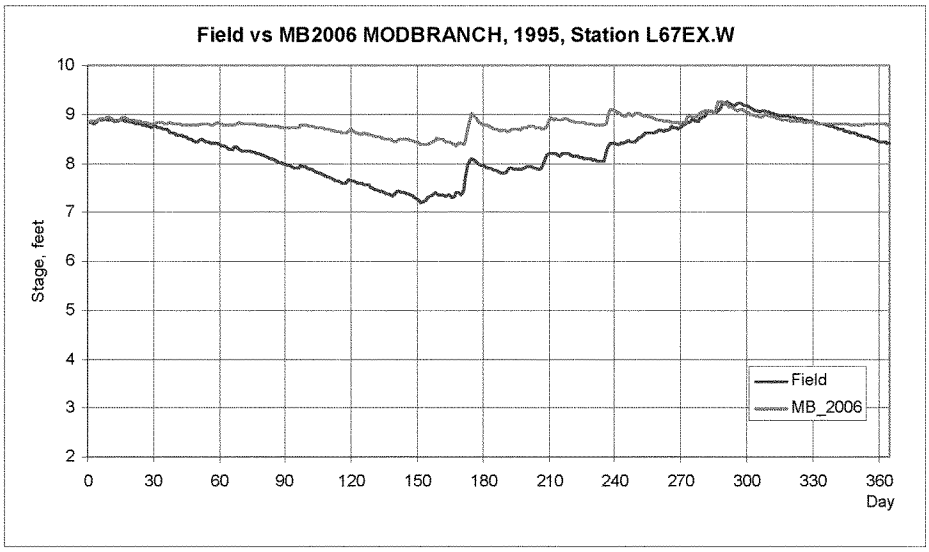
360


Field vs MB2006 MODBRANCH, 1995, Station L67EX.W
Stage, feet
Day
Field
MB_2006
2
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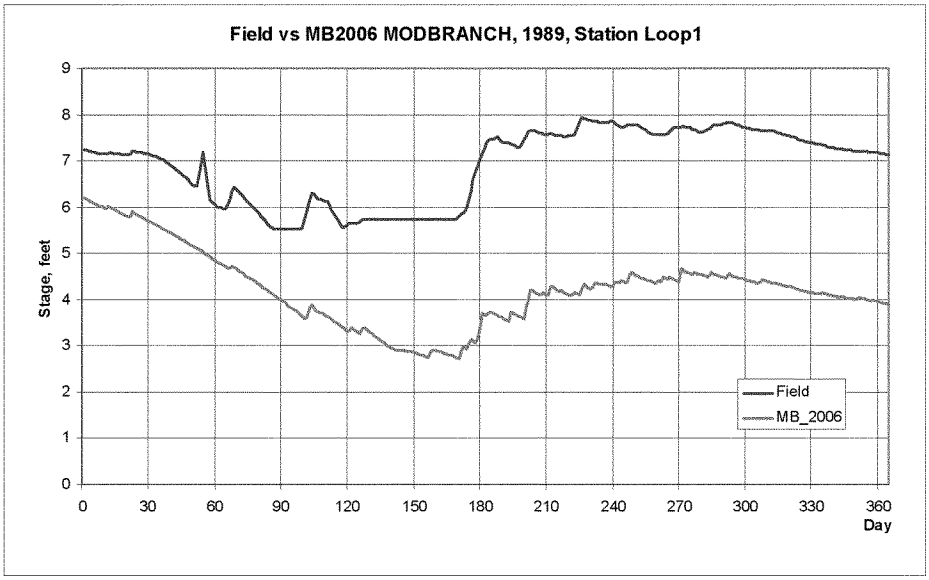
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station Loop1
Stage, feet
Day
Field
MB_2006
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1
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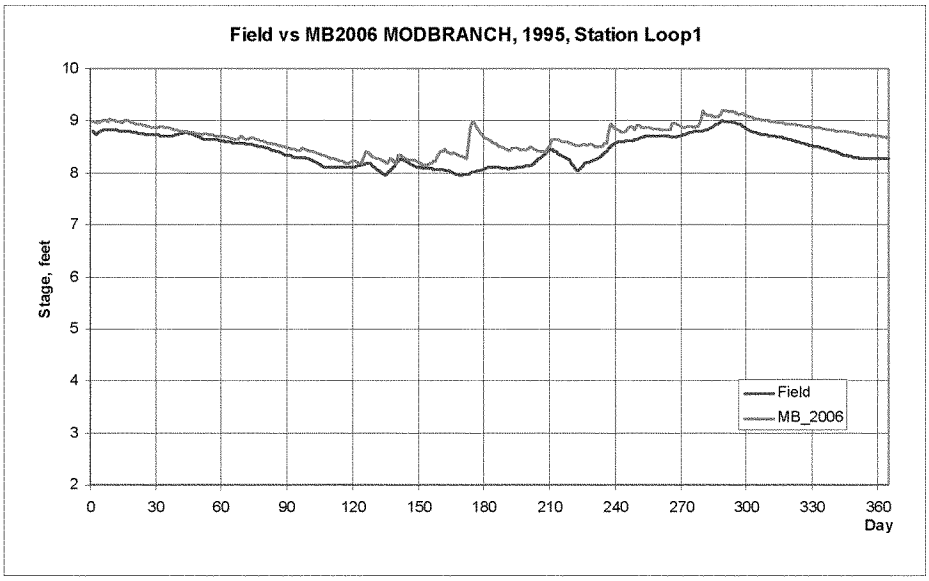
Field vs MB2006 MODBRANCH, 1995, Station Loop1
Stage, feet
Day
Field
MB_2006
2
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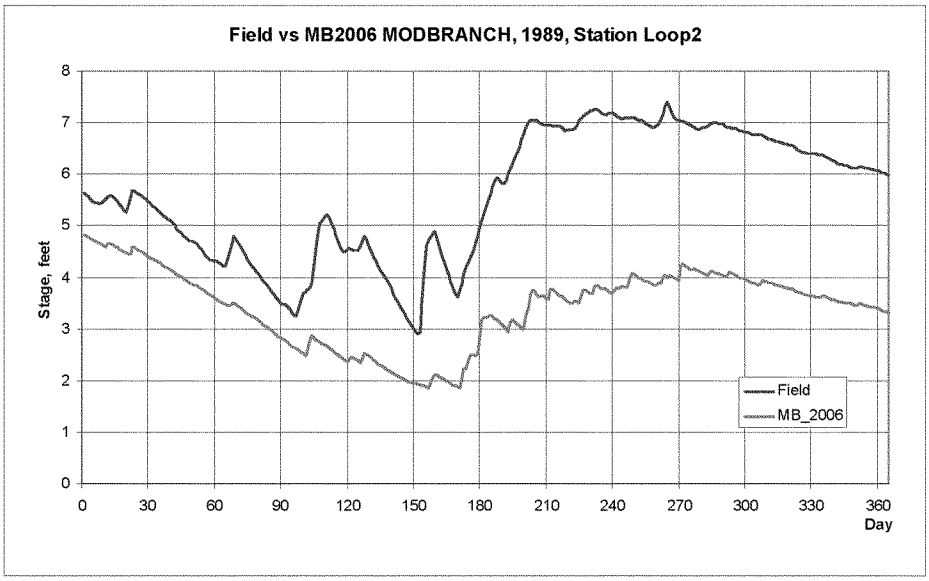
Field vs MB2006 MODBRANCH, 1989, Station Loop2
Stage, feet
Day
Field
MB_2006
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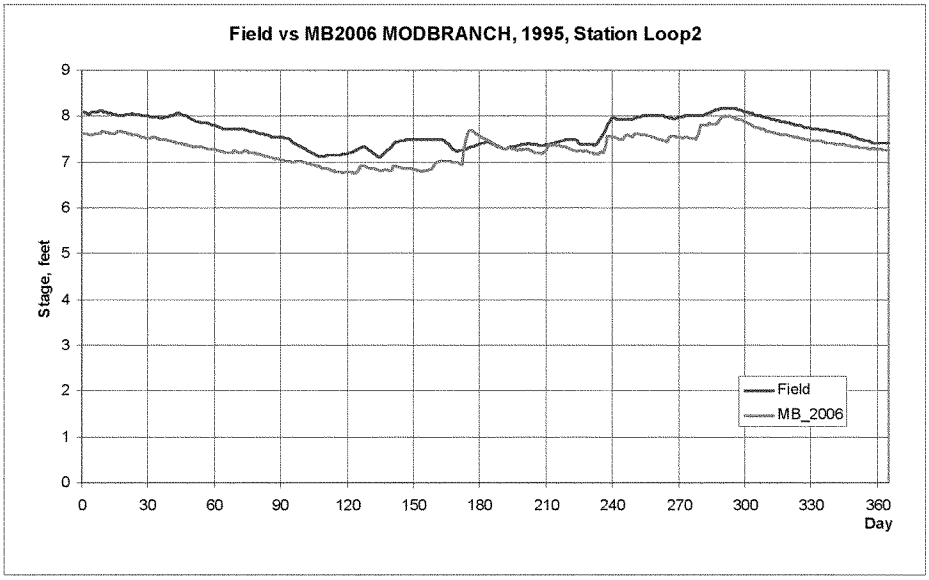
360


Field vs MB2006 MODBRANCH, 1995, Station Loop2
Stage, feet
Day
Field
MB_2006
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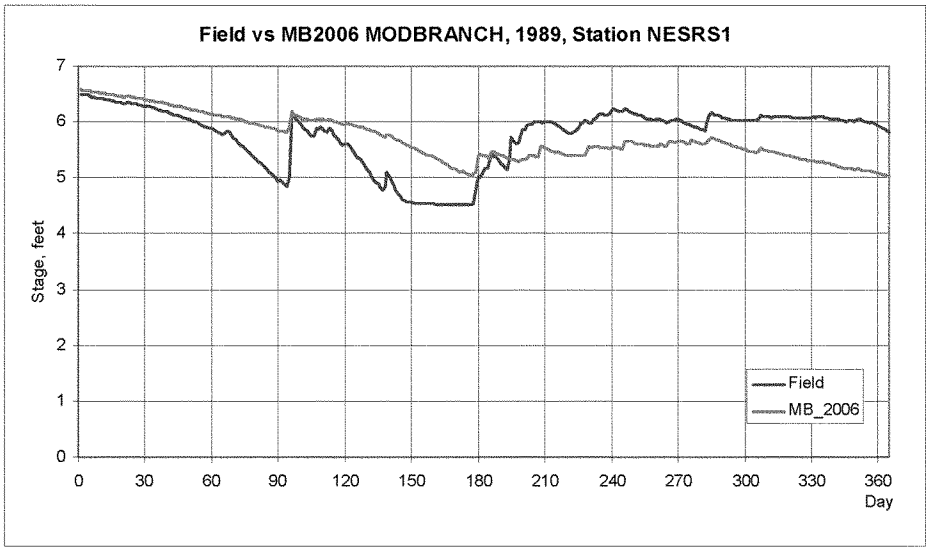
Field vs MB2006 MODBRANCH, 1989, Station NESRS1
Stage, feet
Day
Field
MB_2006
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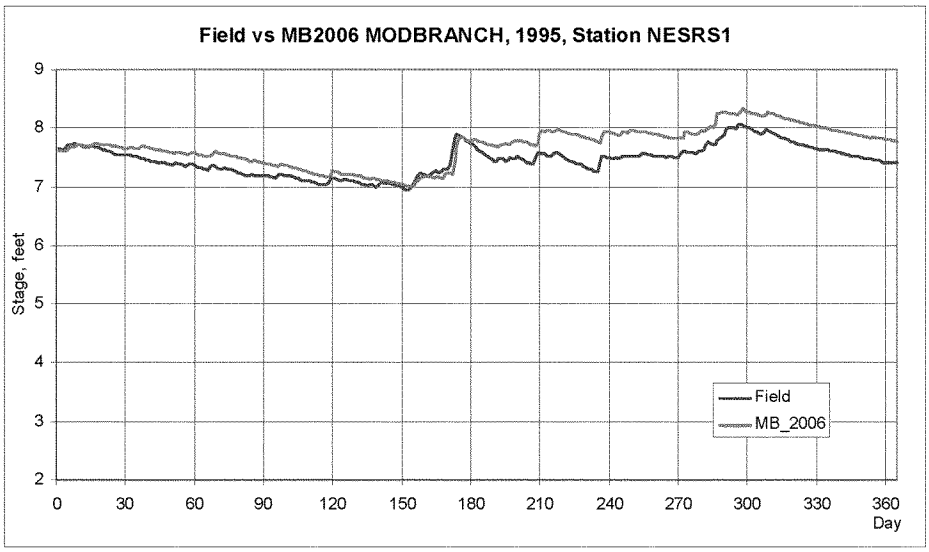
Field vs MB2006 MODBRANCH, 1995, Station NESRS1
Stage, feet
Day
Field
MB_2006
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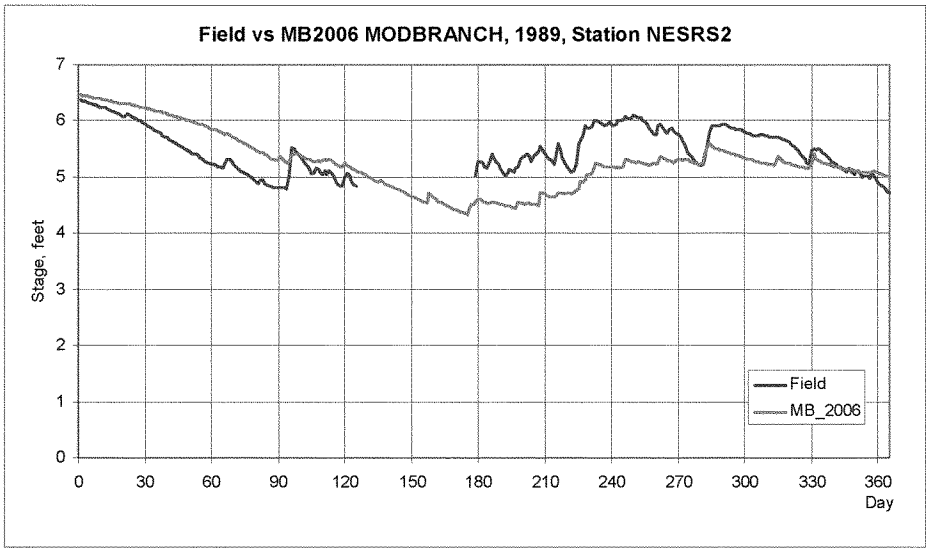
Field vs MB2006 MODBRANCH, 1989, Station NESRS2
Stage, feet
Day
Field
MB_2006
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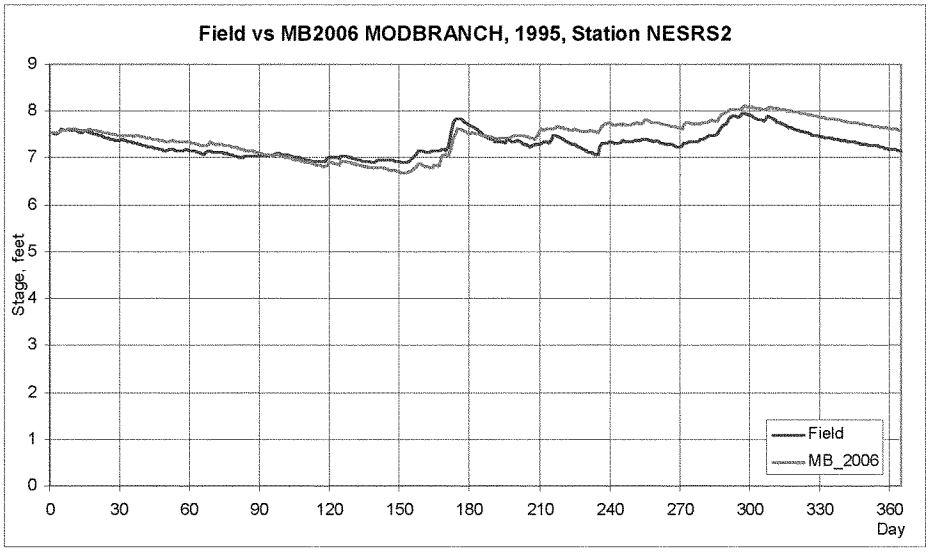
Field vs MB2006 MODBRANCH, 1995, Station NESRS2
Stage, feet
Day
Field
MB_2006
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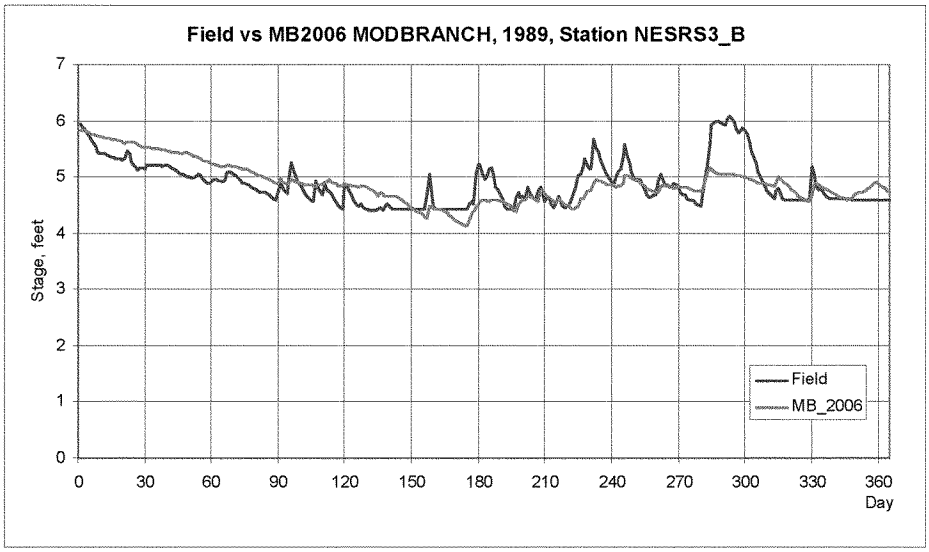
Field vs MB2006 MODBRANCH, 1989, Station NESRS3_B
Stage, feet
Day
Field
MB_2006
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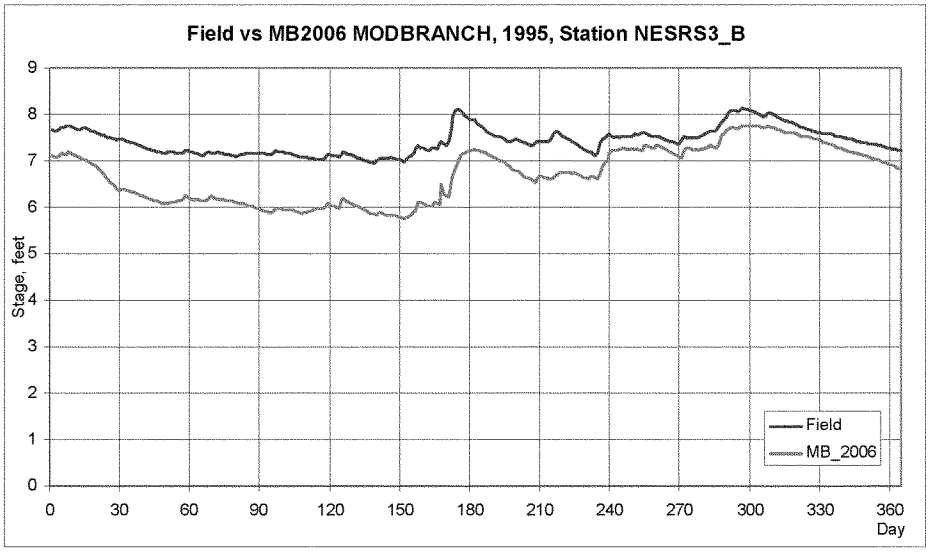
Field vs MB2006 MODBRANCH, 1995, Station NESRS3_B
Stage, feet
Day
Field
MB_2006
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360

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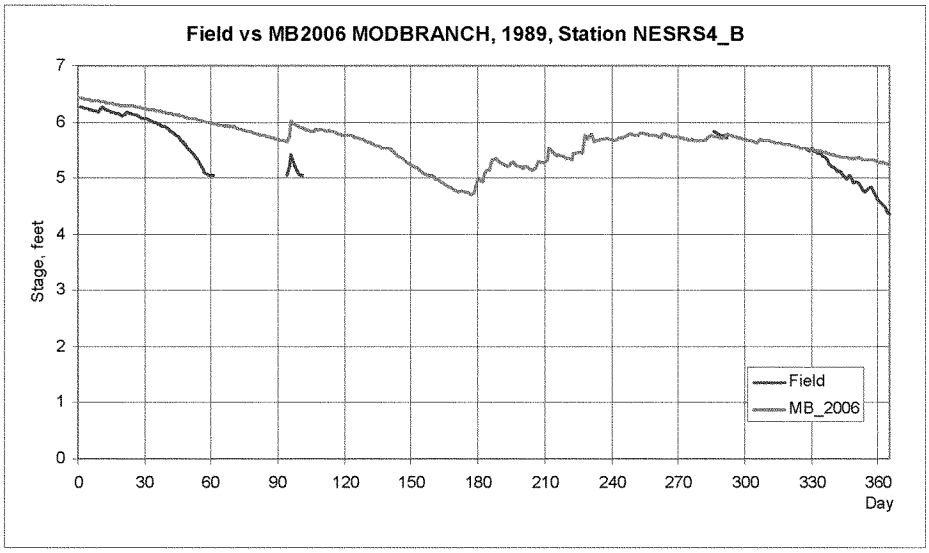
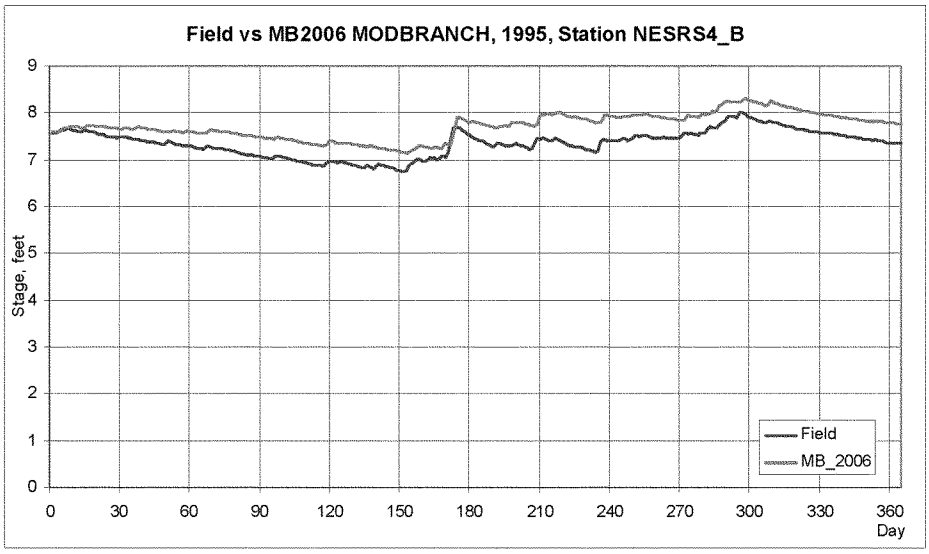

Field vs MB2006 MODBRANCH, 1989, Station NESRS4_B
Stage, feet
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NESRS4_B
Stage, feet
Day
Field
MB_2006

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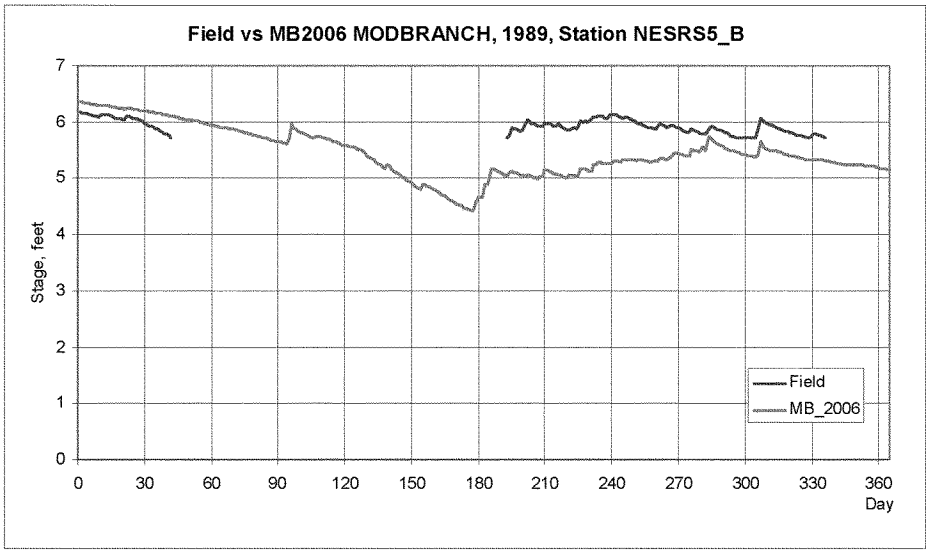
Field vs MB2006 MODBRANCH, 1989, Station NESRS5_B
Stage, feet
Day
Field
MB_2006
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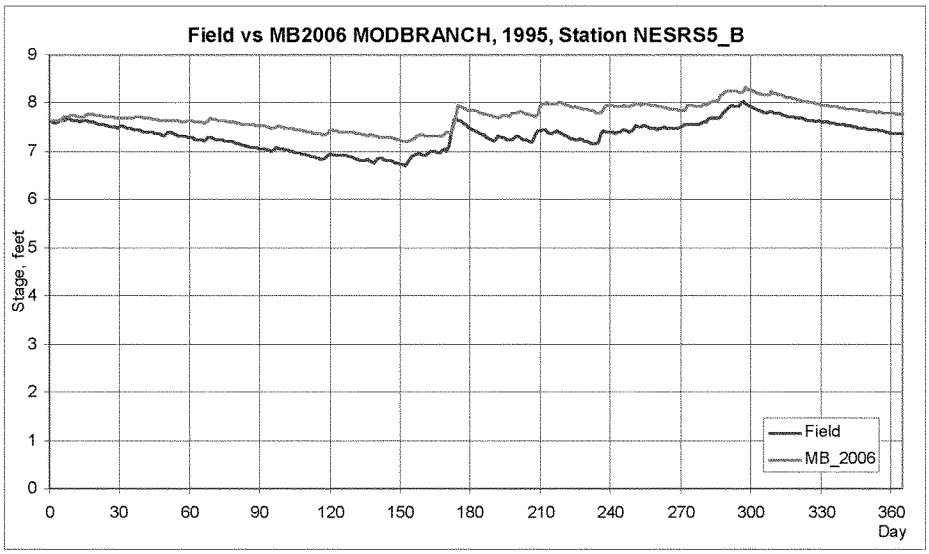
330
360


Field vs MB2006 MODBRANCH, 1995, Station NESRS5_B
Stage, feet
Day
Field
MB_2006
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1
2
3
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360

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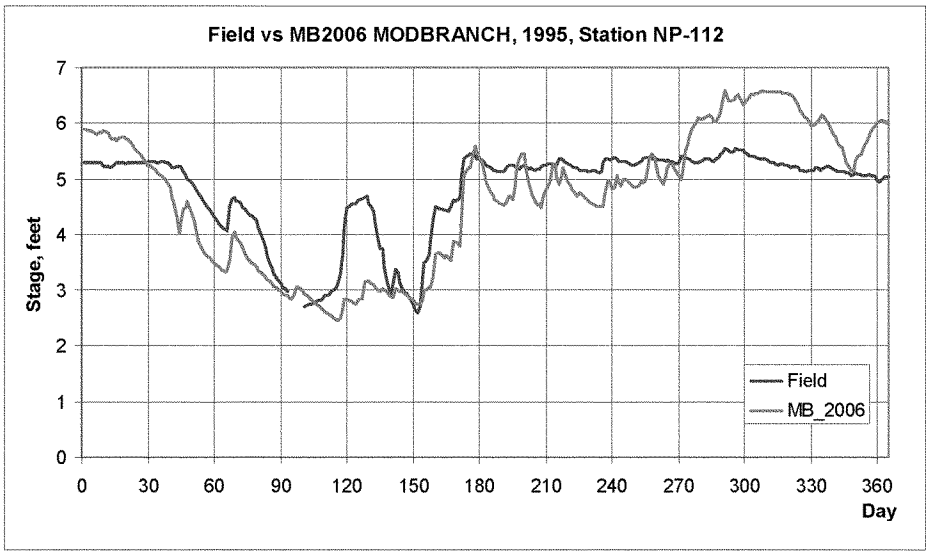
Field vs MB2006 MODBRANCH, 1995, Station NP-112
Stage, feet
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4
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300
330
360
Day
Field
MB_2006

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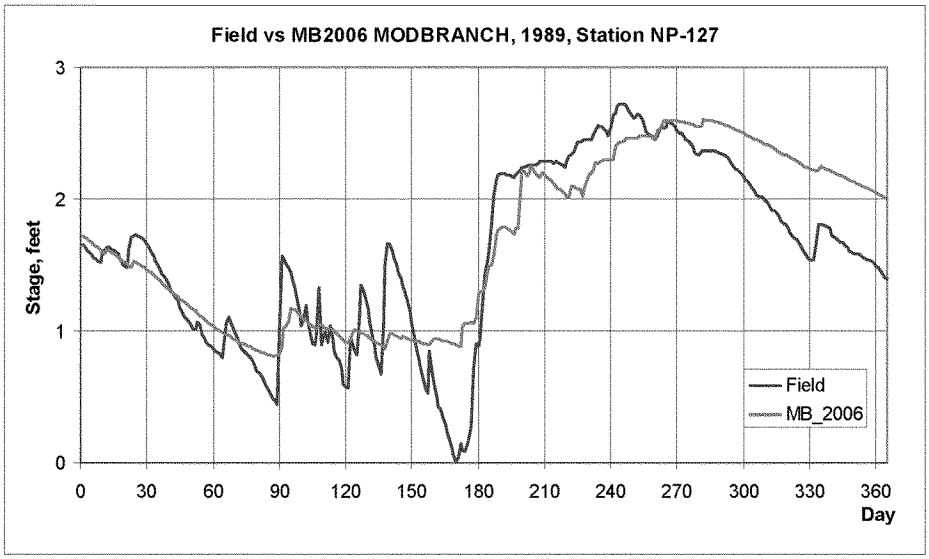
Field vs MB2006 MODBRANCH, 1989, Station NP-127
Stage, feet
Day
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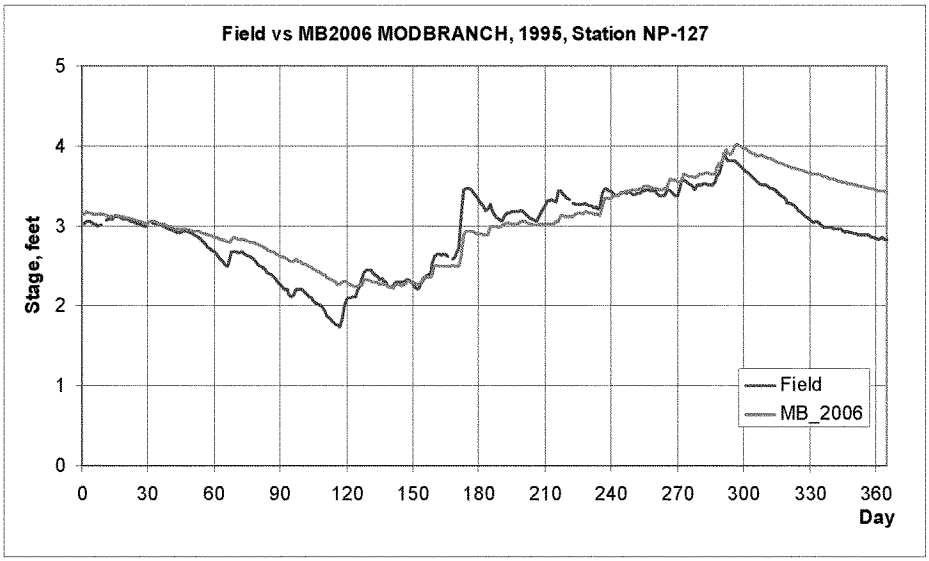
Field vs MB2006 MODBRANCH, 1995, Station NP-127
Stage, feet
Day
Field
MB_2006
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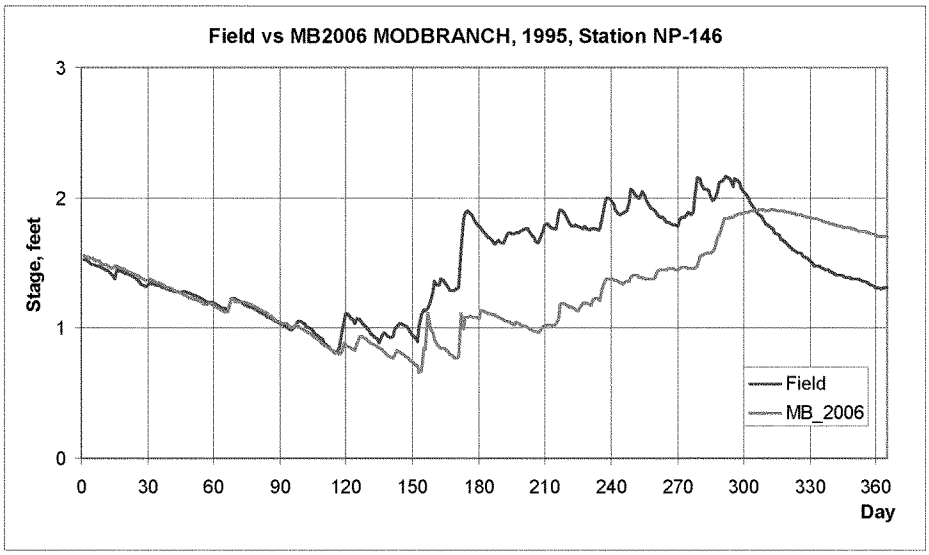
Field vs MB2006 MODBRANCH, 1995, Station NP-146
Stage, feet
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360
Day
Field
MB_2006

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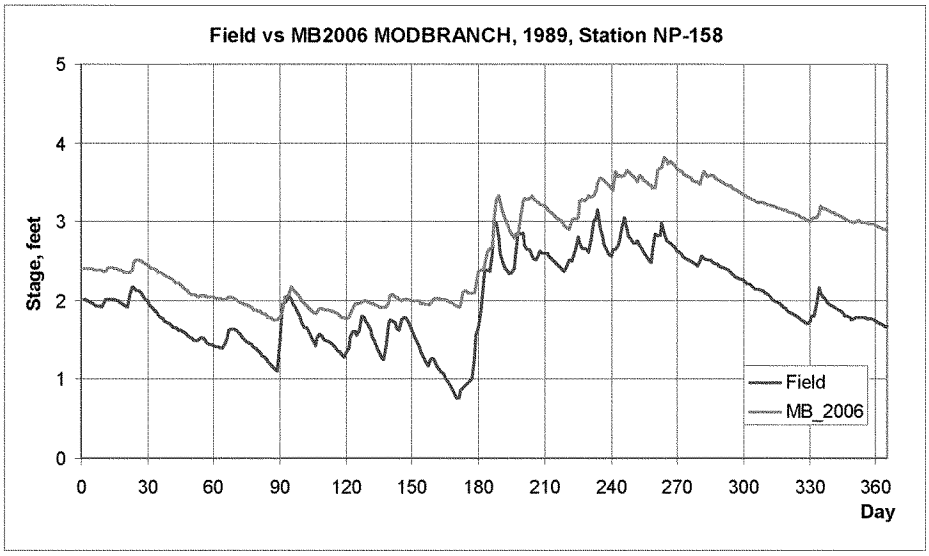
Field vs MB2006 MODBRANCH, 1989, Station NP-158
Stage, feet
Day
Field
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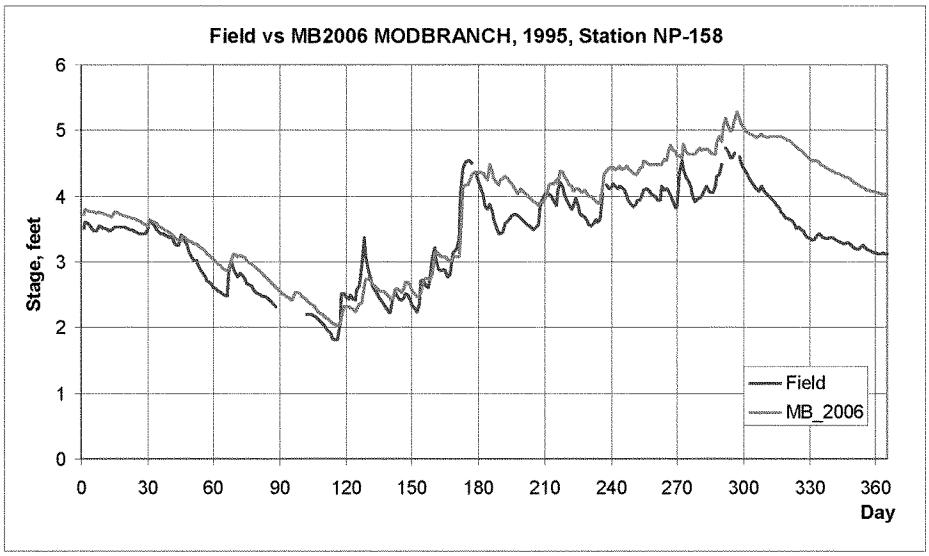
Field vs MB2006 MODBRANCH, 1995, Station NP-158
Stage, feet
Day
Field
MB_2006
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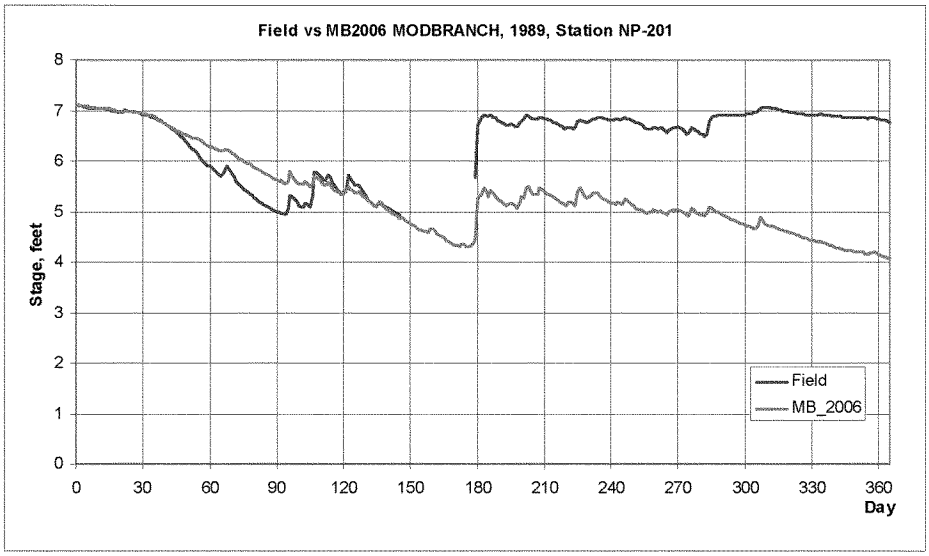
Field vs MB2006 MODBRANCH, 1989, Station NP-201
Stage, feet
Day
Field
MB_2006
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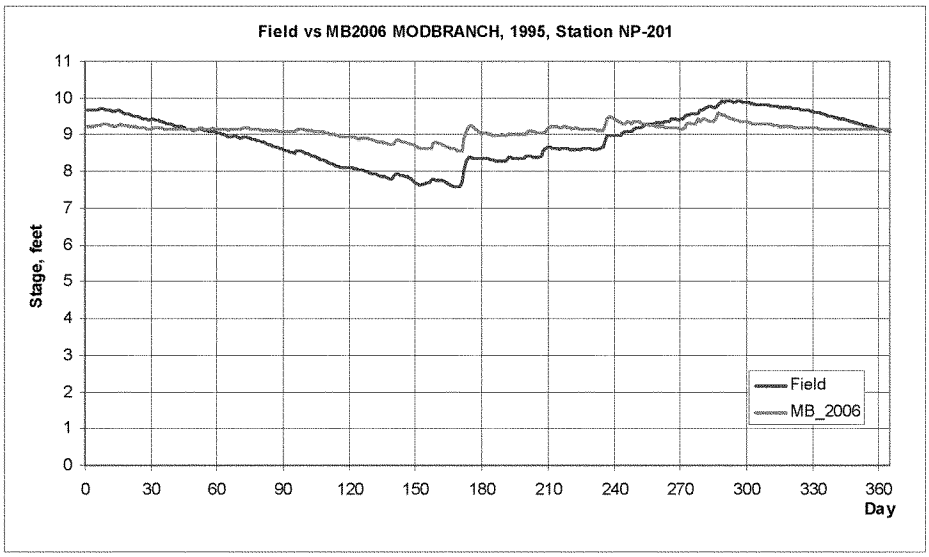
Field vs MB2006 MODBRANCH, 1995, Station NP-201
Stage, feet
Day
Field
MB_2006
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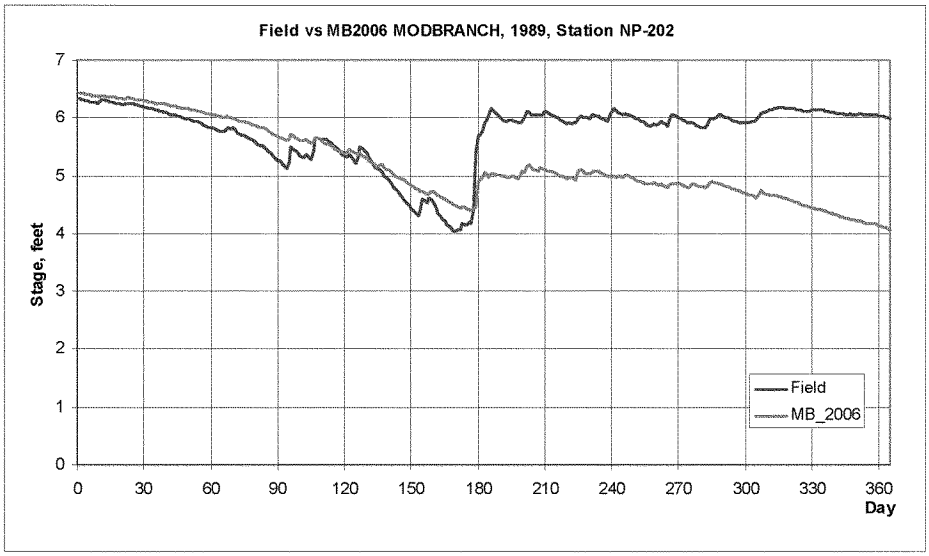
Field vs MB2006 MODBRANCH, 1989, Station NP-202
Stage, feet
Day
Field
MB_2006
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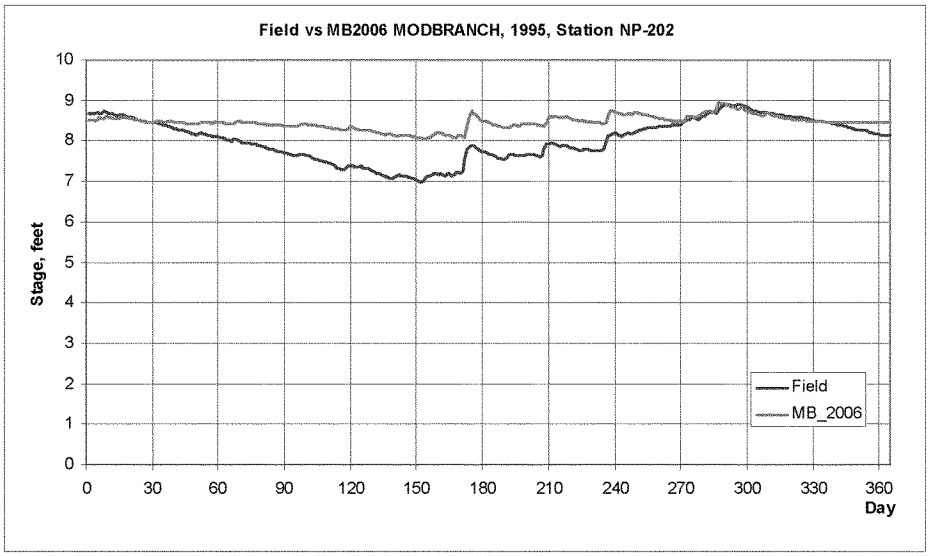
Field vs MB2006 MODBRANCH, 1995, Station NP-202
Stage, feet
Day
Field
MB_2006
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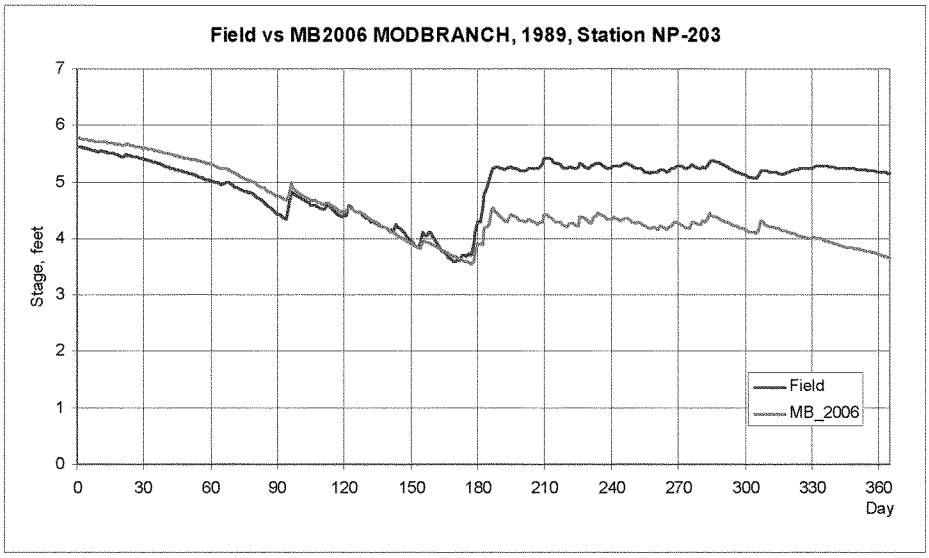
Field vs MB2006 MODBRANCH, 1989, Station NP-203
Stage, feet
Day
Field
MB_2006
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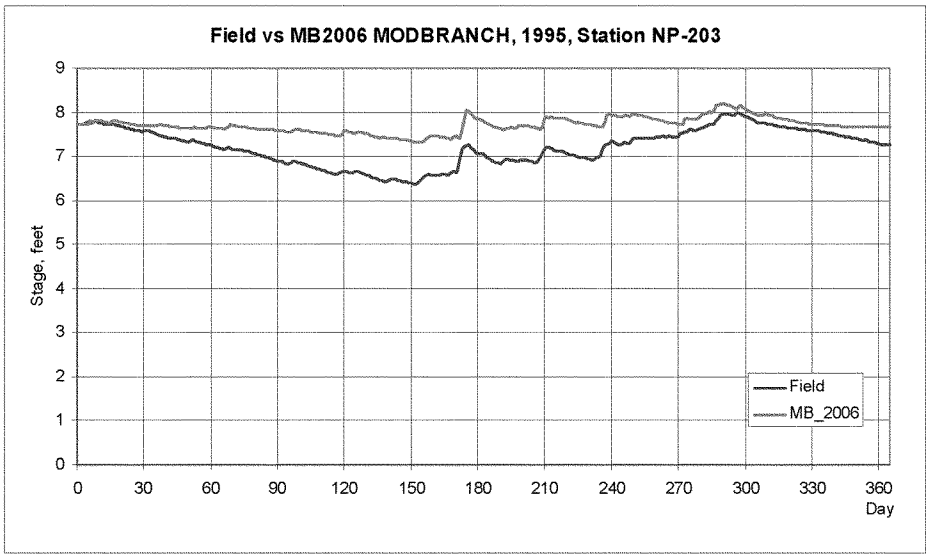
Field vs MB2006 MODBRANCH, 1995, Station NP-203
Stage, feet
Day
Field
MB_2006
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2
3
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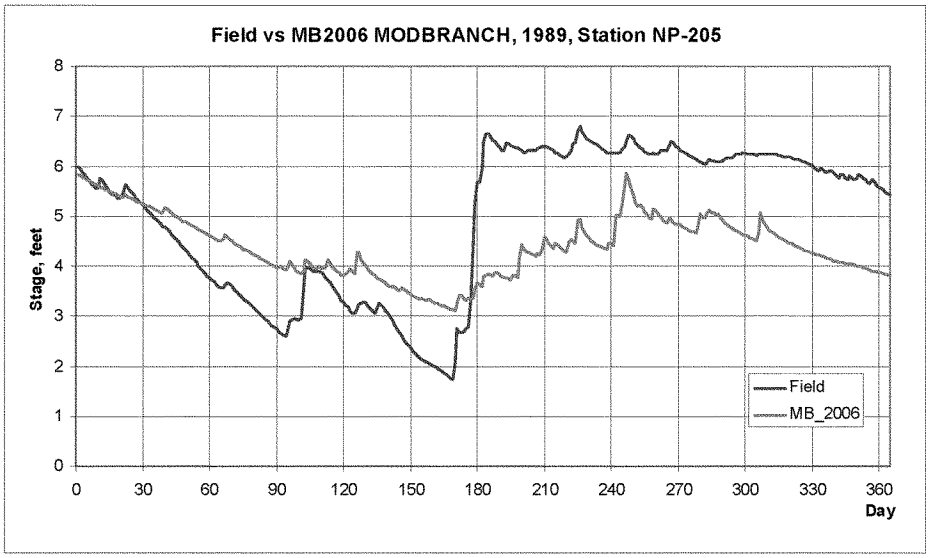
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-205
Stage, feet
Day
Field
MB_2006
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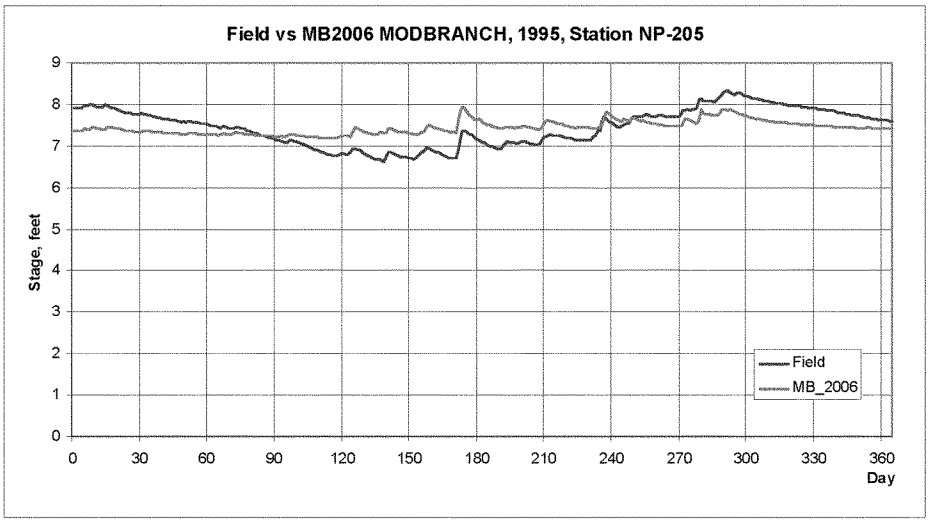
Field vs MB2006 MODBRANCH, 1995, Station NP-205
Stage, feet
Day
Field
MB_2006
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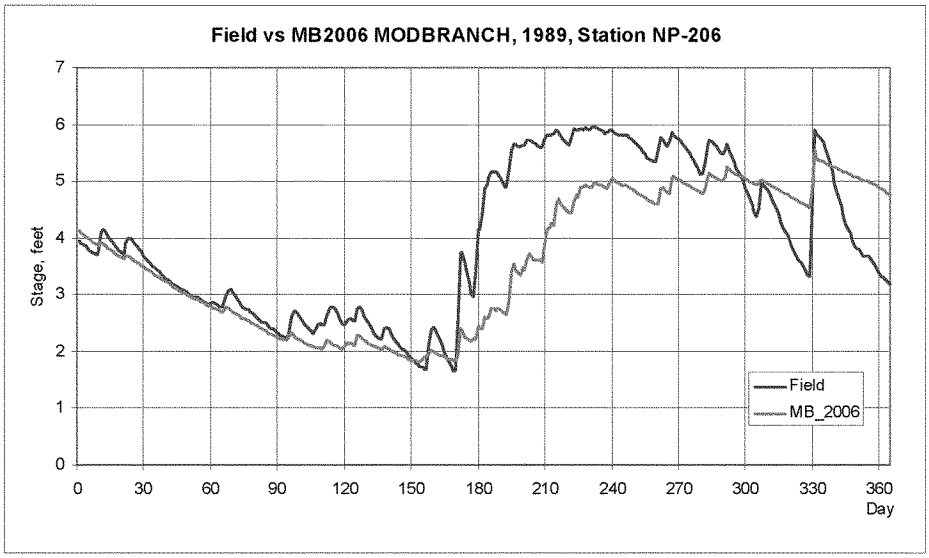
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-206
Stage, feet
Day
Field
MB_2006
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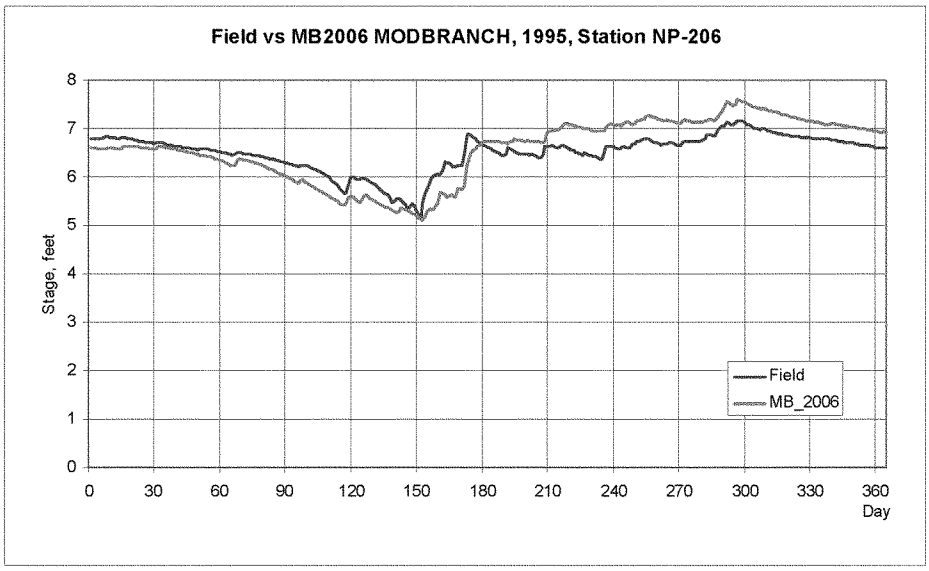
Field vs MB2006 MODBRANCH, 1995, Station NP-206
Stage, feet
Day
Field
MB_2006
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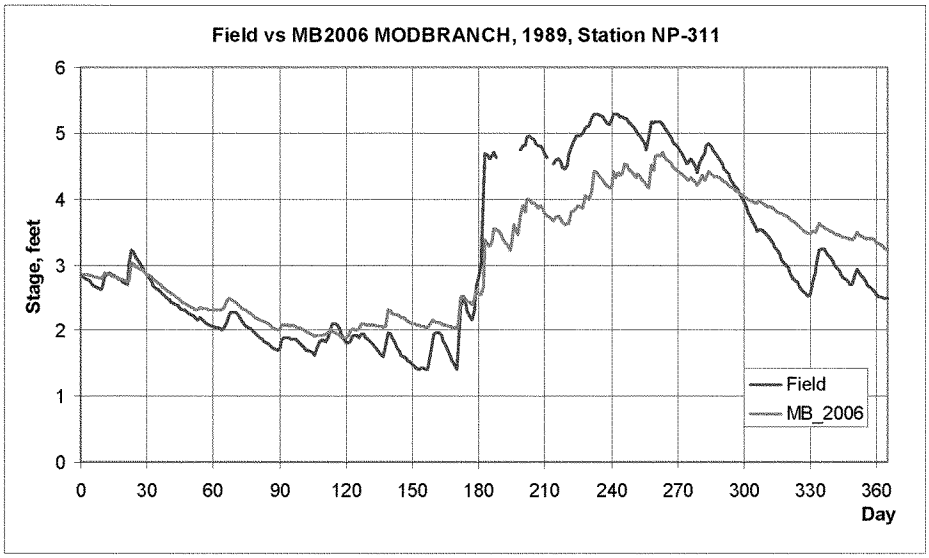
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-311
Stage, feet
Day
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MB_2006
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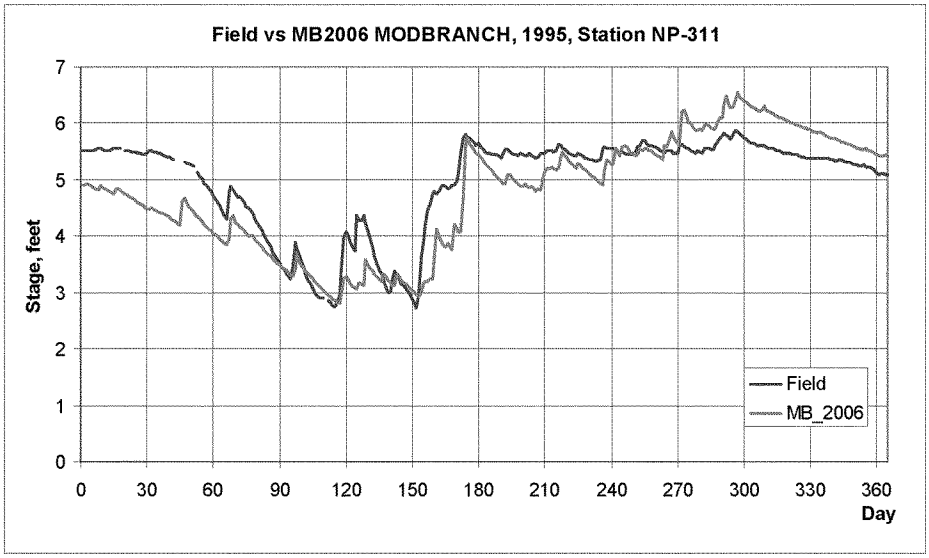
Field vs MB2006 MODBRANCH, 1995, Station NP-311
Stage, feet
Day
Field
MB_2006
0
1
2
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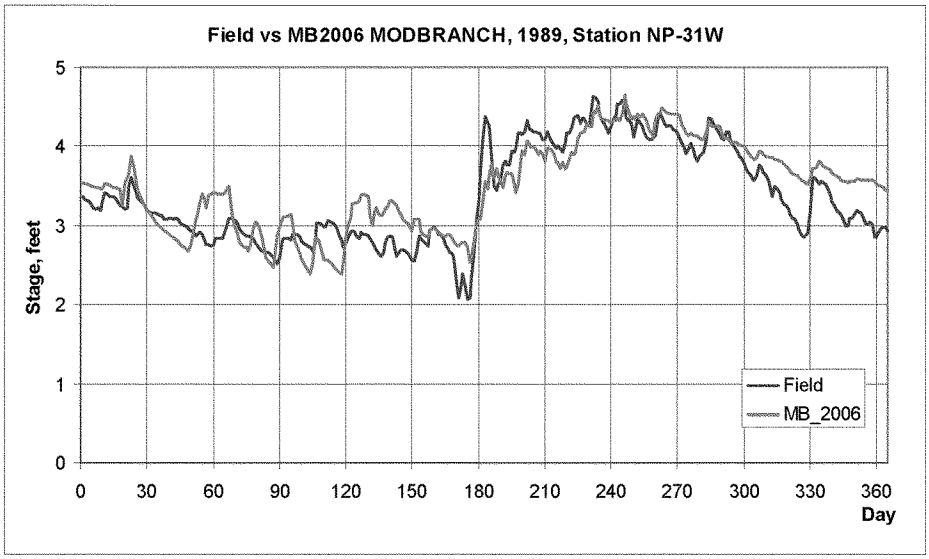
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-31W
Stage, feet
Day
Field
MB_2006
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3
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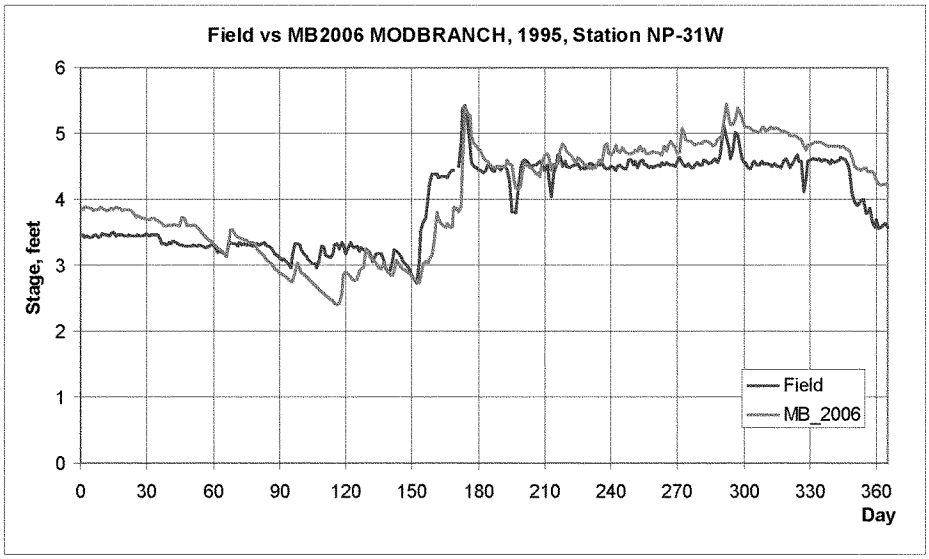
Field vs MB2006 MODBRANCH, 1995, Station NP-31W
Stage, feet
Day
Field
MB_2006
0
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0
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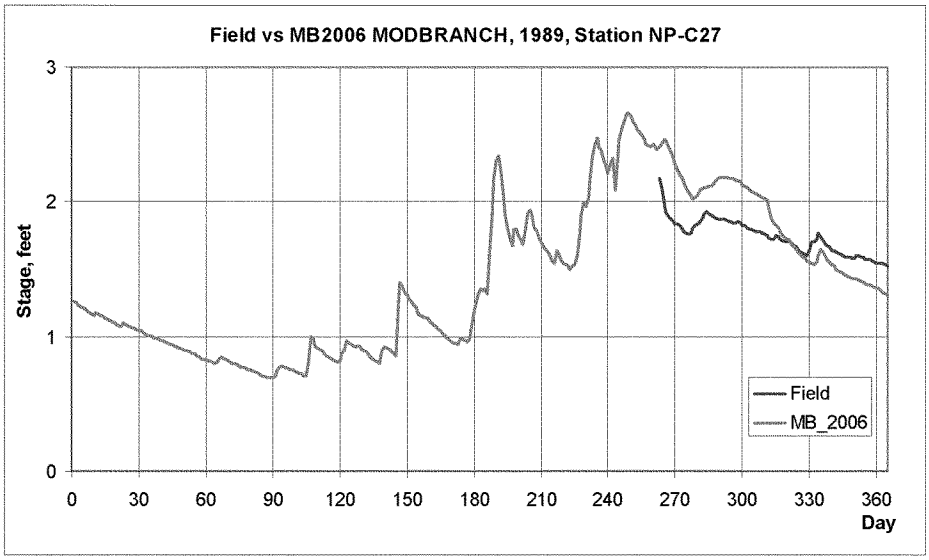
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-C27
Stage, feet
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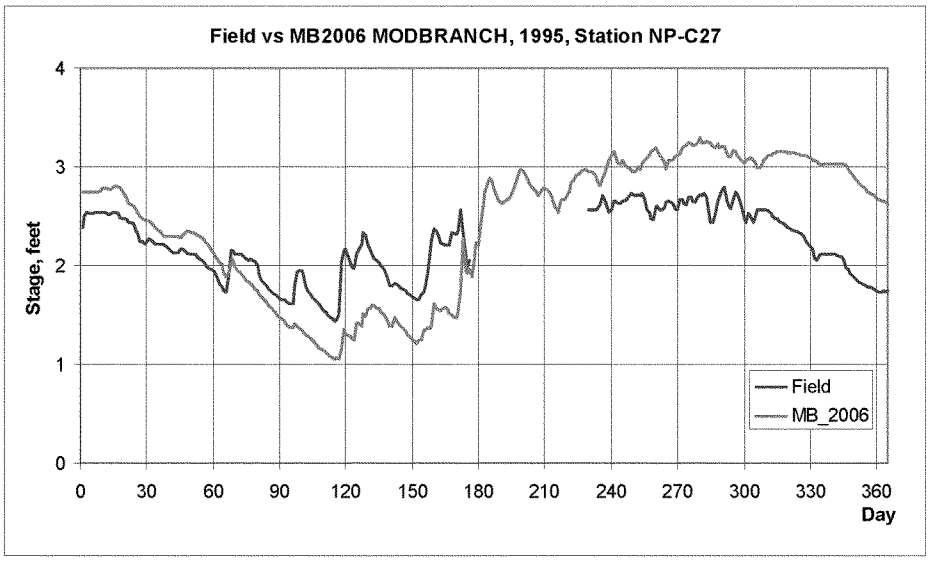
Field vs MB2006 MODBRANCH, 1995, Station NP-C27
Stage, feet
Day
Field
MB_2006
0
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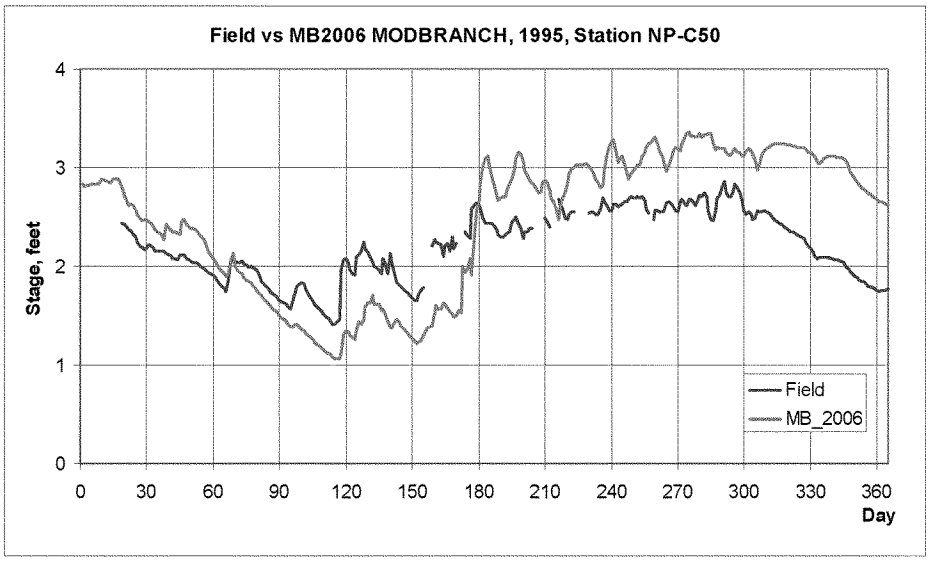
360

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station NP-C50
Stage, feet
Day
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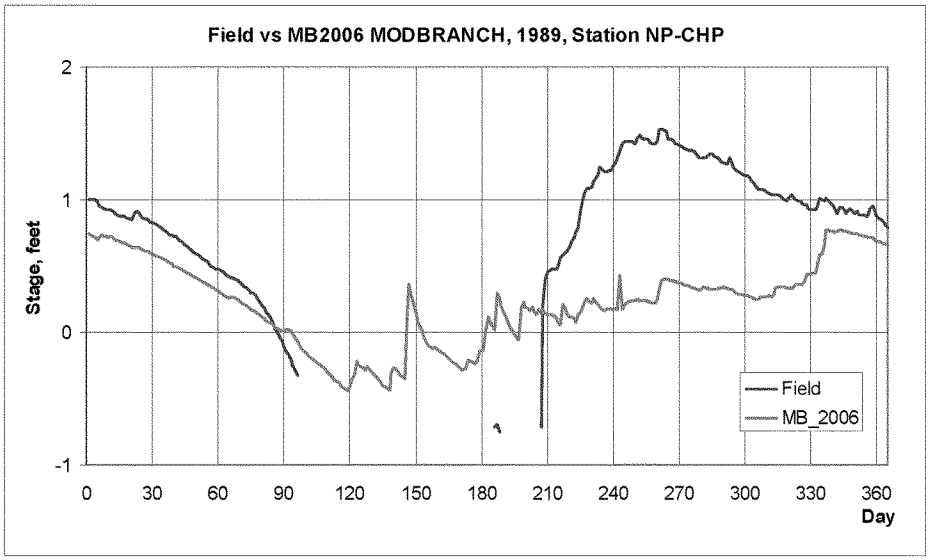
360
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CHP
Stage, feet
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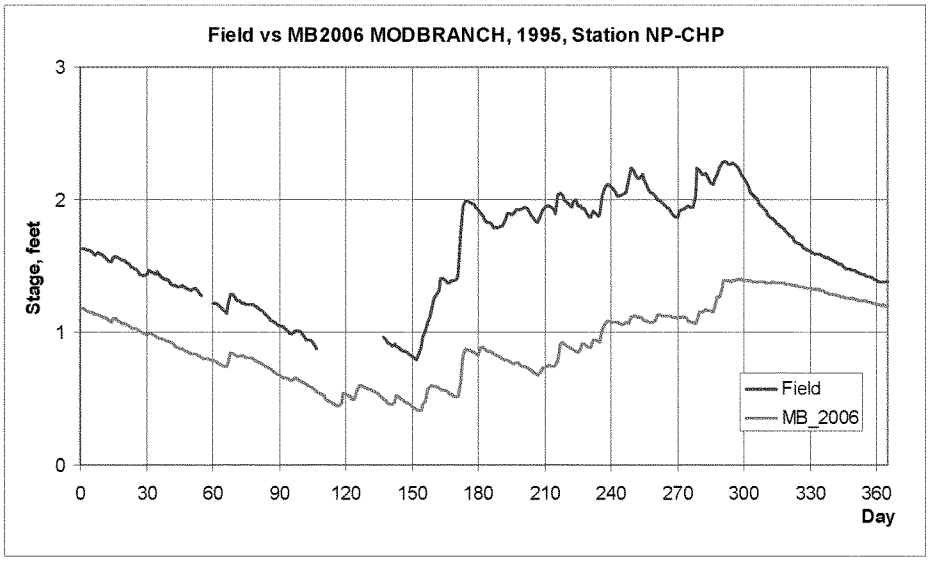
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NP-CHP
Stage, feet
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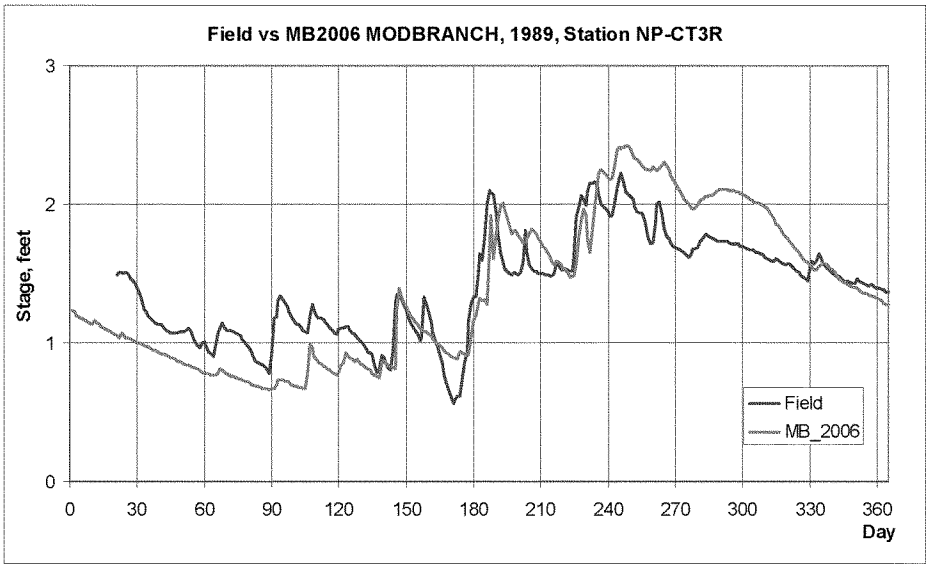
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CT3R
Stage, feet
3
2
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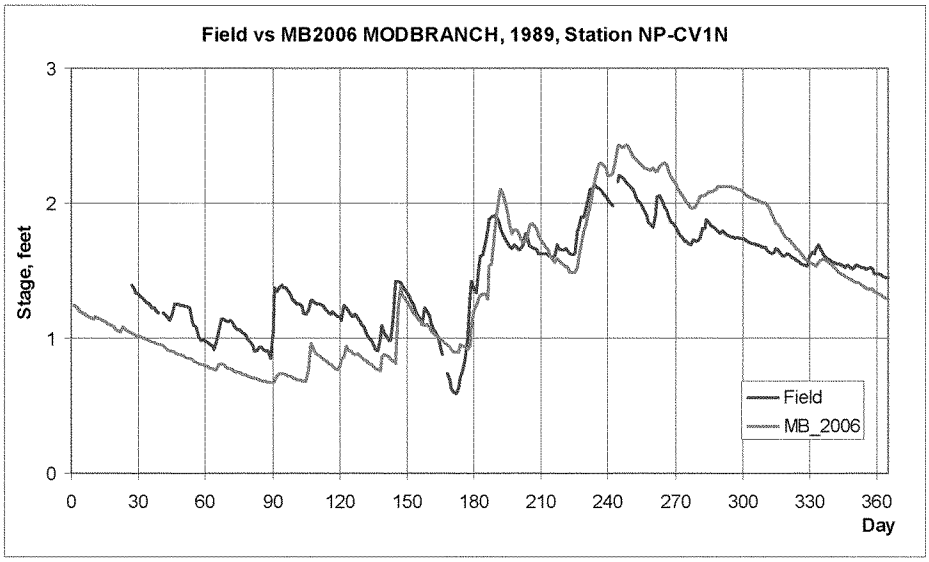
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV1N
Stage, feet
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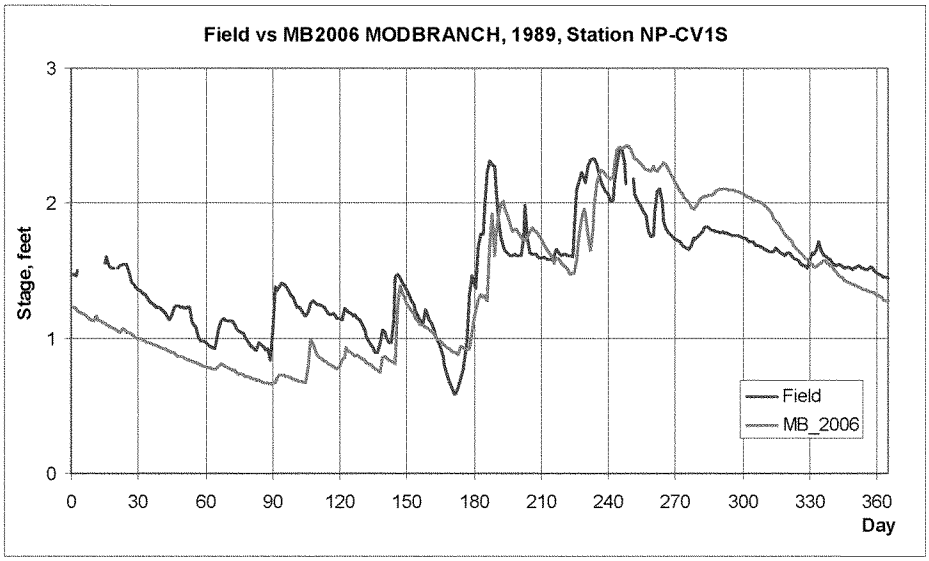
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV1S
Stage, feet
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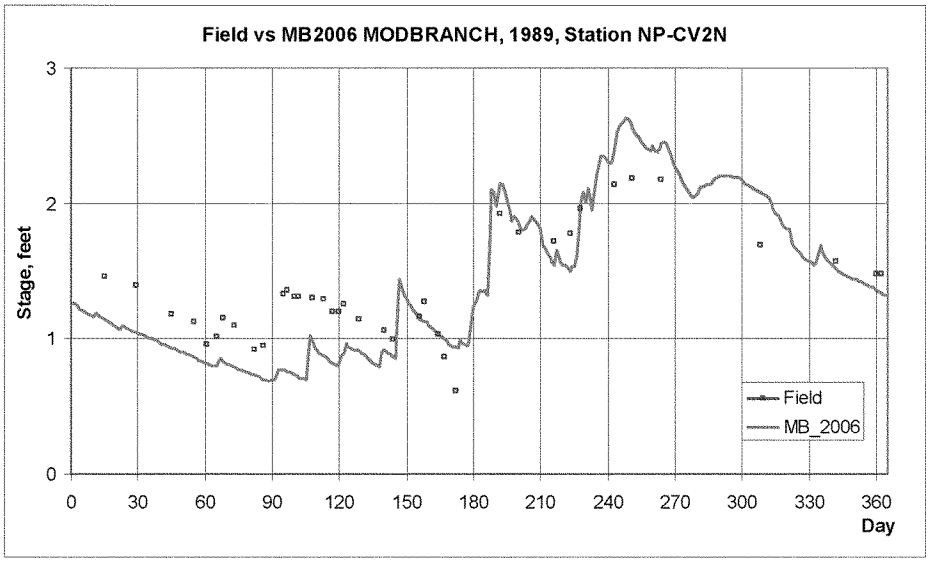
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV2N
Stage, feet
Day
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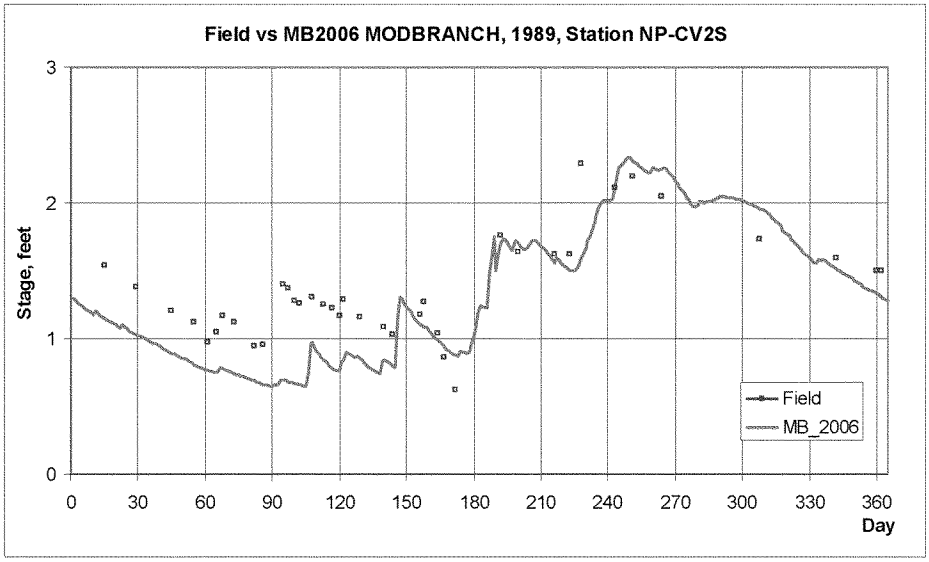
330
360
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV2S
Stage, feet
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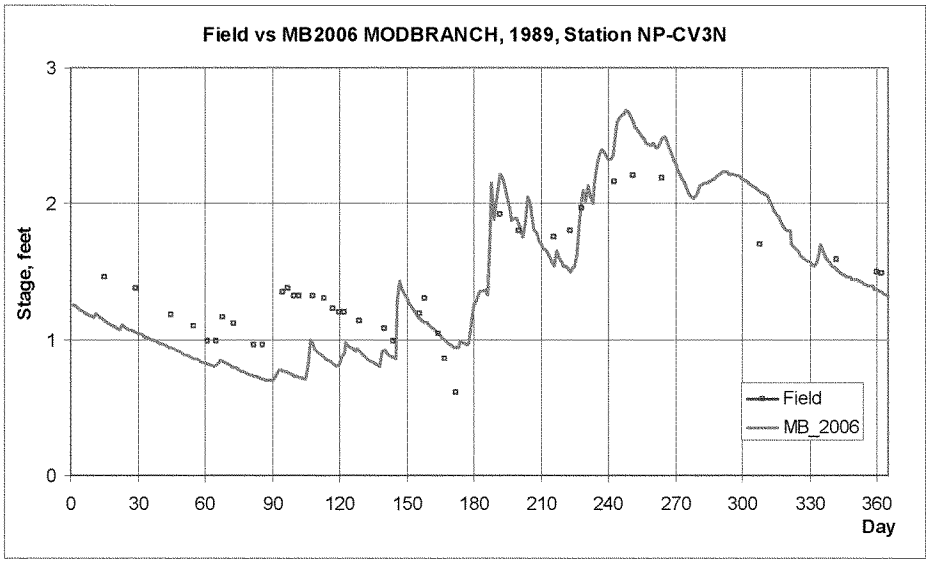
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV3N
Stage, feet
Day
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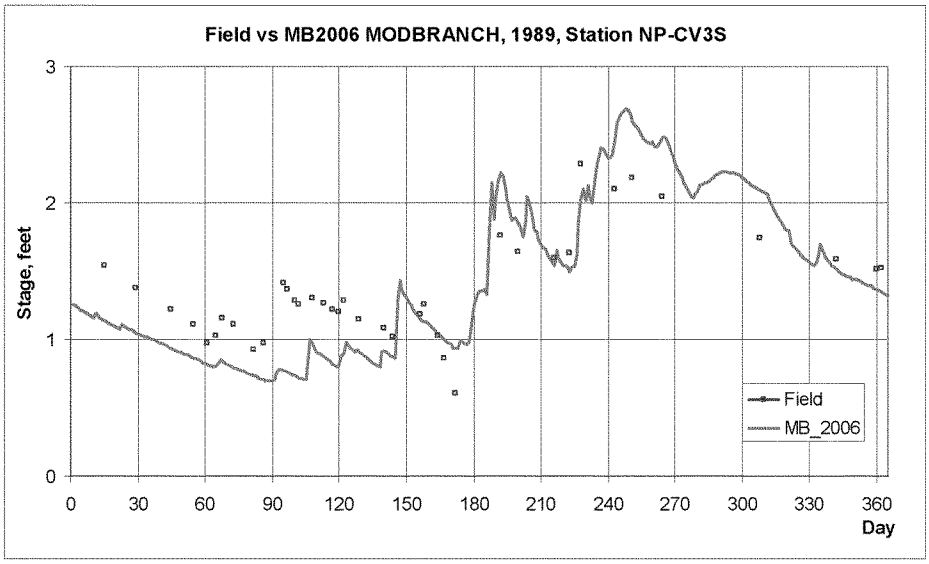
360
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV3S
Stage, feet
Day
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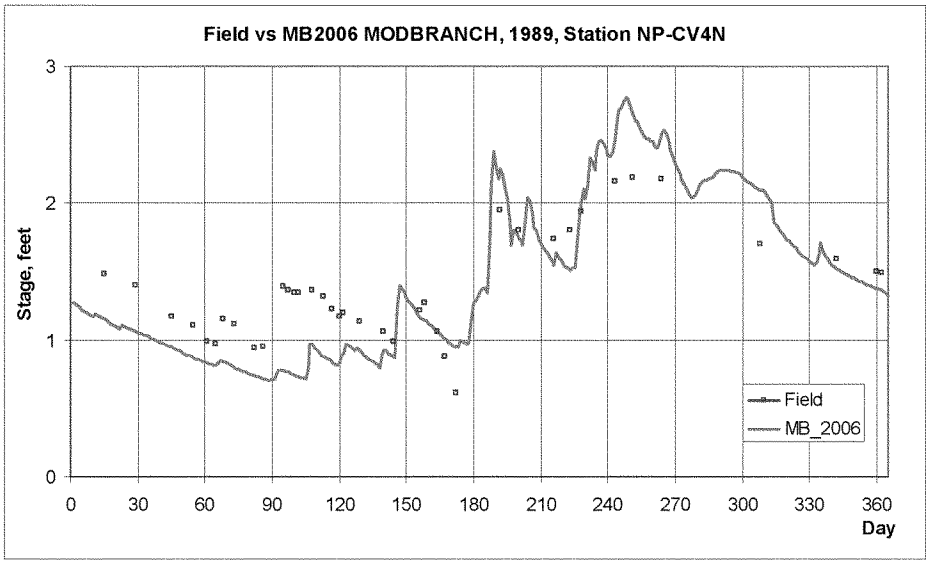
360
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV4N
Stage, feet
3
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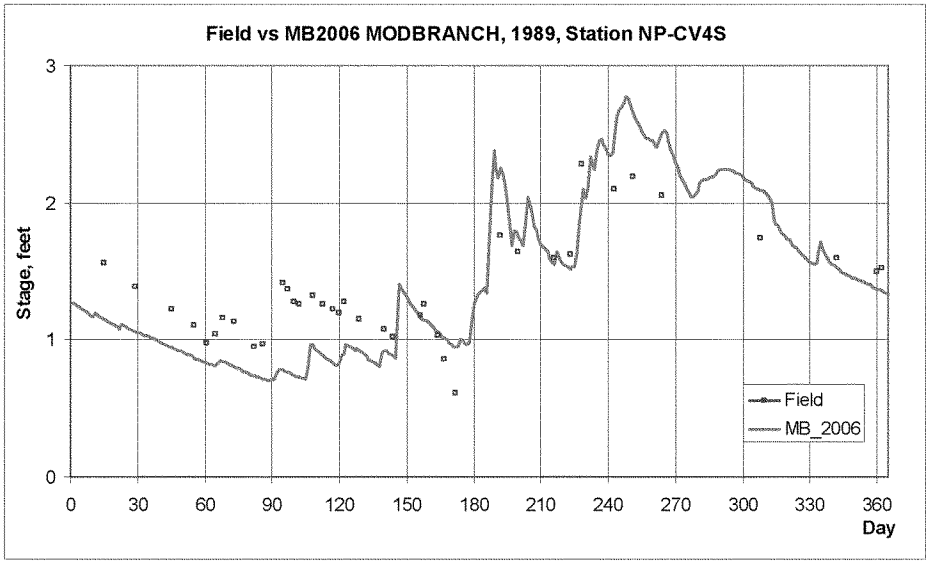
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV4S
Stage, feet
3
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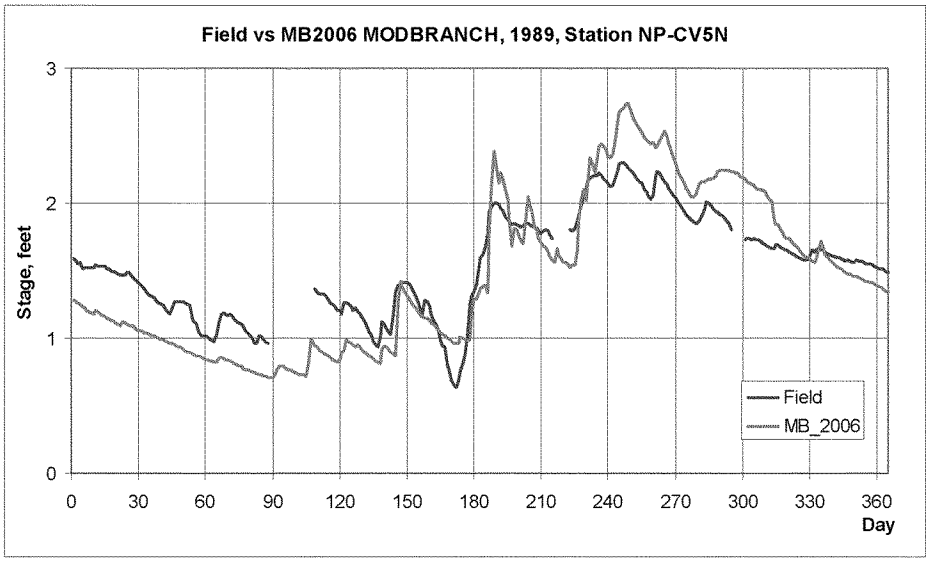
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV5N
Stage, feet
Day
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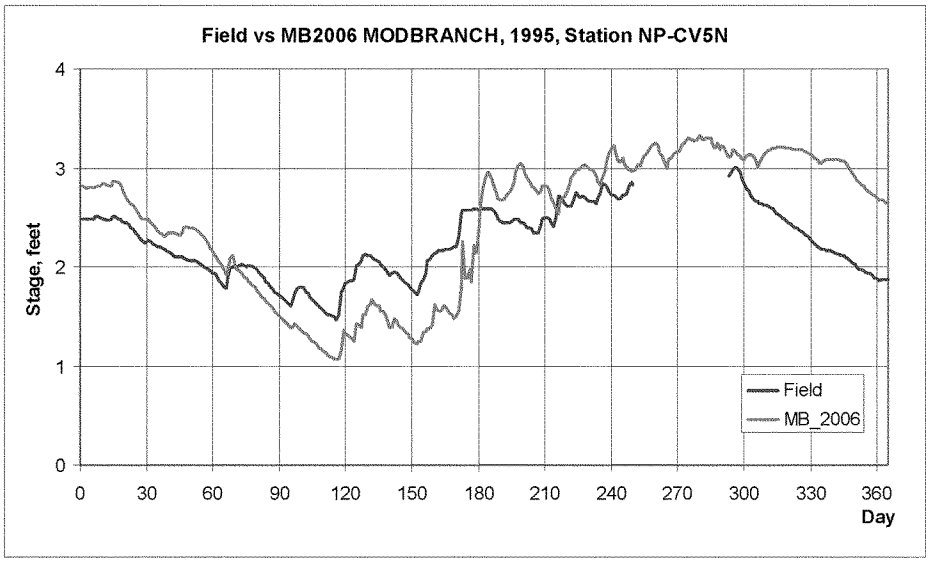
Field vs MB2006 MODBRANCH, 1995, Station NP-CV5N
Stage, feet
Day
Field
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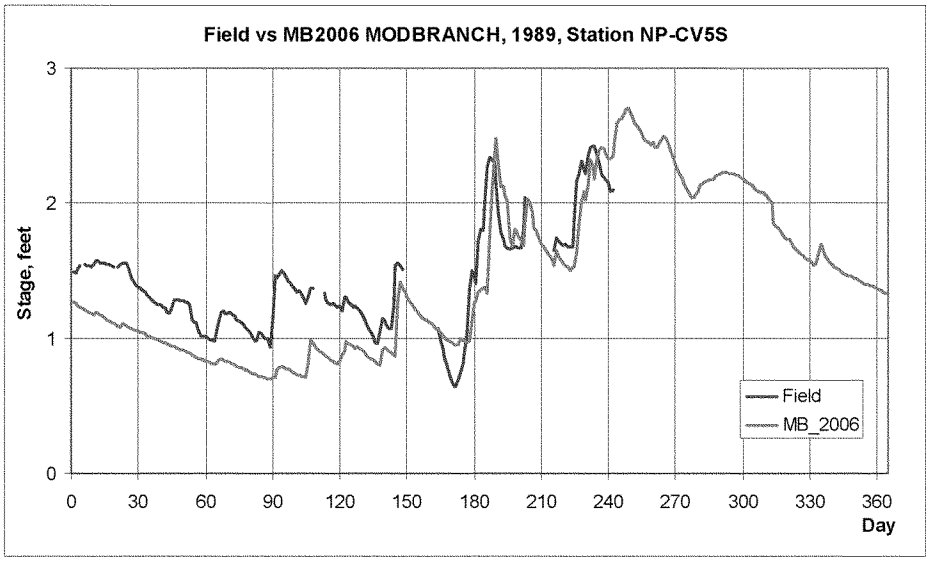
Field vs MB2006 MODBRANCH, 1989, Station NP-CV5S
Stage, feet
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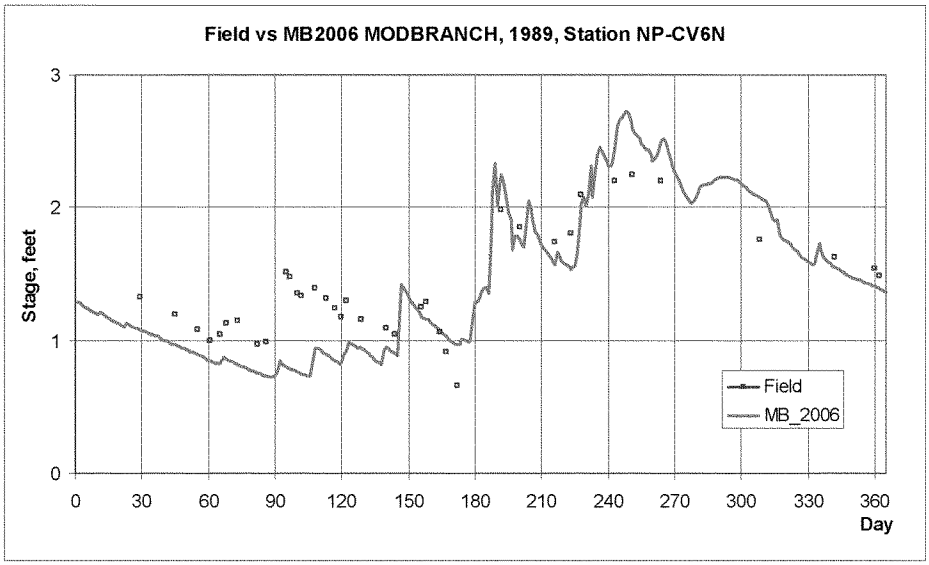
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV6N
Stage, feet
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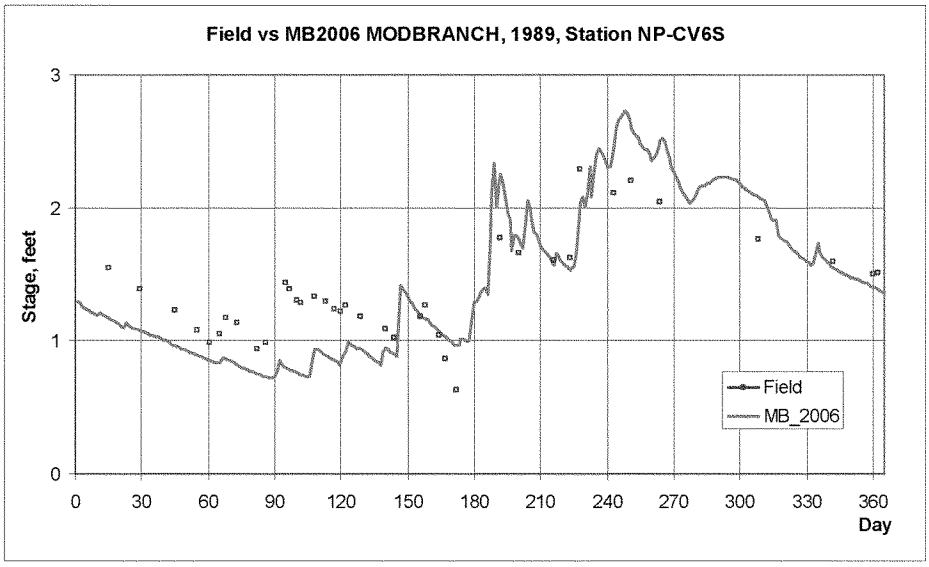
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV6S
Stage, feet
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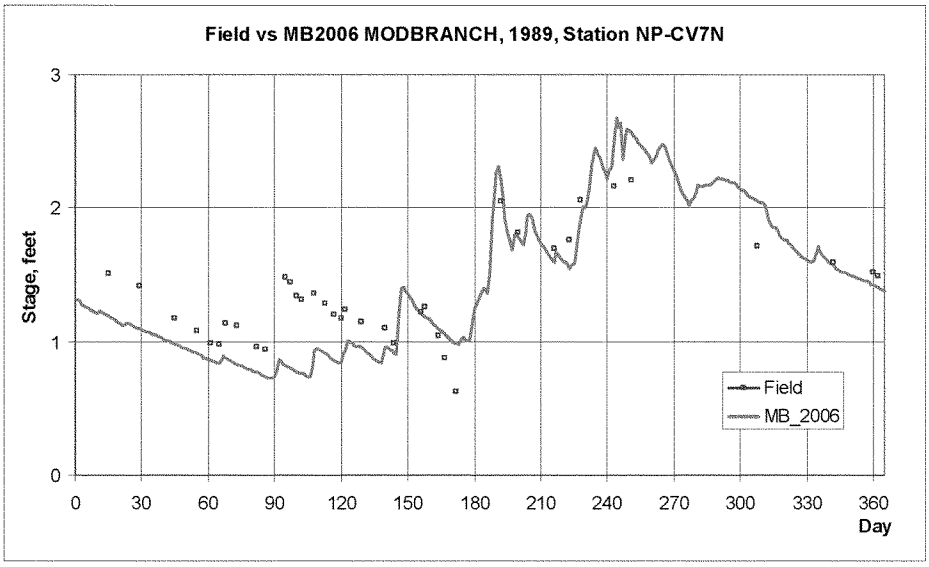
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV7N
Stage, feet
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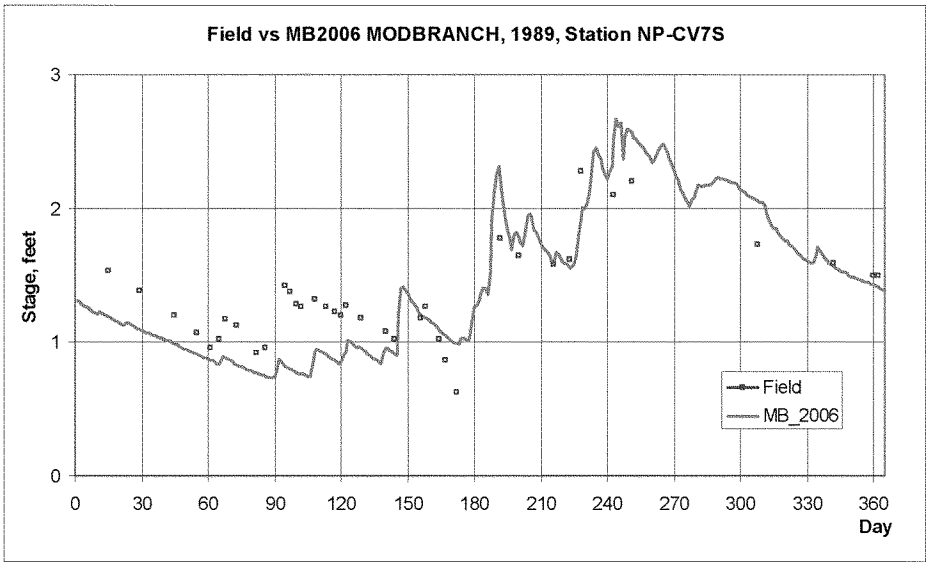
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV7S
Stage, feet
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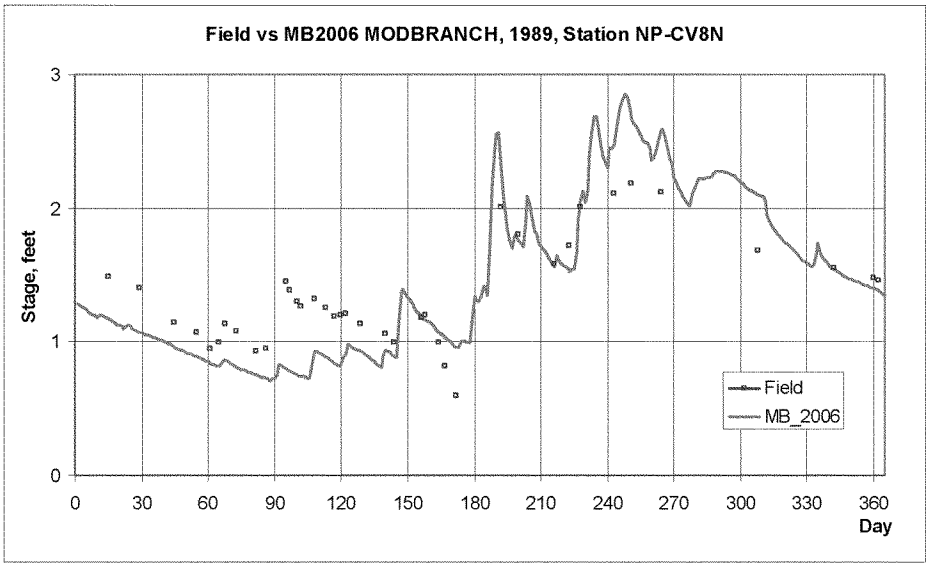
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV8N
Stage, feet
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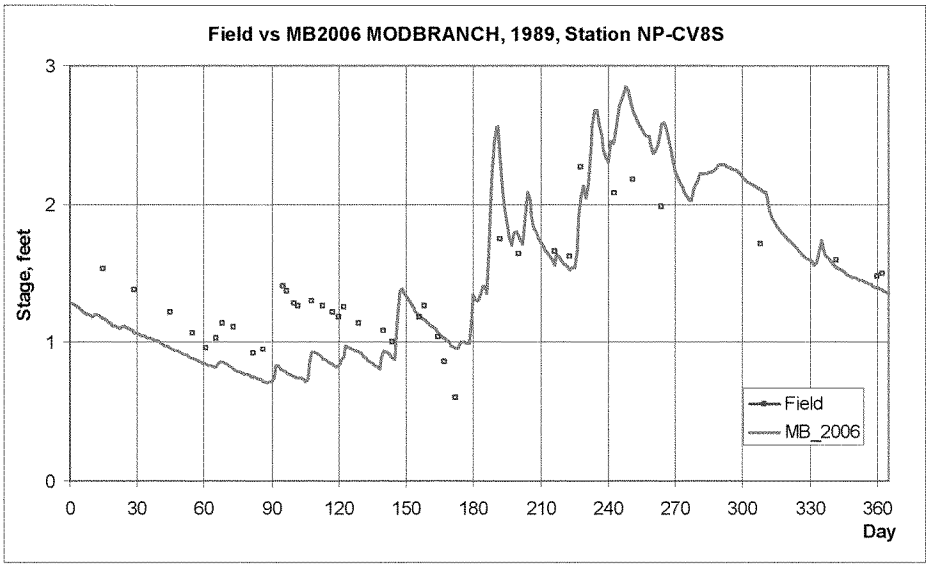
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV8S
Stage, feet
Day
Field
MB_2006
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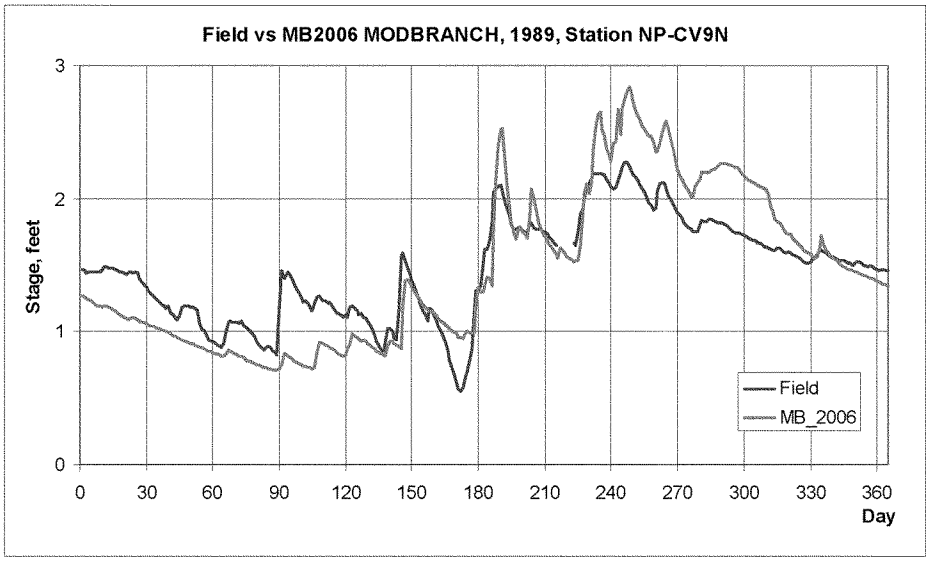
Field vs MB2006 MODBRANCH, 1989, Station NP-CV9N
Stage, feet
Day
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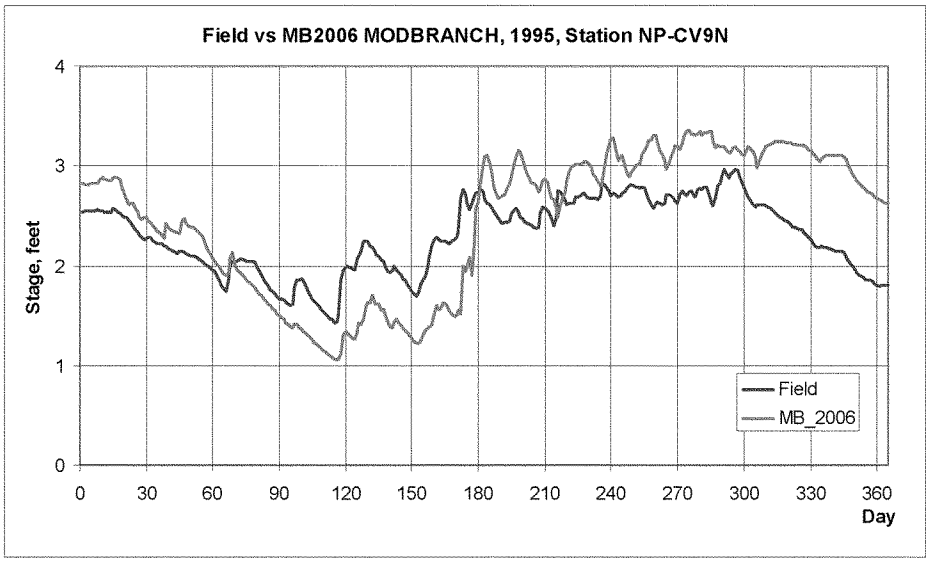
Field vs MB2006 MODBRANCH, 1995, Station NP-CV9N
Stage, feet
Day
Field
MB_2006
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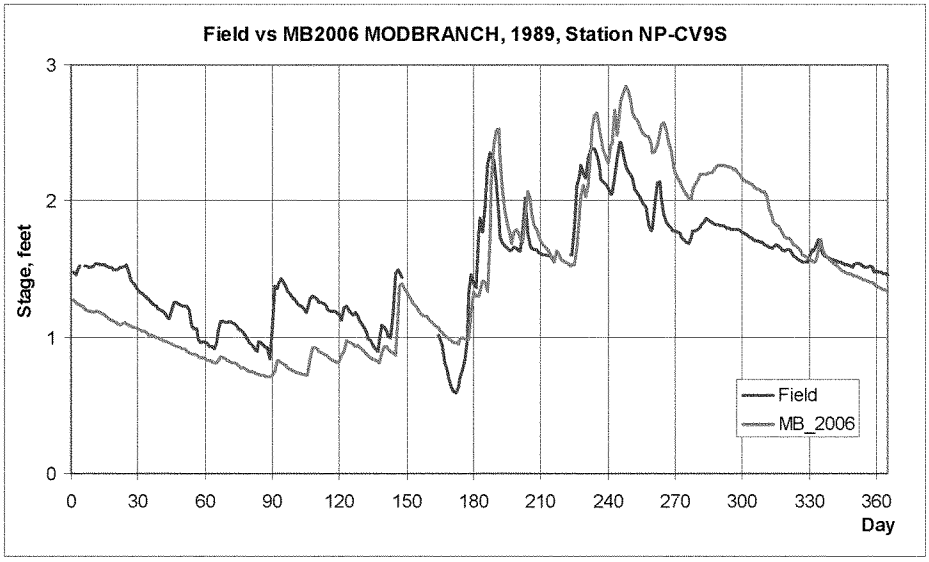
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-CV9S
Stage, feet
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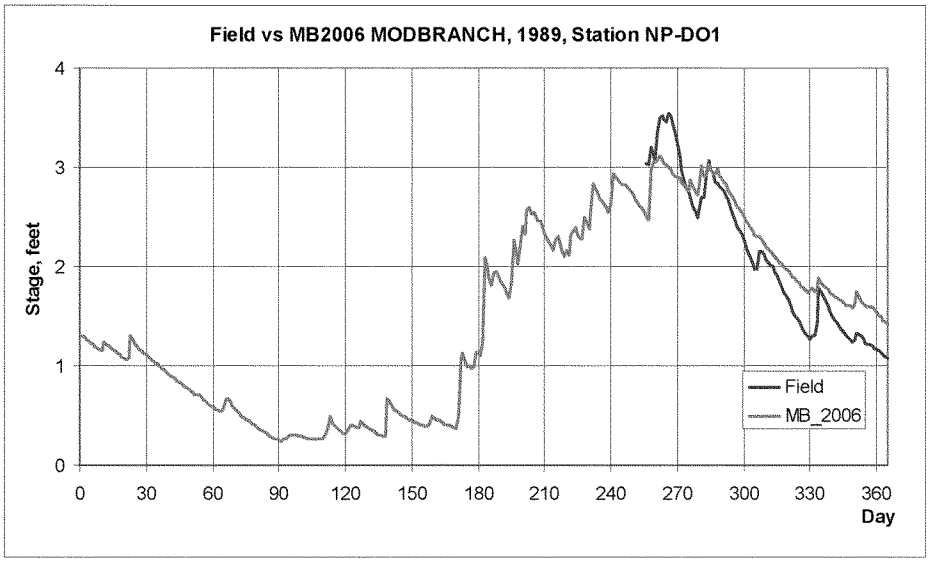
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-DO1
Stage, feet
0
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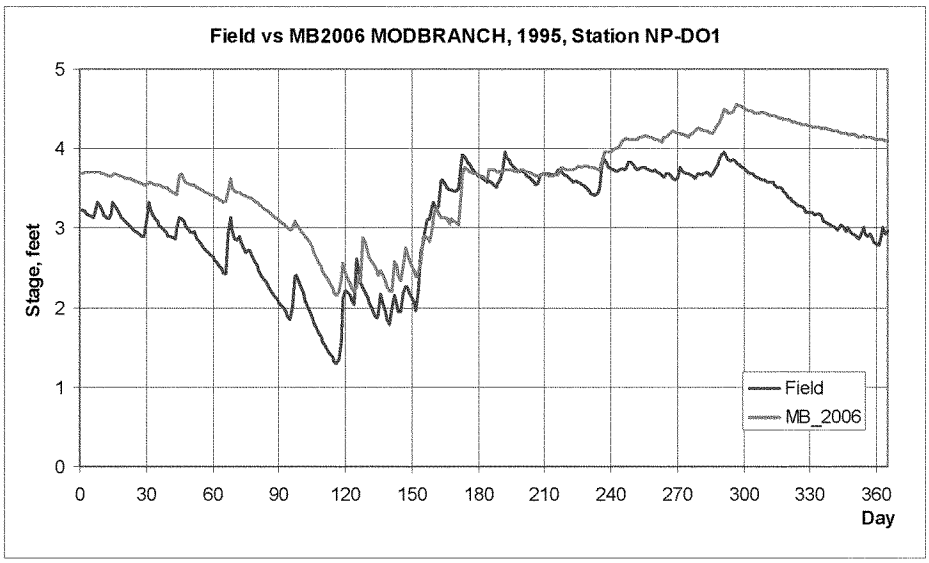
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NP-DO1
Stage, feet
0
1
2
3
4
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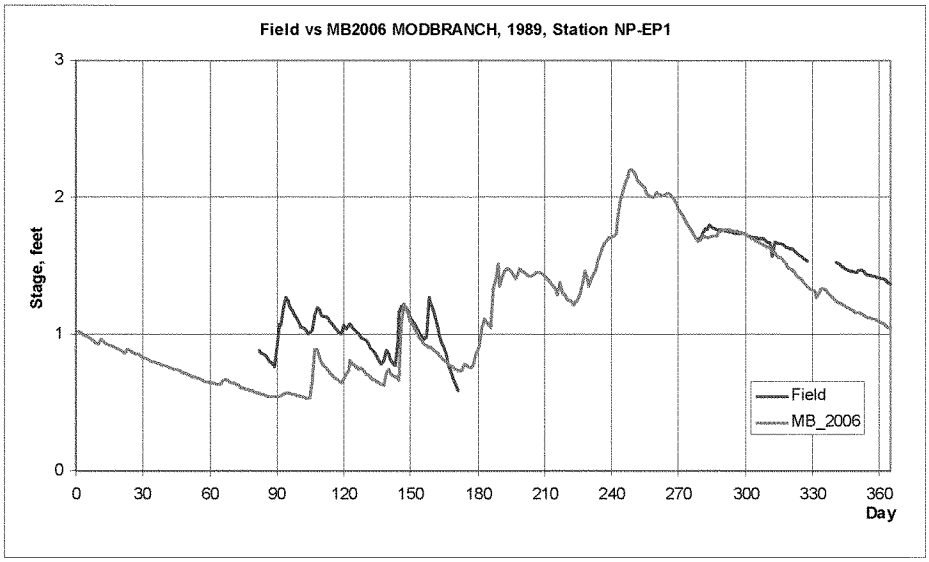
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-EP1
Stage, feet
Day
Field
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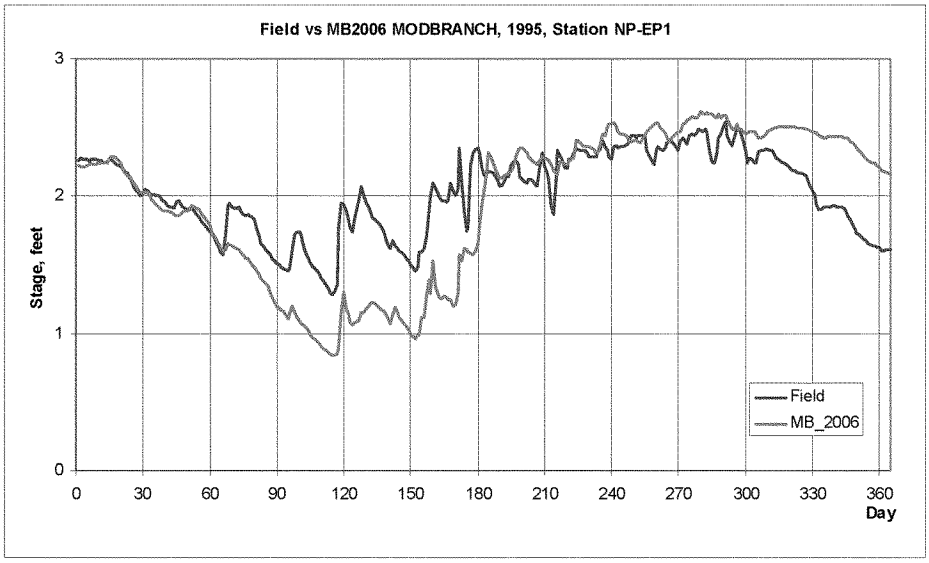
Field vs MB2006 MODBRANCH, 1995, Station NP-EP1
Stage, feet
Day
Field
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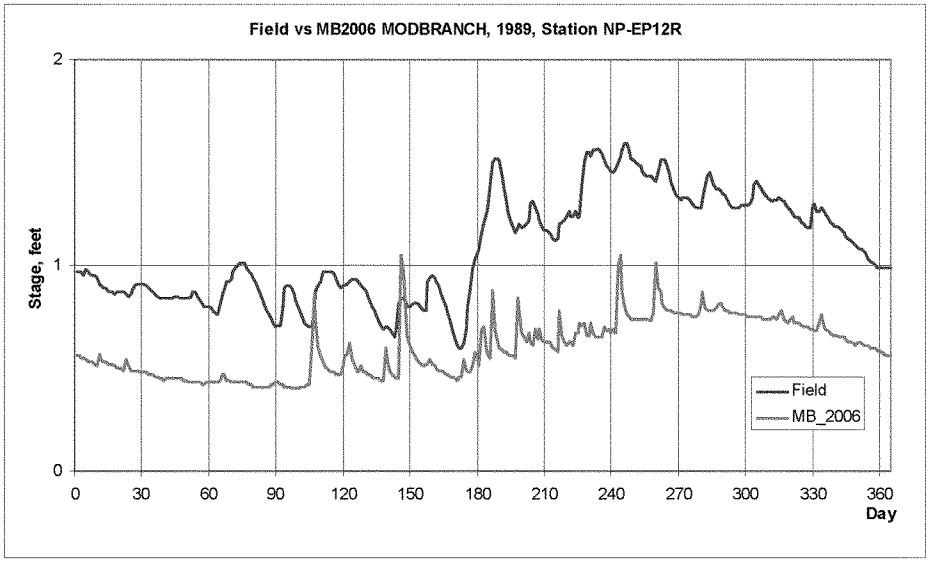
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-EP12R
Stage, feet
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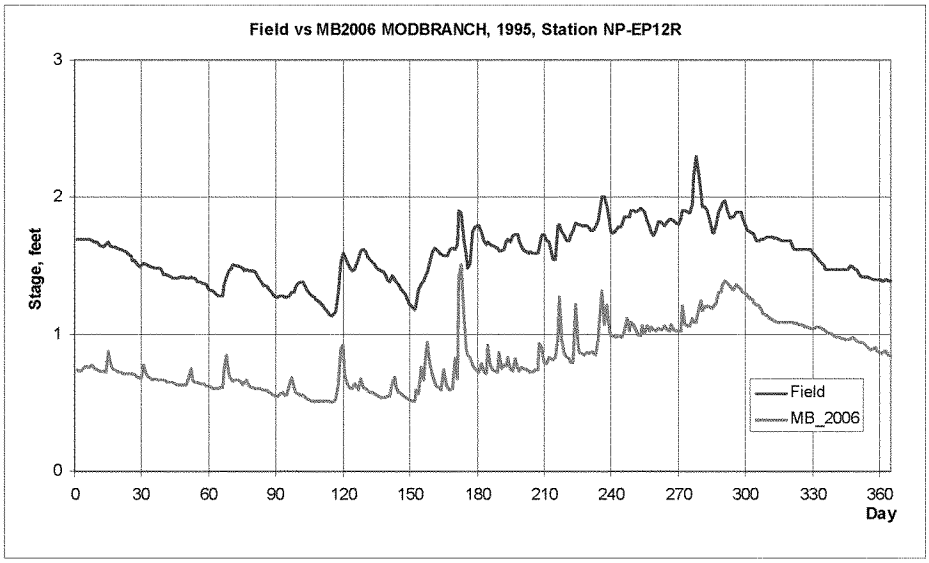
Field vs MB2006 MODBRANCH, 1995, Station NP-EP12R
Stage, feet
Day
Field
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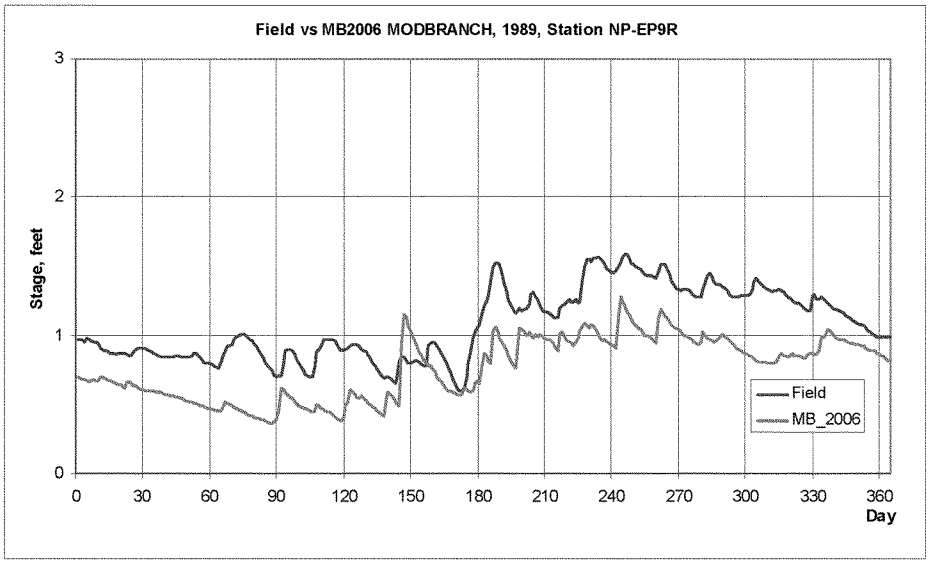
Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-EP9R
Stage, feet
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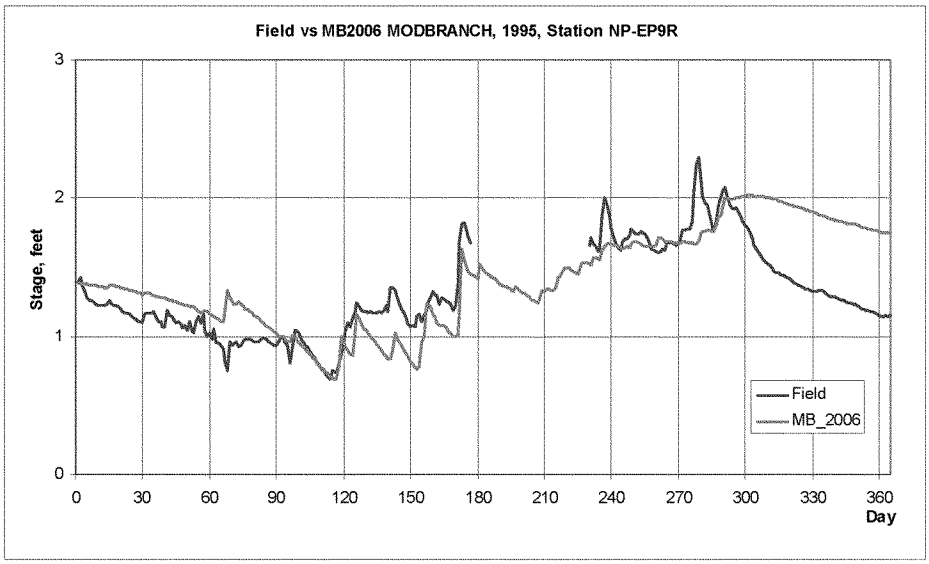
Field vs MB2006 MODBRANCH, 1995, Station NP-EP9R
Stage, feet
Day
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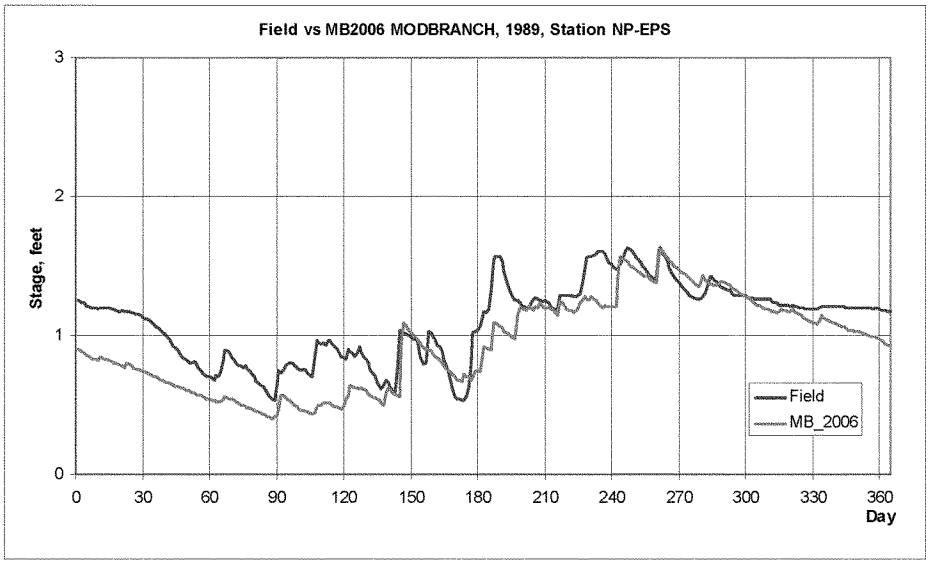
Field vs MB2006 MODBRANCH, 1989, Station NP-EPS
Stage, feet
Day
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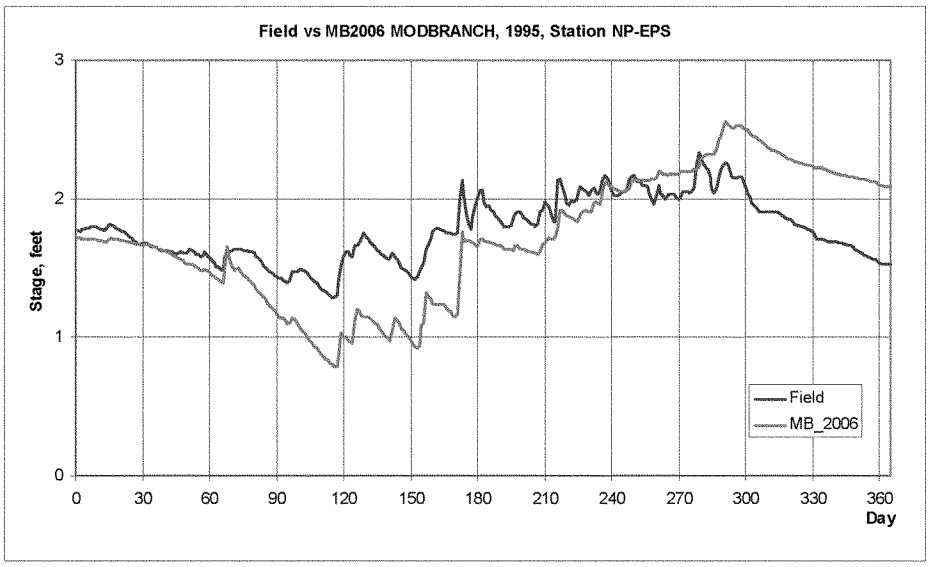
Field vs MB2006 MODBRANCH, 1995, Station NP-EPS
Stage, feet
Day
Field
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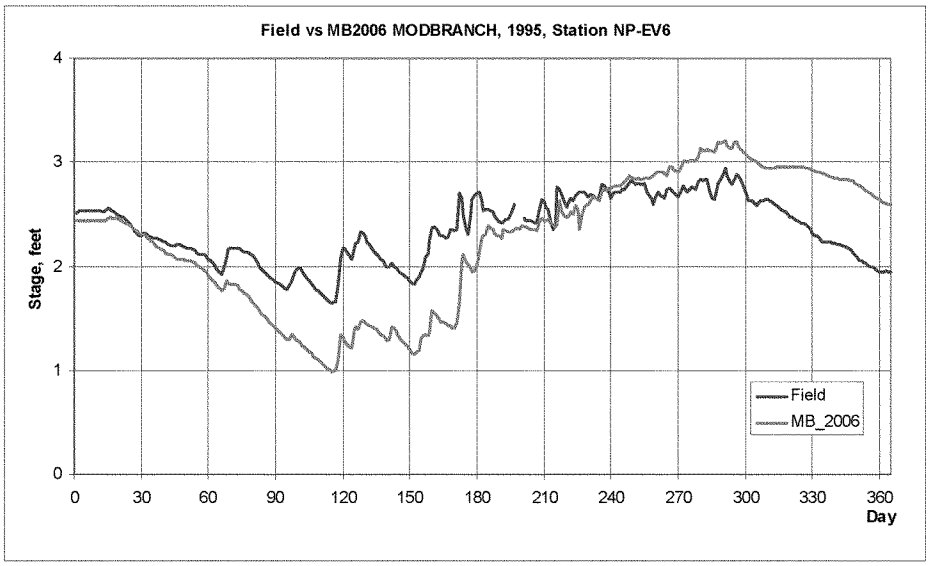
Appendix D


Field vs MB2006 MODBRANCH, 1995, Station NP-EV6
Stage, feet
Day
Field
MB_2006
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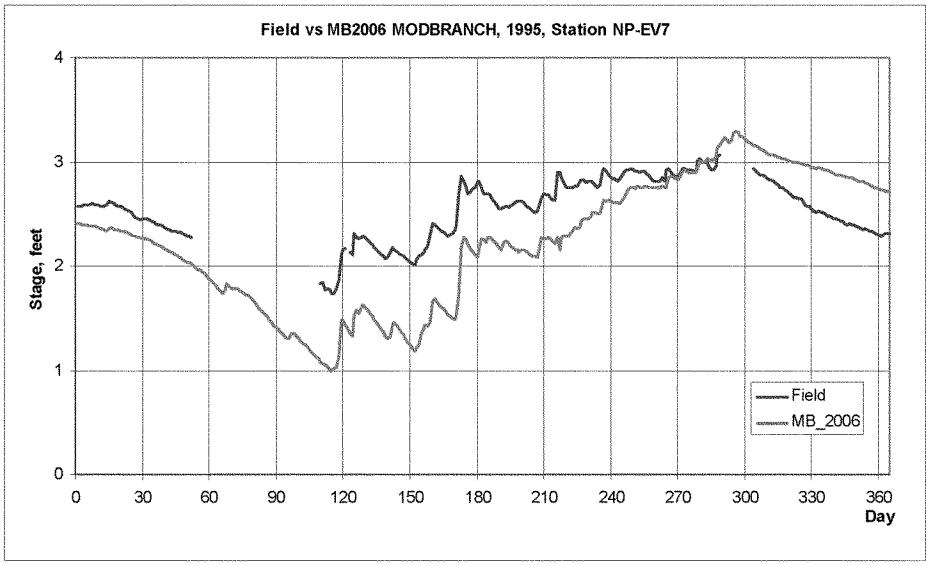
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station NP-EV7
Stage, feet
Day
0
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300
330
360
Field
MB_2006

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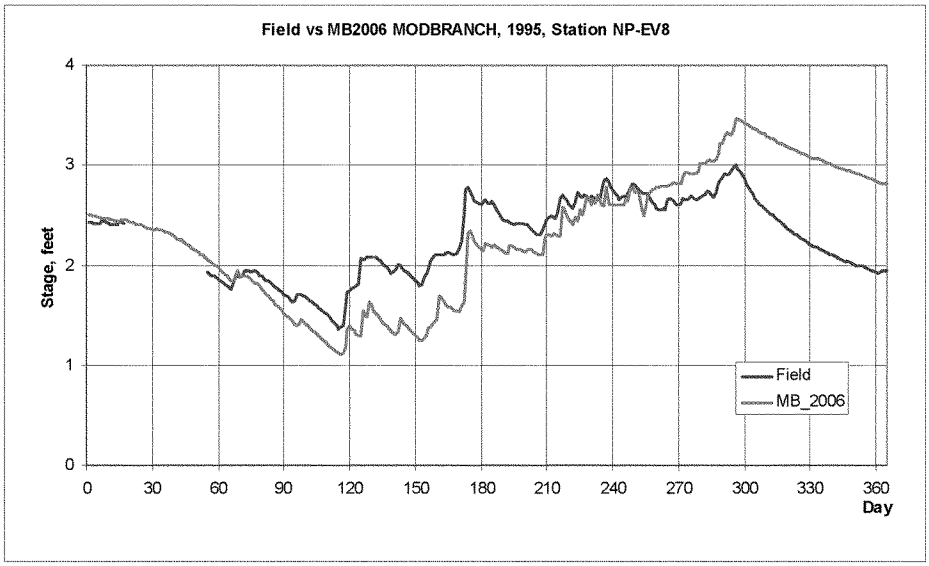
Field vs MB2006 MODBRANCH, 1995, Station NP-EV8
Stage, feet
Day
0
1
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3
4
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60
90
120
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210
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270
300
330
360
Field
MB_2006

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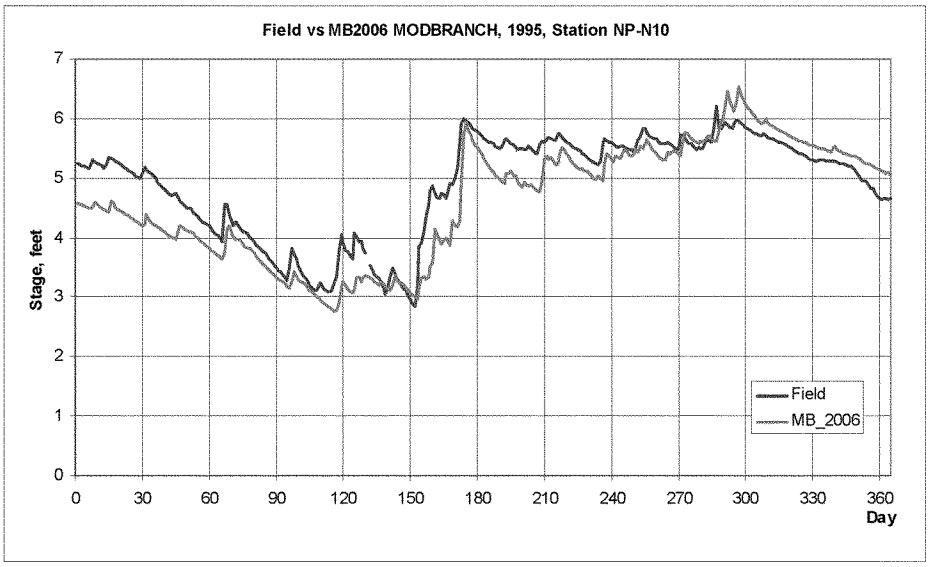
Field vs MB2006 MODBRANCH, 1995, Station NP-N10
Stage, feet
Day
Field
MB_2006
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1
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4
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6
7
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180
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240
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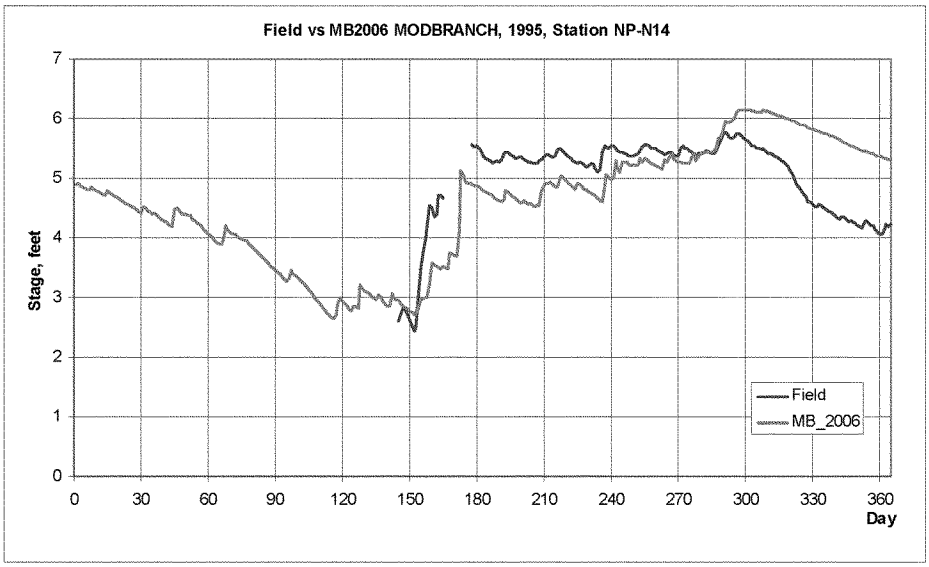
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station NP-N14
Stage, feet
Day
Field
MB_2006
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300
330
360

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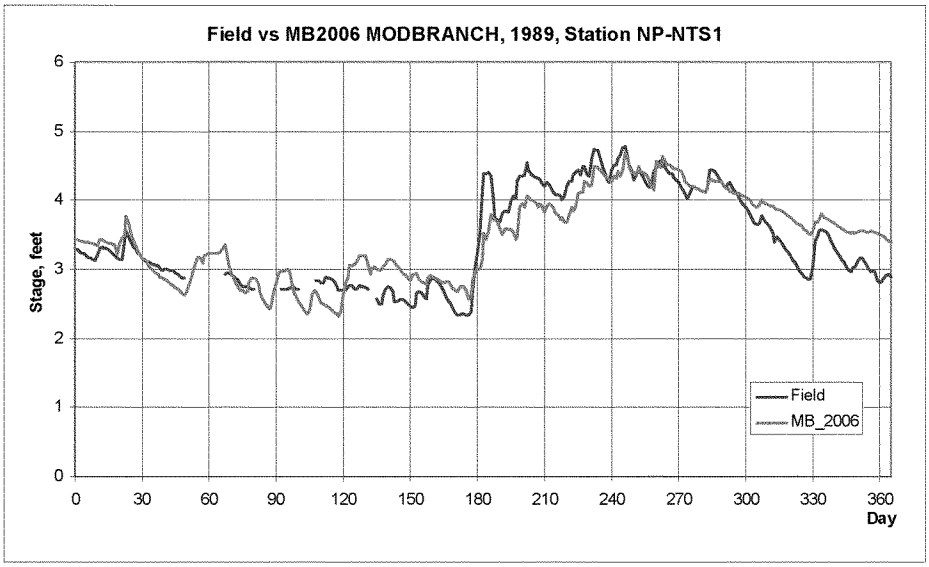
Field vs MB2006 MODBRANCH, 1989, Station NP-NTS1
Stage, feet
Day
Field
MB_2006
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150
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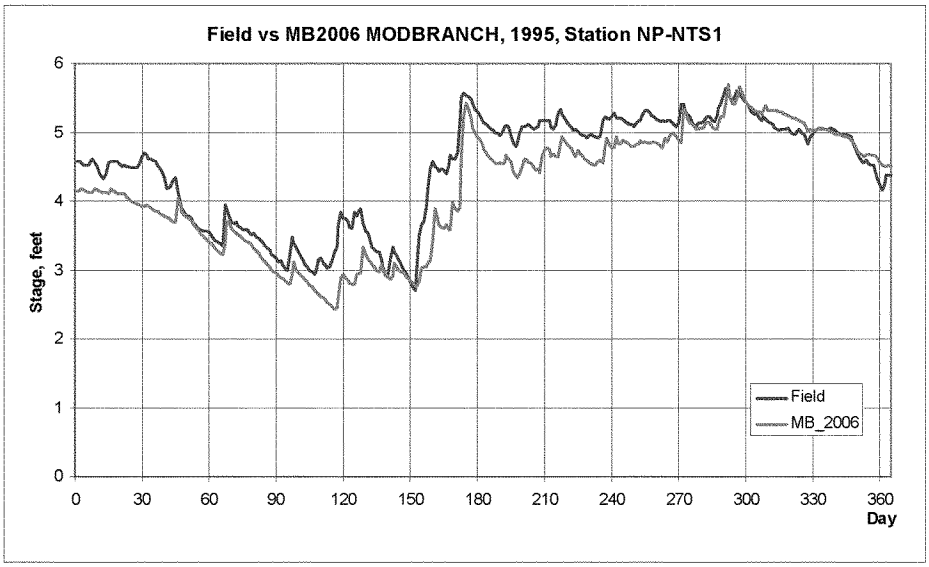
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-NTS1
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
0
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60
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120
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330
360

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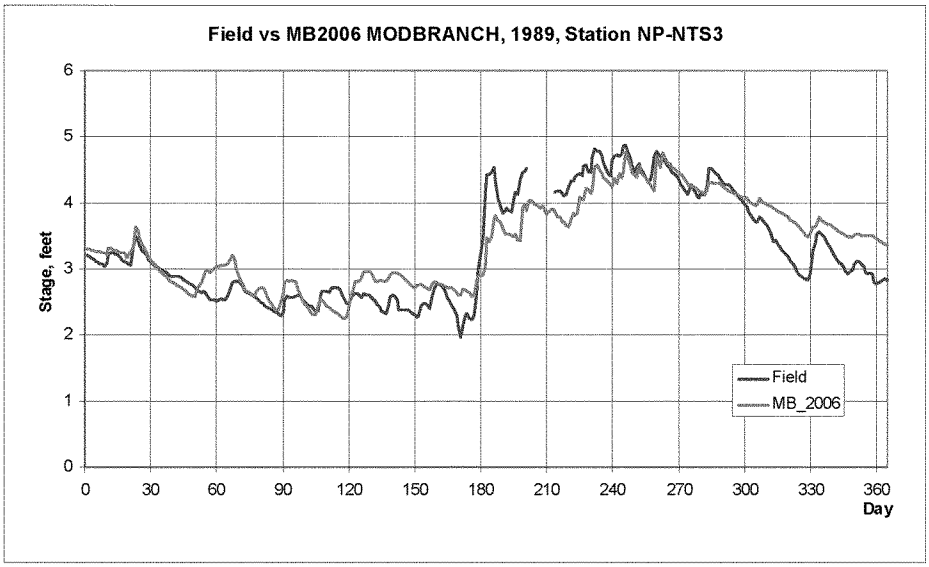
Field vs MB2006 MODBRANCH, 1989, Station NP-NTS3
Stage, feet
0
1
2
3
4
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300
330
360
Day
Field
MB_2006

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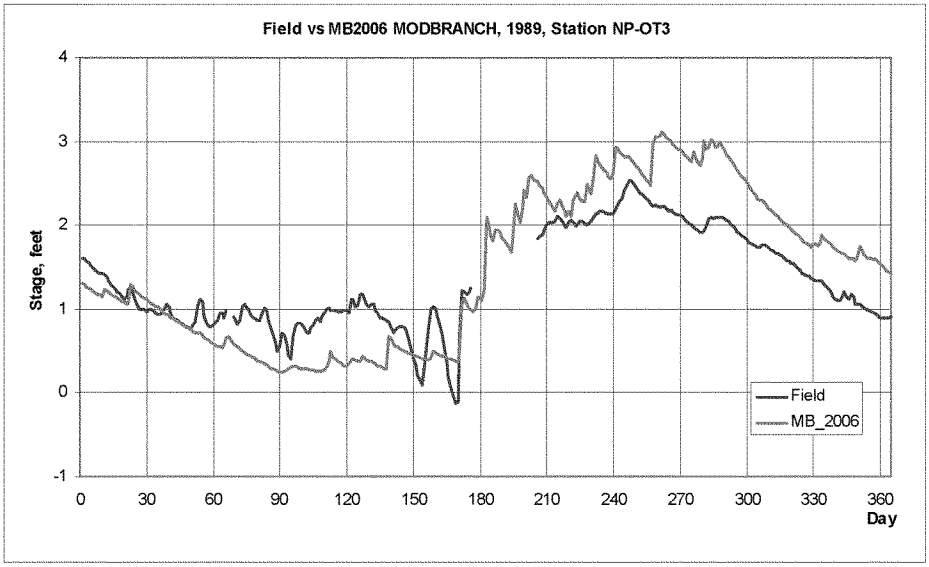
Field vs MB2006 MODBRANCH, 1989, Station NP-OT3
Stage, feet
Day
Field
MB_2006
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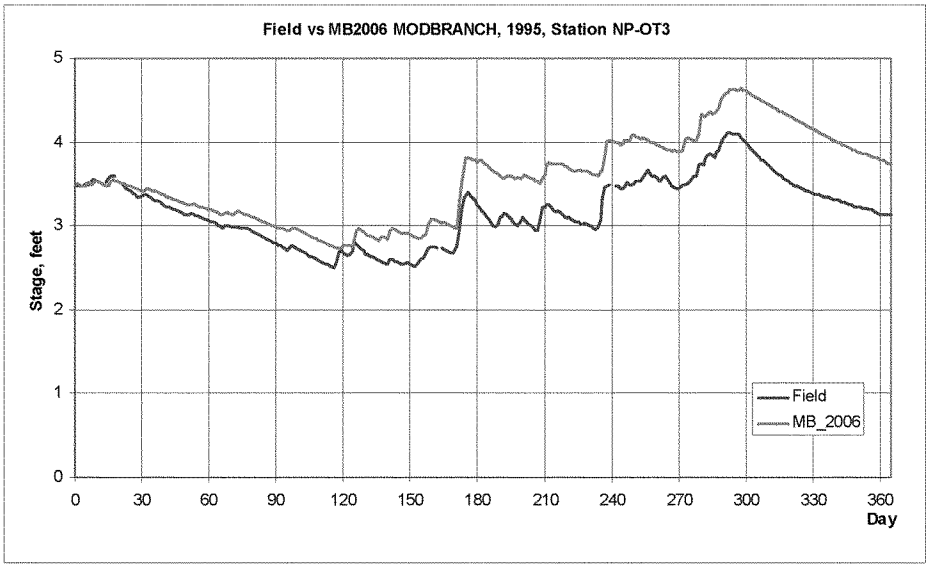
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-OT3
Stage, feet
Day
Field
MB_2006
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4
3
2
1
0
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60
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120
150
180
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240
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300
330
360

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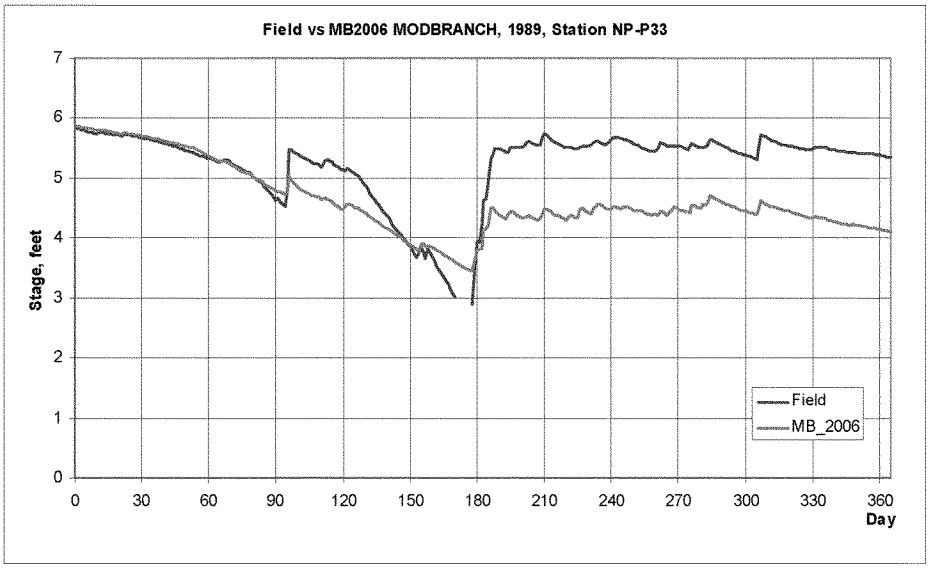
Field vs MB2006 MODBRANCH, 1989, Station NP-P33
Stage, feet
Day
Field
MB_2006
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3
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5
6
7
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90
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150
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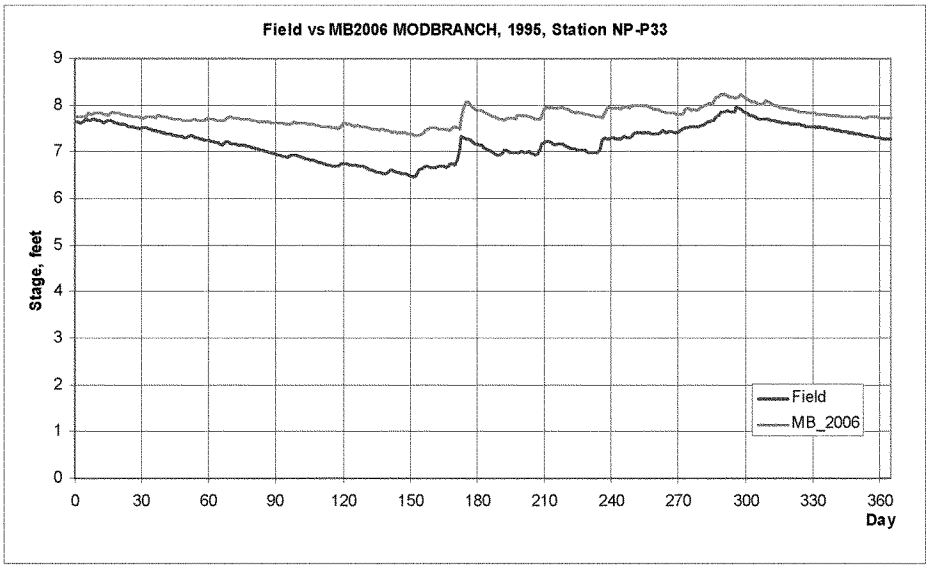
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P33
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
9
0
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60
90
120
150
180
210
240
270
300
330
360

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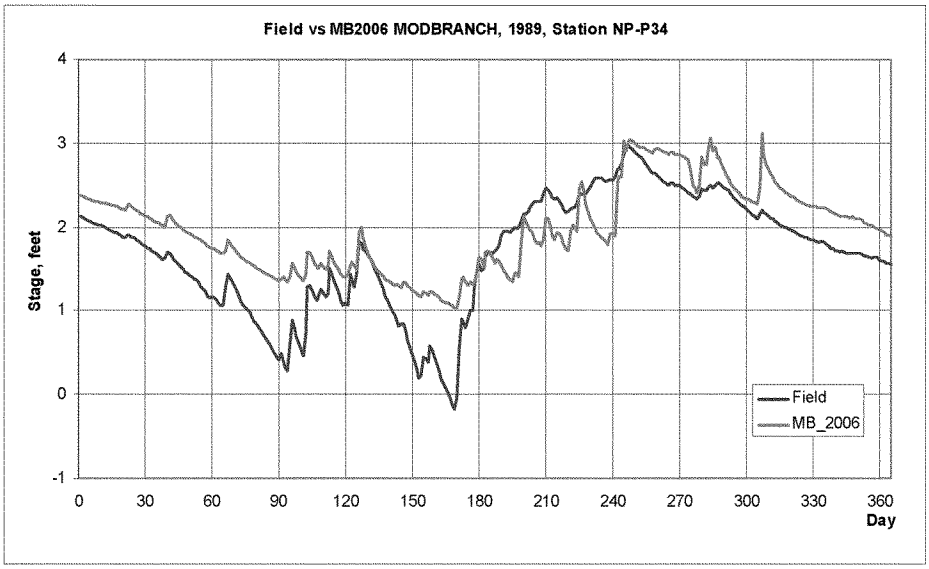
Field vs MB2006 MODBRANCH, 1989, Station NP-P34
Stage, feet
Day
Field
MB_2006
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1
0
-1
0
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90
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150
180
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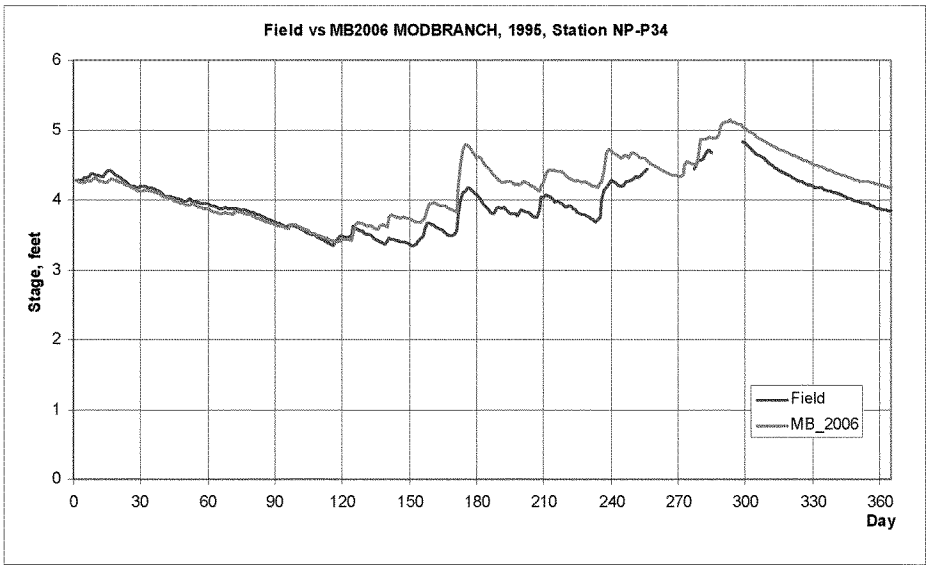
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P34
Stage, feet
Day
Field
MB_2006
6
5
4
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1
0
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60
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120
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300
330
360

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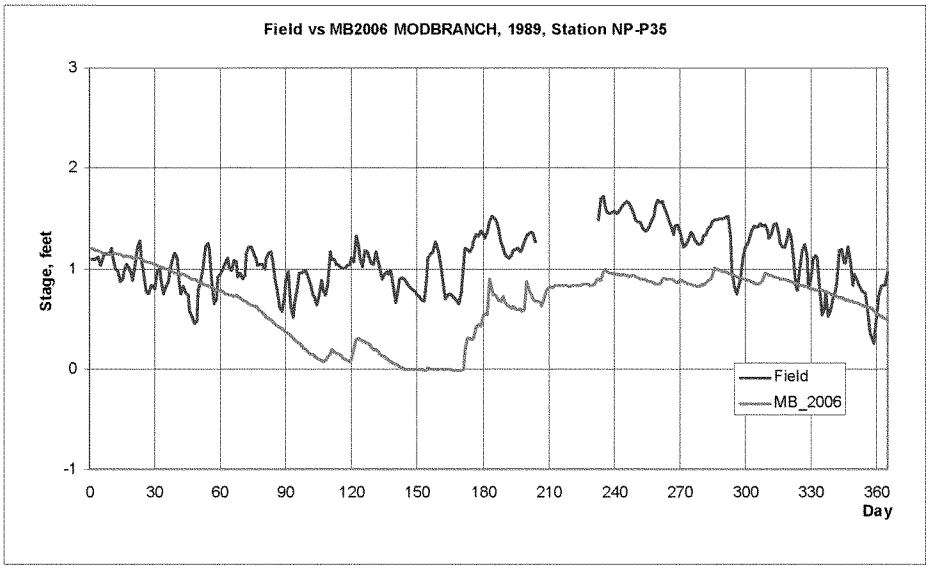
Field vs MB2006 MODBRANCH, 1989, Station NP-P35
Stage, feet
3
2
1
0
-1
0
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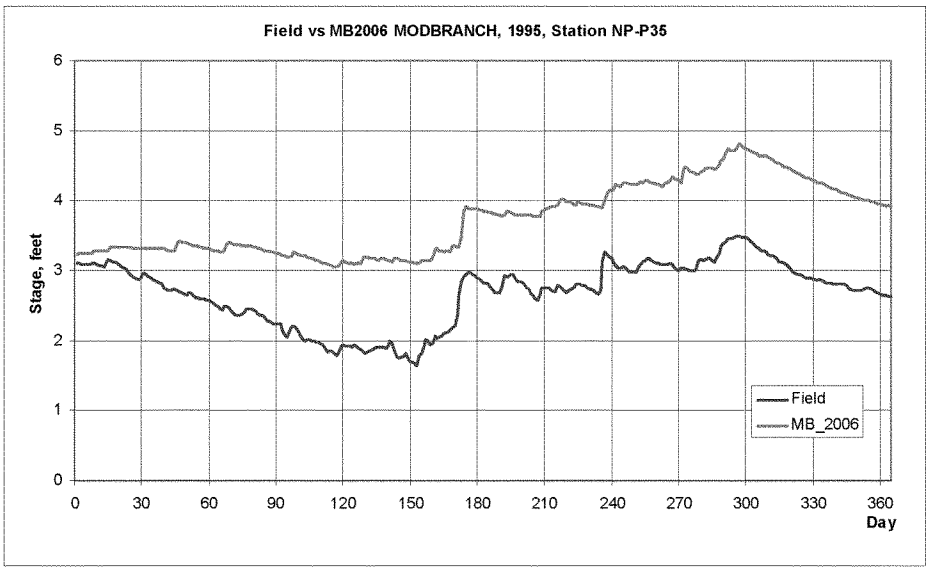
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NP-P35
Stage, feet
6
5
4
3
2
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300
330
360
Day
Field
MB_2006

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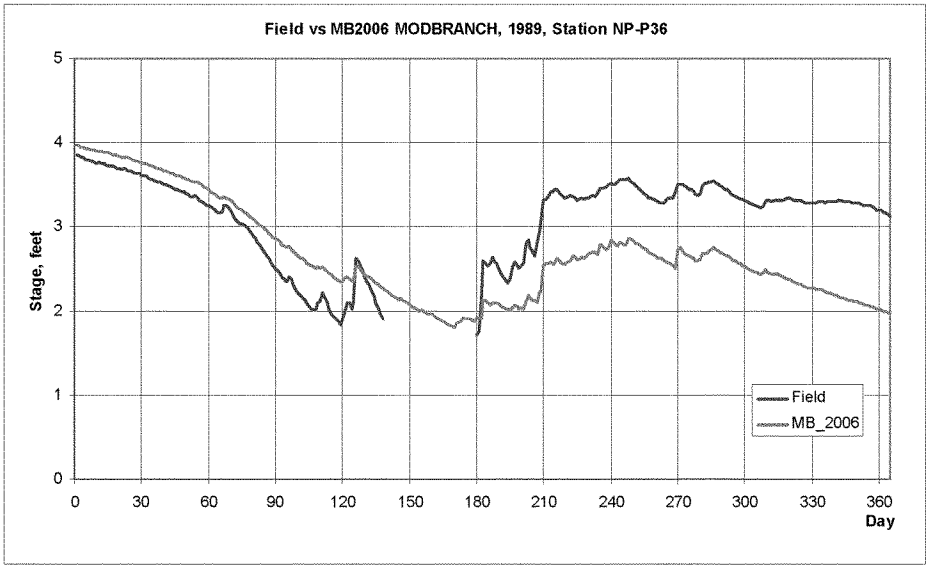
Field vs MB2006 MODBRANCH, 1989, Station NP-P36
Stage, feet
Day
Field
MB_2006
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2
3
4
5
0
30
60
90
120
150
180
210
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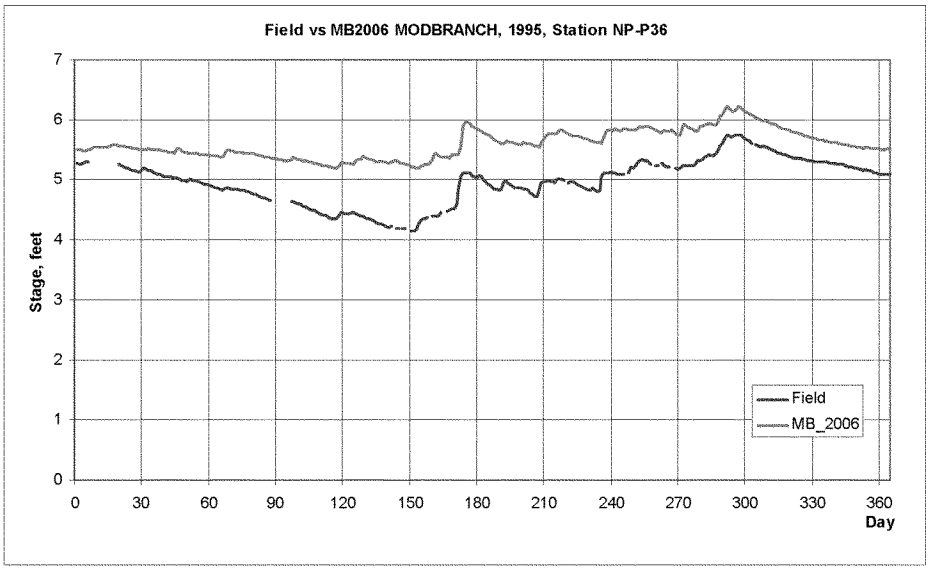
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P36
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
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6
7
0
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60
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120
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180
210
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300
330
360

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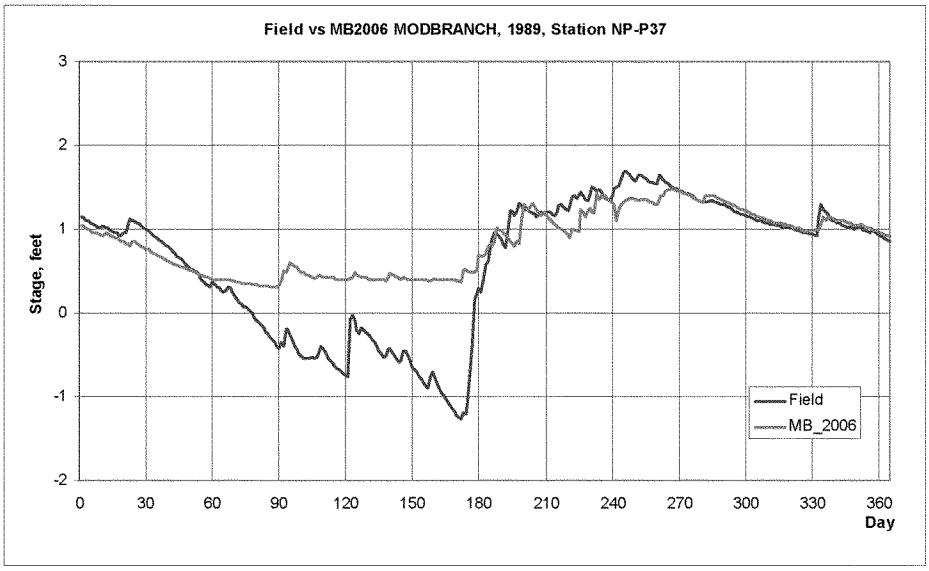
Field vs MB2006 MODBRANCH, 1989, Station NP-P37
Stage, feet
Day
Field
MB_2006
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2
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0
-1
-2
0
30
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150
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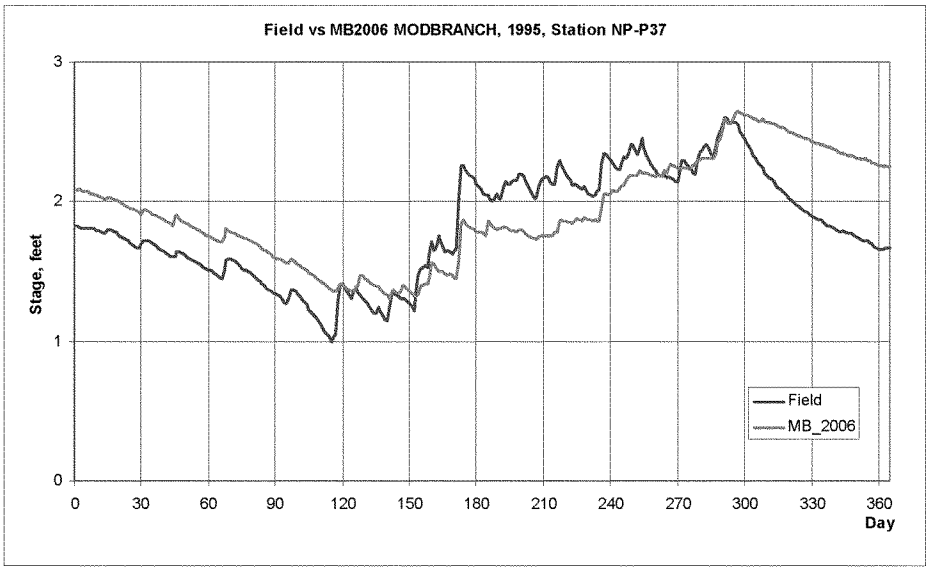
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P37
Stage, feet
Day
Field
MB_2006
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120
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300
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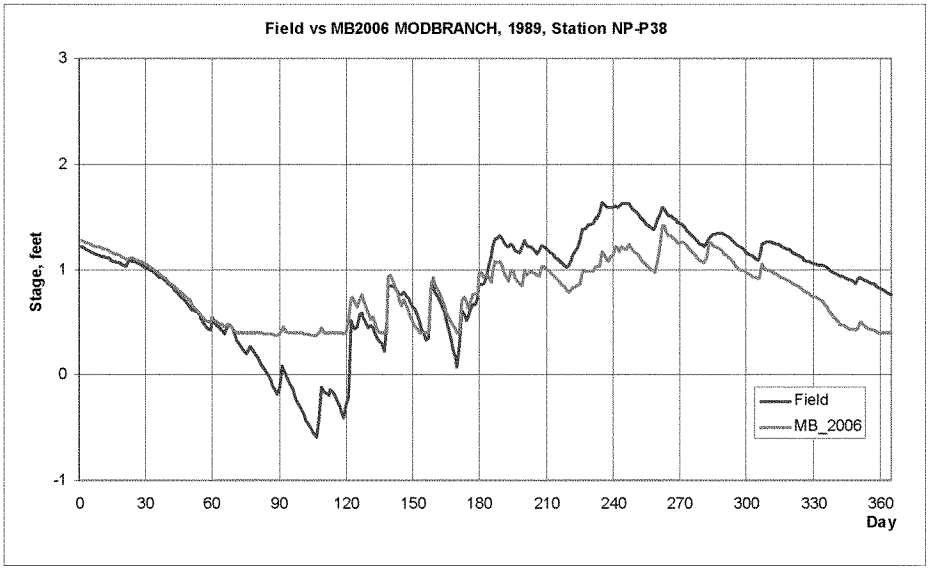
Field vs MB2006 MODBRANCH, 1989, Station NP-P38
Stage, feet
3
2
1
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-1
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60
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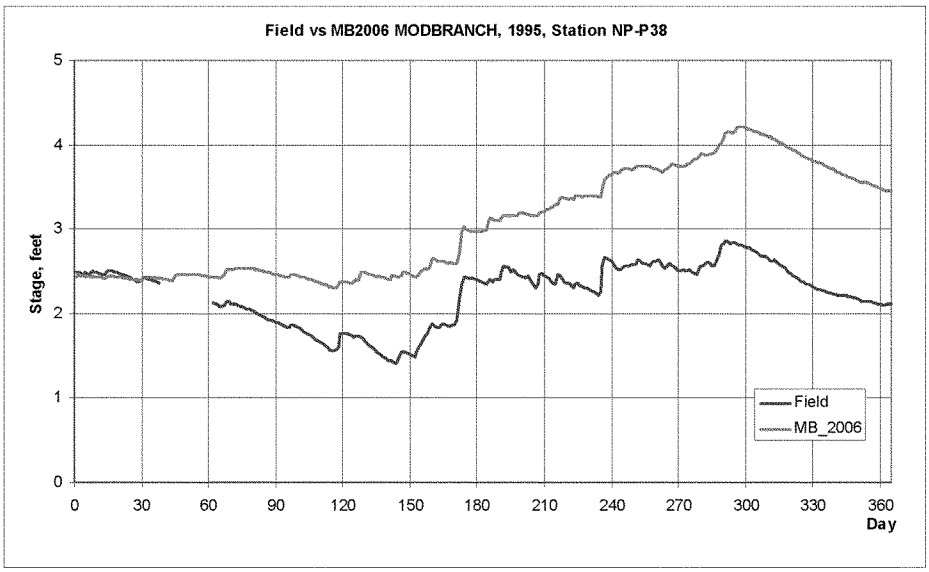
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NP-P38
Stage, feet
5
4
3
2
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90
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240
270
300
330
360
Day
Field
MB_2006

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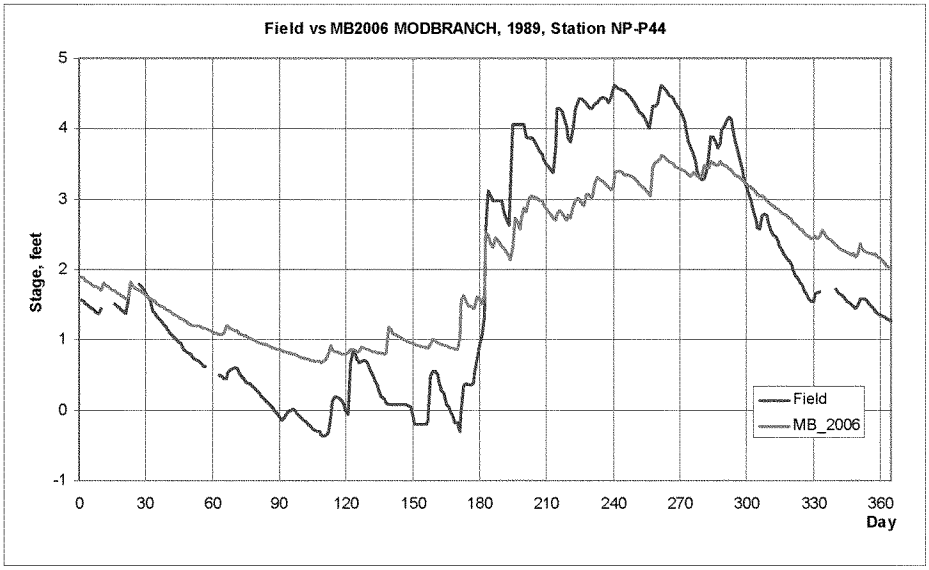
Field vs MB2006 MODBRANCH, 1989, Station NP-P44
Stage, feet
Day
Field
MB_2006
5
4
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2
1
0
-1
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30
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150
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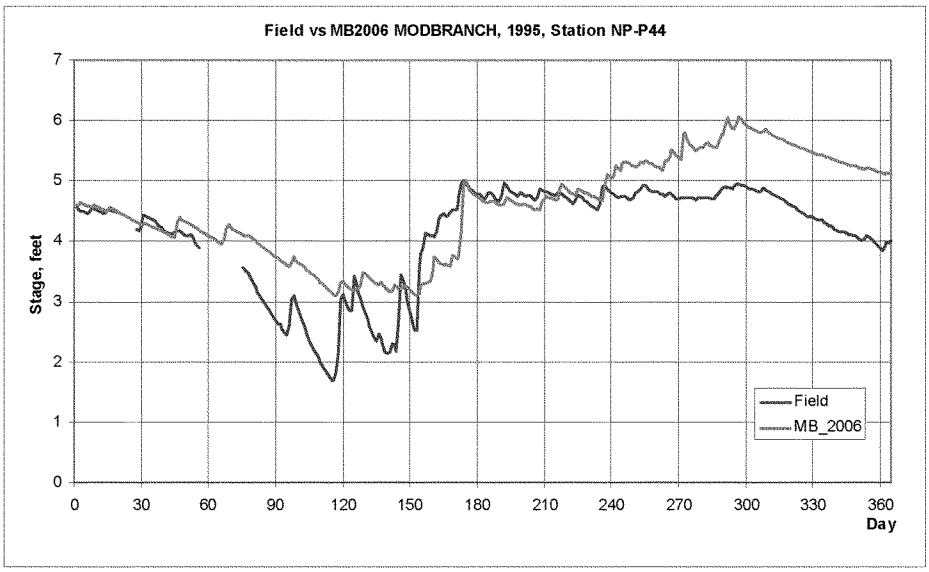
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P44
Stage, feet
Day
Field
MB_2006
7
6
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360

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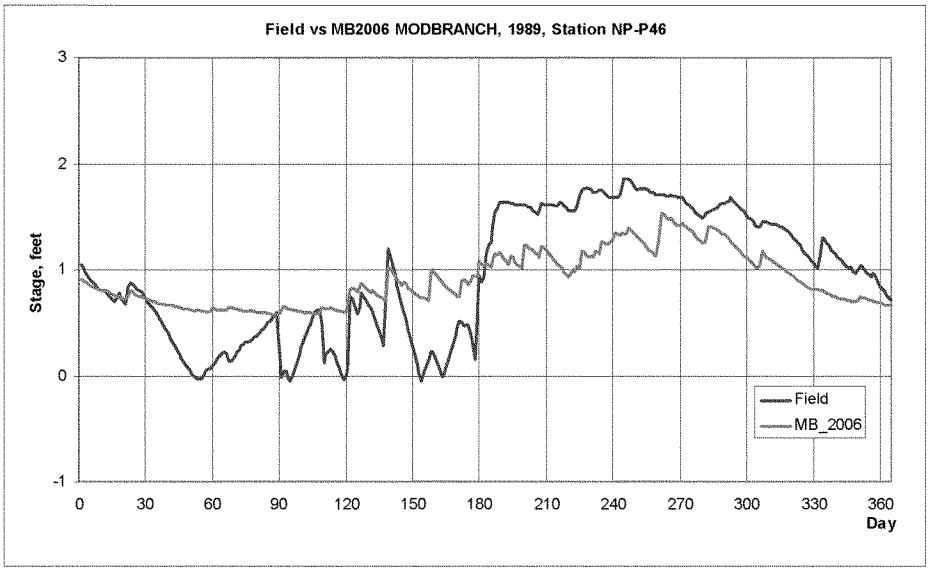
Field vs MB2006 MODBRANCH, 1989, Station NP-P46
Stage, feet
3
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-1
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210
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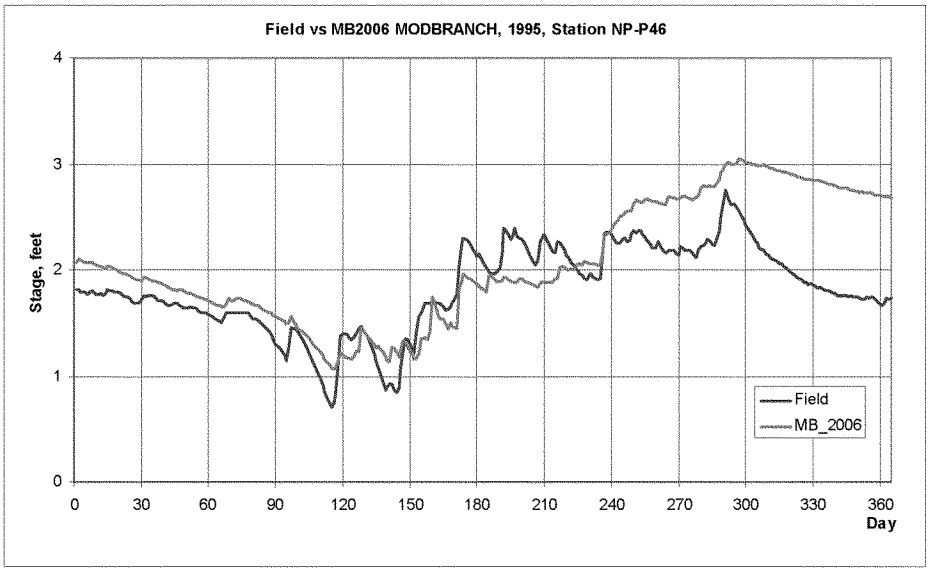
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NP-P46
Stage, feet
4
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2
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270
300
330
360
Day
Field
MB_2006

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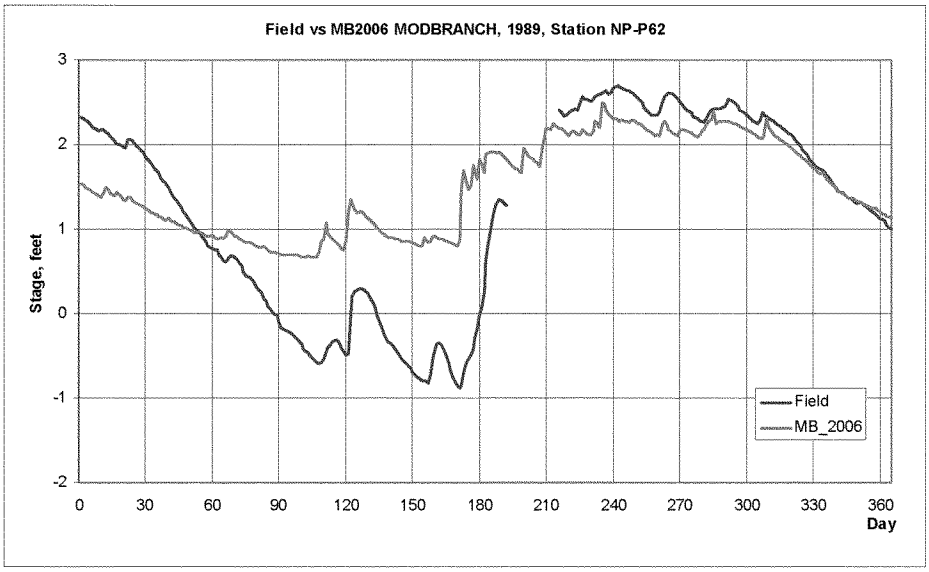
Field vs MB2006 MODBRANCH, 1989, Station NP-P62
Stage, feet
Day
Field
MB_2006
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-1
-2
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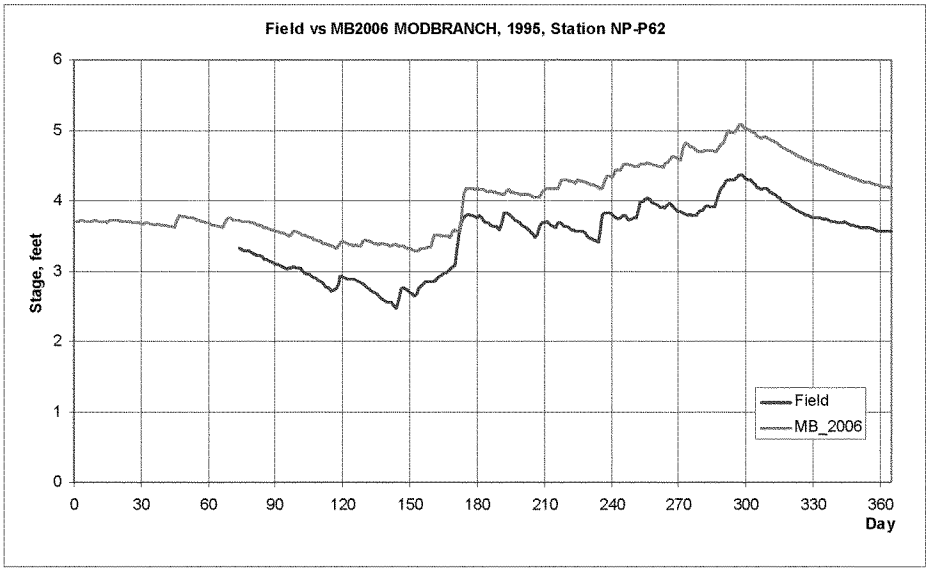
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P62
Stage, feet
Day
Field
MB_2006
6
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360

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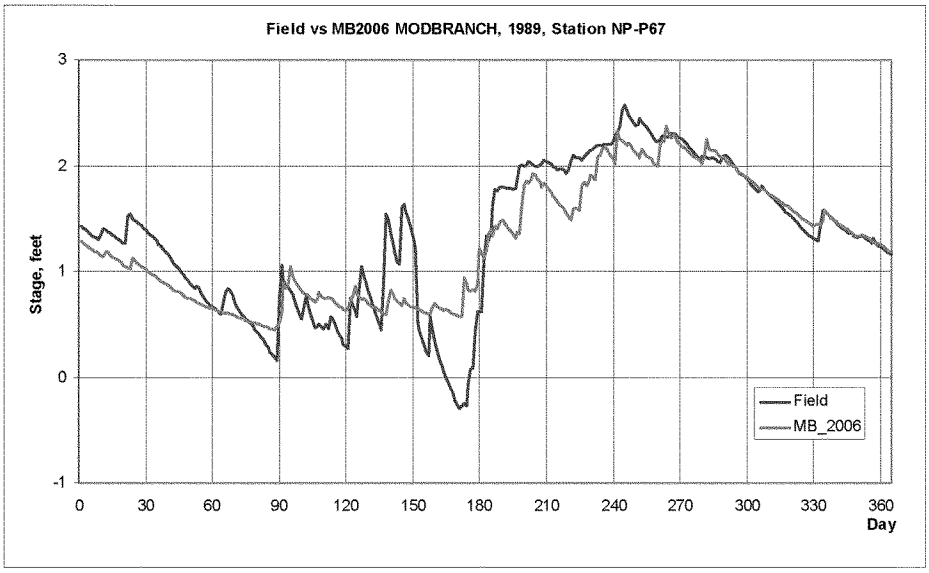
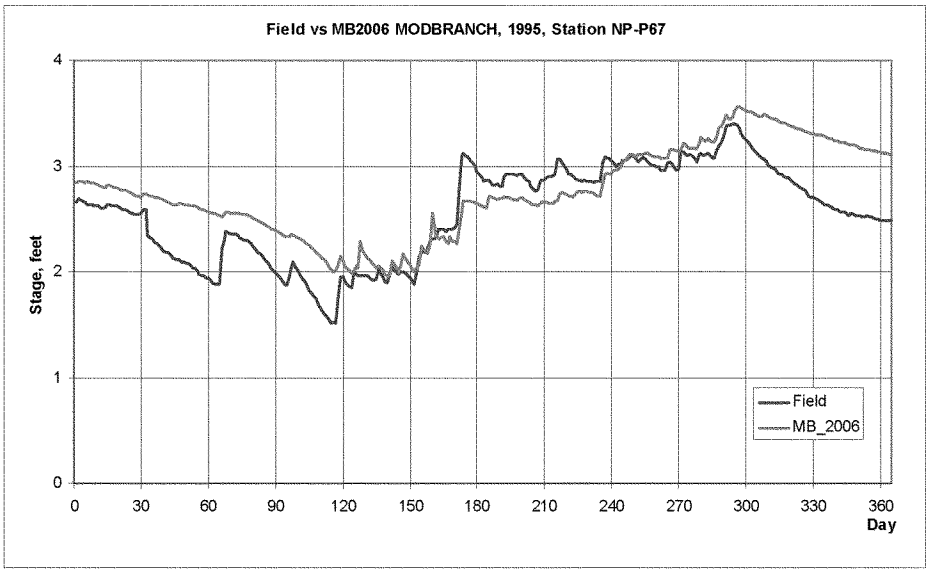

Field vs MB2006 MODBRANCH, 1989, Station NP-P67
Stage, feet
3
2
1
0
-1
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station NP-P67
Stage, feet
4
3
2
1
0
0
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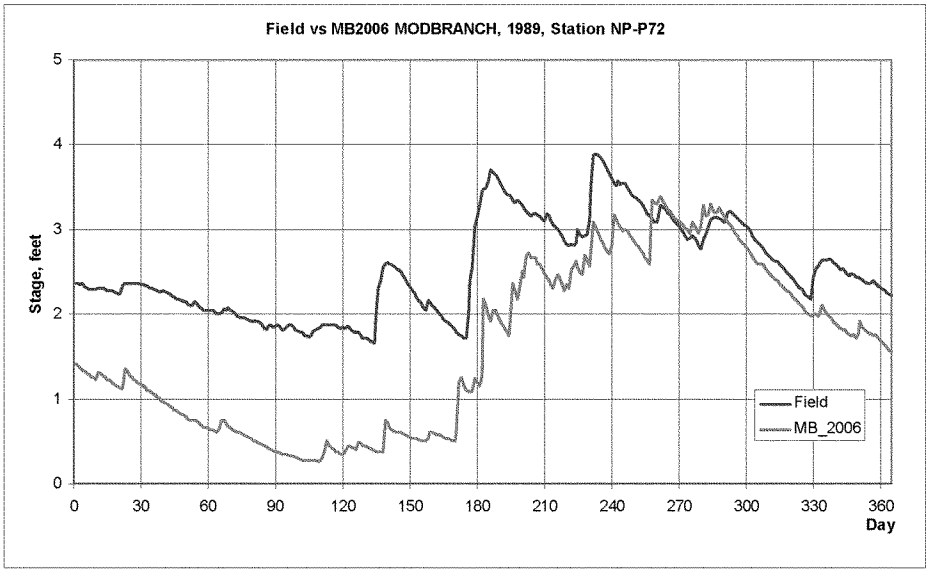
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station NP-P72
Stage, feet
Day
Field
MB_2006
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1
2
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4
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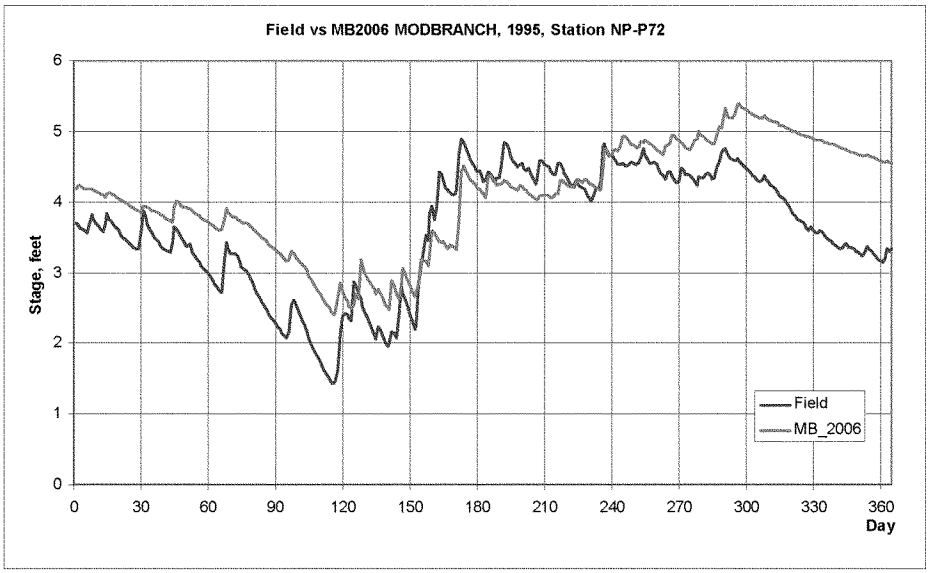
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station NP-P72
Stage, feet
Day
Field
MB_2006
0
1
2
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120
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300
330
360

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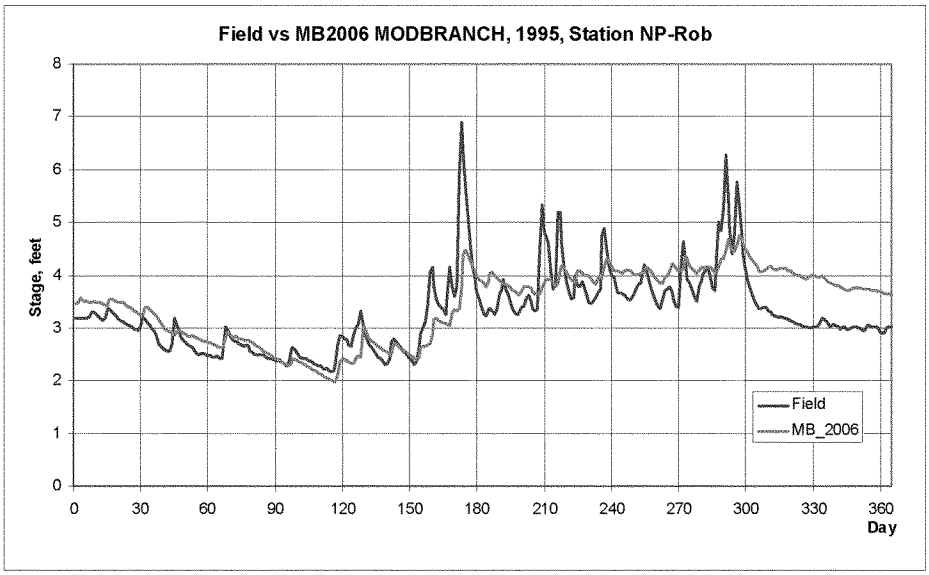
Field vs MB2006 MODBRANCH, 1995, Station NP-Rob
Stage, feet
Day
Field
MB_2006
0
1
2
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60
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120
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180
210
240
270
300
330
360

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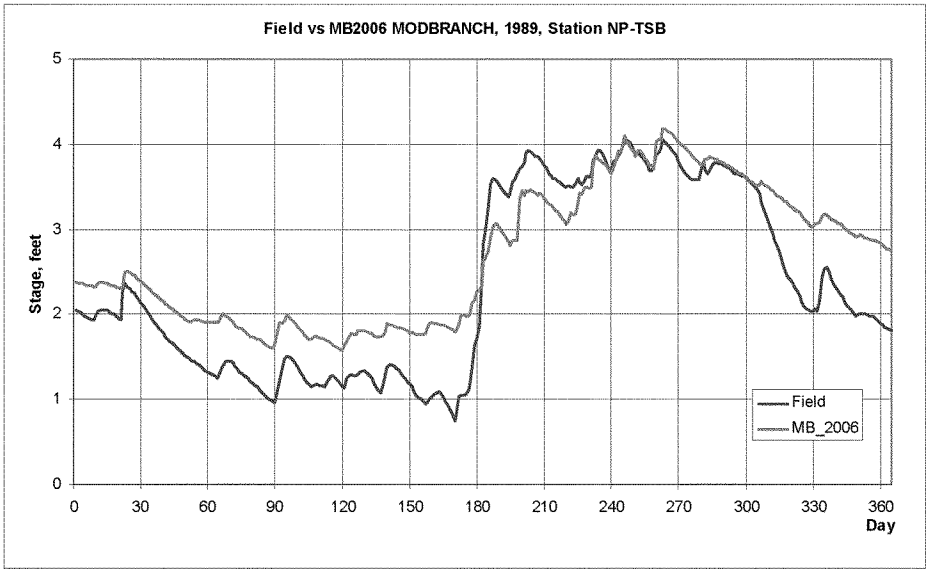
Field vs MB2006 MODBRANCH, 1989, Station NP-TSB
Stage, feet
Day
Field
MB_2006
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1
2
3
4
5
0
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60
90
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150
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270
300
330
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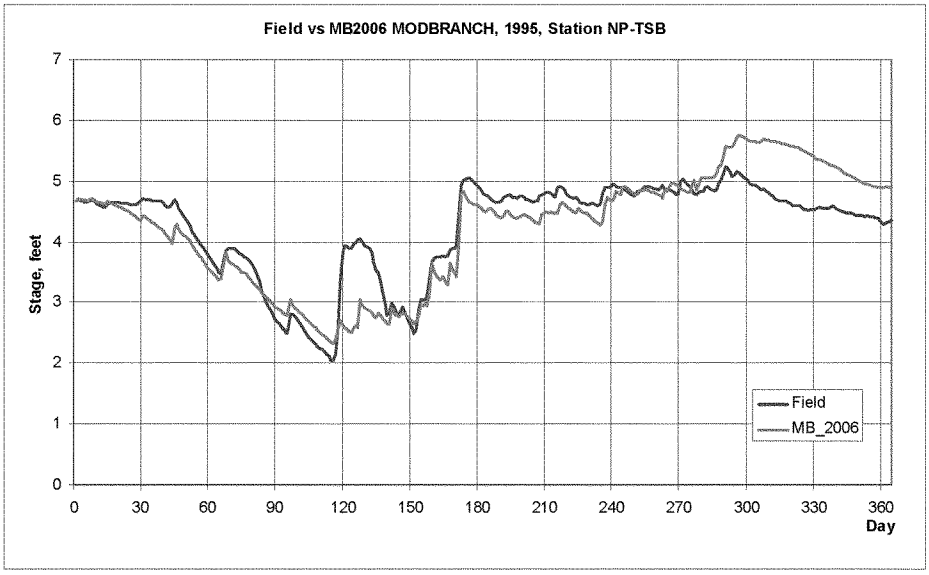
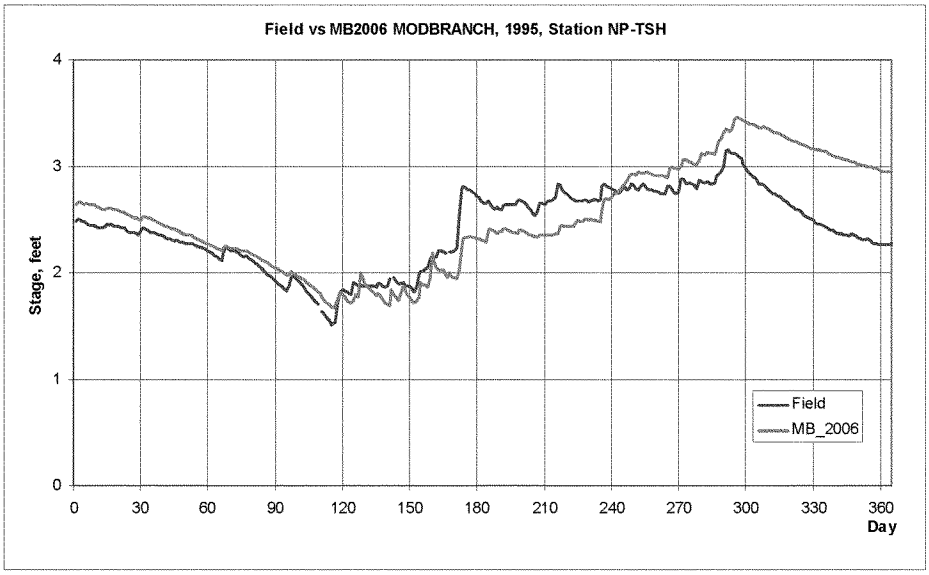

Field vs MB2006 MODBRANCH, 1995, Station NP-TSB
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station NP-TSH
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
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120
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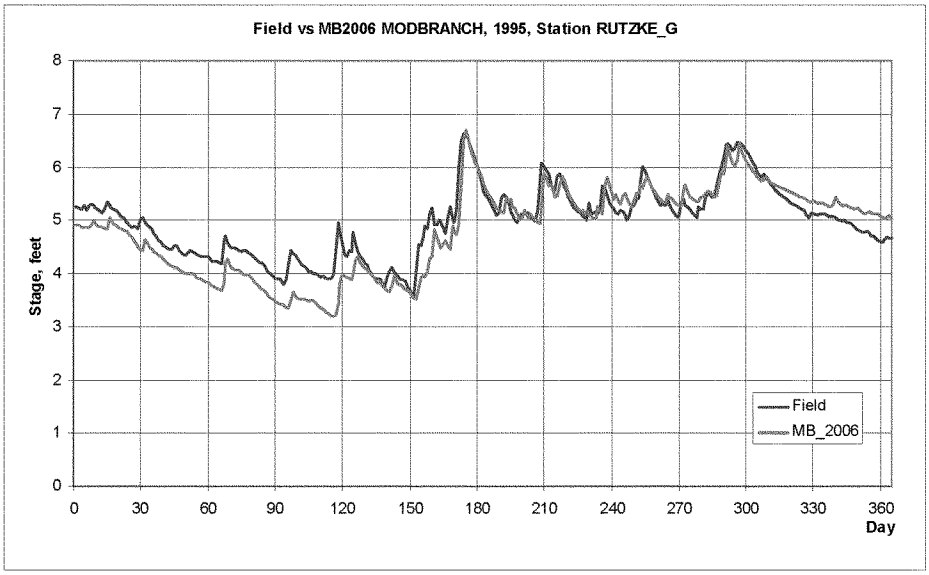
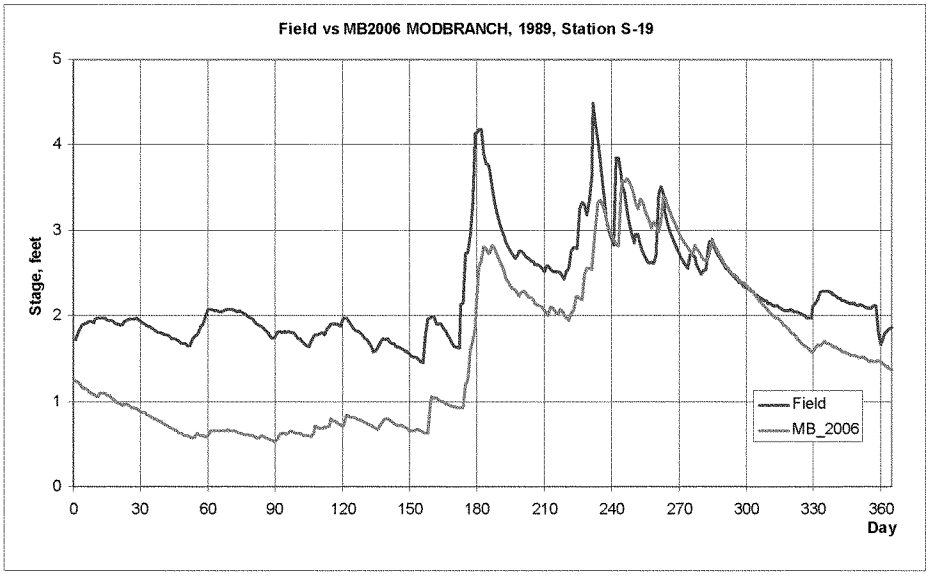
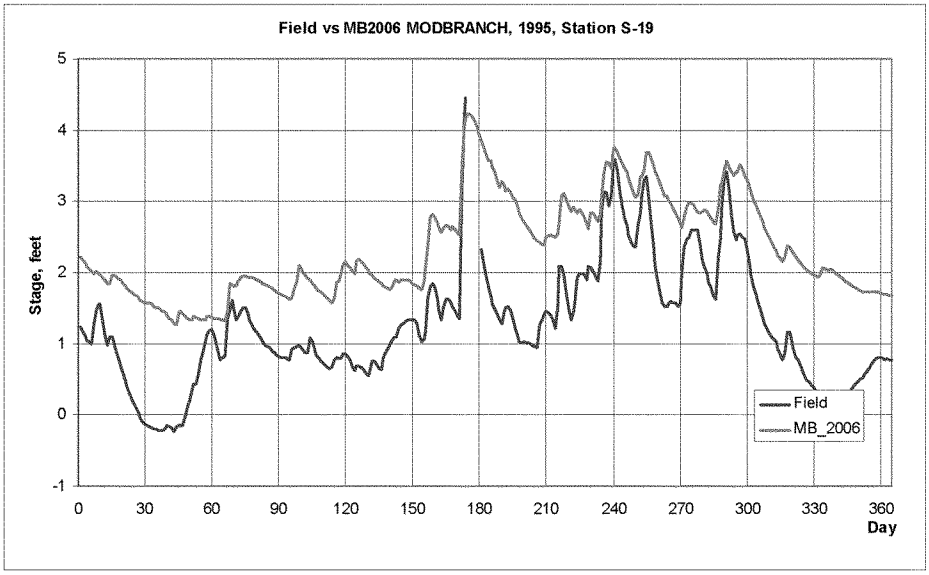
180
210
240
270
300
330
360

Appendix D

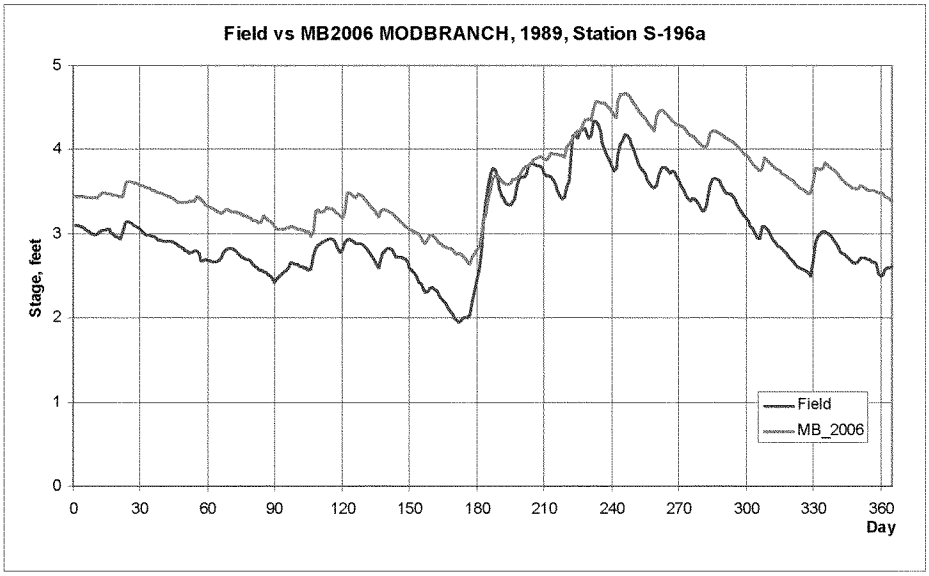

Field vs MB2006 MODBRANCH, 1995, Station RUTZKE_G
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station S-19
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station S-19
Stage, feet
Day
Field
MB_2006
-1
0
1
2
3
4
5
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station S-196a
Stage, feet
Day
Field
MB_2006
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1
2
3
4
5
0
30
60
90
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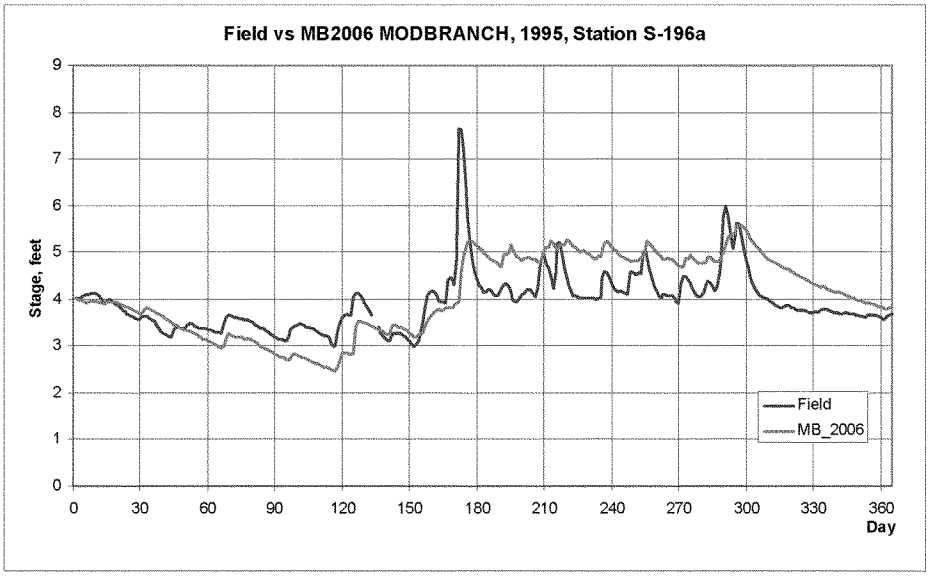
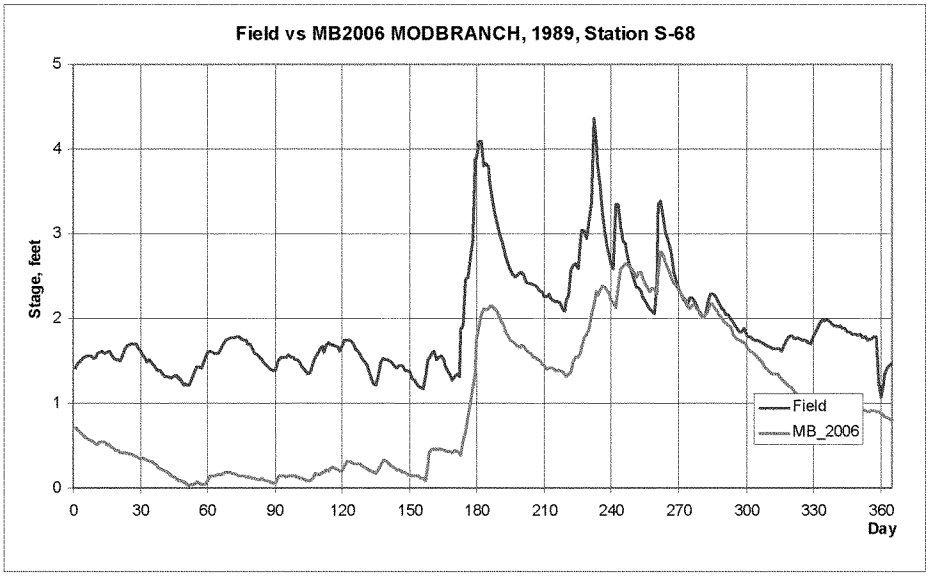
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station S-196a
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
5
6
7
8
9
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station S-68
Stage, feet
Day
Field
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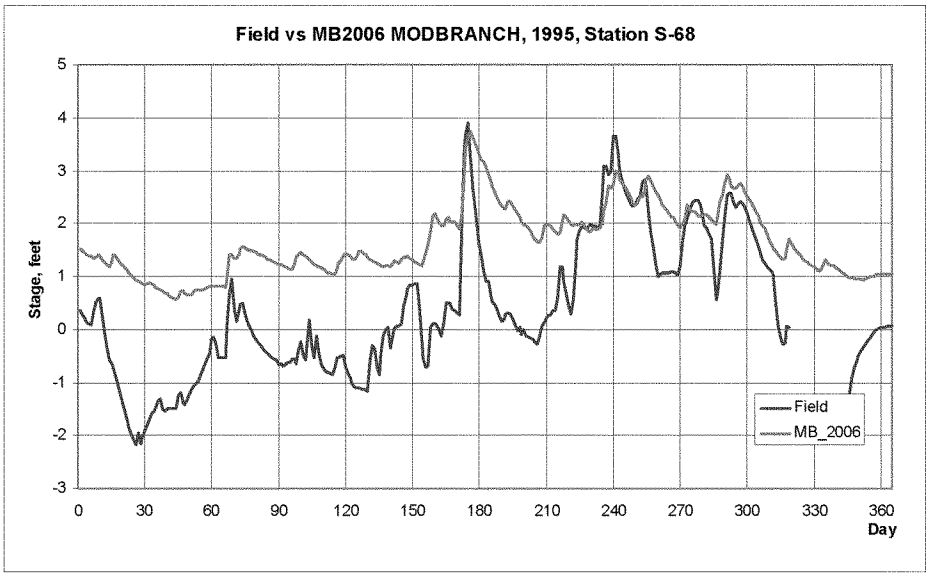
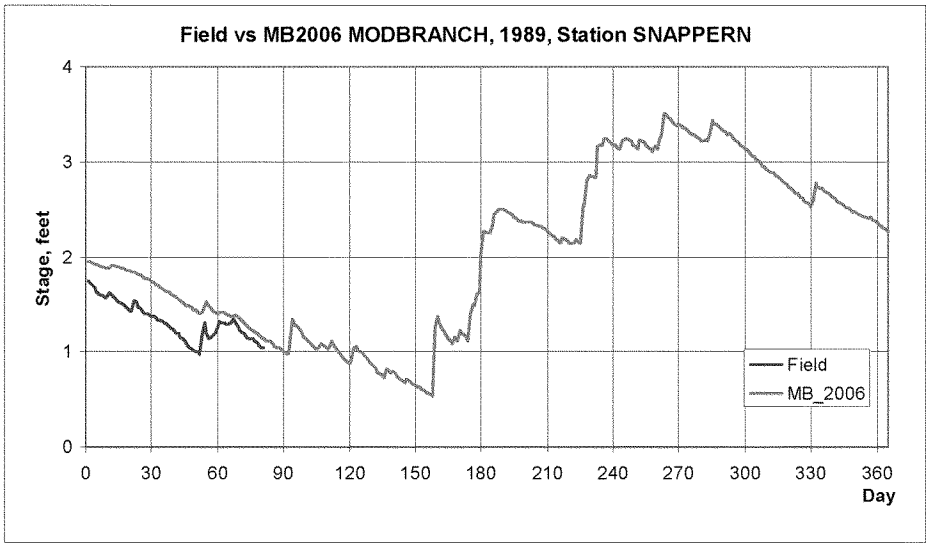
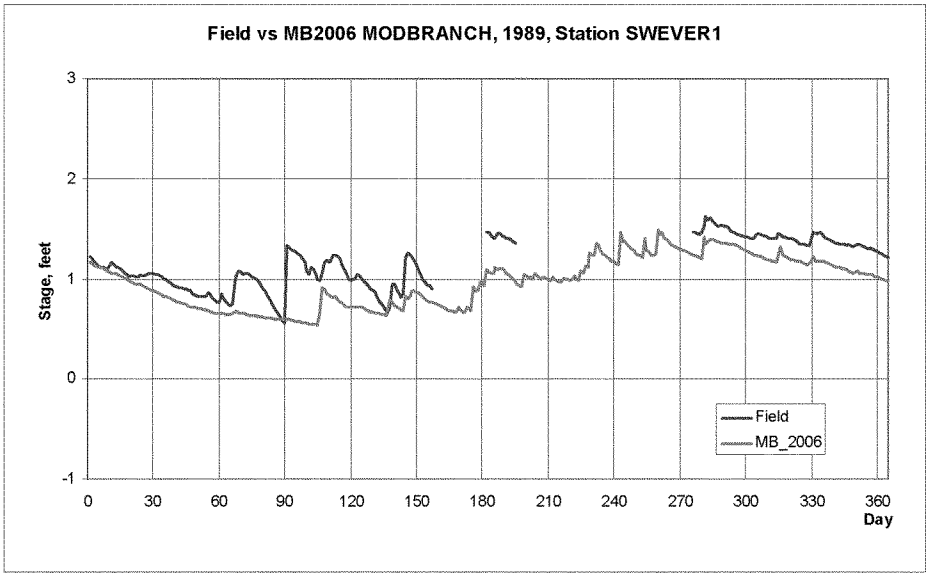
0
1
2
3
4
5
0
30
60
90
120
150
180
210
240
270
300
330
360

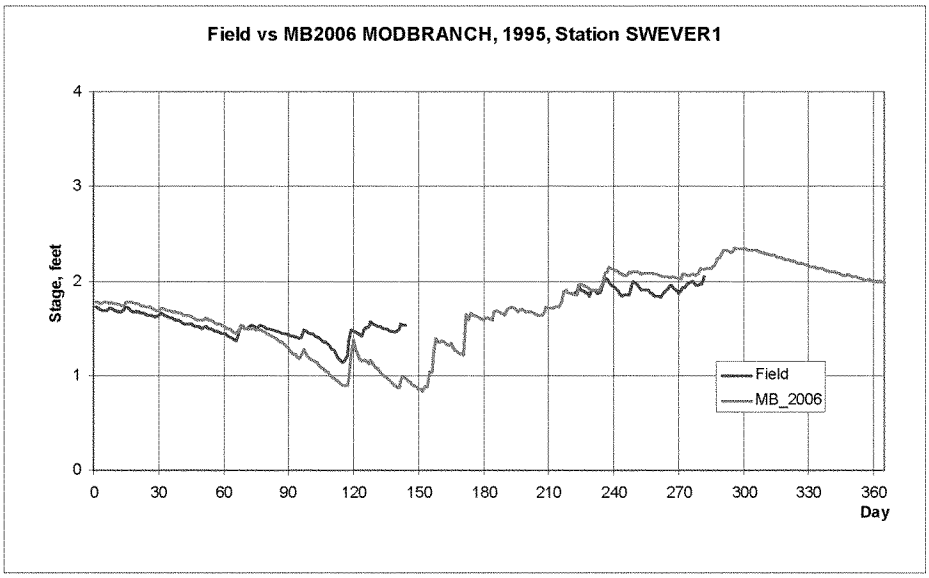

Field vs MB2006 MODBRANCH, 1995, Station S-68
Stage, feet
Day
Field
MB_2006
-3
-2
-1
0
1
2
3
4
5
0
30
60
90
120
150
180
210
240
270
300
330
360

Appendix D

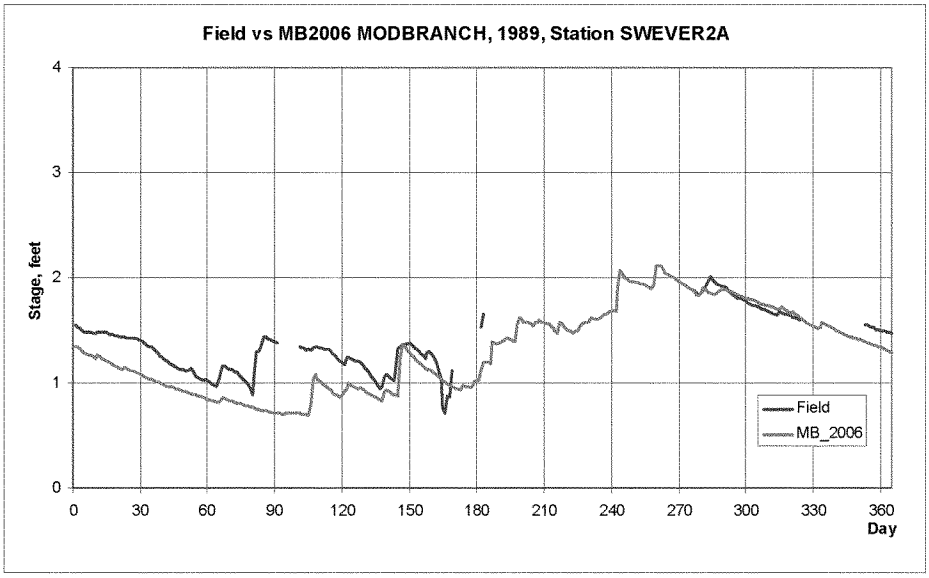

Field vs MB2006 MODBRANCH, 1989, Station SNAPPERN
Stage, feet
0
1
2
3
4
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station SWEVER1
Stage, feet
3
2
1
0
-1
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station SWEVER1
Stage, feet
4
3
2
1
0
0
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station SWEVER2A
Stage, feet
Day
Field
MB_2006
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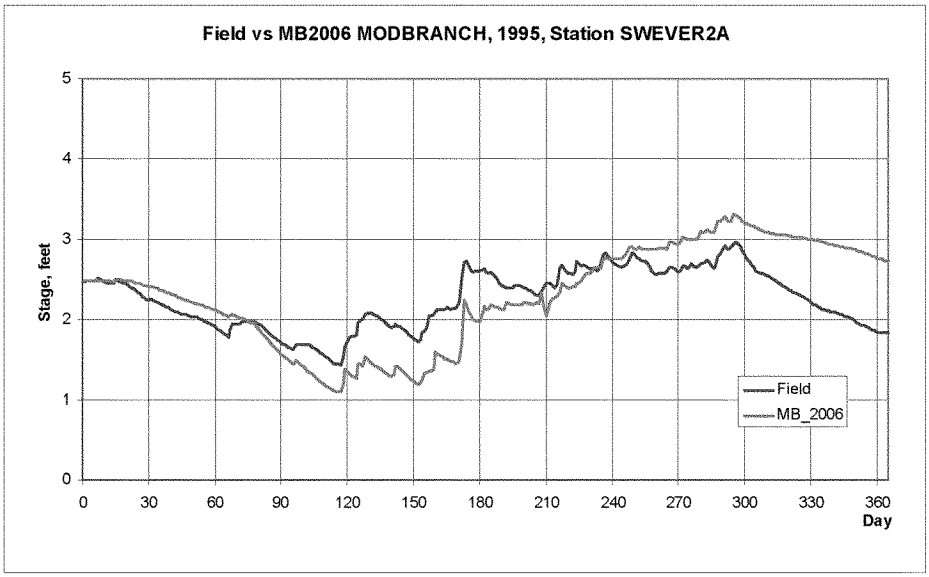
1
2
3
4
0
30
60
90
120
150
180
210
240
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station SWEVER2A
Stage, feet
Day
Field
MB_2006
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1
2
3
4
5
0
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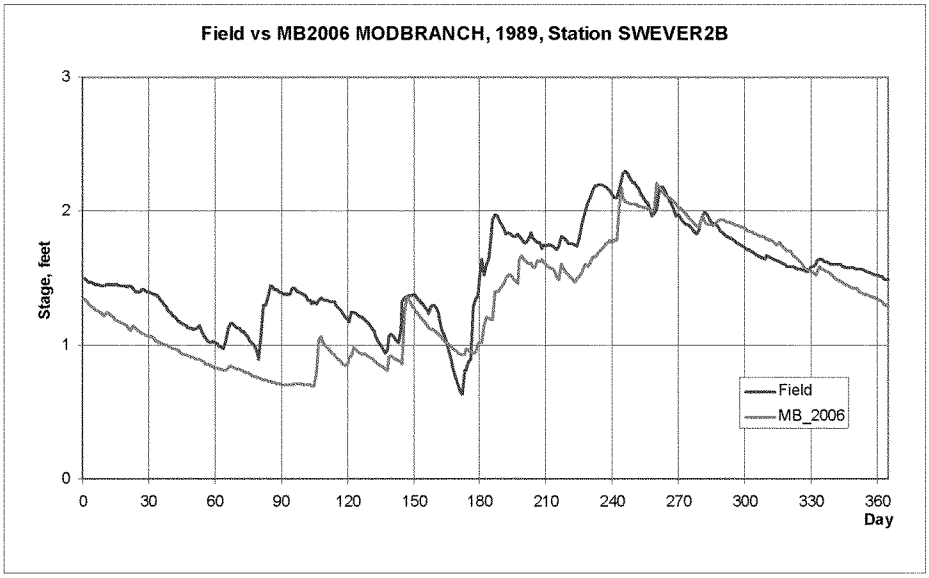
60
90
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station SWEVER2B
Stage, feet
Day
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60
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150
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210
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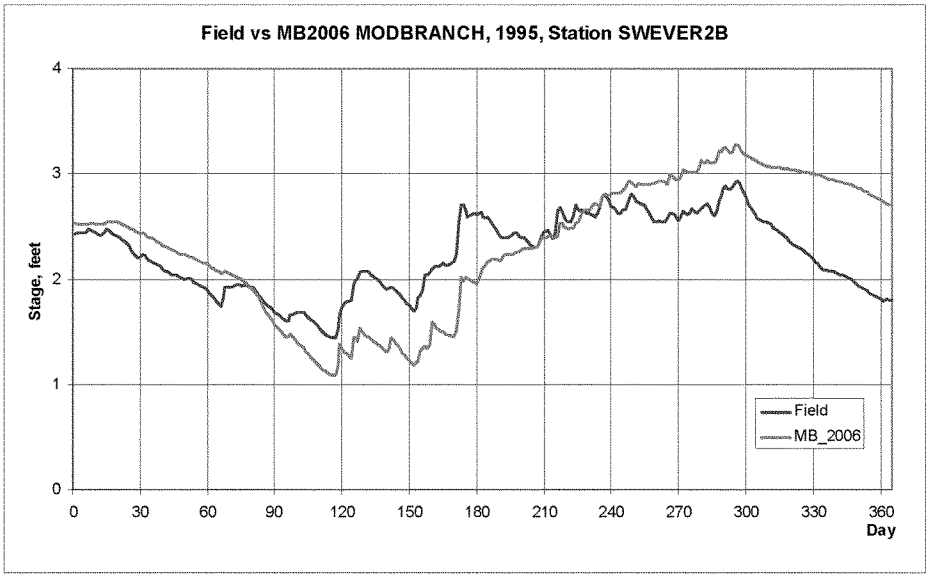
270
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station SWEVER2B
Stage, feet
Day
Field
MB_2006
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3
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60
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120
150
180
210
240
270
300
330
360

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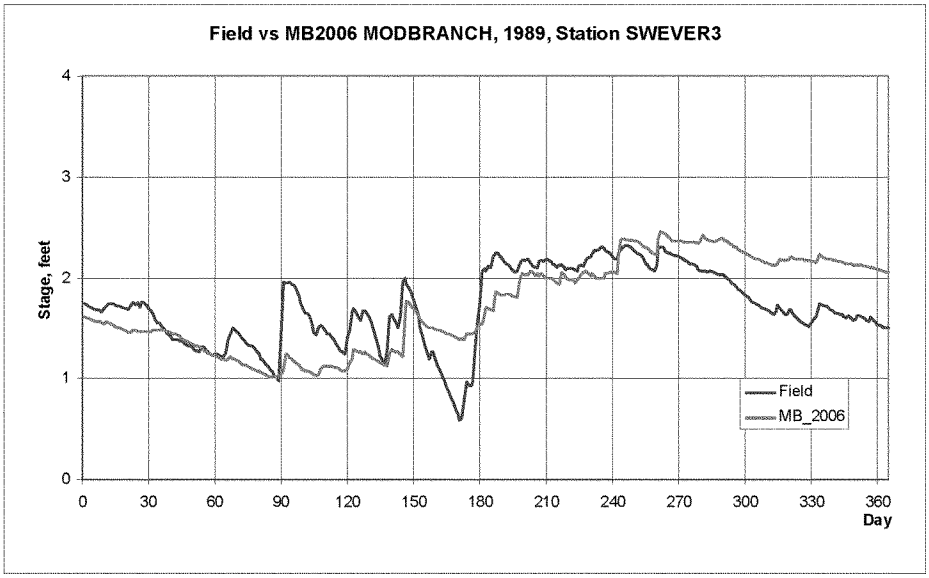
Field vs MB2006 MODBRANCH, 1989, Station SWEVER3
Stage, feet
Day
Field
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3
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330
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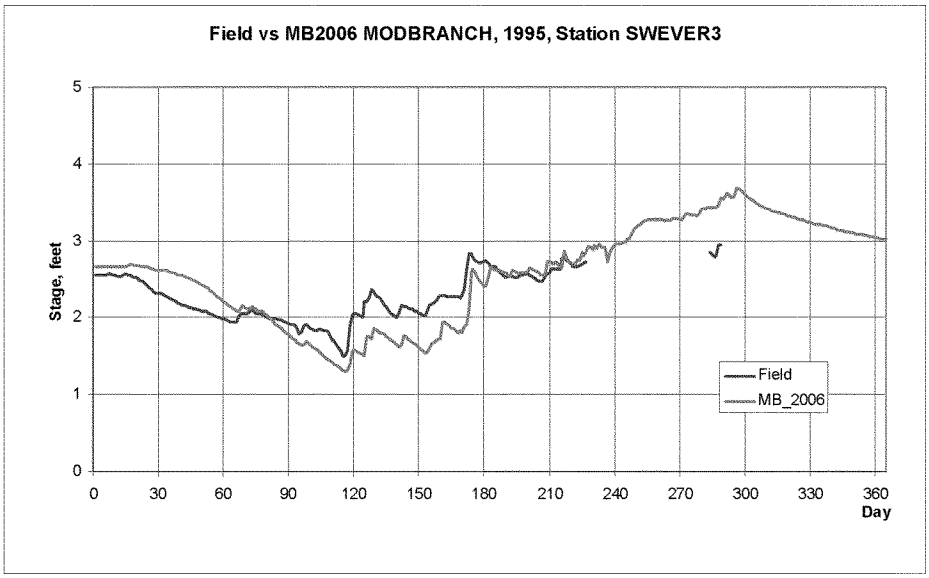
Field vs MB2006 MODBRANCH, 1995, Station SWEVER3
Stage, feet
Day
Field
MB_2006
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120
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180
210
240
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300
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360

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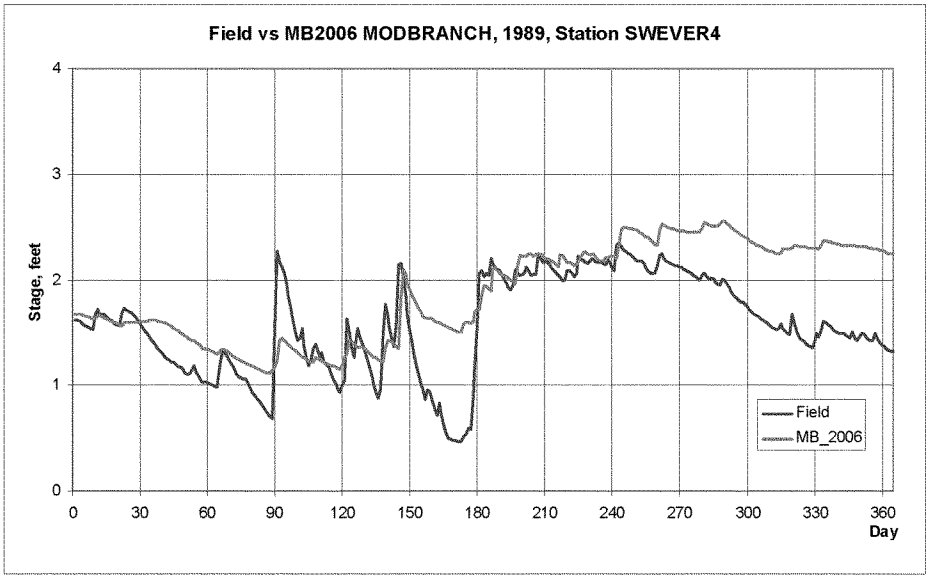
Field vs MB2006 MODBRANCH, 1989, Station SWEVER4
Stage, feet
Day
Field
MB_2006
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2
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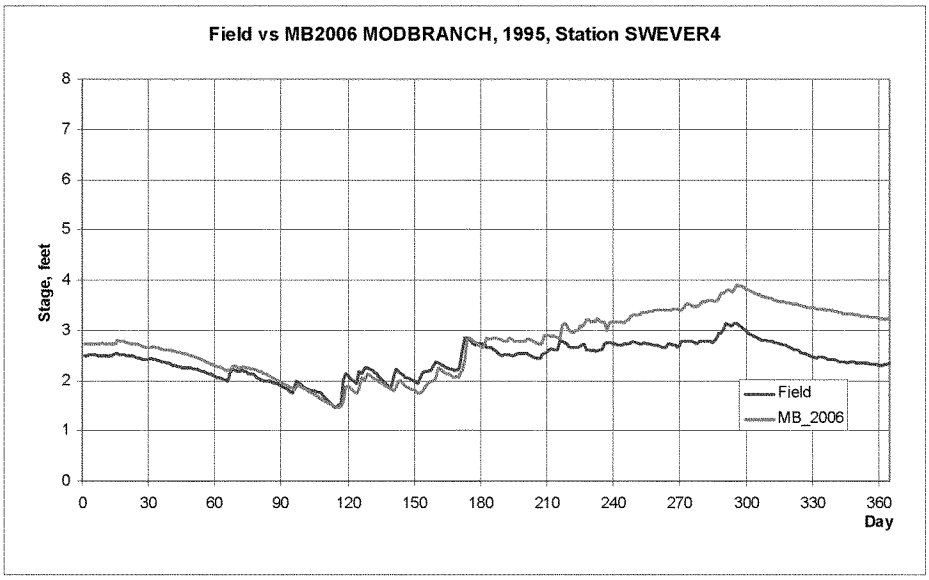
330
360


Field vs MB2006 MODBRANCH, 1995, Station SWEVER4
Stage, feet
Day
Field
MB_2006
0
1
2
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210
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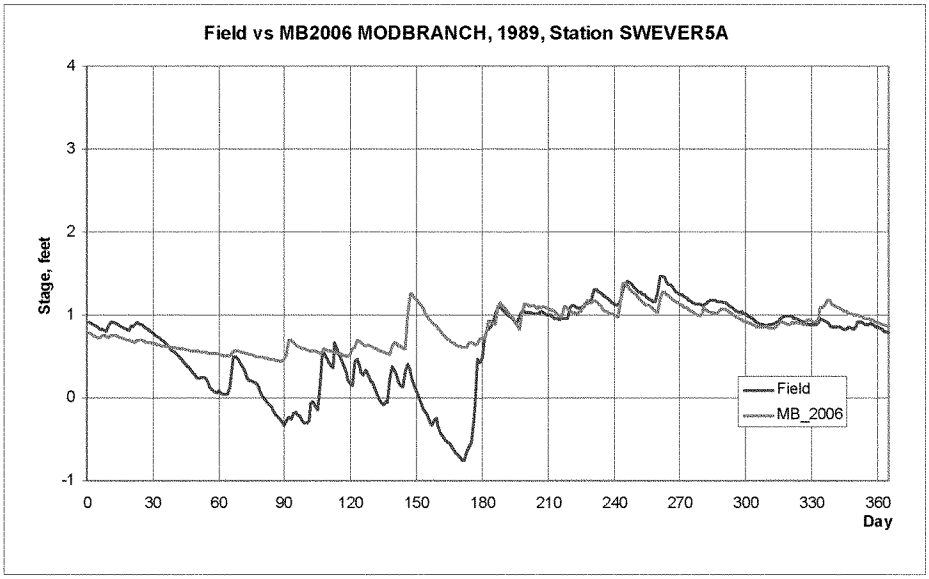
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station SWEVER5A
Stage, feet
4
3
2
1
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-1
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30
60
90
120
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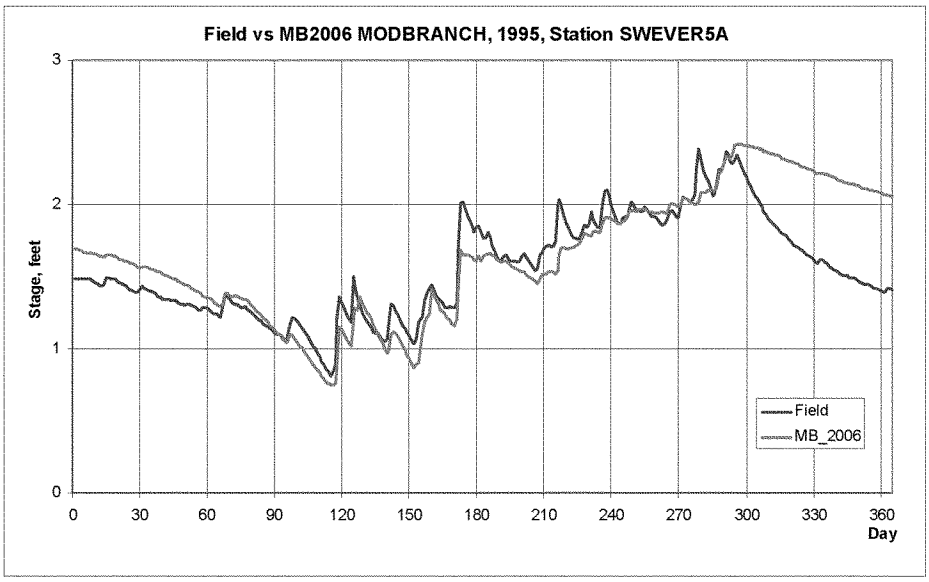
300
330
360
Day
Field
MB_2006


Field vs MB2006 MODBRANCH, 1995, Station SWEVER5A
Stage, feet
3
2
1
0
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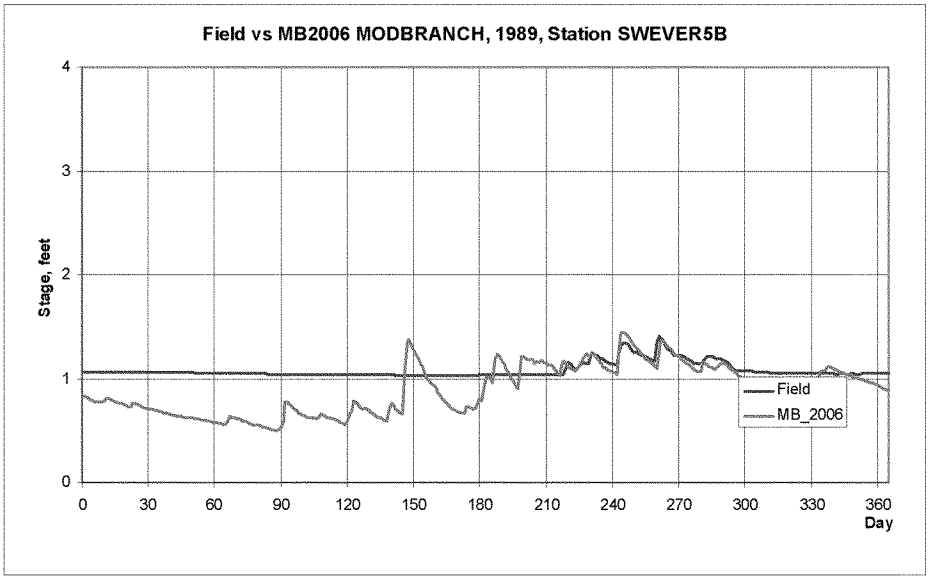
30
60
90
120
150
180
210
240
270
300
330
360
Day
Field
MB_2006

Appendix D


Field vs MB2006 MODBRANCH, 1989, Station SWEVER5B
Stage, feet
Day
Field
MB_2006
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150
180
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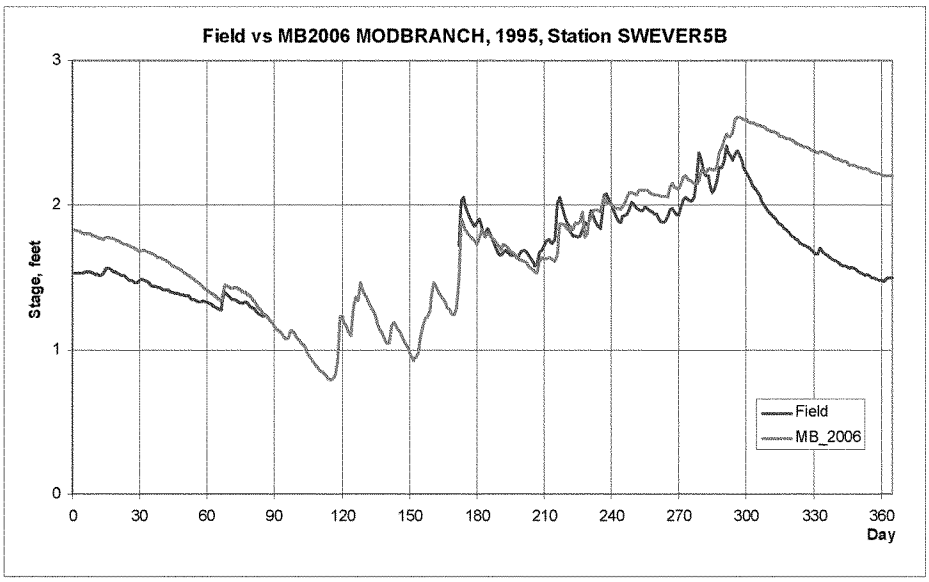
300
330
360


Field vs MB2006 MODBRANCH, 1995, Station SWEVER5B
Stage, feet
Day
Field
MB_2006
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60
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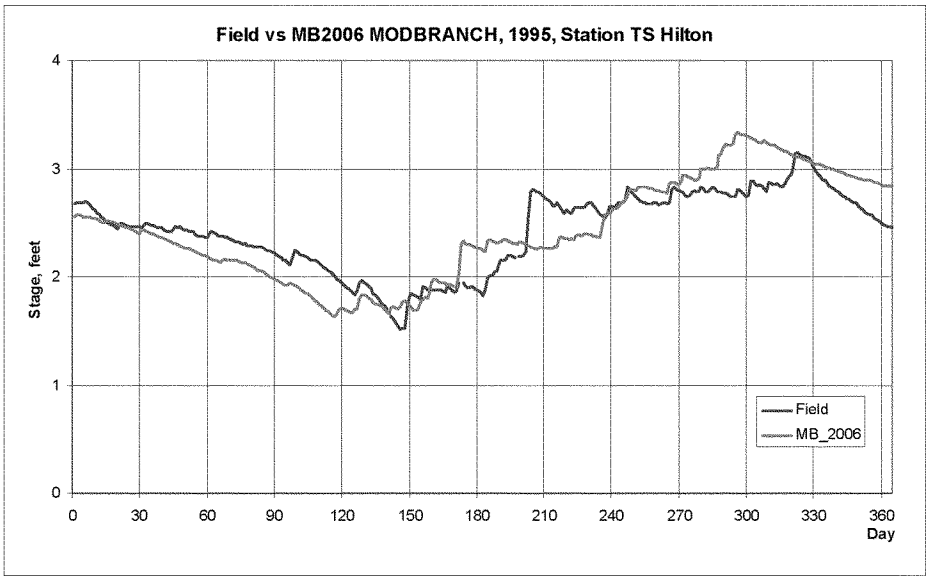
120
150
180
210
240
270
300
330
360

Appendix D


Field vs MB2006 MODBRANCH, 1995, Station TS Hilton
Stage, feet
Day
Field
MB_2006
0
1
2
3
4
0
30
60
90
120
150
180
210
240
270
300
330
360

C.3.5 Attachment 1E: Appendix E; The Effect of Varying the Number of Outer Iterations of the PCG2 Solver with the MODBRANCH P-D-M Model

Appendix E

The effect of varying the number of outer iterations of the PCG2 solver with the MODBRANCH P-D-M model

The MODFLOW model with the Preconditioned Conjugate-Gradient Package 2 (PCG2) requires that the user input the number of outer (Picard) and inner iterations. The number of outer iterations required to reach a solution varies depending on whether a problem is linear or non-linear. In general, a MODFLOW model is non-linear if the aquifers are unconfined or if certain packages are used. These packages include the River package, the Stream Package, the Evapo-transpiration package, and the Drain package. In the case of this study, the aquifers are unconfined and the Evapo-transpiration package is also used. Although neither the River nor Stream package is used, coupling the BRANCH model with the MODFLOW model can also be expected to introduce non-linearity.

Test simulations were performed using 1, 30, and 100 outer iterations and 4 inner iterations. These tests used the complete branch network of canals but with all the structures removed. The required run times to complete 13 months of simulation for each of these tests were 0.6, 11, and 23* cpu days, respectively. It is obvious that run times of 11 to 23 cpu days are impractical. However, the remarkable, and unexpected, result is that the output of the model is essentially the same whether the number of outer iterations is 1 or 100. Figure E-1 shows the areas where there is significant difference between a 255-day simulation using 1 outer iteration and a simulation using 100 maximum outer iteration. The largest differences occur near canals. This can be expected since the BRANCH function is iterated along with the MODFLOW function in the coupled MODBRANCH code.

Why, if the aquifers are generally unconfined, the evapo-transpiration package is used, and there is stream/branch interaction, does the model essentially exhibit linear qualities? The answer is probably due to the fact that the water table is generally flat or with gentle slopes throughout the region. The most extreme changes would be found near canals. However, the extremely large values of hydraulic conductivity together with the large grid sizes (relative to the canal widths) effectively minimize the non-linearity of the water surface profile of the ground water.

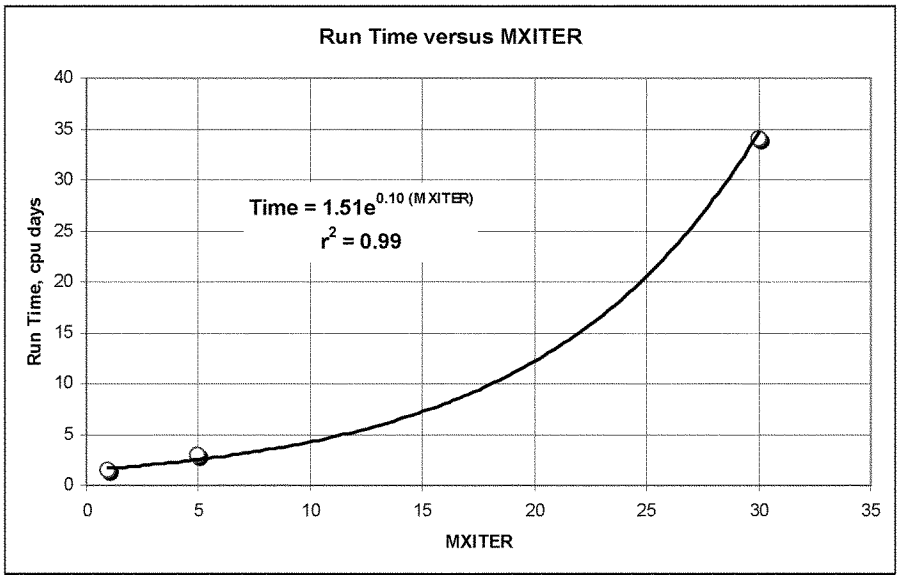
The simulations discussed above were without structures. The results are different when structures are included. Figure E-2 shows the differences between MXITER=1 and MXITER=30 for a 137 day simulation with structures. There are obvious and significant differences. Figure E-3 shows the differences when MXITER=5 and

* The simulation with 100 outer iterations never completed due to the computer being powered down. It had successfully completed 225 stress periods (out of 396) in 12.9 cpu days. The 23 cpu days is an extrapolated value.
If the structures were included, it is expected that these run times would increase 2-3 times.

MXITER=30 for the same simulation. This figure indicates that the differences are not significant when compared to the total amount of error found in the model results.

Run Times	
MXITER	**CPU Time, days**
1	1.5
5	2.9
30	34

The amount of CPU times required for the PDM model is not insignificant. The table above illustrates that the increase in run time is more than a linear function of the value of MXITER. In fact, run time exhibits an exponential character, as shown below.



The use of MXITER=5 is appropriate given:

a) The loss in accuracy is small compared to the overall error to be expected.

b) There is an order of magnitude improvement in computation times.

It is concluded that, for the region covered by the MB 2006 model, the use of 5 outer iterations is sufficient.

Appendix E

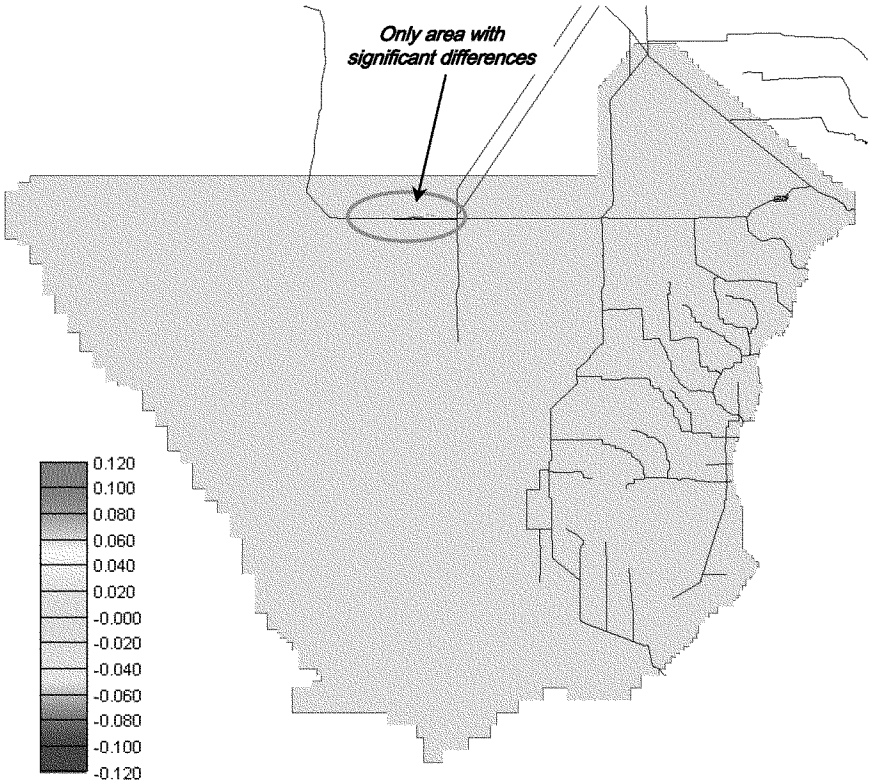


Figure E-1. Areas of Significant Difference between simulations <u>without</u> Structures when MXITER = 1 and 100 in PCG2 Solver

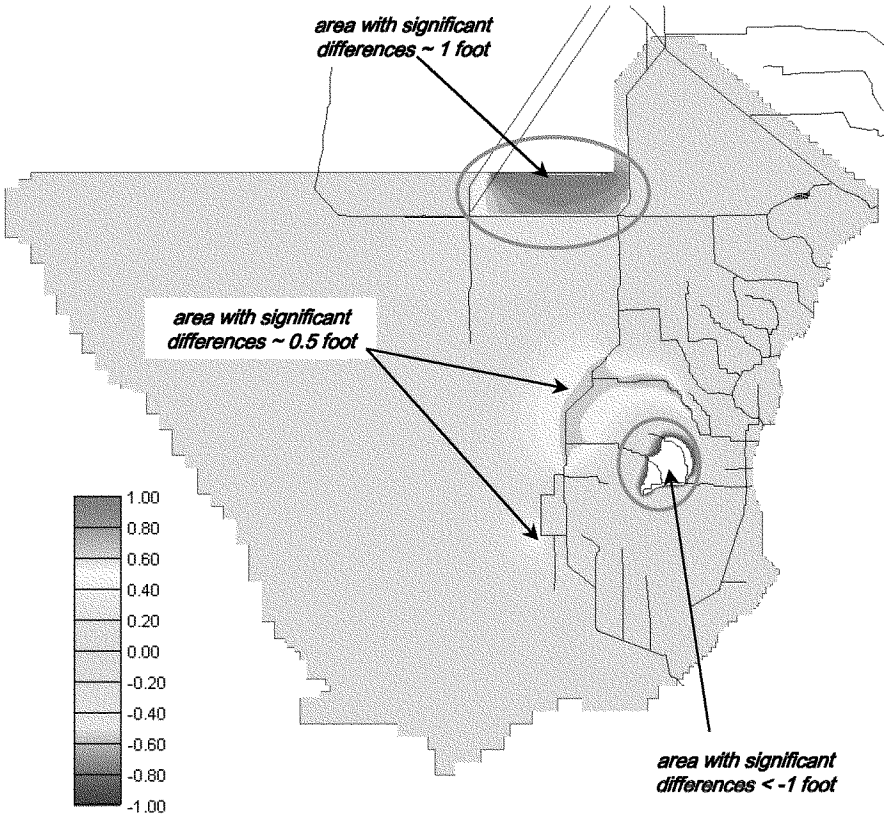
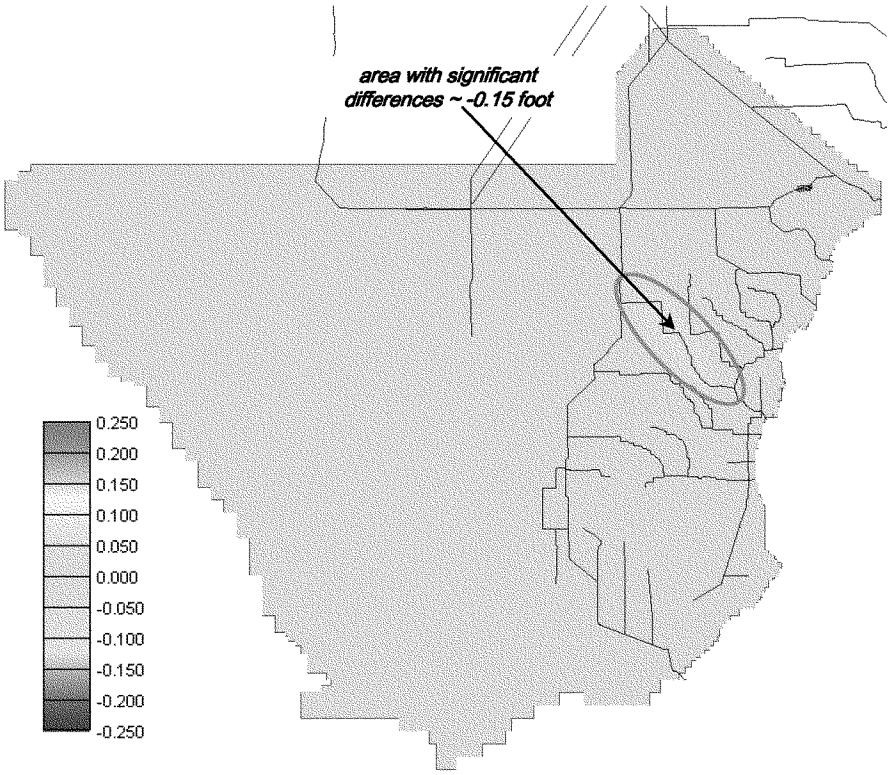


Figure E-2. Areas of Significant Difference between simulations <u>with</u> Structures when MXITER = 1 and 30 in PCG2 Solver



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D.0 DRAFT PROJECT OPERATING MANUAL

D.1 INTRODUCTION

The main purpose of this Draft Project Operating Manual is to provide a comprehensive description of the Biscayne Bay Coastal Wetlands project operations. It is intended to be used by those responsible for day-to-day operations of the project features and should provide guidance for essentially all foreseeable conditions affecting a project. Development of a Project Operating Manual is an iterative process that would continue throughout the life of the project.

A Draft Project Operating Manual is required pursuant to Engineering Regulation (ER) 1110-2-240, and is in accordance with guidance contained in Engineering Manual (EM) 1110-2-3600 and ER 1110-2-8156. This Draft Project Operating Manual describes the criteria that apply for implementation of the initial operating regime and includes a conceptual discussion of operations necessary to achieve project benefits for the next added increment condition as required by the Comprehensive Everglades Restoration Plan (CERP) Guidance Memorandum #5. All elevations referenced in this Draft Project Operating Manual are in feet, using the 1988 North American Vertical Datum (NAVD), unless otherwise stated.

The next version of the operating manual, the Preliminary Project Operating Manual, will describe any operating refinements developed based on the detailed design and construction phases of the project and will represent the water management operations for use during the operational testing and monitoring phase. Following completion of the Operational Testing and Monitoring Phase, the Final Project Operating Manual will be completed and may be revised based on future information.

D.2 GENERAL PROJECT PURPOSES, GOALS, OBJECTIVES AND BENEFITS

The purpose and overall operational intent of the Biscayne Bay Coastal Wetlands project is to contribute to the goals and objectives of the Central and Southern Florida (C&SF) Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement (USACE and SFWMD, 1999) by:

- Re-establish productive nursery habitat along the Biscayne Bay shoreline
- Improve freshwater and estuarine habitat by redistributing freshwater flow to minimize point source discharges
- Enhance quantity, quality, timing and distribution of freshwater to the Biscayne Bay, including Biscayne National Park (BNP)

- Preserve the spatial extent of natural coastal glades habitat
- Restore tidal wetland salinity regimes

D.3 PROJECT FEATURES

D.3.1 Existing Features

Existing features will work in conjunction with Biscayne Bay Coastal Wetlands features and existing water management operating criteria will be maintained. Operations of the existing coastal outfalls are based upon existing operating criteria at existing coastal structures S-123, S-21, S-21A, S-20G, and S-20F, including the high, intermediate and low range operating rules in accordance with the Master Water Control Manual for East Control Canals, Volume 5, March 1995 and existing manatee rules. The high range operational criteria apply to the period from April 30th through October 16th. Low range operation criteria are for the period from October 15th through December 30th and are in effect whenever rainfall raises the regional water table into the seasonal agricultural crop root zone during the period from October 15th through April 30th. The intermediate range operational criteria are in effect from December 30th through April 30th.

Structure 123 (S-123): This structure is an automatically operated gated spillway. S-123 is located near the mouth of Canal 100 (C-100) below the junction of C-100, C-100A and C-100B and is approximately 600 feet from the Biscayne Bay shore. The purpose of S-123 is to maintain optimum water control stages upstream in Canal 100 (C-100), Canal 100A (C-100A), and Canal 100B (C-100B). S-123 passes 40 percent of the standard project flood. In addition, S-123 prevents salinity intrusion during periods of high flood tides. The existing operating criteria and characteristics for S-123 from the South Florida Water Management District (SFWMD) Structure Book are highlighted in ***Table D-1***.

Structure 21 (S-21): This structure is an automatically operated gated spillway. S-21 is located near the mouth of Canal 1(C-1) at its junction with L-31E and is approximately 3,500 feet from the shore of Biscayne Bay. The purpose of S-21 is to maintain the optimum water control stages upstream in C-1. S-21 passes 40 percent of standard project flood. In addition, S-21 prevents salinity intrusion during periods of high flood tides. The operating criteria and characteristics for S-21 from the SFWMD Structure Book are highlighted in ***Table D-2***.

Structure 21A (S-21A): This structure is an automatically operated gated spillway located near the mouth of Canal 102 (C-102). The purpose of S-21A is to maintain optimum upstream water control stages in C-102; S-21A passes 40 percent of the standard project flood. S-21A prevents salinity intrusion during periods of high flood tides.

Structure 20F (S-20F): This structure is a three-bay, reinforced-concrete gated spillway with gates that are automatically controlled. S-20F is located near the mouth of Canal 103 (C-103) at its junction with Levee 31E (L-31E) and approximately 2,000 feet from the shore of Biscayne Bay. The purpose of S-20F is to maintain optimum water control stages upstream in Canal 103 (C-103); S-20F passes 40 percent of the standard project flood. S-20F prevents salinity intrusion during periods of high flood tides.

Structure 20G (S-20G): This structure is an automatically operated gated spillway located near the mouth of the Military Canal at its junction with L-31E. The purpose of S-20G is to maintain optimum upstream water control stages in the Military Canal; S-20G passes 40 percent of the standard project flood. S-20G prevents salinity intrusion during periods of high flood tides.

S-21A, S-20F and S-20G maintain stages in the lower reaches of C-102, C-103 and Military Canal and the L-31E Borrow Canal in accordance with the seasonal control strategies. ***Table D-3*** provides the seasonal gate operation elevations for the three structures, which are based on the SFWMD Operations Control Center Structure Book.

D.3.1.1 Deering Estate

Deering Estate is located in the C-100 Basin, also known as the Cutler Drainage Basin. This basin has an area of approximately 41 square miles and includes four main canals: C-100, C-100A, C-110B, and C-100C. These canals have three functions:

1) To provide drainage and flood protection for the C-100 Basin
2) To supply water to the basin for irrigation
3) To maintain a groundwater table elevation near the lower reach of C-100 adequate to prevent saltwater intrusion to local groundwater

Water is supplied to the basin during periods of low natural flow from C-1 Flow Way by way of S-122 and C-100B and from C-2 by way of S-121 and C-100C. There are six major control structures in the C-100 Basin: S-118, S-119, S-120, S-121, S-122, and S-123.

D.3.1.2 Cutler C-1 Flow Way

The Cutler C-1 Flow Way (also known as Black Creek Basin) is located in the C-1 Basin, which has an area of approximately 57 square miles. There are four main canals in the C-1 Basin: C-1, C-1W, C-1N, and the L-31N Borrow Canal. These canals and structures have three functions:

1) To provide drainage and flood protection for the C-1 Basin,
2) To supply water to the C-1 and the C-100 basins for irrigation, and
3) To maintain a groundwater table elevation near the lower reach of the C-1 Canal adequate to prevent saltwater intrusion to local groundwater.

There are ten major water management structures in the C-1 Basin. S-21, S-148, S-338, S-149, and S-122 are directly related to the operation of the C-1/C-1W and C-1N system. The other five structures (S-173, S-331, S-334, S-335, and S-336) along with the L-31E Borrow Canal are part of the South Dade Conveyance System which supplies water to basins in south Miami-Dade County.

Control structure S-21 is a coastal structure that provides stage control for the C-1 Canal. The structure consists of a reinforced concrete spillway with three vertical lift gates, a service bridge and control building. Operation of the gates is normally automatically controlled so that the gate's operating system opens or closes the gates in accordance with the seasonal operational criteria. The structure maintains an optimum headwater control elevation, which varies seasonally.

The operating criteria and characteristics for S-21 from the SFWMD Structure Book are highlighted in ***Table D-2***.

D.3.1.3 L-31E Project Area (North and South of Military Canal)

The L-31E Levee was designed as a hurricane surge protection levee for the coastal areas. The canal located on the west side of this levee was specifically excavated for the purpose of providing the borrow material to construct the levee. As a result, it is known as the L-31E Borrow Canal.

Stages in the L-31E Canal are regulated by control structures. The S-21A, S-20F and S-20G control structures are located in the canals just downstream of the L-31E Canal in the area where the culverts would be located.

Plugs and two gated culverts in the L-31E Canal on either side of the intersection of the L-31E Borrow Canal and Military Canal divide the northern and southern reaches of the L-31E Borrow Canal. They can be opened for maintenance of S-20G.

Additional physical and structural features located in the L-31E project area relevant to the Biscayne Bay Coastal Wetlands project include:

- Two 36-inch culverts in L-31E south of the Military Canal
- Two 72-inch culverts south of C-102 at Military Canal

- Additional culverts along North Canal
- Numerous drainage and mosquito ditches

D.3.2 Proposed Features

The following summarizes a list of the proposed features within the Biscayne Bay Coastal Wetlands project: Deering Estate, the C-1 Flow Way and L-31E components. Details of all new structures can be found in ***Appendix A – Engineering***. Refer to ***Figure D-1*** for a map of all the proposed water management features.

D.3.2.1 Deering Estate Features

The Deering Estate Flow Way, shown in ***Figure D-2***, includes the following project elements:

- 510-foot extension of the Spur Canal from the C-100A across the southern portion of the Powers Addition Parcel
- 100 cubic feet per second (cfs) capacity pump station (S-700)
- Approximately 540 feet of 60-inch reinforced concrete discharge pipe for conveyance of water from the pump station under Old Cutler Road
- 40-foot outlet spreader structure, east of Old Cutler Road, to distribute flow to the Cutler Drain and Biscayne Bay Coastal Wetlands
- Rehydration of approximately two-acres freshwater wetland

The Deering Estate Flow Way is comprised of an extension of the C-100A Spur Canal, construction of a freshwater wetland on the Power's Addition Parcel, and delivery of freshwater under Old Cutler Road to the Cutler Drain and ultimately to coastal wetlands along Biscayne Bay.

The Spur Canal extension and freshwater wetland will run approximately 500 feet through the Power's Addition Parcel. The pump station required to move the water is also located on the Power's Addition Parcel and has a 100 cfs total capacity. The pump would discharge to a surcharge chamber and then to the 60-inch diameter discharge pipe running under Old Cutler Road and to the outlet structure found on the east side of Old Cutler Road. No further structures are required downstream of the outlet structure as the Cutler Drain is found immediately east of the roadway.

D.3.2.2 Cutler C-1 Flow Way Features

The Cutler C-1 Flow Way component, shown in ***Figure D-3***, includes the following project elements:

- 400 cfs capacity pump station (S-701) with its intake on the C-1 Canal
- Reinforced concrete culvert crossing at SW 97th Avenue
- Reinforced concrete culvert with slide gates crossing at SW 87th Avenue
- At-grade, lined conveyance channel with culvert crossings
- Spreader canal (C-702) for distribution of the primary flows to the rehydration area

The Cutler Wetlands C-1 Flow Way consists of a pump station, a conveyance canal, culverts for roadway and canal crossings, and a spreader canal. Other project features in this area include a gated culvert structure in L-31E Canal and the plugging of existing drainage and mosquito ditches found in the saltwater wetlands east of L-31E Levee and Canal. S-701 is located on C-1 and will have a 400 cfs total capacity. Water pumped by S-701 will be delivered to the 6,900 foot C-701 Canal. The conveyance canal will run under the existing SW 97th Avenue, SW 87th Avenue (L-31E Levee), and across the L-31E Canal via concrete box culverts and deliver water to the spreader canal located in the saltwater wetlands. This spreader canal is divided up into four segments:

- First segment runs from the box culverts south for 2,980 feet
- Second segment runs from the box culverts north for 4,867 feet
- Third segment runs from the second segment northeast for 2,500 feet – "tail" one
- Fourth segment is a second "tail" to the spreader canal system that continues a little farther to the north than Segment 3 before it turns eastward and has a length of 2,813 feet

These separate tails are aligned to connect with historic low-lying areas that are primary concerns for rehydration.

Approximately 2,500 linear feet of mosquito ditches will be plugged. The intent is to discourage the channelization of the water delivered to the area by the spreader canals.

D.3.2.3 L-31E Features–North of Military Canal

The L-31E North Component, shown in ***Figure D-4,*** includes the following project elements:

- Submerged riser culverts in the L-31E Borrow Canal south of the interconnection with the C-102 Canal
- Five-flap gated culverts in the L-31E Levee
- 50 cfs pump station (S-703) to deliver water from C-102 to the east of the L-31E Levee just north of C-102

- 100 cfs pump station (S-705) to deliver water from C-102 into the L-31E Borrow Canal between C-102 and the Military Canal
- One siphon in the L-31E Borrow Canal at the intersection with the Military Canal

The L-31E North area generally is described as the portion of the project located between C-1 on the north and Military Canal on the south. These features include structures that would isolate the L-31E Canal from the major discharge canals (C-102 and Military Canal) as well as gated riser culverts (L-31E culverts) that would deliver water from the L-31E Canal, through the L-31E Levee, and discharge in the saltwater wetlands to the east. In addition, a pump station would be constructed to deliver water into the saltwater wetlands north of C-102 where higher topography makes culverts less effective.

A 50 cfs pump station (S-703) is designed to deliver water from C-102 east of the L-31E Levee north of C-102 would be operated any time the L-31E stage is above the S-21A "close" stage.

A 100 cfs pump station (S-705), which is designed to deliver water from C-102 into the L-31E Borrow Canal south of the plug in the L-31E Borrow Canal near C-102, would generally be operated anytime the C-102 stage is above the S-21A "close" stage, and L-31E stages will accept discharge without overtopping the L-31E Canal bank(s). As described in the Hydrometeorological Monitoring Plan (Annex E – Part I), existing monitoring wells BBCMW3 and BBCMW4 will be monitored whenever S-705 is pumping, and operations will be adaptively managed to ensure no adverse impacts to existing levels of flood protection until one (or more) of the following events has occurred; 1) Detailed engineering studies performed during the Advance Planning Phase confirm that pumping into the reach of L-31E between C-102 and C-103 will not adversely affect existing levels of flood protection provided to privately owned lands west of L-31E; 2) privately owned lands west of L-31E are provided equivalent flood protection through alternative means; and/or 3) affected lands are acquired in support of the project. Further south, a gated siphon would be installed underneath the intersection of the L-31E Borrow Canal and the Military Canal. These structures would allow operating L-31E Borrow Canal at a higher average water level than currently possible to promote more flow by gravity through culverts in the levee. Within this reach five individual 36-inch culverts would be installed through the levee. A 100 cfs pump station located just south of C-102 (in the same physical structure as the gated riser culvert) will pump available water into the L-31E Borrow Canal isolated by the structures to maintain optimum water stage elevations. The culverts installed in the levee would be five (5) 36-inch corrugated aluminum alloy with flap gates and manatee protective barriers.

D.3.2.4 L-31E Features–South of Military Canal

The L-31E South component, shown in ***Figure D-5***, includes the following project elements:

- One siphon with risers in the L-31E Canal at the intersection with the Military Canal
- Seven flap-gated culverts in the L-31E Levee
- 40 cfs pump station (S-711) located along the C-103 Canal near S.W. 112th Avenue
- 40 cfs pump station (S-710) located along the C-103 Canal near S.W. 103rd Avenue
- 40 cfs pump station (S-709) located near the intersection of the C-103 Canal and the L-31E Borrow Canal
- Seepage canal along S.W. 112th Avenue between C-103 and North Canal
- Approximate 420 acre impoundment

The L-31E South area generally is described as the portion of the project located between Military Canal on the north and North Canal to the south. These features include structures that would isolate the L-31E Canal from the major discharge canals (Military Canal and C-103) and culverts (L-31E Culverts) that would deliver water from the L-31E Canal, through the L-31E Levee, and discharge into the saltwater wetlands to the east. A pump station would be constructed to supply the isolated reaches of L-31E Canal with water. A freshwater wetland system is included in this region.

A gated riser structure with 36-inch culverts would be installed or improved within a plug located at intersection of the L-31E Borrow Canal and C-103 Canal to isolate this reach of L-31E Borrow Canal. A 40 cfs pump (S-709) would pump water into this reach of the L-31E Borrow Canal to maintain optimum water stage elevations. Similar to S-705 operations, existing monitoring wells BBCMW3 and BBCMW4 will be monitored whenever S-709 is pumping, and operations adaptively managed to ensure no adverse impacts to existing levels of flood protection until one (or more) of the following events has occurred; 1) detailed engineering studies performed during the Advance Planning Phase confirm that pumping into the reach of L-31E between C-102 and C-103 will not adversely affect existing levels of flood protection provided to privately owned lands west of L-31E; 2) privately owned lands west of L-31E are provided equivalent flood protection through alternative means; and/or 3) affected lands are acquired in support of the project.

Five new culverts would be installed in the levee. Three would be between Military Canal and C-103, and two between C-103 and North Canal. The design of these culverts would be identical to those described in ***Section D.3.2.3***, L-31E

North Features. In addition the project would incorporate the operation of two existing culverts.

A freshwater wetland system consists of an impounded area, two pump stations, a spreader canal, a small berm and a seepage collector ditch. The first pump is located on the northwestern edge of the wetland and delivers 40 cfs from C-103 to the spreader canal. The spreader canal extends from C-103 to the North Canal, approximately 2,619 feet. The spreader canal will deliver overland flow of water into the impounded wetland. The seepage management system is intended to constrain water elevations from changing to the west of the impounded area. A small berm and seepage collector ditch would be constructed immediately to the west of the spreader canal. Both components are 2,619 feet, which is the same length as the spreader canal. The seepage collector ditch would discharge via gravity to C-103. A second pump for the wetland is located approximately halfway from the first pump to L-31E Canal, and would deliver an additional 40 cfs to the wetland. No spreader canal is associated with this pump and instead will deliver directly to a spreader ditch.

D.4 PROJECT RELATIONSHIPS

The proposed features of the Biscayne Bay Coastal Wetlands project are designed to work in conjunction with existing features to divert and redistribute water into coastal and estuarine wetland systems in order to improve the ecological health of these wetland communities.

Specifically, the operating capabilities of the proposed Deering Estate pump station were modeled using reported historic operations of control structure S-123 and the water levels in the C-100 Canal system, and will not affect operation of S-123. Operating capabilities of the proposed Cutler Wetlands C-1 pump station were modeled given the historic operations of S-21, along with stages in the C-1 Canal system such that the operation of S-21 would not be affected with the proposed project features. Hydraulic analyses conducted as part of this project were also performed to assess the stage history of the L-31E Canal, predict flow rates and quantities at each of the proposed culverts, and to determine the design concepts for the culverts.

D.5 MAJOR CONSTRAINTS

D.5.1 Operational Safeguards for Initial Operations

This project operation is unique in south Florida. Inflows come from several sources and outflows go into environmentally sensitive areas through a highly controlled managed system. To avoid unintentional adverse impacts within the natural system, precautionary steps have been identified for initial operations before full implementation of the Biscayne Bay Coastal Wetlands project.

The safeguard steps would provide a time for monitoring and evaluation so assumptions and operational guidelines can be safely tested.

- Safeguard 1: Monitor water velocity and soil erosion in the wetlands
- Safeguard 2: Monitor water distribution within the wetlands
- Safeguard 3: Monitor salinity along the shoreline
- Safeguard 4: Existing monitoring wells BBCMW3 and BBCMW4 will be monitored whenever S-705 is pumping, and operations will be adaptively managed to ensure no adverse impacts to existing levels of flood protection until one (or more) of the following events has occurred; 1) Detailed engineering studies performed during the Advance Planning Phase confirm that pumping into the reach of L-31E between C-102 and C-103 will not adversely affect existing levels of flood protection provided to privately owned lands west of L-31E; 2) privately owned lands west of L-31E are provided equivalent flood protection through alternative means; and/or 3) affected lands are acquired in support of the project.

D.5.2 Deering Estate Features

The following pump operational constraints were identified and incorporated into the pump station operation:

- Tailwater due to tidal elevations at the water control structures may require gate closure but may not impact station operation, given available water.
- Range of pump operation for maximum scavenged flow is from the low (gate close) elevation to beyond the control (gate open) elevation. Initial system operation may use the mid-level range point in association with operational monitoring to further evaluate pumping effects on the basin water table prior to commencing full scale operations mode.
- Pump start operating point would consider the effect on the salinity control and the contiguous water table and associated neighborhoods adjacent to the pumping source canals.
- Canal pumping operational levels would be set at levels that maintain groundwater gradients that are consistent with past operations.
- Dry and wet season operations may differ because of limited pumping during the dry season.
- Station operation to minimize power consumption and consistent with meeting project objectives.
- Flexible station operational programming to allow modification of the operation of a pump station to meet changing physical conditions in Biscayne Bay Coastal Wetlands Phase I project.
- Flexible station operation programming to prohibit impacts to the natural environment.

D.5.3 C-1 Flow Way Features (Cutler Wetlands)

The following pump operational constraints have been identified that would be incorporated into the Cutler Wetlands C-1 Flow Way pump station operation:

- Tidal elevations at the water control structures may require gate closure but may not impact pump station operation given available water.
- The intent of pump operations is to divert as much water into the marsh systems as feasible consistent with current system operations while maintaining an appropriate marsh hydropattern.
- Pump start operating point would consider the effect on the salinity control and the contiguous water table.
- Canal pumping operational levels would be set at levels that maintain groundwater gradients that are consistent with past operations.
- Dry and wet season operations may differ because of limited pumping during the dry season.
- Station operation to minimize power consumption consistent with meeting project objectives.
- Flexible station operational programming to allow modification of the operation of a pump station to meet changing physical conditions in the Biscayne Bay Coastal Wetlands Phase I project.
- Flexible station operation programming to prohibit impacts to the natural environment.

D.5.4 L31-E Features (North of Military Canal)

The following constraints have been identified that would be incorporated into the L-31E culverts operation:

- No selected plan driven modifications to current seasonal operational criteria
- Flexible station operation programming to prohibit impacts to the natural environment
- Historic water stage elevations in Military Canal would not be affected

D.5.5 L31-E Features (South of Military Canal)

- A 40 cfs pump station (S-711) to deliver water from C-103 into the L-31E Borrow Canal north of the plug between C-103 and the L-31E Borrow Canal will generally be operated when the C-103 stage is above the S-20F "close" stage, and the pump will not cause stages in L-31E to overtop its bank(s).
- A 40 cfs pump station (S-710) located at C-103 near S.W. 105 Avenue will deliver water into a wetland impoundment would generally be operated any time the C-103 stage is above the S-20F "close" stage, and the water

stage elevation in the wetland does not exceed two feet above average land surface.

- A 40 cfs pump station (S-709) located at C-103 near S.W. 112 Avenue will deliver water into a wetland impoundment which will be operated any time the C-103 stage is above the S-20F "close" stage, and the water stage elevation in the wetland does not exceed two feet above average land surface.
- A spreader ditch south along S.W. 112 Avenue will distribute pumped flows from S-709.
- A seepage management system located along the western margin of the spreader ditch will prevent elevated water stages on land to the west of the impoundment.
- No selected plan driven modifications to current seasonal operational criteria

D.5.6 North Canal Freshwater Wetland

The following constraints have been identified that would be incorporated into the impoundment operation:

- Flexible station operation programming to prohibit impacts to the natural environment

D.6 STANDING INSTRUCTIONS TO PROJECT OPERATORS

Once the operational testing and monitoring phase of the Biscayne Bay Coastal Wetlands project is concluded, the SFWMD would manage the day-to-day project operations of the newly constructed facilities. Standing instructions for the SFWMD project operators would be further developed in the Final Project Operating Manual that would include refinements in operations due to project start-up, operational testing and monitoring, and operational experience, and as a result of changing structural and operations associated with new Comprehensive Everglades Restoration Plan (CERP) or non- (CERP) authorized operating manuals, additional scientific information and system operations manual updates.

D.7 OPERATIONAL STRATEGY TO MEET PROJECT OBJECTIVES

The operations covered in this document represent the start-up operational strategy recognizing that downstream features in the system would change over time due to the completion of other CERP and non-CERP projects. It is intended that the Biscayne Bay Coastal Wetlands project Phase I would be operated to deliver water to downstream natural areas via the Deering Estate, C-1 Wetland and L-31E features in order to achieve benefits to the environment and the distribution of deliveries in a manner consistent with restoration objectives. The

actual releases would be governed by a set of operational protocols designed to achieve the goals and objectives of the project on a long-term basis.

D.7.1 Achieving Natural System Goals, Objectives and Benefits

The intent of the Biscayne Bay Coastal Wetlands project operations is to allow for meeting environmental demands without adversely impacting other water related needs. The initial operating regime is defined as reflecting the hydrologic regime in the south Florida ecosystem at the time a CERP project Recommended Plan is selected. The Biscayne Bay Coastal Wetlands project will become an integral part of a water management system and, for Phase I, which includes the Deering Estate, and Cutler Wetlands (C-1 and C-100) Flow Way components. The operation of Phase I, water management features will be in accordance with the Central and Southern Florida Master Water Control Manual for East Coast Canals, Volume 5, and the SFWMD Operations Control Center Structure Book. Each individual element is expected to work in concert with one another. In the event of a water shortage declaration, the SFWMD Water Shortage Plan will be followed.

The water deliveries anticipated for the Biscayne Bay Coastal Wetlands project features are expected to become an important part of the water budget of this region. As a general operational strategy, project features for the Biscayne Bay Coastal Wetlands project are expected to redistribute water when water is available. Some regulatory releases from the regional water management system can also be beneficial to meeting salinity targets for Biscayne Bay. However, there are times when flood control releases result in much lower salinity restoration targets for the Bay. During those times, the excessive runoff would be discharged through the existing coastal structure outfalls to prevent damage to wetlands.

D.7.1.1 Deering Estate Operations Associated with the Biscayne Bay Coastal Wetlands Project

The Deering Estate Flow Way is located in southeastern Miami-Dade County on the Deering Estate at Cutler, situated in the vicinity of Old Cutler Road and SW 160th Street. The project components included the Spur Canal extension, pump station, discharge piping and outlet spreader structure and educational wetland. Excluding the spreader structure, these components would be constructed on the 9.7-acre parcel located west of and adjacent to the Charles Deering Estate, referred to as the Powers Addition Parcel.

The project would redirect water from the C-100A Canal system through the existing C-100A Spur Canal into the Cutler Drain on the project site and within the Deering Estate, thus restoring a portion of the historic freshwater flow through the Deering Estate and into Biscayne Bay.

The goals and benefits of the project include:

- Redirecting the existing point source discharge from Structure S-123 to Biscayne Bay by optimizing the capture and conveyance of freshwater from the C-100A Spur Canal to the coastal wetlands in the immediate vicinity of the Cutler Drain east of Old Cutler Road.
- Re-hydration of the wetland region east of Old Cutler Road and the restoration of a more natural freshwater flow regime.
- Establishment of an educational wetland on the Power's Addition Parcel.

The operation of the Deering Estate Flow Way pump station is intended to be automated, based on intake stage, which would be dependent on the associated existing water control structures' operational mode. The operation of the pump station would depend on canal levels, and the water levels in the receiving wetland.

The pump station's automatic controls for start and sequencing of the pumps would be triggered by rising levels in the inlet canal to the pump station. The software governing the canal stage starting sequence may be modified in the future after study of the hydrologic response and vegetative change. The pump station control system would include a programmable logic controller that can be programmed to optimize the water delivery. Remote operation of the pump station is provided via a telemetry communication system.

The station's operation would be flexible to address various hydrologic conditions and the coastal wetlands would be monitored to measure response in accordance with the Ecological Monitoring Plan in ***Annex E***. Normal operations would likely be modified at some future date, to optimize the wetland benefits of the project.

Although, the station would be normally operated automatically in accordance with the inflow canal stage, it would have the capabilities to be operated manually or remotely via telemetry communication facilities. There are alternatives as to the pump on/off sequencing that accomplishes the objective of an incremental increase of 25 cfs with an increase in stage. Pumps would be alternated as appropriate to equalize usage. The proposed pump start sequence would be as follows in ***Table D-4***:

The pumps have a low water shut-off stage in the intake of 0.0 feet, which represents the minimum submergence water level above the pump bell as recommended by the standard ANSI/HI 9.8 Intake Standard. This stage assumes a 1.0 foot head differential from the pump shut-off canal design stage of 1.0 foot North American Vertical Datum (NAVD88) across the trash rack due to blockage.

The pumps are subject to high water level shut-off in the discharge chamber of 10.0 feet NAVD88, which represents the invert of the 36-inch diameter discharge of the 50 cfs pump. This shut-off prevents the re-cycling of water back through the pumps and could be caused by a problem in the discharge line such as a blockage of the outlet or a restriction in the line preventing the free gravity discharge. In addition, there is an environmental high water restriction at the outfall to the Cutler Drain. This high water constraint was set at +5.3 feet NAVD88, which provides a 1.5 foot freeboard from the crown of the Old Cutler Road.

D.7.1.2 C-1 Flow Way Operations Associated with the Biscayne Bay Coastal Waters

The operation of the pump station is intended to be automated based on intake stage, which would be dependent on the associated existing water control structure's operational mode. The operation of the pump station would depend on the season (wet or dry), the canal levels, and the water levels in the receiving wetland.

The pump station's automatic controls for start and sequencing of the pumps would be triggered by rising levels in the inlet canal to the station. The canal stage starting sequence may be modified in the future after evaluation of the hydrologic response and ecosystem change in accordance with adaptive management. The pump station control system would include a programmable logic controller that can be programmed to optimize the water delivery.

The station's operation would be flexible to address various hydrologic conditions and the receiving coastal wetlands would be monitored to measure response in accordance with the Ecological Monitoring Plan in ***Annex E***. Normal operations would likely be modified at some future date based on study of the natural systems responses and monitoring of water delivery through system operations.

The station would normally be operated automatically in accordance with the inflow canal stage. In addition, the station would have the capabilities to be operated manually or remotely via telemetry communication facilities. There are alternatives to the pump on/off sequencing that accomplishes the objective of an incremental increase of 100 cfs with an increase in stage. Pumps would be alternated as appropriate to equalize usage. The proposed pump start sequence is shown in ***Table D-5***.

The pumps will have a low water shut-off stage in the intake of -1.0 foot, which represents the minimum submergence water level above the pump bell as recommended by the ANSI/HI 9.8 Intake Standard. This stage assumes a 1.0 foot head differential from the pump shut-off canal design stage of 0.0 feet NAVD88 across the trash rack due to blockage.

The outlet structure pool conditions (design high and low tail water conditions) assumed for the 400 cfs pumping system discharge are shown in ***Table D-6.***

D.7.1.3 L-31E Component Operations (North of Military Canal) Associated with the Biscayne Bay Coastal Waters Project

One riser culvert in the plug in the L-31E Borrow Canal south of the interconnection with the C-102 Canal to maintain water elevations in the L-31E Borrow Canal.

A 100 cfs pump station (S-705) to deliver water from C-102 to the L-31E Canal between C-102 and the Military Canal.

One siphon (S-707) in the L-31E Borrow Canal at the intersection of the Military Canal.

D.7.1.4 C-102 Features Operating Protocols/Sequencing

During periods of discharge from S-21A, the two pumps at C-102 S-703 (50 cfs) and S-705 (100 cfs) will be operating simultaneously.

L-31E culverts would flow as a result of the operation of the S-705 pump station. The quantity of flow at each culvert is affected by both wet season and dry season operational strategies implemented and downstream topographic limitations (wetland elevations). No telemetry or stage monitoring equipment would be installed at these locations given the tidal signal downstream of the culverts. Performance of each culvert would be measured through monitoring of the downstream wetland ecosystem.

The objectives of the culvert function is to increase flow of available freshwater from the L-31E Canal to the coastal wetlands with the anticipation that the freshwater would improve the health of the coastal wetlands, minimize point source discharges of canal water into Biscayne Bay and restore more natural estuarine conditions in a zone along the coastline.

The siphon would remain closed normally to maintain maximum water elevations in the L-31E Borrow Canal without affecting stages in Military Canal. During periods when excess water is available in C-102 versus C-103 (or vice versa), the siphon would be operated to convey water into the alternate reach of the L-31-E Borrow Canal.

D.7.1.5 L-31E Component Operations (South of Military Canal) Associated with the Biscayne Bay Coastal Wetlands Project

One submerged riser culvert in the L-31E Canal at the south intersection of the Military Canal:

- 40 cfs Pump Station S-711
- 40 cfs Pump Station S-710
- 40 cfs Pump Station S-709
- Seepage Canal

D.7.1.6 North Canal Freshwater Wetland-C-103 Features Operating Protocols/Sequencing

A) Moderate to high flow periods (Jan. 1 to April 30)–S-711 West (40 cfs), S-710 East (40 cfs) and S-709 (40 cfs) on simultaneously.
B) Low flow periods (Oct. 16 to Dec. 31)–S-711 (40 cfs) has priority, followed by S-709 (40 cfs), followed by S-710 (40 cfs).
C) C-103-Wet season (April 30 to October 15) 3 on simultaneously, Dry Season S-711 has priority, followed by S-709, by S-710
   a) North Canal Wetland-stage on/off criteria
      i. On at 0.2 feet below C-103 control criteria (S-20F) if stage in wetland is less than 1.5feet to 2.0 feet above ground surface
      ii. Off–exceed inundation depth or below off criteria of S-20F, whichever is first

   The hydropattern target for this wetland is to maintain water levels between -0.5 feet and +2.0 feet, in relation to ground surface, for 28 weeks to 32 weeks (a minimum of 18 weeks and a maximum of 48 weeks). If water level in the wetland has been between -0.5 feet and +2.0 feet for less than 340 days, pumps on when possible; otherwise pumps off.

D) Quantities of flow are affected by both wet season and dry season operational strategies implemented and downstream topographic limitations (wetland elevations) at each culvert location. Performance of each culvert would be measured through monitoring of the downstream wetland ecosystem.

The objectives of the culvert function is to increase flow of available freshwater from the L-31E Canal to the coastal wetlands with the anticipation that the freshwater would improve the health of the coastal wetlands, minimize point source discharges of canal water into Biscayne Bay and restore more natural estuarine conditions in a narrow zone along the coastline.

Each individual element is expected to work in concert with one another. It is recognized that both environmental and existing legal water uses may need to be met simultaneously in consideration of existing water shortage rules.

D.7.2 Flood Damage Reduction

D.7.2.1 Normal and Emergency Operations

The project's flood control objectives are normally limited to preventing un-necessary gate openings at the coastal structures, which will continue to be used when excess runoff exceeds the installed capacity of the pump stations. Under emergency conditions, it will likely be desirable to to use the installed pump capacity in tandem with the gate openings so as to maximize the spatial distribution of valuable freshwater.

The Biscayne Bay Coastal Wetlands project features can generally receive flood runoff anytime the lateral control facilities are open, consistent with project objectives, and constraints, to balance benefits to fresh-water wetlands in Biscayne Bay.

D.7.2.2 Hurricane or Tropical Storm Operations

The official hurricane season is from June 1st through November 30th. However, tropical cyclone activity can occur outside of this timeframe. When there are tropical depressions, tropical storms, and/or hurricanes in the Atlantic/Caribbean Basin or Gulf Coast of Florida, the National Hurricane Center issues tropical cyclone public advisories, forecast advisories, forecast discussions, and strike probability forecasts.

Water management operations within the Biscayne Bay Coastal Wetlands project for hurricanes or tropical storms should follow the SFWMD's Emergency Preparedness Manual–Suggested Hurricane Operating Procedures, April 2004. U.S. Corps of Engineers (USACE), Jacksonville District Standard Operating Procedure 500-1-1 dated September 9, 2002 should be consulted for emergency preparation and actions.

D.7.2.3 Storage Area Weir Discharge.

Not applicable to this project.

D.7.2.4 Uncontrolled Discharge

Under the current plan, there are no uncontrolled discharges.

D.7.3 Water Quality

This project is expected to improve water quality in the region by virtue of better management of regulatory releases. The intent of project operations for water quality improvement is tied to the optimum management of stages and flows within the area. Incidental inorganic nutrient loading and suspended solids to the bay would be reduced as a result of diverting water into the freshwater and saltwater wetlands.

D.7.4 Water Supply Operations

There are no water supply operations associated with this project.

D.7.5 Recreation

See ***Appendix H.***

D.7.6 Fish and Wildlife

There are no specific operations for fish and wildlife.

D.7.7 Navigation

Not applicable to this project.

D.8 PRE-STORM/STORM OPERATIONS

In anticipation of heavy rainfall based on National Weather Service Advisories and SFWMD forecasts, the canal water levels would be drawn down as much as practicable in order to allow for the maximum amount of canal and groundwater storage. Water management operations within the basin for hurricanes or tropical storms should follow the SFWMD Emergency Preparedness Manual–Suggested Hurricane Operating Procedures, April 2004. USACE, Jacksonville District Standard Operating Procedure 500-1-1 dated September 9, 2002 should be consulted for emergency preparation and actions. Such operations may include a partial draw-down of the level in the canals to provide for storage of tropical rains and basin runoff.

D.9 CONSISTENCY WITH THE IDENTIFICATION OF WATER AND RESERVATIONS OR ALLOCATIONS OF WATER FOR THE NATURAL SYSTEM

The operating criteria within the Draft Project Operating Manual are consistent with the operating criteria used to identify the water made available for the natural system by the Biscayne Bay Coastal Wetlands project Phase 1 as identified in ***Annex C*** of the Project Implementation Report (PIR).

Furthermore, the operating criteria are consistent with the water to be reserved or allocated for the natural system (freshwater marshes and downstream estuaries) by the State in accordance with section 601 of Water Resources Development Act (WRDA) 2000.

D.10 CONSISTENCY WITH SAVINGS CLAUSE AND STATE ASSURANCES PROVISIONS

The operating criteria within the Draft Project Operating Manual are consistent with those used for evaluating conformance with the Savings Clause during development of the PIR. Specifically, the canal stages upstream of the coastal control structures existing prior to December 11, 2000 will not be affected by the project nor will other project features significantly and adversely increase surface and groundwater levels outside of the project area. In addition, the project results in no elimination or transfer of water from existing legal sources, because canal flows and levels upstream of the coastal control structures will not be affected by project. Lastly, the operating criteria within the Draft Project Operating Manual is consistent with the criteria applied to ensure conformance with State Assurances (Section 373.1501, F.S.) provisions during development of the PIR.

D.11 DROUGHT CONTINGENCY PLAN

During a drought in the project area, operations would be in accordance with SFWMD Rules, Chapter 40E-21, Water Shortage Plan. The Drought Contingency Plan in ***Appendix B*** of the Lake Okeechobee Water Control Plan should be referenced for operations. The document is available for review in the office at the U.S. Army Corps of Engineers, Jacksonville District Office, 701 San Marco Boulevard, Jacksonville, Florida 32207.

D.12 FLOOD EMERGENCY ACTION PLAN

The Flood Emergency Action Plan would be completed for the Biscayne Bay Coastal Wetlands project during the detailed design phase of the project prior to construction completion and may be included in a future revision of the Draft Project Operating Manual. The Flood Emergency Action Plan to be developed should be consulted for related emergency preparation and action. Local emergency management offices would be provided copies of the Flood Emergency Action Plan as necessary. This plan may be used to supplement hurricane or tropical storm regulations. As outlined in ER 1130-2-530, the Flood Emergency Action Plan shall include:

- A written emergency notification procedure for serious abnormal conditions to provide for safety of people in the vicinity of the storage area

and to trigger immediate response for remedial assistance to the levee/water control structure.

- A description or list of conditions leading to emergency situations and ways of dealing with them should they occur.
- Storage area de-watering procedures.
- Levee/water control structure failure inundation maps.
- Listing of location, types, and quantity of emergency repair materials and equipment.
- Details outlining responsibilities for inspection and execution of emergency repairs.
- List of contractors available within a reasonable distance of the project area.

D.13 DEVIATION FROM NORMAL REGULATION

The USACE's District Commander is occasionally requested by the non-Federal sponsor to approve deviations from normal operating criteria. Prior approval for a deviation is required from the USACE, South Atlantic Division. Deviation requests usually fall into the following categories:

D.13.1 Emergencies

Some emergencies that can be expected include drowning and other accidents, failure of project facilities, and flushing of pollutants. Antecedent conditions, as well as forecasted storm events, may result in SFWMD declaring an emergency authorization order, which would result in an emergency deviation. Water control actions necessary to abate the problem should be implemented immediately unless such action would create equal or worse conditions. The USACE, South Atlantic Division Office must be informed of the problem and the emergency operating changes as soon as practicable. In addition, the non-Federal sponsor (the SFWMD), the State of Florida, the Florida Department of Environmental Protection (FDEP), and the Department of the Interior (DOI) should be informed.

D.13.2 Unplanned Minor Deviations

There are unplanned instances that create a temporary need for minor deviations from the normal operating criteria, although these deviations are not considered emergencies. Construction accounts for the major portion of these incidents requiring minor deviations. Examples of activities that may require short-term deviations include construction of utility stream/canal crossings and bridge work. Deviations are sometimes necessary to carry out maintenance, repair and inspection of facilities. Requests for changes in release rates generally involve time periods ranging from a few hours to a few days. Each request should be analyzed on its own merits. In evaluating the proposed

deviation, consideration must be given to upstream watershed conditions, potential flood threat, existing condition of the basin, and alternative measures that can be taken. In the interest of maintaining good public relations, requests for minor deviations are generally granted, providing that these deviations would not have adverse effects on the ability of the project (or projects) to achieve the authorized purposes. Approval for these minor deviations normally would be obtained from the USACE, Jacksonville District Engineer by telephone. Written confirmation explaining the deviation and the cause would be furnished to the USACE, Jacksonville District Engineer. In addition, the non-Federal sponsor, the State of Florida, FDEP and the DOI should be informed.

D.13.3 Planned Deviations

Each circumstance should be analyzed on its own merits. Sufficient data on flood potential, lake and watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other authorized and useful purposes, together with the USACE, Jacksonville District recommendation, would be presented by memorandum, facsimile, or electronic mail to USACE, South Atlantic Division for review and approval. In addition, the non-Federal sponsor, the State of Florida (SFWMD and FDEP), and the DOI should be consulted as part of the process of receiving approval from USACE, South Atlantic Division for the deviation.

D.14 RATE OF RELEASE CHANGE

This section is not applicable to this project.

D.15 SEEPAGE CONTROL

The Biscayne Bay Coastal Wetlands project includes seepage collection and pumping facilities, to control and manage seepage in order to minimize impacts on adjacent properties.

Deering Estate Feature: The intake stage would be in accordance with the regional water supply and flood control system. There would be no changes upstream of the Deering Estate pump station in the groundwater stages with operation of the system as proposed.

The freshwater wetland located between C-103 and North Canal (west of L-31E) would be surrounded on all sides by either existing canals or seepage collection ditches. The seepage collection ditches would be connected directly to the C-103 Canal, thus eliminating any off-site seepage impacts.

D.16 INITIAL RESERVOIR FILLING PLAN

This section is not applicable to this project.

D.17 NON-TYPICAL OPERATIONS FOR PERFORMANCE

There are no unforeseen non-typical operations that have been identified in the PIR Phase. This section would be updated in the future if necessary.

D.18 AQUIFER STORAGE AND RECOVERY SYSTEM PLAN

This section is not applicable to this project.

D.19 WATER CONTROL DATA ACQUISITION SYSTEM PLAN

For the Biscayne Bay Coastal Wetlands project, all pump stations and water control structures with gates would be equipped with remote automation components and operated by use of a remote telemetry system known as Supervisory Control and Data Acquisition. The automation components of all pump stations and structures that would eventually be operated and maintained by the SFWMD must conform to SFWMD standards. Equipment used in data acquisition essential to the water control management function would be included in the Water Control Data Acquisition System Plan. This includes all hardware and software to be used for acquisition, transmission, processing, display, and dissemination of hydrologic, meteorological, water quality, and project data for the purpose of supporting the water control mission. For the Biscayne Bay Coastal Wetlands project, this includes, but is not limited to; uninterruptible power supplies, field data collection platforms, and data communication devices and circuits. The Water Control Data Acquisition System Plan would also identify site location of all hardware included within the plan. Hardware location would be determined through coordination with appropriate agencies including the U.S. Geological Survey (USGS) and the SFWMD. The Water Control Data Acquisition System Plan would be completed during the plans and specifications phase and would be a subset of the Water Control Data System.

Inflow and outflow data for the Biscayne Bay Coastal Wetlands project will be maintained in a database for future analysis. Specific frequency of data acquisition for project features would be determined during the plans and specifications phase. In addition, the specific method for quantification of flows will be dependent on the project features' specifications provided by the manufacturer, which will be determined during the plans and specifications phase. The water management data may be used to demonstrate the project performance. Adaptive management practices would be implemented accordingly.

All hydrologic, meteorological, ecological and water quality monitoring, recording, transmitting and verifying will be completed in accordance with CERP Guidance Memorandum 40. Specific guidance for monitoring is provided in Quality Assurance Systems Requirements (QASR) Chapter 6. Refer to ***Annex E, Project Monitoring and Adaptive Management Plans*** for details regarding Ecological and Water Quality Monitoring.

D.20 CONSISTENCY WITH THE ADAPTIVE MANAGEMENT PROGRAM AND PERIODIC COMPREHENSIVE EVERGLADES RESTORATION PLAN UPDATES

After initiation of long-term operations and maintenance of this project, the operating manual may be further modified based on operating criteria approved by USACE and SFWMD that results from CERP updates and/or recommendations from the adaptive assessment process as outlined in Guidance Memorandum #6, Section 6.3.1.

D.21 INTERIM OPERATIONS DURING CONSTRUCTION

During the detailed design phase of the project, the Draft Project Operating Manual may be further developed and modified for use during construction. This updated Draft Project Operating Manual would focus on facilitating construction of the project components while maintaining established levels of project purposes as set forth in ***Section 2*** of this operating manual. Some Draft Project Operating Manual modifications may result from value engineering analyses conducted during the detailed design phase of the project. Defining operating criteria to be used during construction would require consideration of issues that are unique to the construction phase such as real estate issues, construction schedules, contract sequencing, temporary by-pass canals, and dewatering activities. As a result, this modified Draft Project Operating Manual would likely contain operating criteria that are only applicable during the construction phase.

D.22 INTERIM OPERATIONS DURING OPERATIONAL TESTING AND MONITORING PHASE

The next version of the operating manual, the Preliminary Draft Project Operating Manual, would describe the operating refinements that have been developed during the detailed design and construction phases of the project and would represent the operating instructions for operators to use to begin the Operational Testing and Monitoring Phase.

D.23 CONCEPTUAL DESCRIPTION OF PROJECT OPERATIONS FOR TRANSITION FROM THE INITIAL OPERATING REGIME TO THE NEXT ADDED INCREMENT CONDITION

The Next Added Increment (NAI) represents project operations as if the Biscayne Bay Coastal Wetlands project were the only additional CERP project authorized and operational in the next 50 years. Under the NAI condition, the operations would be expected to be the same as those in the initial operating regime condition. There is no change proposed between the initial operating regime and next added increment operating criteria.

TABLES

TABLE D-1: STRUCTURE S-123 OPERATING CRITERIA

	Operation Criteria	Operating Characteristics
Non-Flood Condition	When the headwater elevation rises to 2.0 feet, the gates open at six inches per minute. The gates become stationary when the headwater elevation becomes 1.5 feet.	When the headwater elevation falls to 1.0 feet the gates would close at six inches per minute.
Flood Condition	When the headwater elevation rises to 0.9 feet, the gates open at six inches per minute. The gates become stationary when the headwater elevation becomes 0.5 feet.	When the headwater elevation falls to 0.1 feet the gates would close at six inches per minute.
Tide	N/A	When the differential between the headwater and tailwater elevations reaches 0.3 feet the gates automatically close.
Discharge Rate	2,300 cubic feet per second–this passes the design flood which is 40 percent of the standard project flood.	Water elevation that would by-pass the structure is 8.5 feet.

TABLE D-2: OPERATING CRITERIA AND CHARACTERISTICS FOR S-21

	Operation Criteria	Operating Characteristics
Non-Flood Condition	When the headwater elevation rises to 0.5 feet, the gates open at six inches per minute. The gates become stationary when the headwater elevation becomes 0.0 feet.	When the headwater elevation rises or falls to -0.5 feet the gates would close at six inches per minute.
Flood Condition	When the headwater elevation rises to 0.9 feet, the gates open at six inches per minute. The gates become stationary when the headwater elevation becomes 0.4 feet.	When the headwater elevation rises or falls to 0.0 ft. the gates would close at six inches per minute.
Tide	N/A	When the differential between the headwater and tailwater elevations reaches 0.2 feet the gates automatically close.

TABLE D-3: SEASONAL GATE OPERATIONS

Range	Period	Gates Open (feet)	Gates Hold (feet)	Gates Close (feet)
S-21A Control Structure				
High	April 30th to October 15th	+0.68 (+2.20)	+0.48 (+2.00)	+0.28 (+1.80)
Intermediate	December 30th to April 30th	+0.28 (+1.80)	+0.08 (+1.60)	-0.12 (+1.40)
Low	October 15th to December 30th	-0.12 (+1.40)	-0.32 (+1.20)	-0.52 (+1.00)
S-20F Control Structure				
High	April 30th to October 15th	+0.68 (+2.20)	+0.48 (+2.00)	+0.28 (+1.80)
Intermediate	December 30th to April 30th	+0.18 (+1.70)	-0.02 (+1.50)	-0.22 (+1.30)
Low	October 15th to December 30th	-0.12 (+1.40)	-0.32 (+1.20)	-0.52 (+1.00)
S-20G Control Structure				
High	April 30th to October 15th	+0.68 (+2.20)	+0.48 (+2.00)	+0.28 (+1.80)
Intermediate	December 30th to April 30th	+0.28 (+1.80)	+0.08 (+1.60)	-0.12 (+1.40)
Low	October 15th to December 30th	-0.12 (+1.40)	-0.32t (+1.20)	-0.52 ft (+1.00)

Note: All elevations reported in feet, NAVD 1988 (NGVD 1929)
NAVD North American Vertical Datum
NGVD National Geodetic Vertical Datum

TABLE D-4: DEERING ESTATE FLOW WAY PUMP STATION SEQUENCE
Deering Estate Flow Way Final Design

Stage (Feet NAVD88)	Pump Operation 25 cfs	25 cfs	50 cfs	Total Discharge (cfs)
1.5	✓			25
1.7			✓	50
1.9		✓	✓	75
2.1	✓	✓	✓	100

Notes:
1) ✓ denotes pump on.
2) Pumps continue to run until stage recedes to 1.0 foot, then all pumps off.

TABLE D-5: CUTLER WETLANDS FLOW WAY PUMP STATION SEQUENCE
Cutler Wetlands C-1 Flow Way Pre-Final Design

Stage (Feet NAVD 88)	Pump Operation
0.25	One (1) 100 cfs pump on
0.75	Two (2) 100 cfs pump on
1.25	Three (3) 100 cfs pump on
1.75	Four (4) 100 cfs pump on

Note: Pumps continue to run until stage recedes to 0.0 feet, then all pumps off
Key: cfs cubic feet per second

TABLE D-6: PUMPING SYSTEM DISCHARGE
Cutler Wetlands C-1 Flow Way Pre-Final Design

Maximum Elevation (NAVD)	Minimum Elevation (NAVD)
+10.5	0.0

Key: NAVD: North American Vertical Datum

TABLE D-7: S-703 AND S-705 FOLLOW S-21A OPERATIONS

Pump	Schedule		Open/On (feet)	Close/Off (feet)
S-703, S-705	Wet	April 30th–October 15th	2.2	1.8
	Inter	January 1st–April 30th	1.7	1.3
	Dry	October 16th –December 31st	1.4	1.0

TABLE D-8: S-711, S-710 AND S-709 FOLLOW S-20F OPERATIONS

Structure		Schedule	Open/On (feet)	Close/Off (feet)
Pumps: S-703, S-705, S-711, S-710, S-709				
	Wet	April 30th–October 15th	2.2	1.8
	Inter	January 1st–April 30th	1.7	1.3
	Dry	October 16th–December 31th	1.4	1.0
S-21A (Current operations)				
	Wet	April 30th–October 15th	2.2	1.8
	Inter	January 1st–April 30th	1.7	1.3
	Dry	October 16th–December 31th	1.4	1.0
S-20G (Current operations)				
	Wet	April 30th–October 15th	2.2	1.8
	Inter	January 1st–April 30th	1.7	1.3
	Dry	October 16th–December 31th	1.4	1.0
S-20F (Current operations)				
	Wet	April 30th–October 15th	2.2	1.8
	Inter	January 1st–April 30th	1.7	1.3
	Dry	October 16th–December 31th	1.4	1.0

FIGURES

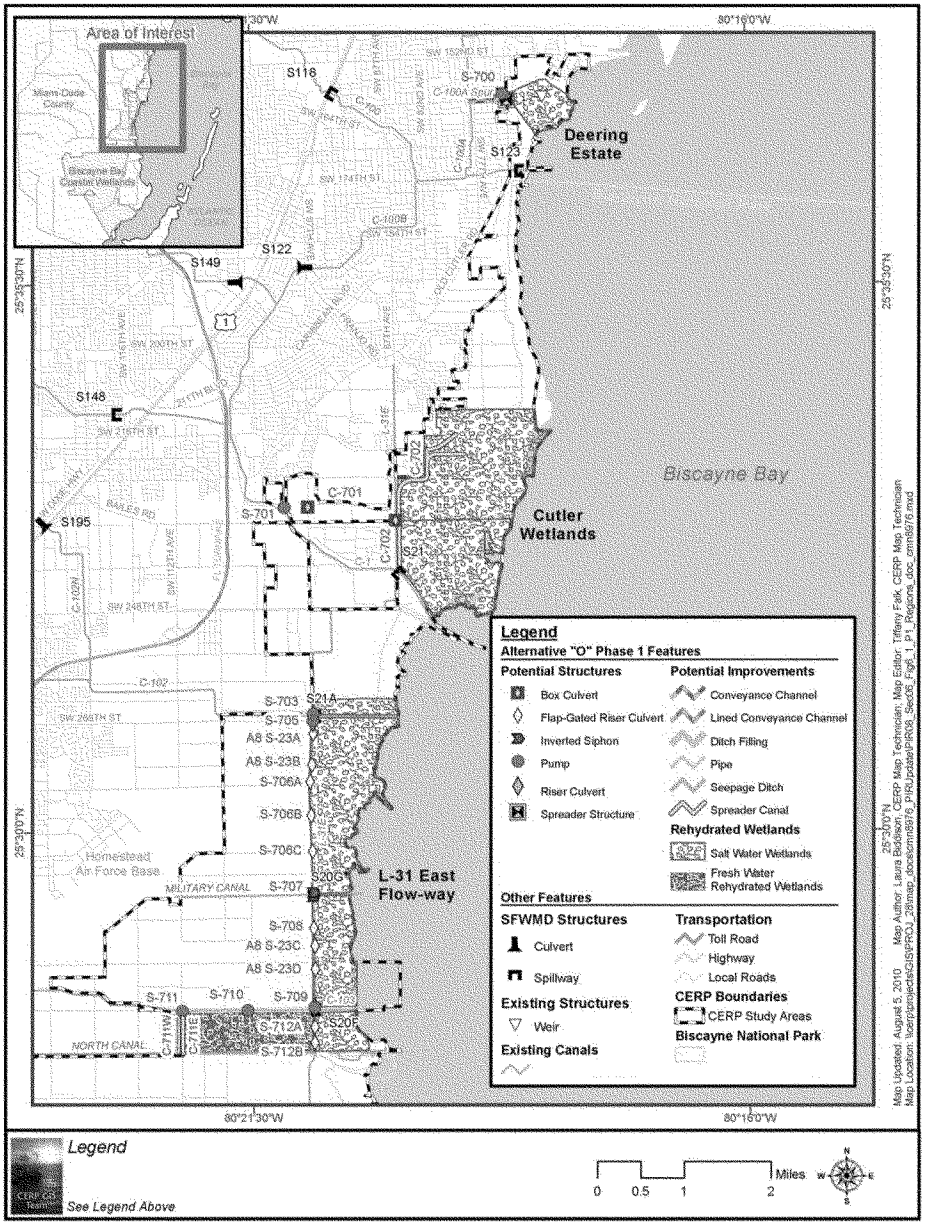

FIGURE D-1: BISCAYNE BAY COASTAL WETLANDS PROJECT PHASE I FEATURES

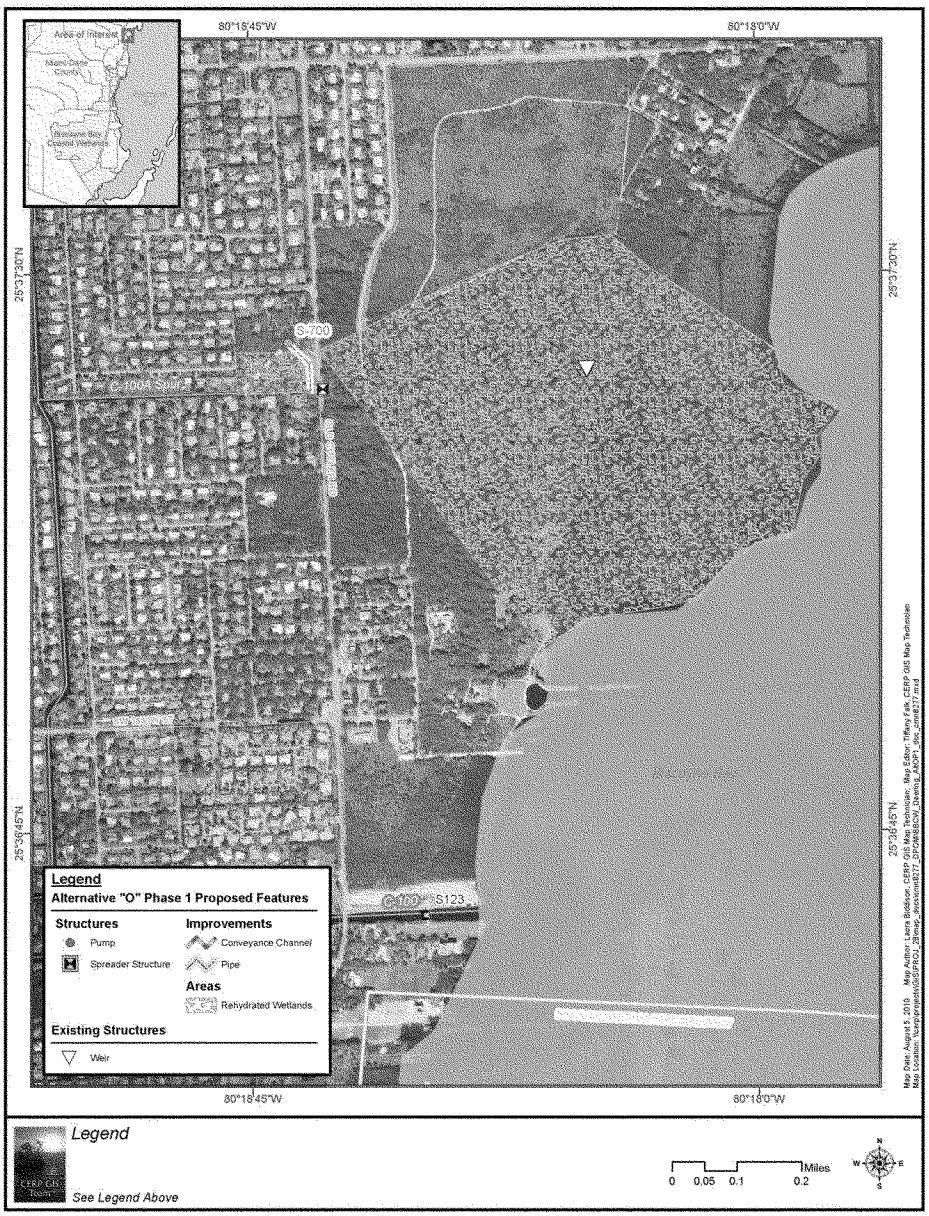

FIGURE D-2: DEERING ESTATE PROJECT FEATURES

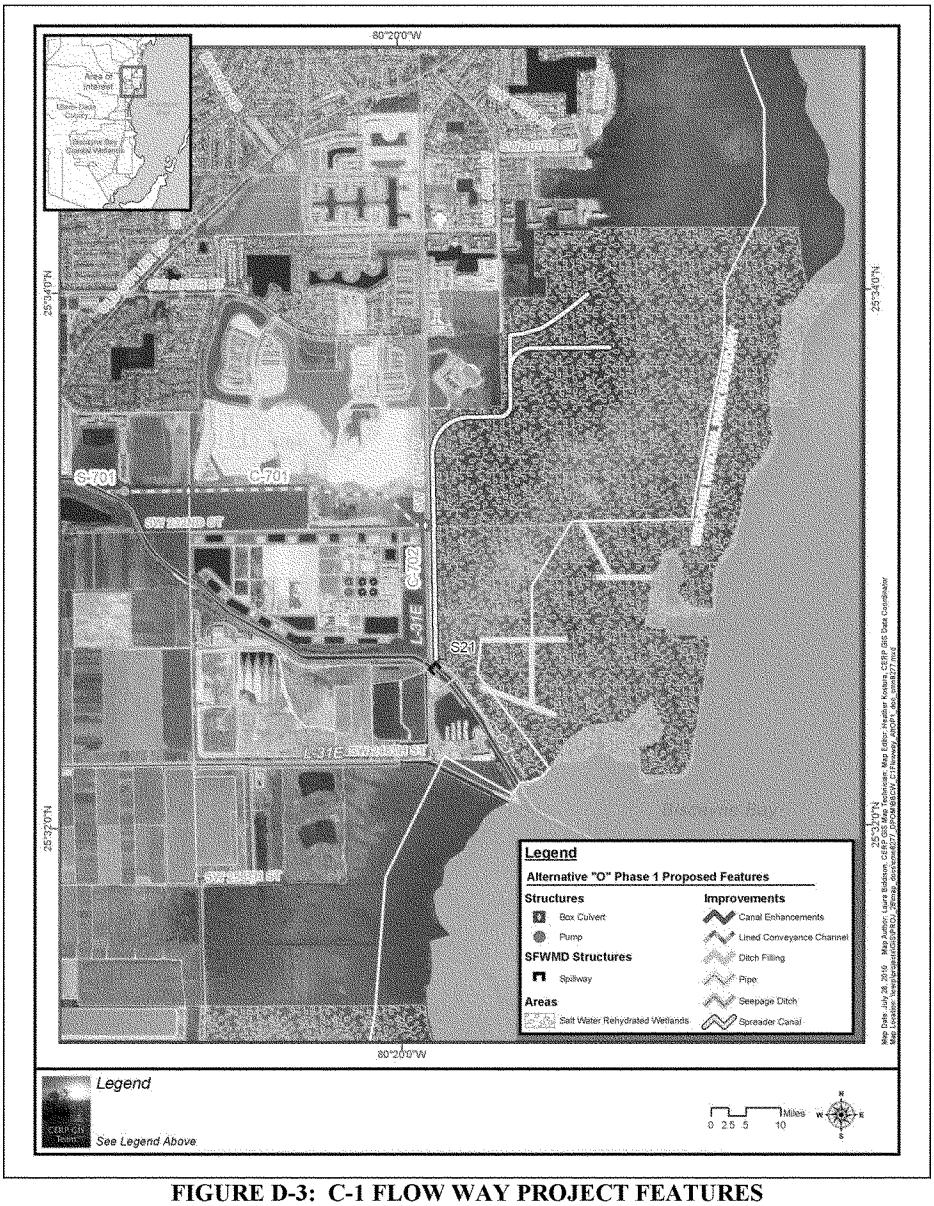

FIGURE D-3: C-1 FLOW WAY PROJECT FEATURES

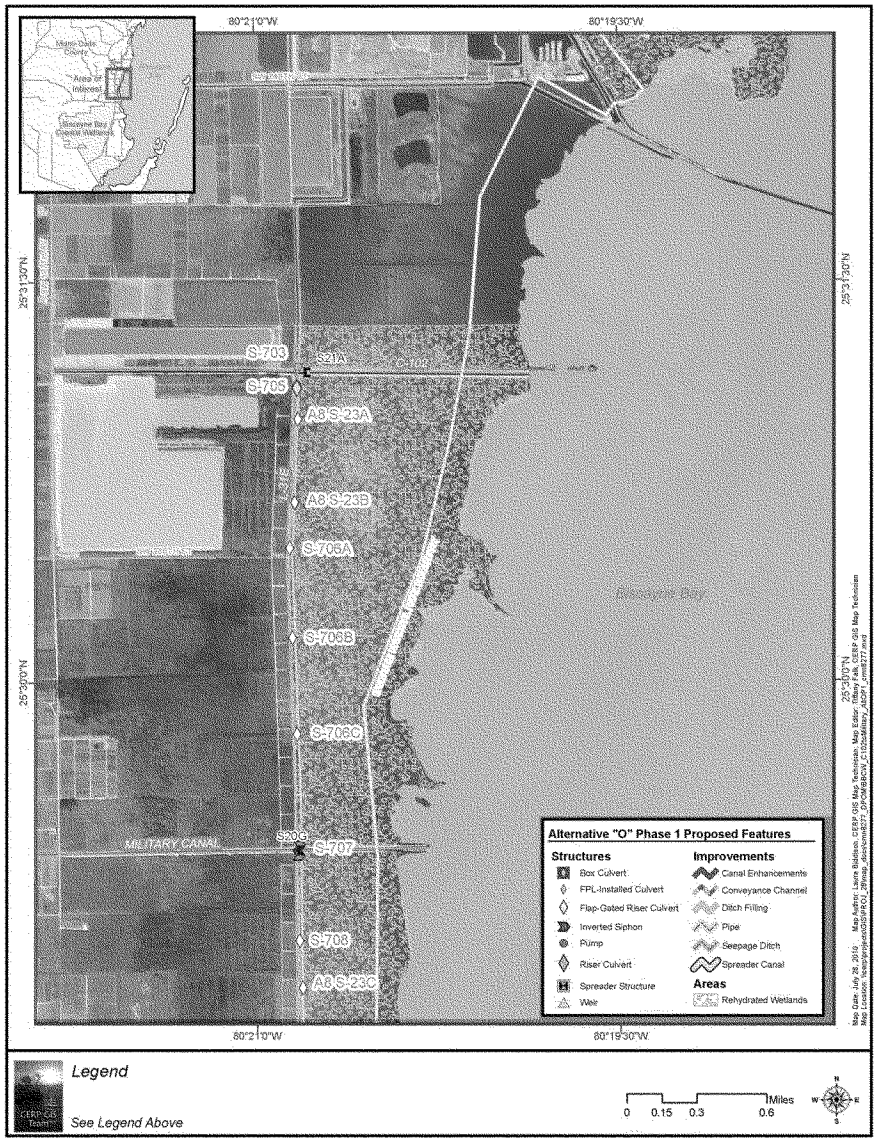

FIGURE D-4: L-31E NORTH OF MILITARY CANAL FEATURES

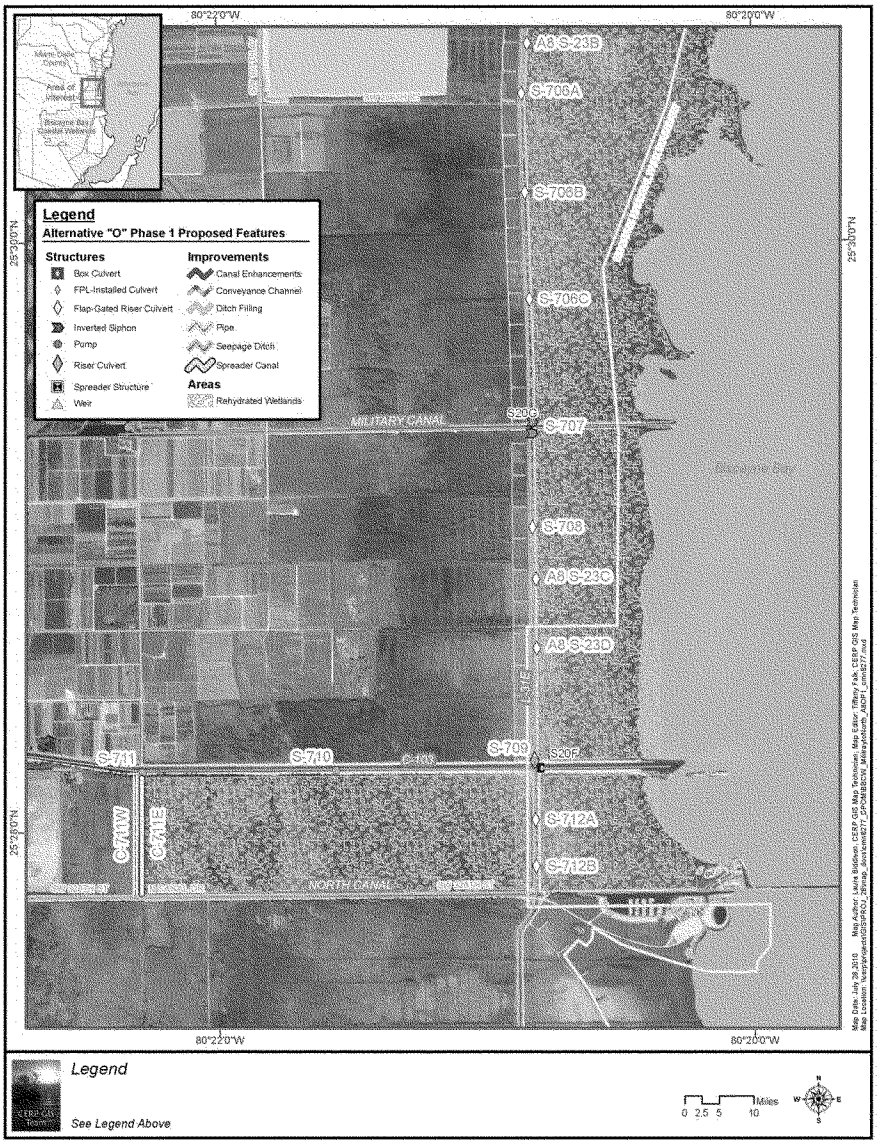

FIGURE D-5: L-31E SOUTH OF MILITARY CANAL FEATURES

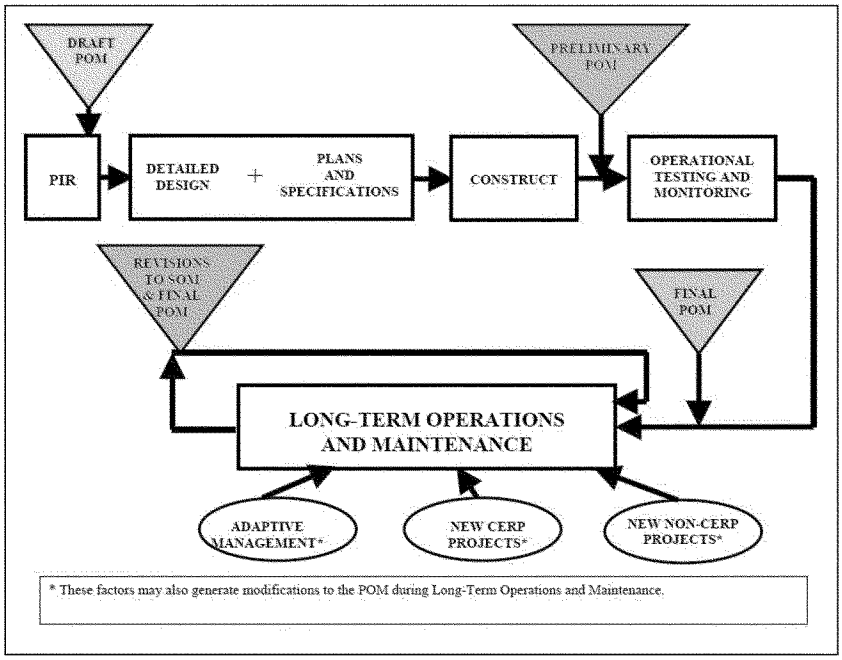

FIGURE D-6: PROJECT OPERATING MANUAL REVISION PROCESS

ANNEX E
PROJECT MONITORING PLAN

PART 1 **HYDROMETEOROLOGICAL MONITORING**

PART 2 **REGULATORY PLAN: WATER QUALITY COMPLIANCE**

PART 3 **ECOLOGICAL MONITORING**

PART 4 **ADAPTIVE MANAGEMENT PLAN**

PART 5 **NUISANCE AND EXOTIC VEGETATION CONTROL PLAN**

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E.1.3 Project Phasing ..... Annex E Intro--E-3
E.1.4 Project Monitoring Plan Guidance ..... Annex E Intro--E-3

ATTACHED DOCUMENTS:

Part 1 Hydrometeorological Monitoring Plan
Part 2 Regulatory Plan – Water Quality Compliance
Part 3 Ecological Monitoring Plan
Part 4 Adaptive Management Plan
Part 5 Nuisance and Exotic Vegetation Control Plan

E PROJECT MONITORING PLAN

E.1 INTRODUCTION

The Biscayne Bay Coastal Wetlands system has been significantly altered by human activities. Historically, Biscayne Bay served as the eastern outlet of Everglades stormwater runoff, and freshwater flowed overland to the bay through broad channels in the coastal ridge known as transverse glades and then through a system of 20-30 tidally influenced creeks, and as groundwater through the Biscayne Aquifer (See ***Section 4 - Identification of Problems and Opportunities*** for details). This natural pattern was altered by regional drainage, canal construction and the operation of canals (particularly C-100, C-1, C-102, C-103 and C-111), urban development, as well as construction of roads, levees, and other hydrologic barriers to surface flow.

Over the last century the patterns of freshwater discharge changed from long, slow releases over a broad front to "pulse" releases from canals following rain events, and hydroperiods in wetlands along the western shore of the bay have decreased. This hydrologic change to the system has caused a significant degradation of the estuarine environment in the coastal wetlands and nearshore bay.

Prior to the hydrologic changes described above, oyster and submerged aquatic vegetation beds provided important habitat for numerous organisms. These habitats, together with juvenile fishes and various macroinvertebrates, are indicators of a healthy estuary. Similarly, marl marshes and mangrove marshes provide important habitat for wetland species and are indicators of healthy south Florida coastal wetlands. Efforts of the Biscayne Bay Coastal Wetlands project and the Comprehensive Everglades Restoration Plan (CERP) focus on re-directing flow from canals into the coastal wetlands to re-establish more natural overland flow regimes that will provide appropriate hydropatterns and salinity regimes to re-establish and maintain these key habitats along southwestern Biscayne Bay.

The objective of the Biscayne Bay Coastal Wetlands Ecological Monitoring Plan is to determine if restoring beneficial patterns of freshwater flow, salinity, and water quality to nearshore waters of southwestern Biscayne Bay will achieve the expected distribution, community structure and viability of oyster bars, submerged aquatic vegetation beds, and associated biota. The Biscayne Bay Coastal Wetlands Ecological Monitoring Plan will monitor ecosystem responses to changes in hydroperiod depth and duration within the coastal wetlands (particularly the freshwater wetlands component) that are expected to provide ecological conditions suitable for expanded and intensified wildlife utilization through improvements in wetland habitat functional quality, and improvements

in native plant and animal species diversity and abundance. There must be agreement on performance targets, and on the ecological changes that constitute improvements, as a prerequisite for determining which parameters in the system must be monitored. Because of the uncertainties inherent in any effort to restore such a complex and altered system such as the Biscayne Bay Coastal Wetlands project area, the performance targets and the measures of success must be cognizant of the broad range of potential outcomes. Nevertheless, these targets and measures need definition to design a monitoring program that is well focused and efficient, thereby ensuring that it will provide the kind of information necessary for the implementation of an adaptive assessment and management strategy.

E.1.1 Coordination with the Monitoring and Assessment Plan

The CERP Restoration, Coordination, and Verification (RECOVER) organization and the CERP Project Delivery Teams (PDT) recognize that the effects from implementing the CERP projects must be monitored at both system-wide and local scales. Responsibility for the design and implementation of system-wide monitoring is in the hands of RECOVER, while the design and implementation of monitoring to determine local effects and project performance is the responsibility of the individual CERP PDTs. To implement the system-wide program, RECOVER has developed the CERP Monitoring and Assessment Plan (MAP) (MAP; RECOVER 2004a) and an associated quality assurance/quality control document (i.e., Quality Assurance Systems Requirements; RECOVER 2004b). The MAP and the individual project monitoring plans must be closely coordinated to ensure that measures and targets selected by the project teams are consistent with system-wide measures and that duplication of effort is avoided. The project level monitoring plan should ensure appropriate temporal and spatial coverage of monitoring parameters, which will likely mean filling gaps in the MAP monitoring parameters and adding additional project-level parameters not included in the MAP. RECOVER is developing a guidance memorandum for standardizing assessment activities. The Biscayne Bay Coastal Wetlands Ecological Monitoring Plan will implement those procedures when finalized.

The Biscayne Bay Coastal Wetlands Ecological Monitoring Plan will utilize the protocols and results of the MAP whenever possible. However, since the primary purpose of the MAP is to detect system-wide or regional changes, only certain parameters are measured, and are measured across large spatial scales. Thus, changes resulting from individual projects affecting Biscayne Bay, such as the Biscayne Bay Coastal Wetlands project, may not be adequately detected using the MAP parameters and sampling site arrays. It is very important to be able to detect ecological and water quality changes resulting from project-level implementation to detect changes in the system, and to evaluate project success.

Therefore, to detect project-specific changes, additional parameters and sampling sites may be required and are addressed in this monitoring plan.

E.1.2 Structure of the Biscayne Bay Coastal Wetlands Monitoring Plan

The ecological section is sub-divided into two geographic components: (1) the nearshore waters of southwestern Biscayne Bay, and (2) the adjacent coastal wetlands area (including both the freshwater and salt water wetlands). The nearshore bay component will include as monitoring parameters oysters, submerged aquatic vegetation (SAV), estuarine fishes, juvenile crocodiles, and salinity. The wetland component will include monitoring for hydropattern (stage and hydroperiod), wetland macro vegetation, and wetland algae. Monitoring wetland algae serves partly as a surrogate for detecting changes in wetland salinity and water quality. Project objectives applicable to each component are identified, and the monitoring parameters that will evaluate the extent to which each objective is achieved are presented. For each monitoring parameter, the following are provided: (1) justification for monitoring and relevance to performance measures, (2) project-level monitoring component, (3) MAP monitoring component, (4) comparison of project-level and MAP components, (5) data management and quality assurance and quality control, and (6) monitoring cost estimates. Ecological monitoring will be used to support adaptive assessment efforts outlined in the Biscayne Bay Coastal Wetlands Adaptive Management Plan (***Part 4, Section E.4***).

E.1.3 Project Phasing

Construction of the selected plan (Alternative O Phase I) may be phased over time, which could possibly affect how monitoring will be conducted over the life of the project. It may be possible to reduce some monitoring over time as the system stabilizes in response to implementation of the plan. It is intended that the monitoring program be assessed annually, and revised as needed to optimize its effectiveness and efficiency.

E.1.4 Project Monitoring Plan Guidance

Implementation guidance for Section 2039 of the Water Resources Development Act of 2007 has been provided in a memorandum from the Chief of Planning and Policy Division of Civil Works dated 31 August 2009. In summary, the guidance states that ecosystem restoration project monitoring will be initiated upon the completion of project construction until ecological success is determined. Necessary monitoring for a period not to exceed 10 years will be considered a project cost and will be cost shared as a project construction cost and funded under Construction. This guidance is effective immediately and will be incorporated into ER 1105-2-100 upon the next revision.

The total amount for the proposed Project Monitoring Plan over a 10 year period is approximately $3,287,163. Justification for implementing the project-level monitoring plan in its entirety is based on the need for greater spatial and temporal resolution in its monitoring data in order to detect ecological changes resulting from project operations.

ANNEX E
PROJECT MONITORING PLAN

PART I: HYDROMETEOROLOGICAL MONITORING PLAN

HYDROMETEOROLOGIC MONITORING PLAN	PROJECT	STATUS	REVISION DATE
	BBCW Phase I	Final	
	AUTHORING ORGANIZATION	DATE	REVISION NUMBER
	USACE & SFWMD	*10/1/09*	0
	USACE & SFWMD	*1/20/10*	1

Hydrometeorological Monitoring Plan

For

Biscayne Bay Coastal Wetlands Project

January 20, 2010

Authoring Organization's Representative (Monitoring Plan Coordinator) **Date**

Lead CERP Project Manager **Date**

Representative, Local Sponsor (Monitoring Organization) **Date**

Representative, Federal Sponsor (Monitoring Organization) **Date**

Project Quality Assurance Officer **Date**

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GLOSSARY

ADaPT – Automated Data Processing Tool software.

ADR – Automated Data Review software

Assessment – to interpret responses in natural and/or human systems based on data acquired though monitoring activities.

Constraint – a condition that is to be minimized or avoided in the plan formulation and selection process to ensure that the project component does not result in undesirable changes in the project area or downstream waters. Example: The component shall not cause or contribute to a violation of state water quality standards.

Data Quality Objectives (DQO) – is a process that identifies the intended use of the data including the types of decisions that will be made based on the results. The analytes of interest, corresponding action levels, sampling design and quality control measures are also identified as well as data repositories into which the data will be entered, the mechanisms used to ensure that the data are accurately entered into a database and to verify that the data in the database are correct, and the level of data quality acceptable for this project.

EDMS – Environmental Data Management System

EM – Engineering Manual: USACE documents that provide guidance on various aspects of project design and implementation.

EMCT – Environmental Monitoring Coordination Team, a group of senior-level managers that participate in planning and reviewing project-level monitoring activities. Representatives from the District and the USACE are members of the team.

FDEP – Florida Department of Environmental Protection

Local Sponsor – the agency responsible for matching the Federal funding available for a project. The South Florida Water Management District (SFWMD) is the local sponsor for the majority of CERP projects.

Matrix – refers to the material from which the sample is taken, such as surface water, ground water, pore water, sediment, soil or air.

Monitoring – all of the activities required to acquire, process, store, retrieve and analyze data used to assess the status of water resources. It includes data collection, data analysis, data validation, and data management.

Monitoring Data – data that are collected for the purpose of determining the water quality and hydrologic conditions/effects for CERP projects at a given location.

Monitoring Plan – the plan to acquire additional meteorological, hydrologic, hydraulic or water quality data. It includes considerations of sampling location, frequency, method, parameters and duration. It should be based on the elements identified in the development of data quality objectives for the project.

MOSCAD – MOtorola SCADa (SCADA – Supervisory Control And Data Acquisition). An intelligent communications device used in data acquisition and remote system control.

CR1000 – an intelligent communication device used in data acquisition and remote control

Objective – a measurable element of the goal(s) of a project or plan. Project objectives and constraints are identified in the Project Management Plan (PMP).

Permit Requirement – certain analytes are sampled, tested and results reported to state and/or federal agencies as a condition of a permit to build or operate a project.

PLMP – Project-Level Monitoring Plan

Project-level – A project has a defined scope, quality objectives, schedule, and cost. Project-level activities refer to those that are within the scope of a specific project.

QA – Quality Assurance: the system of management activities and quality control procedures implemented to produce and evaluate data according to pre-established data quality objectives.

QAPP – Quality Assurance Project Plan, a QA plan written for a specific project outlining data quality objectives, sampling and analytical protocols and QC measures needed to satisfy the intended uses of the data.

QAOT – Quality Assurance Oversight Team, comprised of representatives from USACE, SFWMD, FDEP, and USEPA, ultimately responsible for implementation of the QASR for CERP.

QASR – Quality Assurance System Requirements, a CERP manual that establishes minimum criteria for environmental data quality.

QC – Quality Control: The system of measurement activities used to document and control the quality of data so that it meets the needs of data users as specified by pre-established data quality objectives.

QA/QC – Quality Assurance and Quality Control. A process that insures that the data available for assessment is of an acceptable level of quality.

RACU – Remote Acquisition and Command Unit. A device used for data acquisition and remote system control.

RECOVER – REstoration COordination and VERification (RECOVER) evaluates and assesses CERP performance by linking scientific and technical information throughout the planning and implementation period to ensure that a system-wide perspective is maintained throughout the restoration program.

RECOVER AT - The RECOVER Assessment Team is a standing, interagency, interdisciplinary team of scientists and resource specialists who are responsible for achieving the five primary tasks of RECOVER: 1) create, refine and provide documentation for a set of conceptual ecological models for the total system and a set of attribute-based biological performance measures for the Comprehensive Plan; 3) design and review the system-wide monitoring and data management program needed to support the Comprehensive Plan; 4) use the information coming from the system-wide monitoring program to assess actual system responses as components of the Comprehensive Plan are implemented and produce an annual assessment report describing and interpreting these responses; and 5) coordinate all scientific peer reviews of RECOVER documents.

Sampling Frequency – how often samples are collected.

Sampling Methods – the methods used to collect samples in the field. The methods should be standard methods, methods based on a standard operating procedure, or a method that has been approved by the participating agencies.

SFWMD – South Florida Water Management District

USACE – U. S. Army Corps of Engineers

WBS – Work Breakdown Structure: The WBS specifies a hierarchy of tasks and activities necessary to fulfill the objectives of the project. The WBS is structured in levels of work detail, beginning with the deliverable itself, and is then separated into identifiable work elements.

Zone of Influence – the area over which a project alters or impacts the environment.

Additional terms and definitions for CERP can be found in CGM 13 – Acronyms and Glossary of Terms. http://www.cerpzone.org/documents/cgm/cgm_013.03.pdf

E.1 HYDROMETEOROLICAL MONITORING PLAN

E.2 PROJECT DESCRIPTION

E.2.1 INTRODUCTION AND BACKGROUND

This document serves as guidance for hydrologic and meteorological monitoring data collection and management for post-project objectives of Phase I of the Biscayne Bay Coastal Wetlands (BBCW) Comprehensive Everglades Restoration Plan (CERP) project. The guidance contained in this document is intended to ensure consistency of methodology with existing systems as applicable, type of data needed, locations and frequencies of collection, and generally provide an initial scope of a hydrometeorological monitoring program. Prior to implementation of any aspect of this monitoring plan signature approval of the plan is required by the project manager, and representatives of the monitoring departments or divisions of the sponsoring agencies.

The Biscayne Bay Coastal Wetlands Phase I project is intended to contribute to the restoration of Biscayne Bay and adjacent wetlands as part of the overarching CERP. The BBCW project study area as defined in the Yellow Book extends from Shoal Point (near the Charles Deering Estate) south along the western shore of Biscayne Bay to U.S. Highway 1, most of the saltwater wetlands and low lying areas adjacent to Biscayne Bay including all of the Model Land basin east of U.S. Highway 1 (***Figure E-1***). The geographically extent of the Phase 1 footprint is smaller, and extends approximately from Shoal Point south along the shore to North Canal at Biscayne National Park headquarters. For a complete description of the project, and goals and objectives see Section 4.

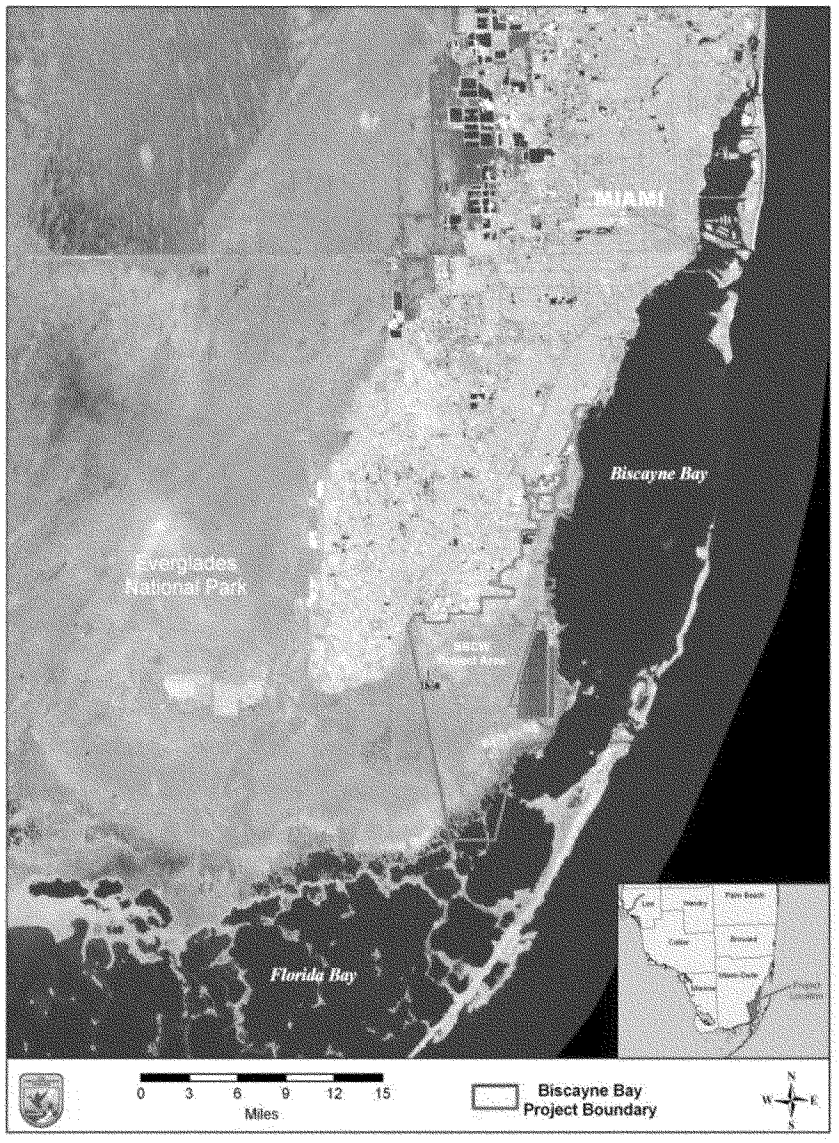


FIGURE E-1: BISCAYNE BAY COASTAL WETLANDS PROJECT LOCATION

The Biscayne Bay Coastal Wetlands Phase 1 Project can be described within three hydrologically distinct regions or components, which encompass about 3,943 acres of the overall study area. Within this document, the three distinct regions are known as the Deering Estate Slough, Cutler Wetlands, and L-31 East Flow Way and Impoundment, as shown in ***Figure E-1***.

Deering Estate Flow-way

This region includes an approximate 500-foot extension of the C-100A Spur Canal through an upland area (Power's Parcel), with a small freshwater constructed wetland, and a pump station. Water will be pumped when available and discharged into a historical slough downstream. An existing weir will impound water in the lower part of the slough, and overflow into saltwater wetlands.

Cutler Flow-way

Features in this region include a pump station, a conveyance canal, a spreader canal, culverts and some ditch plugs. The pump station, located on the C-1 Canal, will deliver water to a 6,900-foot lined conveyance canal that will pass under S.W. 97th Avenue, S.W. 87th Avenue and the L-31E Levee, via concrete box culverts, and deliver water into a spreader canal that will distribute the water north and south into a mix of fresh and saltwater wetlands east of the L-31E.

L-31 East Flow Way and Impoundment

Features in this region will hydrologically control the L-31E Borrow Canal between the C-102, Military and C-103 Canals. Gated culverts and an inverted siphon structure will be installed. Two pump stations will be used to increase stages within the L-31E Borrow Canal using available water from the C-102 and C-103 Canals. A series of culverts will be installed under the levee so that water within the L-31E Borrow Canal will discharge into the saltwater wetlands east of L-31E. An additional pump station on the C-102 Canal will pump available water from the canal directly into a saltwater wetlands north of the C-102 Canal and east of the L-31E. A 400 acre freshwater wetland area will be impounded between the C-103 Canal and North Canal, and two pumps on the C-103 Canal will deliver available water into the impoundment to maintain increased hydroperiods and storage in the wetlands.

E.2.2 PURPOSE AND SCOPE

Hydrological data will be needed to ensure project objectives and meet regulatory requirements. For example, various results will be combined and interpreted to adaptively manage operations as needed to maximize the ecosystem benefits of the proposed project. Some of the results will be used to report back to regulatory organizations as required by permits. One objective guiding the design is to include only those elements that are clearly necessary to

understand project performance and impacts. Another objective is to utilize the extensive existing monitoring network as much as possible.

Information is needed primarily to understand water levels and water flow rates for the purposes of understanding water budgets, distribution and to operate specific features. In some cases, existing ancillary data such as rainfall may be used to help interpret hydrological results.

Altogether, essential data will be utilized from about 36 data records. This includes 27 water level stations, out of which 11 are part of an existing monitoring network. Therefore this plan includes 15 new water level instruments. The hydrological monitoring system will be adaptively managed as necessary to ensure sufficient information is available post project to meet all project objectives and constraints (e.g. rainfall).

E.2.3 ACTIVE MANDATES AND/OR PERMITS

Specific monitoring requirements are contained within the Florida CERPA Permit Number 0271729-001, State CERPA Permit Modification Number 0271729-002, and USACE Section 404 Permit SAJ-1994-1327 (IP-TKW) issued thus far for expedited construction features. Since permits have not yet been issued for all features, it is anticipated that additional monitoring requirements will be imposed, however, this plan includes monitoring that is anticipated will be required for all current and future CERPA, and USACE Section 404 permit requirements. If necessary, the plan will be modified to reflect additional required hydrometerological monitoring.

The list of Hydrometeorological monitoring parameters is generally limited to collection of stage data and calculating flows based on in-situ developed rating curves. Data Quality Objectives (DQOs) are used to define the type, quality, and quantity of data needed to make defensible decisions for a project. This process systematically defines the requirements for a field investigation and the limits on tolerable error rates. It also identifies the intended end use of the data, including decisions that may be made based on the results of a project. The specific DQOs for each parameter will be developed as part of the detailed Monitoring Work Plan, and will be incorporated into the individual Statements of Work for the individual monitoring contracts.

E.3 DATA COLLECTION

Hydrologic data will primarily be collected by electronic instrumentation (e.g. pressure transducers) and transmitted via Remote Terminal Units (RTU's) to an existing control center. In some cases, staff gauges will be manually monitored monthly by sending a technician to the site to observe in-situ water levels. While these data will not likely be as accurate or precise as the electronically

transmitted stage, they will provide an important data set. All raw data whether manually or electronically collected, will be checked for quality assurance (QA) according to standardized SFWMD protocols, and all data meeting QA criteria will be archived in an existing database (DBHYDRO).

The CERP Quality Assurance System Requirements (QASR) manual established QA protocols for hydrologic and meteorological data. These protocols describe operating standards for the collection of a variety of data types that relate to the hydrologic system. The purpose of these protocols is to provide for the efficient and effective analysis of data collected by various agencies in central and south Florida. The standardized protocols provide users some degree of confidence that the data were collected with similar accuracy and processing standards agreed to by participating organizations. In addition, the protocols provide guidance, with respect to accuracy and precision necessary for the design of new monitoring stations.

The scope of the QASR Chapter 6 procedures is focused on hydrologic and meteorological data types, such as surface water level, rainfall, structure flow rate, groundwater level, etc. The approach is to provide broad guidelines that establish criteria for accuracy and precision for each data type. The actual procedures for calibrating and using the wide variety of instruments that may be deployed to actually measure, record and transmit these data will be contained within June 2010 revised QASR, and will include a process for reviewing sensor and/or measurement device documentation to ensure that a sensor or method is capable of achieving the accuracy and precision specified.

E.3.1 MONITORING DATA ELEMENTS

Monitoring data elements include surface water stage elevation and flow rate. Flow rates are derived using water level and structure metrics, and therefore not a direct field measurement. The specific sites to be monitored, frequency of data collection, and use of data has been provided in the tables included within the project component sections which follow.

E.3.2 MONITORING LOCATIONS

The majority of the monitoring sites will be located at existing or proposed structures, such as pumps, water control structures or weirs. There are a few additional water level monitoring locations in canals or wetlands. Much of the hydrometerological monitoring described herein will be supported by the existing monitoring network maintained by SFWMD, ENP, USGS or others. Two existing SFWMD well sites, BBCMW2 and BBCMW4, will be used to evaluate groundwater profiles and signal any adverse impacts to agricultural lands west of L-31E (between the C-102 and C-103 Canals). A total of fifteen (15) new surface water level monitoring sites are proposed to be installed. With

exception of upstream of S-703, S-705, and S-709, new surface water level monitoring sites will be established upstream and downstream of each of proposed six new pump stations. The upstream sides of S-703 and S-705 will not require instrumentation because the stages at these locations are already being monitored by existing site S-21A_H. Similarly, the upstream side of S-709 will not require instrumentation because the stage at this location is already being monitored by existing site S-20F_H. Three (3) new surface monitoring sites will also be established within wetlands. All monitoring sites are to remain active until it is demonstrated they are no longer needed for day to day operations, for adaptive management, or to meet applicable permit conditions. ***Table E-1*** to ***E-3*** provides the location coordinates for each of the monitoring locations, as well as the monitoring parameters and data collection frequency. The locations of the monitoring sites are depicted on ***Figure E-3*** to ***E-5***.

E.3.3 DATA COLLECTION FREQUENCY AND PARAMETER LISTS

As shown in ***Figure E-2***, the proposed project is made up of geographically distinct project components, as follows;

- Deering Estate Flow-way
- Cutler Flow-way
- L-31 E Flow- way and Impoundment

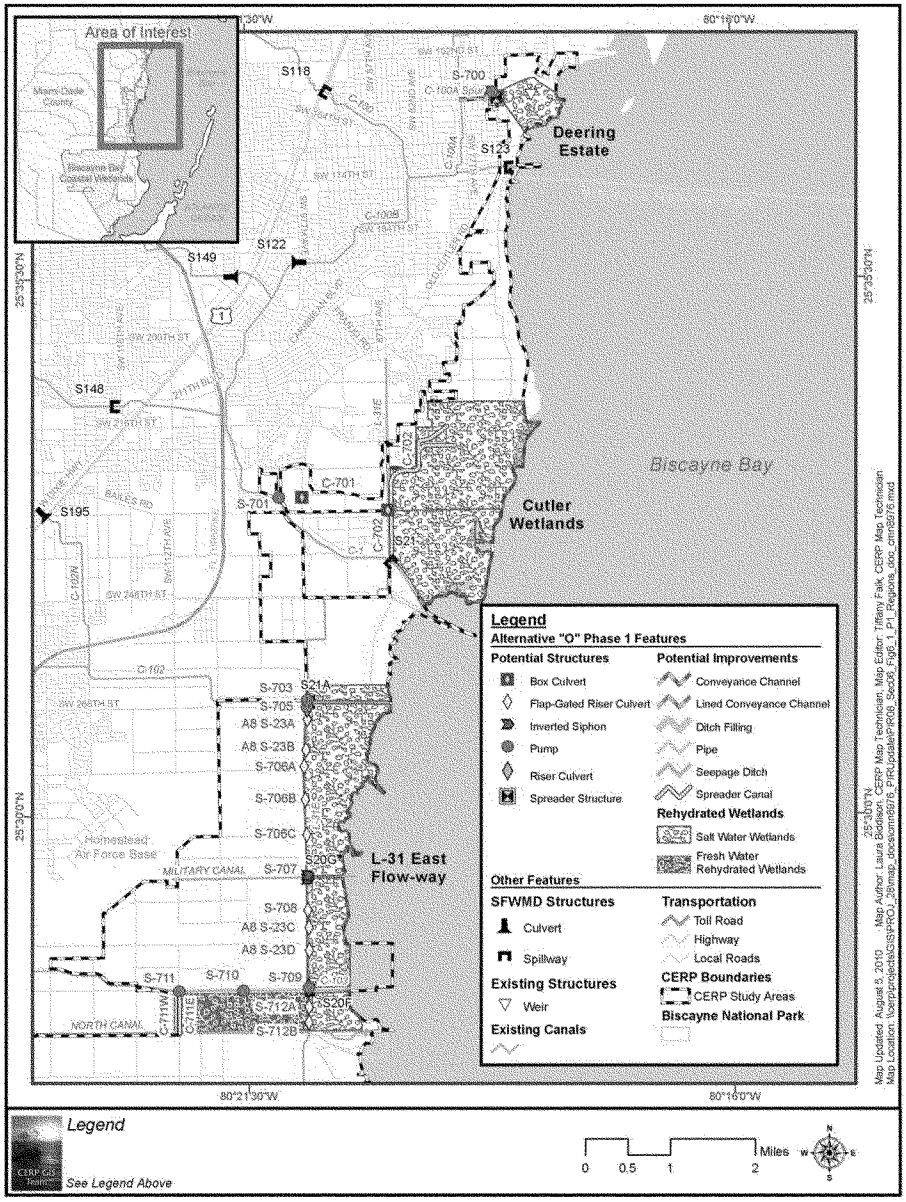


FIGURE E-2: PROJECT FEATURES AND RELATED AREAS OF INTEREST

E.3.3.1 Deering Estate Slough Monitoring

E.3.3.1.1 Surface Water Stage Elevation

Stage monitoring associated with the Deering Estate Slough and Wetlands project component will support operation of a pump station designed to divert water from a canal into the slough, and track water levels impounded in the slough itself. Specifically, head water stage elevation information will be used to start and stop individual pumps within the proposed S-700 pump station, and to support decisions to adaptively revise the pumping protocols to optimize water flows into the slough.

Stage measurements upstream of S-700 (head) will indicate if water level meet operational criteria as described in the Operations Plan, Annex D, while stage measurements downstream of S-700 (tail) will be primarily used in conjunction with head water and pump capacity to calculate flow rate. This will require installation of telemetric surface water level recorders both upstream (S-700_H) and downstream (S-700_T) of S-700.

An existing staff gauge within the freshwater slough downstream (BBCW PL 1) will be manually monitored for water depth. The gauge is located upstream of an existing weir (S-D1) that impounds water in the freshwater wetlands. The site will be registered within the DBHYDRO database.

Existing water stage elevation sites (S-123_H and S-123_T) used to monitor water levels in the C-100 canal and operate the coastal water control structure S-123 will be part of the project monitoring network to track water levels within the C-100 canal, and to calculate flow rate through the structure. These results are already in SFWMD's monitoring network and available within the DBHYDRO database.

Additional detail regarding the proposed (and relevant existing) Deering Estate Slough stage monitoring stations is provided in ***Table E-1,*** and their locations are shown on ***Figure E-3***.

E.3.3.1.2 Flow

Estimated flow rates at the S-700 pump station will be used to both document the quantity of water delivered into the slough and optimize the rate seasonally. The S-700 pump station will consist of three individual pumps that will be operated based on water level within the C-100 Canal. Some uncertainty exists about the optimum approach so that neither too much, nor too little, water is delivered into the slough for restoration. Flow rate will be used to estimate the quantity delivered under varying circumstances, and with observations about

the condition of the slough and areas downstream in the saltwater wetlands will be used to adaptively manage operations.

Flow rate at the coastal water control structures (derived from on-going head water elevation, tailwater elevation, and gate opening monitoring) will be used to compare to historical rates, and measure the impact of the S-700 pump station on discharges from the C-100 Canal directly into Biscayne Bay. An objective of the project is to minimize the direct discharge of freshwater through the S-123 structure.

TABLE E-1: DEERING ESTATE SLOUGH MONITORING SITES

Station Name	Type	Approximate Latitude	Approximate Longitude	Description	New or Existing	Frequency
S-700_H	Surface Water Elevation	25d37'25"	80d18'42"	Headwater Elevation at Pump Station	New	15 Minutes
S-700_T	Surface Water Elevation	25d37'25"	80d18'42"	Tailwater Elevation at New Pump Station	New	15 Minutes
S-700	Calculated Flow	25d37'25"	80d18'42"	Flow Calculated from HW & TW Elevations	New	15 Minutes
BBCW PL_1	Surface Water Elevation	25d37'25"	80d18'17"	Headwater Elevation at Existing Structure	Existing	Monthly
S-123H	Surface Water Elevation	25d36'37.377"	80d18'28.188"	Headwater Elevation at Existing S-123 Structure	Existing	15 Minutes
S-123T	Surface Water Elevation	25d36'37.377"	80d18'28.188"	Tailwater Elevation at Existing S-123 Structure	Existing	15 Minutes
S-123	Calculated Flow	25d36'37.377"	80d18'28.188"	Flow Calculated from HW & HT Elevations	Existing	15 Minutes

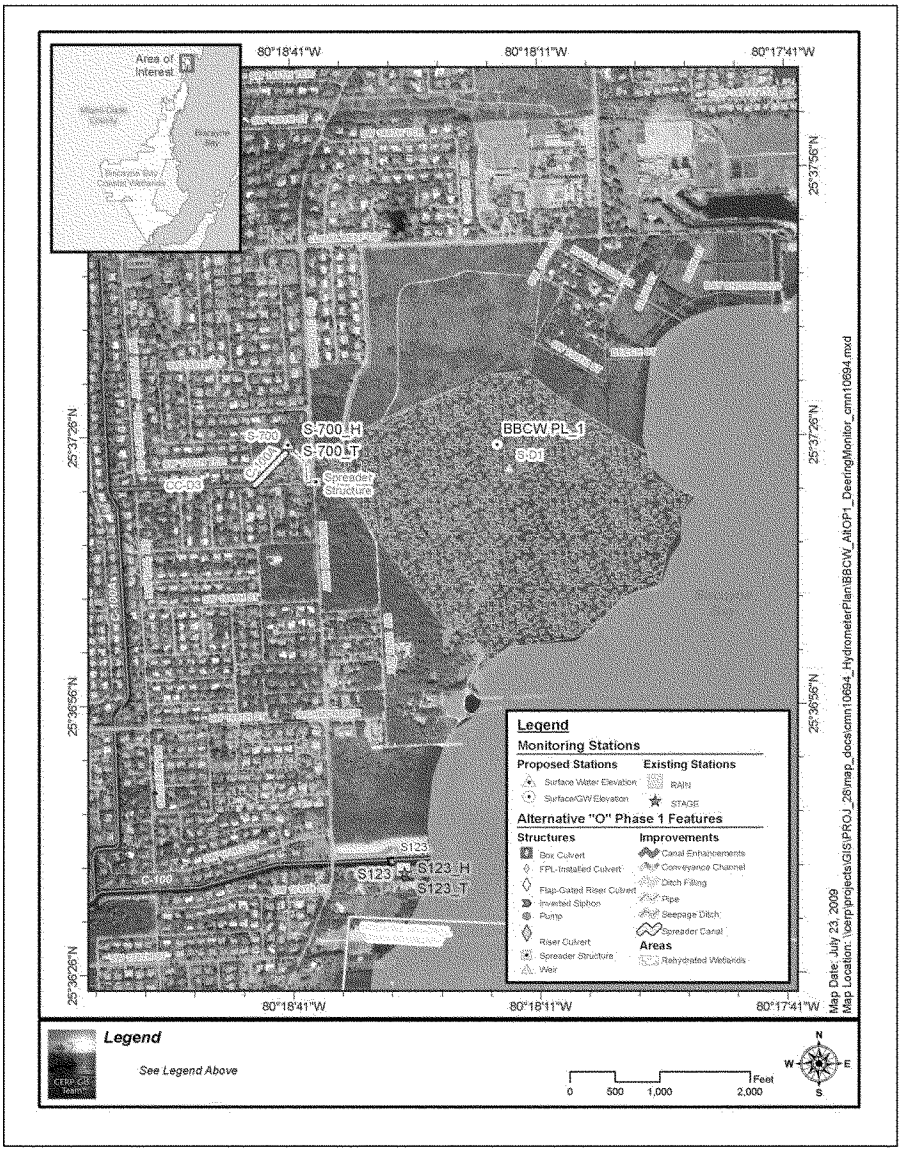


FIGURE E-3: DEERING ESTATE SLOUGH WATER STAGE ELEVATION MONITORING SITES

E.3.3.2 Cutler Wetlands Monitoring

E.3.3.2.1 Surface Water Stage Elevation

Although involving different station locations, stage monitoring associated with the Cutler Wetlands project component supports similar functions as those described within ***Section E.3.3.1.1*** for the Deering Estate Slough. In the case of Cutler, stage information will be used to start and stop the individual pumps within the proposed S-701 pump station, and will be used to support decisions to adaptively revise the pumping protocols to maximize benefits to the natural and human ecosystem.

Stages measurements upstream of S-701 will indicate if water is available for the project component, while stage measurements downstream of S-701 will be used to calculate flow rate. This will require installation of telemetric surface water level recorders both upstream (S-701_H) and downstream (S-701_T) of S-701.

Two staff gauges will be added within the Cutler Wetlands receiving marsh, to indicate surface water level throughout the wetlands. The gauges are BBCW PL 2A, centrally located in the wetlands directly east of the terminus of C-701 at C-702, and BBCW PL 2B, located directly east of the northern terminus of C-702. These gauges will be manually monitored when S-701 is flowing or, at a minimum, monthly by sending a technician to the site to observe in-situ water levels. Existing water stage elevation sites (S-21_H and S-21_T), used to monitor water levels in the C-1 canal and operate the coastal water control structure S-21, will be part of the project monitoring network to track water levels within the C-1 canal and to calculate flow rate through the structure. These results are already in SFWMD's monitoring network and available within the DBHYDRO database.

Additional detail regarding the proposed (and relevant existing) Cutler Wetlands stage monitoring stations is provided in ***Table E-2,*** and their locations are shown on ***Figure E-3***. To improve ease of access and use of data, the final locations of the BBCW PL 2A & 2B monitoring locations should be co-located with vegetation transects in this region.

E.3.3.2.2 Flow

As previously described, the Cutler Wetlands project component will include construction of a 400 CFS pump station (S-701) to withdraw water from the C-1 Canal. S-21 is the coastal structure from which C-1 discharges. Operation of the S-701 will divert a portion of the water which would otherwise be discharged via S-21.

Estimated flow rates at the S-701 pump station will be used to both document the quantity of water delivered into the wetlands and optimize the rate seasonally. The S-701 pump station will consist of four individual pumps that will be operated based on water level within the C-1 Canal. Some uncertainty exists about the optimum approach so that neither too much, nor too little, water is delivered into the wetlands for restoration. Flow rate will be used to estimate the quantity delivered under varying circumstances, and observations of stage and the condition of the near-field wetlands and areas downstream in the saltwater wetlands will be used to adaptively manage operations.

Flow rate at the coastal water control structures (derived from on-going head water elevation, tailwater elevation, and gate opening monitoring) will be used to compare to historical rates, and measure the impact of the S-701 pump station on discharges from the C-1 Canal directly into Biscayne Bay. An objective of the project is to minimize the direct discharge of freshwater through the S-21 structure.

TABLE E-2: CUTLER WETLANDS MONITORING SITES

Station Name	Type	Approximate Latitude	Approximate Longitude	Description	New or Existing	Frequency
S-701_H	Surface Water Elevation	25d33'16"	80d21'08"	Headwater Elevation at New Pump Station	New	15 Minutes
S-701_T	Surface Water Elevation	25d33'16"	80d21'08"	Tailwater Elevation at New Pump Station	New	15 Minutes
S-700	Calculated Flow	25d33'16"	80d21'08"	Flow Calculated from HW & TW Elevations	New	15 Minutes
BBCW PL_2A	Surface Water Elevation	25d33'06"	80d19'30"	SW Elevation in Receiving Marsh	New	Monthly
BBCW PL_2B	Surface Water Elevation	25d33'50"	80d18'55"	SW Elevation in Receiving Marsh	New	Monthly
S-21H	Surface Water Elevation	25d32'35.474"	80d19'51.368"	Headwater Elevation at Existing S-21 Structure	Existing	15 Minutes
S-21T	Surface Water Elevation	25d32'35.474"	80d19'51.368"	Tailwater Elevation at Existing S-21 Structure	Existing	15 Minutes
S-21	Calculated Flow	25d32'35.474"	80d19'51.368"	Flow Calculated from HW & TW Elevations	Existing	15 Minutes

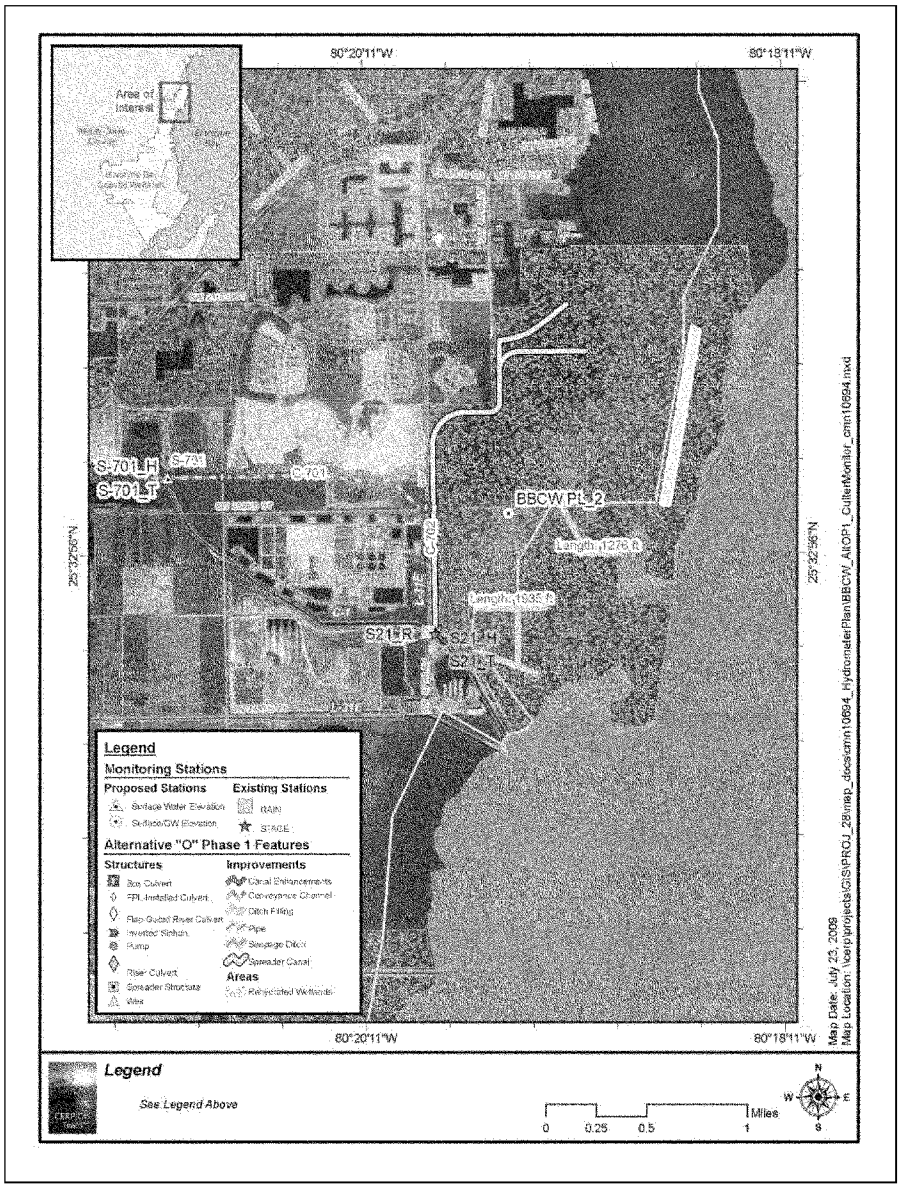


FIGURE E-4: CUTLER WETLANDS MONITORING SITES

E.3.3.3 L-31E Flow Way and Impoundment Monitoring

E.3.3.3.1 Water Stage Elevation

Although the L-31E component contains both fresh, and tidal, wetland sub-components, stage monitoring supports similar functions as those described within ***Section E.3.3.1.1*** for the Deering Estate Slough, and described within ***Section E.3.3.2.1*** for the Cutler Wetlands project components. In the case of the L-31E component, stage information will be used to start and stop the individual pumps within the proposed S-703, S-705, S-709, S-710, and S-711 pump stations, and will be used to support decisions to adaptively revise the pumping protocols to maximize benefits to the natural and human ecosystem. As previously described, existing well sites, BBCMW2 and BBCMW4 will be used to evaluate groundwater profiles and signal any adverse impacts to agricultural lands west of L-31E (between the C-102 and C-103 Canals).

Stage measurements upstream (headwater) of the five aforementioned pump stations will indicate if water is available according to the draft operational protocols, while stage measurements downstream of the pump stations will be used to calculate flow and, in some cases, indicate if the tailwater conditions meet operational criteria. This will require installation of telemetric surface water level recorders upstream and downstream of the individual pump stations which do not have an existing monitoring station nearby (e.g. S-703_T, S-705_T, S-709_T, S-710_H, S-710_T, S-711_H, S-711_T).

Two staff gauges will be located in saltwater wetlands east of the levee (BBCW PL-3 and PL-4) to indicate general conditions in the wetlands. Additional detail regarding the proposed L-31E Flow Way and Impoundment stage monitoring stations is provided in ***Table E-3,*** and their locations are shown on ***Figure E-3***.

E.3.3.3.2 Flow

As previously described, the L-31E project sub-component includes five pump stations. Flow rate will be calculated based on headwater and tailwater elevation and pump metrics.

Flow rate will be estimated at ten culverts (eight new and two existing) that pass water to the east side of L-31E based on the tailwater elevations at pump stations S-705 and S-709 in the northern reach, and at two new culverts in the southern reach using headwater elevation at S20F. It is likely that flow results will be lumped by reach, and not maintained formally. The estimated culvert flow rate will be used to compare to the pumped flows.

Flow rate at the coastal water control structures (derived from on-going head water elevation, tailwater elevation, and gate opening monitoring) will be used to compare to historical rates, and measure the impact of the pump station on discharges from the C-102 and C-103 Canals directly into Biscayne Bay. An objective of the project is to minimize the direct discharge of freshwater through the S-21A and S-20F structures.

TABLE E-3: L-31E FLOW WAY AND IMPOUNDMENT MONITORING SITES

Station Name	Type	Approximate Latitude	Approximate Longitude	Description	New or Existing	Frequency
S-703_T	Surface Water Elevation	25d31'11"	80d20'49.5"	Tailwater Elevation at New Structure	New	15 Minutes
S-703	Calculated Flow	25d31'11"	80d20'49.5"	Flow Calculated from HW & TW Elevations	New	15 Minutes
S-705_T	Surface Water Elevation	25d31'08"	80d20'49.5"	Tailwater Elevation at New Structure	New	15 Minutes
S-705	Calculated Flow	25d31'08"	80d20'49.5"	Flow Calculated from HW & TW Elevations	New	15 Minutes
S-709_T	Surface Water Elevation	25d28'13"	80d20'49"	Tailwater Elevation at New Structure	New	15 Minutes
S-709	Calculated Flow	25d28'13"	80d20'49"	Flow Calculated from HW & TW Elevations	New	15 Minutes
S-710_H	Surface Water Elevation	25d28'13"	80d21'36"	Headwater Elevation at New Structure	New	15 Minutes
S-710_T	Surface Water Elevation	25d28'13"	80d21'36"	Tailwater Elevation at New Structure	New	15 Minutes
S-710	Calculated Flow	25d28'13"	80d21'36"	Flow Calculated from HW & TW Elevations	New	15 Minutes

S-711_H	Surface Water Elevation	25d28'13"	80d22'17"	Headwater Elevation at New Structure	New	15 Minutes
S-711_T	Surface Water Elevation	25d28'13"	80d22'17"	Tailwater Elevation at New Structure	New	15 Minutes
S-711	Calculated Flow	25d28'13"	80d22'17"	Flow Calculated from HW & TW Elevations	New	15 Minutes
BBCMW3	Surface Water Elevation	25d29'34"	80d21'35"	Ground & SW Elevation on Private Lands	New	15 Minutes
BBCMW4	Surface Water Elevation	25d29'34"	80d21'35"	Ground & SW Elevation on Private Lands	New	15 Minutes
BBCW PL_3	Surface Water Elevation	25d30'59"	80d20'49"	SW Elevation in Wetlands	New	Monthly
BBCW PL_4	Surface Water Elevation	25d30'40"	80d20'51"	SW Elevation in Wetlands	New	Monthly
BBCW PL_5	Surface Water Elevation	25d28'51"	80d20'49"	SW Elevation in Wetlands	New	Monthly
BBCW PL_6	Surface Water Elevation	25d28'37"	80d20'49"	SW Elevation in Wetlands	New	Monthly
S-21A_H	Surface Water Elevation	25d31'09.390"	80d20'46.194"	Headwater Elevation at Existing S-21A Structure	Existing	15 Minutes
S-21A_T	Surface Water Elevation	25d31'09.390"	80d20'46.194"	Tailwater Elevation at Existing S-21A Structure	Existing	15 Minutes
S-21	Calculated Flow	25d31'09.390"	80d20'46.194"	Flow Calculated from HW & TW Elevations	Existing	15 Minutes

S-20F_H	Surface Water Elevation	25d28'12.92"	80d20'47.64"	Headwater Elevation at Existing S-20F Structure	Existing	15 Minutes
S-20F_T	Surface Water Elevation	25d28'12.92"	80d20'47.64"	Tailwater Elevation at Existing S-20F Structure	Existing	15 Minutes
S-20F	Calculated Flow	25d28'12.92"	80d20'47.64"	Flow Calculated from HW & TW Elevations	Existing	15 Minutes

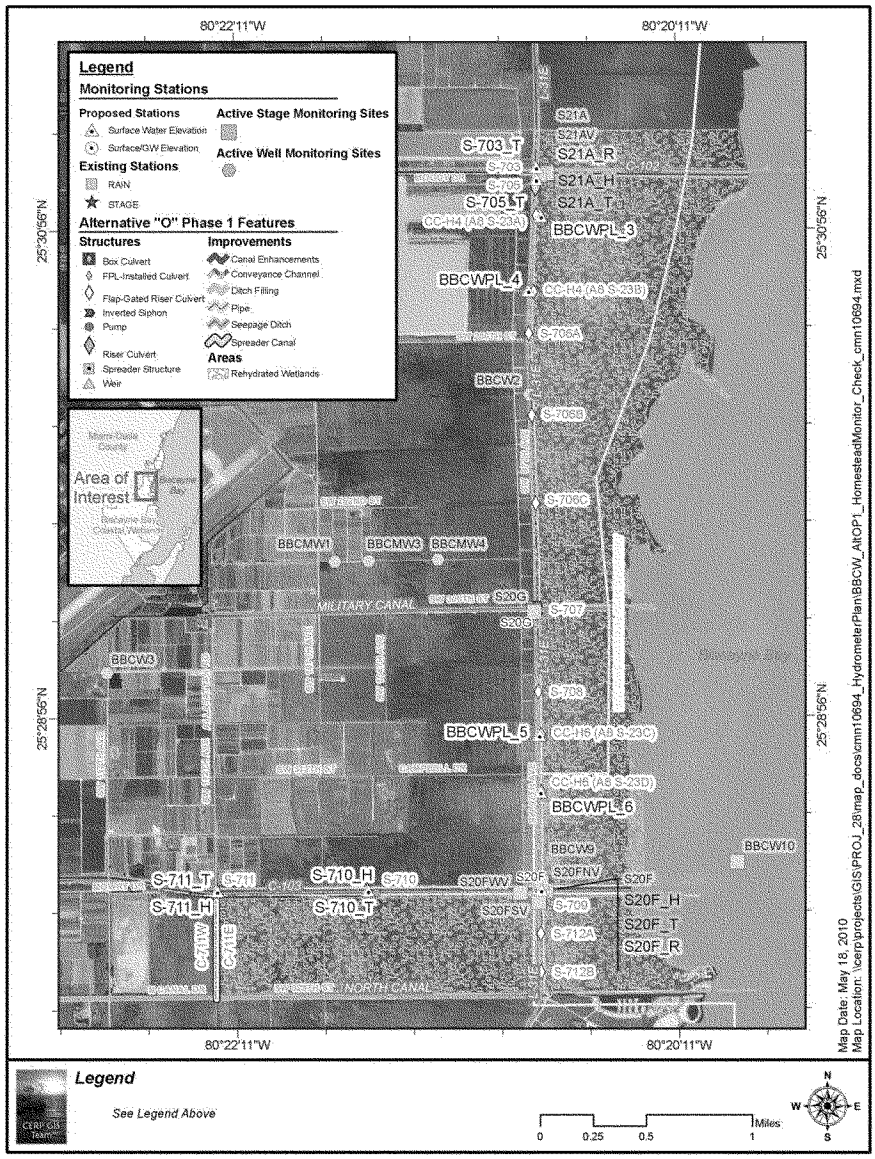


FIGURE E-5: L-31E FLOW WAY AND IMPOUNDMENT MONITORING SITES

E.3.3.4 Instrumentation and Structure Ratings

The hydrologic data collection instruments utilized for this project will be installed as part of the construction contract or under separate contract, and will be compatible with SFWMD equipment. As currently envisioned, CR1000 (or equivalent) programmable data loggers will store, and telemetrically transmit to the control room, stage data at 15 minute intervals. Stage based structure ratings will be developed in accordance with standard rating procedures.

E.3.3.5 Elevation Survey of Monitoring Site Installations

All new surface and ground water monitoring installations will be surveyed to a first order accuracy using the nearest geodetic benchmark. Reference elevations will be reported in both NAVD 88 and NGVD 29 datum.

E.3.3.6 Data Validation, Data Storage, and Archival

Guidelines for Quality Control and Quality Assurance of Hydrologic and Meteorological Data – Volume 2: Data Management (2000) prepared by the St. Johns River, South Florida, Southwest Florida and Suwannee River Water Management Districts contains detailed general procedures for validation, verification and correction of hydrologic and meteorological data collected through every means of data collection known by these agencies. This document is referenced in the QASR Manual. Specific guidance with respect to data management is provided in CGM 040.00, Project-level Water Quality and Hydrometeorologic Monitoring and Assessment, and the Program Management Plan for Information and Data Management (April 2007). Some of the most common data management methods are:

- Standard for formatting electronic data files: raw data and data intended for archive will be submitted using an approved, prescribed format

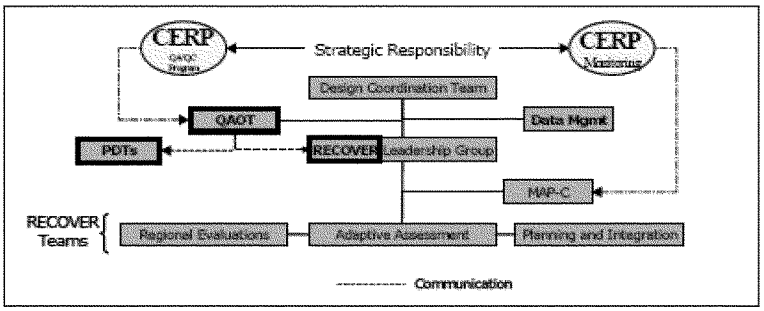
- Scientifically-based, robust quality assurance and data validation procedures: all data submitted for archive will undergo a QA/QC review

- Common and standard naming conventions for data collection locations: station and site names for new monitoring will be approved and registered prior to use in the database

  Preservation and storage of raw data values: all raw data will be maintained and archived at a minimum by the agency/organization responsible for its generation

The role of the QAOT is to help ensure the accuracy, precision, and reliability of CERP monitoring data and, to the extent practicable, of non-CERP monitoring

data that CERP may be using in evaluating and assessment progress, and to help ensure that the system-wide goals and purposes of the CERP are achieved. While QAOT is an interdisciplinary, interagency body, responsibility for QAOT rests jointly with the USACE and the SFWMD, as the sponsoring agencies. The QAOT is responsible for providing guidance and oversight on monitoring procedures, QA/QC issues, and data validations for CERP projects and RECOVER. The team is also the forum to develop consistency among the various entities involved with monitoring, data quality and QA/QC processes. The QAOT reports to CERP Program Managers (Design Coordination Team - DCT), but also provides feedback directly to the RECOVER Program Managers (RLG), and Project Managers, on QA/QC issues affecting their programs or projects (please see organizational chart below).



E.3.3.7 Raw Data

For the purposes of this section, raw data is defined as any hydrologic or meteorological data described in this document that has been collected from a field data installation location. The methods of collection vary from random, periodic, or distance to water readings to satellite-based collection platforms reporting data values on a real time basis. To be considered as raw data, the data must not be altered in any fashion by manual or electronic means after collection.

E.3.3.8 Validated Data

For the purposes of this section, validated data is defined as any hydrologic or meteorological data described in this document that has been collected from a field data installation location, and passed through a set of quality assurance and data validation procedures. A series of validation checks are performed on hydrologic and meteorological data. The following is a list and explanation of a basic set of validation checks.

- Instrument location – Data recorders may be designated by several databases descriptors for identification. Among these descriptors are parameters, stations or sites. To avoid database degradation, a unique name is established for every recorder location regardless of which designation is used. This name is validated to assure that data collected is attributed to the appropriate station.
- Period of record – The start date of an incoming period of record is checked against the end date of the last period of record received. This check serves two purposes. First, the continuity of the period of record is maintained. Gaps or overlaps in the period of record are identified and resolved. Second, unmatched end-to-start dates of consecutive periods of record might be an early indication that the periods of record may not have been collected at the same location.
- Minimum and maximum values – Although, a very high or very low data value may not necessarily indicate an anomaly, each location should have a range of expected values. Any exceedance of these values is flagged for further investigation.
- Data units – Consistency in using the appropriate data units is maintained. Errors or inconsistencies are magnified due to a series of rounding of numbers and conversions from one unit of measurement to another.

E.3.3.9 Data Storage and Archival – DBHYDRO Database

After data have been validated, and all data anomalies have been investigated and resolved, the data will be loaded in a sponsoring agency-approved database and be available for dissemination to users. This database at the present time is DBHYDRO which is maintained by SFWMD.

E.3.3.10 Quality Assurance and Quality Control

Quality Assurance (QA) and Quality Control (QC) involve the review, interpretation, processing, analysis, and validation of hydrologic and meteorological data collected. Specifically, QA and QC is a set of activities that are performed on raw time-series data so that the data obtained can be relied upon when making day-to-day operational decisions, and for other project related initiatives. The data collected will undergo specific sets of validation processes for each type of data to ensure that the values are reasonable and accurate. Many of these procedures and processes are automatic and are done with various software applications.

The data processing system checks and validation procedures will include: Verification of the identifiers used to distinguish a data collection location from all others, assuring an accurate historical record of hydrologic and meteorologic events for each location. Recorded data values are checked against maximum

and minimum allowable values facilitating the identification of data outliers. All data values are time stamped assuring that the time stamps on recorded values are continuous with previously recorded values already in the database. Continuous data values are checked to assure that the rate of change between them does not exceed allowable maximum and minimum values.

The data will be also reviewed spatiotemporally (space-time) in comparison to other hydrologic and meteorologic events. The review processes assure that data values are scientifically reasonable and accurate. Many of these procedures and processes are automatic and all are done with software applications.

Although certain raw data may necessarily be utilized from time to time, when considered within the context of other reliable information, to support near-real-time decisions, only after validation, verification, and other review processes have been completed satisfactorily, will data be uploaded to the database, and made available for reporting.

E.3.3.11 Cost Estimates

Much of the hydrometerological monitoring described herein will be supported by the existing monitoring network maintained by SFWMD, ENP, USGS or others. A total of thirteen (13) new surface water level monitoring sites are included. These new monitoring sites would remain active until it is demonstrated they are no longer needed for day to day operations, for adaptive management, or to meet applicable permit conditions.

Installation costs include equipment and all necessary installation costs such as platforms, protective housings, cellular or telemetry communications electronics where required for real time data access, labor and any required testing as needed to demonstrate operational readiness. The estimated costs associated with installation, surveying, five years of maintenance, and data processing (including QA/QC have been provided in ***Table E-4.***

TABLE E-4: ESTIMATED 5-YEAR COSTS FOR NEW MONITORING SITES

Site Name	* Equipment	***Installation Costs (labor and hardware)	** Survey Costs	5 Years Maint & Calibration Costs (labor & hardware)	Data Collection, 1st Leval QA and Database	Total 5 Year Cost
S-700_HW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-700_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-700	Calculated Flow	$8,000			$1,000	$9,000
S-701_HW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-701_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-701	Calculated Flow	$8,000			$1,000	$9,000
S-703_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-703	Calculated Flow	$8,000			$1,000	$9,000
S-705_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-705	Calculated Flow	$8,000			$1,000	$9,000
S-709_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-709	Calculated Flow	$8,000			$1,000	$9,000
S-710_HW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-710_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-710	Calculated Flow	$8,000			$1,000	$9,000
S-711_HW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-711_TW	SW Encoder w/ RTU	$40,825	$3,125	$19,750	$2,500	$66,200
S-711	Calculated Flow	$8,000			$1,000	$9,000
BBCW PL 1	Existing Site - No Additional Equipment Required	$0	$3,125	$1,000	$6,500	$10,625
BBCW PL 2	Staff Gage	$2,000	$3,125	$1,000	$6,500	$12,625
BBCW PL 3	Staff Gage	$2,000	$3,125	$1,000	$6,500	$12,625
BBCW PL 4	Staff Gage	$2,000	$3,125	$1,000	$6,500	$12,625
BBCW PL 5	Staff Gage	$2,000	$3,125	$1,000	$6,500	$12,625
BBCW PL 6	Staff Gage	$2,000	$3,125	$1,000	$6,500	$12,625
Total		$515,075	$53,125	$223,250	$73,500	$864,950

Notes;

* Includes Standard Telemetry

** CERP Compatible Higher Order Surveying

*** Installation Costs for Calculated Flows are Costs of Rating Curve Development

As depicted in ***Table E-4,*** the total projected hydrometerological monitoring costs for a five year monitoring period is estimated to be $864,950.

E.4 FUTURE REVISION NOTES AND MODIFICATIONS

[This page is intentionally left blank for use by the project manager to track changes to this document between revisions. These notes are maintained in the PROJECT BINDER by the project manager.]

ANNEX E
PROJECT MONITORING PLAN

PART II: WATER QUALITY MONITORING PLAN

WATER QUALITY PLAN	PROJECT *BBCW Phase I*	STATUS FINAL	REVISION DATE
	AUTHORING ORGANIZATION *USACE & SFWMD*	DATE *12/01/2009*	REVISION NUMBER 0

WATER QUALITY MONITORING PLAN

For

Biscayne Bay Coastal Wetlands Project

May 2010

Authoring Organization's Representative (Monitoring Plan Coordinator)	**Date**
Lead CERP Project Manager	**Date**
Representative, Local Sponsor (Monitoring Organization)	**Date**
Representative, Federal Sponsor (Monitoring Organization)	**Date**
Project Quality Assurance Officer	**Date**

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GLOSSARY

ADaPT – Automated Data Processing Tool software.

ADR – Automated Data Review software

Assessment – to interpret responses in natural and/or human systems based on data acquired though monitoring activities.

Constraint – a condition that is to be minimized or avoided in the plan formulation and selection process to ensure that the project component does not result in undesirable changes in the project area or downstream waters. Example: The component shall not cause or contribute to a violation of state water quality standards.

Data Quality Objectives (DQO) – a process that identifies the intended use of the data including the types of decisions that will be made based on the results. The analytes of interest, corresponding action levels, sampling design and quality control measures are also identified as well as data repositories into which the data will be entered, the mechanisms used to ensure that the data are accurately entered into a database and to verify that the data in the database are correct, and the level of data quality acceptable for this project.

DERM – Department of Environmental Resources Management a department of Miami-Dade County, Florida.

EB – Equipment Blank, collected to evaluate the effectiveness of the laboratory decontamination of sampling equipment and the cleanliness of the sample bottles.

EDMS – Environmental Data Management System

EM – Engineering Manual: USACE documents that provide guidance on various aspects of project design and implementation.

EMCT – Environmental Monitoring Coordination Team, a group of senior-level managers that participate in planning and reviewing project-level monitoring activities. Representatives from the South Florida Water Management District and the USACE are members of the team.

FCEB – Field Cleaned Equipment Blank, collected to assess possible carryover contamination between stations.

FDEP – Florida Department of Environmental Protection

Local Sponsor – the agency responsible for matching the Federal funding available for a project. The South Florida Water Management District (SFWMD) is the local sponsor for the majority of CERP projects.

Matrix – refers to the material from which the sample is taken, such as surface water, ground water, pore water, sediment, soil or air.

Monitoring – all of the activities required to acquire, process, store, retrieve and analyze data used to assess the status of water resources. It includes data collection, data analysis, data validation, and data management.

Monitoring Data – data that are collected for the purpose of determining the effects of CERP projects at a given location.

Monitoring Plan – the plan to acquire additional meteorological, hydrologic, hydraulic, water quality or ecological data. It includes considerations of sampling location, frequency, method, parameters and duration. It is based on the elements identified in the development of data quality objectives for the project.

MOSCAD – MOtorola SCADa (SCADA – Supervisory Control And Data Acquisition). An intelligent communications device used in data acquisition and remote system control.

Objective – a measurable element of the goal(s) of a project or plan. Project objectives and constraints are identified in the Project Management Plan (PMP).

Permit Requirement – certain analytes are sampled, tested and results reported to state and/or federal agencies as a condition of a permit to build or operate a project.

PLMP – Project-Level Monitoring Plan

Project-level – A project has a defined scope, quality objectives, schedule, and cost. Project-level activities refer to those that are within the scope of a specific project.

QA – Quality Assurance: the system of management activities and quality control procedures implemented to produce and evaluate data according to pre-established data quality objectives.

QAPP – Quality Assurance Project Plan, a QA plan written for a specific project outlining data quality objectives, sampling and analytical protocols and QC measures needed to satisfy the intended uses of the data.

QAOT – Quality Assurance Oversight Team, comprised of representatives from USACE, SFWMD, FDEP, and USEPA, ultimately responsible for implementation of the QASR for CERP.

QASR – Quality Assurance System Requirements, a CERP manual that establishes minimum criteria for environmental data quality.

QC – Quality Control: The system of measurement activities used to document and control the quality of data so that it meets the needs of data users as specified by pre-established data quality objectives.

QA/QC – Quality Assurance and Quality Control. A process that insures that the data available for assessment is of an acceptable level of quality.

RACU – Remote Acquisition and Command Unit. A device used for data acquisition and remote system control.

RECOVER – REstoration COordination and VERification (RECOVER) is a process that evaluates and assesses CERP performance by linking scientific and technical information throughout the planning and implementation period to ensure that a system-wide perspective is maintained throughout the restoration program.

RECOVER AT - The RECOVER Assessment Team is a standing, interagency, interdisciplinary team of scientists and resource specialists who are responsible for achieving the five primary tasks of RECOVER: 1) create, refine and provide documentation for a set of conceptual ecological models for the total system and a set of attribute-based biological performance measures for the Comprehensive Plan; 3) design and review the system-wide monitoring and data management program needed to support the Comprehensive Plan; 4) use the information coming from the system-wide monitoring program to assess actual system responses as components of the Comprehensive Plan are implemented and produce an annual assessment report describing and interpreting these responses; and 5) coordinate all scientific peer reviews of RECOVER documents.

RS – Replicate samples defined as two additional samples collected in addition to the routine sample.

Sampling Frequency – how often samples are collected.

Sampling Methods – the methods used to collect samples in the field. The methods should be standard methods, methods based on a standard operating procedure, or a method that has been approved by the participating agencies.

SFWMD – South Florida Water Management District

USACE – United States Army Corps of Engineers

USEPA – United States Environmental Protection Agency

WBS – Work Breakdown Structure: The WBS specifies a hierarchy of tasks and activities necessary to fulfill the objectives of the project. The WBS is structured in levels of work detail, beginning with the deliverable itself, and is then separated into identifiable work elements.

Zone of Influence – the area over which a project alters or impacts the environment.

Additional terms and definitions for CERP can be found in CGM 13 – Acronyms and Glossary of Terms. http://www.cerpzone.org/documents/cgm/cgm_013.03.pdf

E.1 PROJECT DESCRIPTION

E.1.1 INTRODUCTION AND BACKGROUND

This document serves as a reference for monitoring surface water quality for the Biscayne Bay Coastal Wetlands (BBCW) Comprehensive Everglades Restoration Plan (CERP) project. Monitoring will be conducted to evaluate the BBCWs' performance with regard to restoration goals and regulatory requirements. By rehydrating coastal wetlands and redistributing freshwater discharge to Biscayne Bay, the project is integral to the health of the south Florida ecosystem.

The Biscayne Bay Coastal Wetlands project will be conducted in two phases and is intended to contribute to the restoration of Biscayne Bay and adjacent wetlands as part of the overarching CERP. Specifically, the project is intended to redistribute freshwater runoff from the BBCW watershed that is currently discharged to Biscayne Bay directly from a network of canals, into wetlands. The redistributed water will restore the original hydrologic patterns, and improve the wetlands and salinity patterns in the nearshore region of the Bay. Improved salinity patterns will restore more estuarine habitat to Biscayne Bay.

The overall BBCW project area extends from about Shoal Point (north of the Charles Deering Estate) south along the western shore of Biscayne Bay to U.S. Highway 1, and includes all of the Model Land Basin east of U.S. Highway 1. The first Phase of the project has a smaller footprint consisting of about 3,943 acres. The Phase 1 area includes three geographical components: 1) the Deering Estate Flow-way, 2) the Cutler Flow-way, and 3) the L-31E Flow-way (***Figure E-1***).

<u>Deering Estate Flow Way</u>
This region includes an approximate 500-foot extension of the C-100A Spur Canal through a former fruit tree grove, construction of a pump station, and culvert intended to deliver fresh water into the Cutler Drain slough and ultimately into the coastal wetlands fringing Biscayne Bay.

<u>Cutler Wetlands</u>
Features in this region include a pump station, a conveyance canal, a spreader canal, culverts and mosquito control ditch plugs. The pump station, located on the C-1, will deliver water to a 6,900-foot lined conveyance canal traversing under SW 97th Avenue, SW 87th Avenue (L-31E Levee), and beneath the L-31E Borrow Canal via concrete box culverts. The conveyance canal will deliver water to the spreader canal divided into four segments, will be located within the adjacent saltwater wetlands.

L-31 East Flow Way

Gated culverts and inverted siphon structures will be installed to isolate the L-31E Borrow Canal from the current major discharge canals (C-102, Military Canal and C-103), and to increase water levels within the L-31E Borrow Canal. This engineering will raise average stages promoting gravity flow through a series of culverts installed through the levee. An additional pump station will be used to discharge fresh water from L-31E Borrow Canal directly into the saltwater wetlands north of C-102 and east of L-31E. About 400 acres located west of L-31E between C-103 and North Canal will be impounded. Two pumps stations will deliver available water into the impoundment to maintain an optimal stage for freshwater wetlands.

The guidance contained in this document will assist in maintaining consistency in methodology, parameter lists and frequencies as well as providing documentation of the project scope and an ongoing historical perspective. Prior to implementation of any aspect of this monitoring plan signature approval of the plan is required by the project manager, and representatives of the monitoring departments or divisions of the sponsoring agencies.

E.1.2 ACTIVE MANDATES AND/OR PERMITS

The Biscayne Bay Coastal Wetlands project is a component of the Comprehensive Everglades Restoration Plan (CERP). The CERP was approved in Section 601 of the Water Resources Development Act of 2000 (WRDA 2000), Public Law No. 106-541, of the 106th Congress. This water quality monitoring plan meets the requirements outlined in the Comprehensive Everglades Restoration Plan Guidance Memorandum (CGM) 42.00: Toxic Substances Screening Process–Mercury and Pesticides (September 17, 2005), and CGM 040.00: Project Level Water Quality and Hydrometeorologic Monitoring and Assessment (May 25, 2004). These guidance memoranda provide both the suggested format, and content, for the Water Quality Monitoring Plan. This water quality monitoring plan will also be modified, if necessary, to be compliant with any future water quality certification conditions.

The permits and/or agreements that will govern the sampling requirements of this project are being developed through the permitting process. Permitting for the L31-E Project began with the application submittal of the Comprehensive Everglades Restoration Plan Regulation Act 1502 permit and the Department of the Army 404 permit to the U.S. Army Corps of Engineers (Permit no: SAJ-1994-1327[IP-TKW]). Permitting for other sections of the project will occur in the future.

The South Florida Water Management District has received the following permits:

- Comprehensive Everglades Restoration Plan Regulation Act permit for the Biscayne Bay Coastal Wetlands Deering Estate, Permit #0271729-002 (Date of issue: May 23, 2008; Expiration date: May 23, 2013)
- Comprehensive Everglades Restoration Plan Regulation Act permit for the L31E Culverts project, Permit #0271729-001-GL (Date of issue: September 09, 2007; Expiration date: September 09, 2012)
- The Department of the Army 404 permit to the U.S. Army Corps of Engineers, Permit #SAJ-1994-1327[IP-TKW] (Date of issue: May 15, 2008; Expiration date: November 13, 2012)

E.1.3 PURPOSE AND SCOPE

The monitoring stations described in this document were established to satisfy requirements of the Comprehensive Everglades Restoration Plan Project Implementation Report and requirements of (issued or pending) Department of the Army 404 permits and/or State of Florida 373.1502 permits for Start Up and Operational Phase Monitoring. This plan provides an outline for quantifying the quality of surface water entering the project area for a period of five years.

Surface water samples have been collected and analyzed for multiple constituents and at various frequencies within Biscayne Bay and canals from stations adjacent to or nearby the targeted wetlands. These baseline data are compiled in the South Florida Water Management District's DBHYDRO and Miami-Dade County Department of Environmental Resources Management database under project codes BISC and FLAB. Other organizations also collect surface water quality data in this region that may be relevant to the project as baseline data. To access relevant data, contact the program manager at the South Florida Water Management District.

The water quality data obtained under this program will be used to:

1. Evaluate water quality status and trends;
2. Assess compliance with federal and state water quality statutes, the EFA, and the Everglades Settlement Agreement;
3. Aid in determining the nutrient concentrations to quantify the nutrients removed by the project annually;
4. Guide mid- and long-term resource management decisions for nutrient removal capabilities of the project.

E.1.4 DURATION

The monitoring plan will be periodically reviewed for effectiveness and modified. It is fully expected that the requirement to monitor certain parameters, or groups of parameters and frequency, may be reduced following demonstrations that a parameter or group of parameters no longer represent a source of concern.

E.1.4.1 Initiation Conditions

The water quality monitoring plan was initiated by the Water Quality Sub-team of the Biscayne Bay Coastal Wetlands project, and technical review was provided by Comprehensive Everglades Restoration Plan Restoration, Coordination and Verification staff of the South Florida Water Management District and the U.S. Army Corps of Engineers. Development of this plan is required as part of the Project Implementation Report document. The project implementation report development phase calls for sections detailing the water quality monitoring and adaptive assessment methods for the selected alternative. The plan was originally prepared under the assumption that water quality monitoring efforts directly funded by this project will last a total of ten years. This is consistent with the duration of the Comprehensive Everglades Restoration Plan Regulation Act (CERPRA) permits that will be required for the project.

Under a ten-year program, at least three but no more than five of these years will be during the project implementation phase. The remaining five to seven years of monitoring will occur after project completion. Limited baseline data may be collected at some of the new sites proposed in this plan. However, existing monitoring programs will be relied upon for the bulk of baseline data.

E.1.4.2 Modification or Termination Conditions

Modification of the water quality monitoring plan will be determined by the needs of the project annually, and will be completely reassessed after five years from initiation. This plan may be changed to reflect any future design changes or permit requirements. It also may be terminated according to permit expiration dates or changes to the project objectives. The plan will be reviewed and modified annually or more frequently if necessary to reflect new requirements.

This BBCW project monitoring plan was developed assuming that major, ongoing monitoring programs that are not funded directly by the Project would continue to supply data relevant to the Project. Should any of these programs be discontinued or significantly curtailed, then the Federal and local sponsors of the Project will reevaluate monitoring priorities and may redistribute funds for the benefit of the Project, even potentially not funding elements of this monitoring plan.

E.2 GEOGRAPHIC LOCATION

E.2.1 REGIONAL AREA

This project is sited in southeastern Miami-Dade County. The project area is bounded by Deering Estate to the north, Turkey Point to the south, Biscayne Bay to the east, and U.S. Highway 1 to the west. The area is shown in ***Figure E-1***.

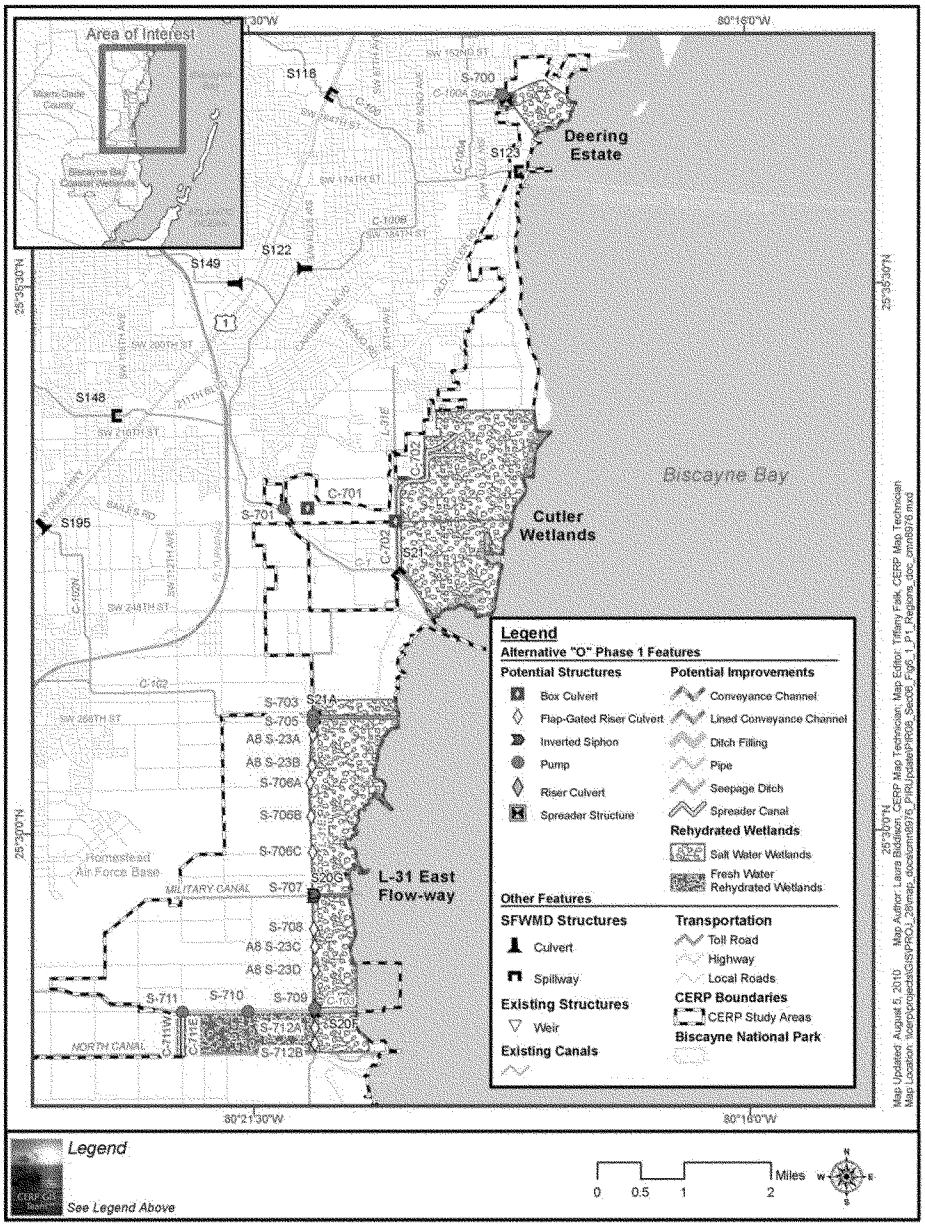

FIGURE E-1: BISCAYNE BAY PHASE 1 COASTAL WETLANDS PROJECT LOCATION

E.2.2 SAMPLING LOCATIONS

A total of seventeen (17) monitoring locations will be used to supply data relative to this plan. Most of the stations are being sampled as part of an existing monitoring network(s) maintained by SFWMD and Miami-Dade DERM. Five new stations will be added: pumps S-700 (Deering Estate), and S-701 (Cutler Flow-way), at the mouth of Cutler Creek (CC01), in the L-31E borrow canal north of C-102 and in the L-31E borrow canal south of C-103. Sampling stations will be registered in the Laboratory Information Management System (LIMS), DBHYDRO and the CERPZone database. ***Table E-1*** provides the coordinates for each monitoring location. The locations of all monitoring stations are depicted on the map in ***Figure-2***.

E.2.3 ACCESS AND AUTHORITY

Monitoring stations within the Biscayne Bay Coastal Wetlands project area will be accessed along the system of levees.

TABLE E-1: WATER QUALITY MONITORING STATIONS LOCATIONS

Station Name[1]	Existing / New	Water Feature	Approx. Coordinates[2]		Description	Source of Water
			Longitude (-)	Latitude		
CD02	Existing	Canal	80.30987	25.61118	Upstream of S-123 on C-100 canal.	C-100 canal
S-700	New	Pump	80.3117	25.6232	At S-700 pump station (100 cfs) in spur canal near Old Cutler Rd, west of Deering Estate Property	C-100A canal
CC01	New	Canal	80.3016	25.6178	Near mouth of Cutler Creek	C-100A canal
BL03	Existing	Canal	80.34772	25.54884	On C-1 Canal at SW 97th Avenue	C-1 canal
LE01	New	Canal	80.3470	25.5223	At bridge crossing L-31E borrow canal north of junction with C-102	L-31E borrow canal
BB52	Existing	Nearshore	80.30485	25.56461	Near shore north of Black Point	Biscayne Bay
BB53	Existing	Nearshore	80.33228	25.50248	Near shore near Fender Point	Biscayne Bay
PR03	Existing	Canal	80.36358	25.51979	Upstream on C-102 Canal	C-102 canal
PR01	Existing	Canal	80.33198	25.51959	Mouth of C-102 Canal	C-102 canal
MW04	Existing	Canal	80.37928	25.47129	Upstream of the S-20F structure on the C-103 canal.	C-103 canal
MW01	Existing	Canal	80.34068	25.47079	At mouth or C-103 canal	C-103 canal
LE02	New	Canal	80.3470	25.4694	In the L-31E borrow canal east of the L-31E wetland impoundment and south of the junction with C-103	L-31E Wetlands
MI01	Existing	Canal	80.33814	25.48936	At mouth of Military canal	Military Canal
Bisc101	Existing	Nearshore	80.32083	25.47833	Biscayne Bay about 2 km from shoreline nearC-103 canal	Biscayne Bay
Bisc102A	New	Nearshore	80.3109	25.5454	Near shore about 100 m east of the mouth of the embayment north of Black Point	Biscayne Bay
BB39A	Existing	Nearshore	80.30706	25.52643	Near shore near Black Creek Channel	Biscayne Bay
S-701	New	Canal	80.3527	25.5543	At S-701 pump (400 cfs) on C-1 Canal just west of South Dade Wastewater Treatment Plant	C-1 canal

[1]Final station names will be assigned following established SFWMD naming conventions. New station locations are dependent upon access restraints including travel logistics.
[2]The standard positional goal for station coordinates is ±1 meter. This standard can be obtained with a professional grade DGPS system. The preferred coordinates are relative to NAD83 HARN horizontal datum. (see CGM 28 for further details).

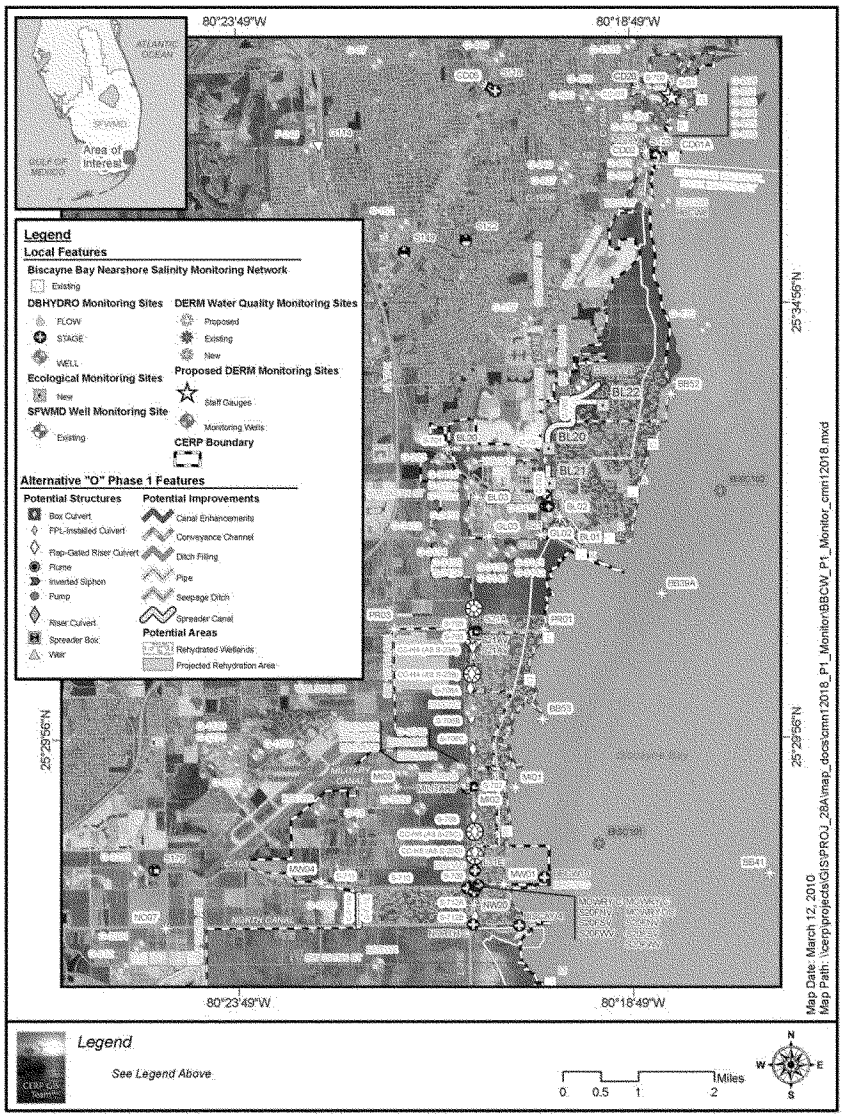

FIGURE-2: LOCATION OF EXISTING AND PROPOSED MONITORING NETWORK

E.3 DATA QUALITY

E.3.1 DATA USES

The data from this project will be compiled and reported in the SFWMD's Annual South Florida Environmental Report (SFER) located at www.sfwmd.gov/sfer/.

E.3.2 DATA QUALITY QUALIFIERS

While it is recognized that data quality objectives (DQOs) are typically developed separately for each specific monitoring project, all mandated monitoring conducted by the SFWMD must meet the objectives conveyed in the FDEP's Quality Assurance Rule, 62-160 F.A.C. Historically, the SFWMD's field collection staff and chemistry laboratory, and their contractors, have met or exceeded these DQOs, as reflected in their respective quality manuals, for all data generated. As a result, unless otherwise specified, the SFWMD has adopted a uniform set of DQOs following criteria detailed within the "Analytical Methods and Default QA/QC Targets" table of the SFWMD's Chemistry Laboratory Quality Manual (CLQM). For those samples analyzed by the FDEP Laboratory, the SFWMD has adopted the DQOs within the most recent version of the FDEP's Laboratory Chemistry Quality Manual.

Surface water samples, including field testing and field quality control samples, are collected in accordance with the FDEP Quality Assurance Rule, 62-160 F.A.C. and the current version of the FSQM. Applicable sections of the FSQM include, but are not limited to, field sample collection procedures, decontamination procedures, field testing and quality control requirements.

The DQOs of the field testing parameters for this project are covered by the table Field Quality Assurance Objectives in the field testing section of the FSQM. This manual is updated annually, and therefore, the most recent version of the FSQM details the specific field testing data quality objectives for this project at the time of sample collection.

Samples are analyzed according to the provisions within the FDEP Rule 62-160 F.A.C. and the CLQM. The CLQM details analytical procedures, preventative maintenance, calibration procedures and frequency, laboratory QC procedures, performance and system audits, corrective actions, data reduction, data verification and calculation of data quality indicators. This manual is annually updated, and therefore, the most recent version of the CLQM details the specific laboratory analyses' DQOs for this project at the time of sample collection

Data not meeting the quality objectives must be qualified using standard FDEP qualifier codes (F.A.C. 62-160) or corrective actions may be taken as outlined in

the CERP Quality Assurance Systems Requirements (QASR) Manual Chapters 3 through 5. Data are qualified in accordance with the SFWMD's FSQM and CLQM data validation and reporting sections.

E.3.3 PARAMETER AND FREQUENCY RATIONAL

TABLE E-2: SITE/STATION MONITORING REQUIREMENTS

Sampling Location	Sample Type	Sampling Frequency	Parameter
CD02, BL03, PR03, MW04 (S-712A & S-712B), LE01, PR01, MW01, PR01, LE02	In-situ measurements	Monthly	Specific Conductance (uS/cm), Color (PCU) , pH(SU), Dissolved Oxygen (mg/l), Temperature (deg. C)
	Grab Sample		TKN(mg/l), NOX(mg/l),TPO4 (mg/l), Turbidity (NTU), NH4 (mg/l)
CC01, BB52, BB39A, PR01, MI01, BB53, MW01, BISC101, BISC102	In-situ measurements	Monthly	Specific Conductance (mS/cm), pH(SU),Dissolved Oxygen (mg/l), Salinity (psu) , Color (PCU) , Temperature (deg. C)
	Grab Sample		TKN(mg/l), NOX(mg/l),TPO4 (mg/l), Turbidity (NTU), NH4 (mg/l)
S-701, S-700	In-situ measurements	Biweekly if recorded flow	Specific Conductance (uS/cm), pH(SU),Dissolved Oxygen (mg/l), Color (PCU) , Temperature (deg. C)
	Grab Sample		TKN(mg/l), NOX(mg/l),TPO4 (mg/l), Turbidity (NTU), NH4(mg/l)

E.4 QUALITY CONTROL AND CUSTODY

E.4.1 ETHICS

All staff performing field sampling must commit to following project specific requirements, field Standard Operating Procedures (SOPs), the requirements in the QASR, and other instructions as issued, to ensure that samples collected are of acceptable quality and defensible.

E.4.2 QUALITY CONTROL SAMPLES

Quality control (QC) samples should comply with section 5.8 of the QASR manual, the FDEP's QC requirements and those developed during the DQO process. All QA samples (FCEB, EB, RS) will conform to the requirements outlined in the SFWMD's Restoration Sciences Department's FSQM.

E.4.3 DOCUMENTATION

Each sampling event and associated information must be documented using standard documents such as field notes, the PSR, and the field test report (FTR). These documents are considered vital and must be protected against tampering, moisture, and other adverse conditions. Using intermediate notes and transferring information to standard documents is not acceptable under normal circumstances. Any non-standard documentation used in the field must meet the minimum documentation requirements specified in this section. The Original PSR and FTR must be submitted to the SFWMD's Laboratory. All original, signed field notes must be retained by the internal collection sampling group. Contractors must submit original field notes to the contract manager on at least a quarterly basis.

E.4.3.1 Pre-Login Summary Report (PSR)

PSRs contain field information about the samples collected. These documents may be in hard copy (paper) or electronic format. The electronic PSRs must be uploaded by the field technician or laboratory login staff to LIMS (SFWMD lab only), printed, signed and submitted with the samples to the laboratory.

E.4.3.2 Field Notes

Field notes are documented using permanent, waterproof ink on standardized field note sheets or electronically in the Horizon Field Data Manager (HFDM). The field note sheets must be printed and placed in binders organized by sampling trip or project. Each binder may contain notes from one or more projects.

Field notes must be documented at the respective sampling station at the time of sample collection. Creating documentation after leaving the station **must not be** done. Field notes must be stored in a filing cabinet designated for access by field staff and the FPM.

E.4.3.3 Field Test Reports, Maintenance, and Troubleshooting Logs

Field technicians must record all field instrument calibration and verification information on the field test report (FTR) or in HFDM. The calibration information must be transferred to LIMS at login by the field technician via HFDM or laboratory login staff. The original FTR must be kept with the PSR and login report files. Field equipment maintenance logs must be maintained by field technicians and kept at the field group's base of operations. These logs must be maintained using the same documentation requirements as field notes, including corrections, signature sign off, and documentation retention.

E.4.3.4 Performance Validation Studies

All procedural changes must be documented, including the development and utilization of new methodologies and/or other validation studies, including the description of the study and validation data. Documentation must be maintained by the QA Administrator and archived for a minimum of five (5) years following completion of the project.

E.4.3.5 Field Documentation and Review

Each sampling team is responsible for ensuring the accuracy and completeness of the pre-login summary report, field test report, and field notes. The FPM is responsible for reviewing these documents within two weeks of their receipt. The FPM shall assure that a) the PSR, FTR and field notes information and calibration results are in agreement, and b) collection, measurements, and documentation were completed properly, and shall check for any entries or observations that may call the validity of the sample or measurement into question. The FPM is also responsible for entering these observations and other comments into LIMS and for ensuing that the field documentation is scanned into NuGenesis. These processes are described in the *Review and Correction of Monitoring Event Documentation SOP* SFWMD-FIELD-SOP-003-01).

Further review of field documentation may be conducted by a QA and/or a Data Validation Section staff member during a comprehensive review of the data and/or during an audit.

E.4.3.6 Laboratory Data Validation

The procedure for validation and assessing data quality generated by the SFWMD's internal laboratory is described in SOP QA-001. The QA Officer review the data, tracks laboratory QC performance though QC charts, and provides feedback on QA to the laboratory staff and Division Director.

E.4.3.7 By Field Project Manager

The FPM is responsible for reviewing all field notes for accuracy and assuring they have been electronically scanned into NuGenesis after each sampling event. Field notes are scanned into NuGenesis by the laboratory for retrieval through LIMS or the NuGenesis web portal. The FPM may request scanned copies be provided by the field crew.

E.4.3.8 Corrections

Upon submittal of samples and the accompanying PSR and FTR to the laboratory, the custody of both the sample and documentation must be transferred from the sampling group to the laboratory. After being logged in, all PSRs and FTRs must remain in secure storage with corrections made directly to the original **not** allowed. If additional corrections are necessary, a request must be made using the Correction Form (WQA SOP 5400.1). This form must be attached to the original field document for reference along with a copy of the corrected PSR and/or FTR marked "Corrected Copy."

E.4.4 SAMPLE SUBMISSION

SFWMD field sample collectors personally transport or ship samples to the SFWMD Laboratory for analysis after preservation. Samples not analyzed by the SFWMD Laboratory must be delivered to the appropriate contract laboratory via ground or air shipping carrier, as mentioned above. Samples brought to the SFWMD laboratory must be placed on the workbench in the sample receiving area or in a designated refrigerator. The field personnel delivering samples to the laboratory must sign and stamp the PSR and FTR with the time clock. The PSR, FTR and photocopy of the field notes must be placed on the clipboard labeled "to be logged in" located at the sample receiving desk.

E.4.5 FIELD AUDITS

Field sampling audits are described in detail in the SOP for *Conducting Field Audits (SFWMD-FIELD-SOP-012-00).* Audits are an essential part of the QA program for the field operations. Systems audits are conducted to measure compliance with the *Field Sampling Quality Manual* and project quality assurance plans. Critical findings, including those identified as needing

corrective action, from any of these audits must be addressed accordingly, and corrective actions must be implemented. Recommendations may also be identified in these audits, in which case the field sampling teams may evaluate and implement responses depending on available resources or benefit to the operation.

Any disputes or ambiguity in interpretation of findings or planning for corrective actions must be referred to the QA administrator, who then makes the final call based on available information, regulatory standards, and if necessary, consultation with regulatory agencies.

E.5 DATA AND RECORDS MANAGEMENT

The SFWMD's sampling groups must maintain the required and necessary documentation of all data generated and other relevant information pertinent to the operation of the organization for the entire life of the project and five (5) years thereafter. Records must be kept such that historical reconstruction of all relevant field and laboratory activities is possible. Vital records, including field notes, PSRs, FTRs, and laboratory analytical reports must be scanned into NuGenesis and stored electronically. Pre-login summary report information and other relevant notes must be entered into LIMS. The original PSR and FTR must be attached to the LIMS printout and filed in the laboratory. SOPs, quality manuals, quality assurance project plans, and other technical documents must be controlled to prevent alteration or use of outdated copies. Supervisors must assure that their staff is supplied with the latest controlled copies and that old copies are removed from work areas. At least one copy of each revision of these documents must be retained by the division QAO.

E.6 PROJECT REPORTING

The results from this project will be reported in SFWMD's annual South Florida Environmental Report (SFER) and provided to permitting agencies. The SFER Report can be found at www.sfwmd.gov/sfer/.

E.7 ORGANIZATION AND RESPONSIBILITIES

E.7.1 ORGANIZATION STRUCTURE

TBD

E.7.1.1 Project Manager

TBD

E.7.1.2 Field Project Manager (FPM)

The FPM for this project is TBD. The FPM is responsible for maintaining this document and making sure that any changes are documented and communicated to the field staff and other parties as necessary.

E.7.1.3 Monitoring Field Lead

TBD

E.7.1.4 Analytical Lead/Contract Manager

TBD

E.7.1.5 Quality Assurance Lead

TBD

E.7.1.6 Reporting Lead

TBD

E.8 COST ESTIMATES

Monitoring cost estimates shown herein were prepared by the SFWMD in conjunction with the USACE ***Table E-6*** details the estimated first year, five-year and ten year costs of collecting the water quality data proposed for the Biscayne Bay Coastal Wetlands project. The first year cost is estimated to be approximately $119,100. The annual cost is approximately $119,100 while the five-year cost is estimated to be approximately $582,000. Calculations in this table were done under the assumption that one-third of the cost of the existing Miami-Dade County Department of Environmental Resources Management (Miami-Dade DERM)/SFWMD monitoring being done currently at non-Monitoring and Assessment Plan stations included in this plan will be eligible for cost-share. The reimbursement factor is justified because the ongoing monitoring is done to satisfy NPDES and NECP permits held by Miami-Dade DERM and the SFWMD. The ongoing monitoring will benefit the Biscayne Bay Coastal Wetlands project as well as help fulfill requirements of the FDEP and the associated permits.

E.9 FUTURE REVISION NOTES AND MODIFICATIONS

[This page is intentionally left blank for use by the project manager to track changes to this document between revisions. These notes are maintained in the PROJECT BINDER by the project manager.]

E.10 MERCURY MONITORING

E.10.1 INITIAL START-UP MONITORING PRIOR TO DISCHARGE

The SFWMD shall initiate start-up monitoring prior to discharge as follows (***Table E-3***):

E.10.1.1 Mosquitofish

i) When construction of each phase of the BBCW project (L31E culverts, Deering Estates Flow-way, and Cutler Flow-way) are completed, the SFWMD shall notify the FDEP and, within one month of flooding collect mosquitofish from multiple locations within each project phase area (to total at least 100 fish), and physically composite them into one, spatially-averaged sample per project phase area for THg analysis (note, a single aliquot should be analyzed per composite). Because outfalls will be into saltwater marshes with the receiving waters 1+ km downstream through a mangrove swamp, no mosquitofish will be collected downstream of the project.

ii) The SFWMD shall provide the FDEP with the results of the first collection of mosquitofish as well as the appropriate action levels for comparison (90% upper confidence level of the basin-wide average or the 75th percentile concentration for the period of record for all basins). If tissue-concentrations from each project phase area are below the 90% upper confidence level of the project-wide average, or below the 75th percentile concentration for the period of record for all project areas; after concurrence from the FDEP, the SFWMD may initiate flow-through operation and routine monitoring for that project phase area.

However, if mercury concentration in any of the mosquitofish composites from within a project phase exceeds one of the above referenced action levels, the SFWMD shall immediately (within 14 days of receiving quality assured data from the laboratory) collect a sample(s) to confirm the exceedance(s). In addition, the SFWMD shall consult with the FDEP to determine the most appropriate course of action and obtain authorization to initiate flow-through operation. At a minimum, the course of action will include implementation of Tier 2 Expanded Monitoring and Risk Assessment by the SFWMD during initial flow-through operations (e.g. collection of monthly mosquitofish within the project phase area at a minimum), additional details on expanded monitoring are provided below and in the SFWMD's Guidance in the Design of a Project-level Monitoring and Assessment Plan for Mercury and Other Toxicants dated September, 25 2005 (hereafter referred to in this document as the "Protocol"). The recommended course of action may also include additional measures as determined to be appropriate. When results of expanded monitoring demonstrate concentrations in each project phase area has decreased to acceptable levels (below action levels referenced above) and the concentrations at

the downstream site are not significantly elevated above baseline levels, the SFWMD shall notify the FDEP and request that the monitoring revert back to Tier 1 routine monitoring.

E.10.1.2 Sediment

After sediments have been saturated in excess of one month and prior to discharge, sediment cores will be collected one-time from five representative locations (each surface water sampling station and adjacent to two of the culvert locations) within the project phase areas. Efforts will be made to co-locate sediment sites with mosquitofish collection sites.

At each location or site, a minimum of three cores (number of cores in excess of three will be determined by amount of sediment required for analysis) from the 0-to-4 cm horizon are to be collected and composited as a single sediment sample.

To serve as baseline for future comparison, if future conditions warrant follow-up sampling of sediments (i.e., if Tier 2 were triggered), sediment samples will be analyzed for THg, MeHg, moisture content, total organic carbon (TOC), total sulfur (TS), and total iron (TFe). To allow for possible future analysis, remaining material from each sediment sample will be archived separately for the maximum hold time allowable for the specified parameter list.

Additionally, these sediment samples will be analyzed and assessed for toxicants other than mercury as discussed below.

E.10.1.3 Water

Although bio-accumulative toxicants, in particular mercury, will be monitored and assessed prior to discharge based on tissue concentrations, because of the concern for potential acute toxicity, water will be collected from immediately upstream of inflows (stations S-710, S-700 and S-701) of the project and analyzed for toxicants other than mercury as discussed below.

TABLE E-3: INITIAL START-UP MONITORING PRIOR TO DISCHARGE

Matrix	Sites	Collection Method	Frequency	Parameter
Mosquitofish	S-700, S-701, and S-710**	Net or Trap	One-time; quarterly thereafter if flow-through delayed	Other toxicants*and THg
Sediment		Sediment Core	One-time	Other toxicants, THg, MeHg, Moisture Content, TOC, TS, and TFe
Surface Water		Grab	One-time	Other toxicants (no THg, MeHg, or sulfate for one-time start-up collection)

*In the event monitoring prior to discharge continues beyond one year, monitoring for other toxicants would cease after one year if action levels are not exceeded within that time.
**Final selection of sites will be dependent upon permit requirements.

E.10.1.4 Selection of Toxicants Other Than Mercury

The following information sources have been reviewed for data regarding this project: SFWMD's pesticide network. Based on this review, the parameters identified in ***Table E-4*** will be analyzed in each of the specified matrices.

The SFWMD shall provide the FDEP with the results of these analyses as well as the appropriate action levels for comparison. If the following criteria are met for a given flow way or cell, the SFWMD may initiate flow-through operation and routine monitoring for that flow way or cell (for details on routine monitoring, see below).

- If ambient mosquitofish do not demonstrate excessive bioaccumulation that exceeds a critical tissue benchmark used to establish SQAGs or in site-specific risk assessments;
- If concentrations in sediments do not exceed an effects-based, numerical sediment quality assessment guideline (SQAGs for sediment dwelling organisms, MacDonald Environmental Sciences Ltd. and USGS, 2003);
- If concentrations in sediments do not exceed an established bio-accumulative based SQAG, if available (MacDonald Environmental Sciences Ltd. and USGS, 2003), a action level reported in the ESA or a level that was determined to be critical in a site-specific risk assessment;
- If water-column concentrations do not exceeded a WQS in Chapter 62-302, F.A.C.

However, if one of the above referenced action levels are exceeded, the SFWMD shall immediately (within 14 days of receiving quality assured data from the laboratory) collect a sample(s) to confirm the exceedance(s). In addition, the SFWMD shall consult with the FDEP to determine the most appropriate course of action and obtain authorization to initiate flow-through operation from that cell or flow way. At a minimum, the course of action will include implementation of Tier 2 Expanded Monitoring and Risk Assessment by the SFWMD during initial flow-through operations. The recommended course of action may also include additional measures as determined to be appropriate. When results of expanded monitoring demonstrate concentrations in each flow way has decreased to acceptable levels (below action levels referenced above), and the concentrations at the downstream site are not significantly elevated above baseline levels, the SFWMD shall notify the FDEP and request that the monitoring revert back to Tier 1 routine monitoring.

TABLE E-4: PARAMETER LIST OF TOXICANTS OTHER THAN MERCURY THAT WILL BE ANALYZED IN SPECIFIED MATRIX

Analyte	Surface Water	Sediment	Fish Tissue
o,p-DDD			✓
p,p-DDD	✓	✓	✓
o,p-DDE			✓
o,p-DDT			✓
chlordane	✓	✓	
cis-chlordane			✓
trans-chlordane			✓
dieldrin	✓	✓	✓
cis-nonachlor			✓
trans-nonachlor			✓

E.10.2 MONITORING DURING STABILIZATION PERIOD

The SFWMD shall initiate monitoring after initial discharge and during the stabilization period as follows:

E.10.2.1 Tier 1: Routine Monitoring During Stabilization Period

E.10.2.1.1 Water

On a quarterly basis, an unfiltered surface water sample (n = 1) shall be collected in accordance with Chapter 62-160, F.A.C., immediately upstream of stations S-700 and S-701 and at station S-710 from the project. These samples will be analyzed for THg, MeHg, and sulfate (the latter not to be duplicative if

listed as a parameter under routine monitoring described elsewhere in the general monitoring plan).

Based on the discussion above regarding toxicants other than mercury, a surface water sample will be collected quarterly immediately upstream of stations S-700 and S-701 and at station S-710 and analyzed for the parameters listed in ***Table E-5*** under surface water.

In addition, flow will be monitored at the inflow and outflow to allow for load estimation to and from the project (it should be recognized that quarterly sampling would allow for only rough estimation of loads).

The data will be assessed to determine if outflow concentrations exceed WQS, and whether annual outflow loads of analytes are significantly greater than inflow loads, including atmospheric loading; load estimates will include confidence intervals that describe uncertainty in measures of flow and concentration (e.g., field and analytical precision) and resulting from interpolation (note: assessment protocol to be negotiated with permitting authority). Failure to satisfy these assessment measures would trigger Tier 2 Expanded Monitoring and Risk Assessment (see below).

Because of differences in the anticipated time frames under which sedimentary release are thought to occur (i.e., relative to MeHg that may have time lag associated with changes in biogeochemistry and microbial methylation driven by water quality, especially in sandy soils), monitoring for other toxicants would cease after one year if action levels are not exceeded within that time.

E.10.2.1.2 Fish Tissues

Samples of fish from multiple trophic levels will be collected from each project phase area. Specifically, mosquitofish collections will be made in a similar fashion and continue on a quarterly basis from all sites that were sampled prior to discharge (see above; for rationale for the selection of this and other species listed below, see the Protocol). On an annual basis, bluegill (n should be greater than or equal to 5) should be collected and individually analyzed as whole-fish. For the reasons discussed in the Protocol, collections should target bluegill ranging in size from 102 to 178 mm (i.e., 4 to 7 inches); however, other lepomids (first priority being given to spotted sunfish) or sizes are to be collected if efforts fail to locate targeted fish. These samples will be analyzed for THg and other toxicants listed in ***Table E-4*** under tissues. Monitoring for other toxicants would cease after one year if action levels are not exceeded within that time.

If after one year of monitoring, sufficient data are collected to demonstrate that conditions within the separate operational units (OUs) are equivalent, collection of large-bodied fish can be reduced to one OU and one downstream site.

Alternatively, if OUs are shown to differ in terms of average concentration in mosquitofish, large-bodied fish from the OU with the highest observed concentration may be sampled and results assessed as "worst case". However, mosquitofish collections would continue from all OUs.

E.10.2.1.3 Assessment

To detect and minimize any adverse effects as early as possible (and to provide a basis for identifying adaptive management options, if deemed necessary), the results of this monitoring will be assessed based on the criteria and time table described under Phase 2 - Tier 1 in the Protocol (specifically, A Protocol for Monitoring Mercury and Other Toxicants and appendices, as approved at the time of the assessment). Monitoring results will be provided to the FDEP in accordance with the reporting requirements identified in Section 4.

TABLE E-5: STABILIZATION MONITORING

Matrix	Location	Collection Method	Frequency	Parameter
Surface Water	S-700, S-701, and S-710**	Grab	Quarterly	Other toxicants*, THg, MeHg, and sulfate
Mosquito-fish		Net or Trap	Quarterly	Other toxicants* and THg
Sunfish and Bass (n=5 each)		Electro-shock or Hook and Line	Annually	Other toxicants* and THg

* Monitoring for other toxicants would cease after one year if action levels are not exceeded within that time.
**Final selection of sites will be dependent upon permit requirements and site specific conditions.

E.10.2.2 Tier 2: Expanded Monitoring and Risk Assessment During Stabilization Period

In accordance with the Protocol, if Tier 1 data exceed the action levels identified under Phase 2 – Tier 2 Expanded Monitoring and Risk Assessment, the SFWMD shall notify the FDEP and after obtaining the FDEP's concurrence, shall expand monitoring and undertake all necessary steps consistent with the Protocol.

E.10.3 OPERATIONAL MONITORING FOLLOWING THE STABILIZATION PERIOD

The monitoring plan and associated data will be re-evaluated on a regular basis beginning after year-1 for other toxicants and after year-3 for mercury species to determine if criteria specified in the Protocol are being satisfied. Based on that

assessment, and with the concurrency of the FDEP, monitoring and assessment efforts may be reduced (as identified in Phase 3-Tier 1 Operational monitoring of the Protocol), or eliminated all together at the project level to be subsumed by regional monitoring (as identified in Phase 3-Tier 3 Operational monitoring). However, if monitoring reveals anomalous conditions as described under Phase 3-Tier 2, the SFWMD shall expand monitoring and undertake all necessary steps under Phase 3 – Tier 2 Expanded Monitoring and Risk Assessment.

E.10.4 REPORTING REQUIREMENTS

The permittee shall notify the FDEP immediately if monitoring data indicate that any of the action levels are exceeded. In addition, the permittee shall submit to the FDEP, as part of the annual South Florida Environmental Report, the results of the monitoring as defined above, including the following:

i. Comparison of inflow and discharge concentrations with state water quality criteria;
ii. Comparison of inflow and outflow loads and concentrations for total mercury, methylmercury, and other toxicants; and
iii. Comparison of data with appropriate action levels.

TABLE E-6: ESTIMATED COSTS OF WATER QUALITY DATA COLLECTION AND PROCESSING FOR BISCAYNE BAY COASTAL WETLANDS PROJECT

Period	Type	Estimated Total Cost	Existing Amount Funded	Remainder (Project Cost)
Year 1	General Water Quality	$73,000	$50,400	$22,600
	Mercury	$50,000	$0	$50,000
	Toxicants	$4,500	$0	$4,500
Years 1-5	General Water Quality	$365,000	$252,000	$113,000
	Mercury	$250,000	$0	$250,000
	Toxicants	$22,500	$0	$22,500
Years 6-10	General Water Quality	$365,000	$252,000	$113,000
	Mercury	$0	$0	$0
	Toxicants	$0	$0	$0
TOTAL 10 YEAR COST		$1,002,500	$504,000	$498,500

E.10.5 WATER QUALITY PERMITS

E.10.5.1 Deering Estate Permits

Florida Department of Environmental Protection
Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Charlie Crist
Governor

Jeff Kottkamp
Lt. Governor

Michael W. Sole
Secretary

COMPREHENSIVE EVERGLADES RESTORATION PLAN REGULATION ACT (CERPRA) PERMIT -CONSTRUCTION AND OPERATION AUTHORIZATION

PERMITTEE:
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

ATTENTION:
Ms. Carol Ann Wehle
Executive Director

Permit Number: 0271729-002
Project: Biscayne Bay Coastal Wetland Project: Deering Estate Flow-way
County: Miami - Dade

Date of Issue: 5/23/08
Expiration Date: 5/23/13

This modification is issued under the authority of the Comprehensive Everglades Restoration Plan Regulation Act (CERPRA), Chapter 373.1502, Florida Statutes (F.S.); Title 62, Florida Administrative Code (F.A.C.); and pursuant to the Department of Environmental Protection (Department) authority under Chapter 373 and 403, F.S. The activity is not exempt from the requirement to obtain a CERPRA Permit.

The above named permittee is hereby authorized to initiate the activities described on the application, associated drawing(s), plans, and other documents attached hereto or on file with the Department and made a part hereof. The activities authorized by this permit must be conducted in conformance with all the provisions of this permit. Failure to comply with all permit conditions and documents referenced herein shall constitute grounds for revocation of the permit and appropriate enforcement action.

This modification constitutes a finding of consistency with Florida's Coastal Zone Management Program, as required by Section 307 of the Coastal Management Act, 14 U.S.C. § 1456; constitutes certification of compliance with water quality standards under Section 401 of the Clean Water Act, 33 U.S.C. § 1341; and constitutes consumptive use (general water use) authorization pursuant to Chapter 373, F.S. and Rule 40E-20, F.A.C. Activities described in the related documents are not authorized until the project is determined to be in conformance with all applicable rules and with the general and specific conditions of this permit/certification/modification/authorization, as specifically described below.

PROJECT DESCRIPTION:
The Biscayne Bay Coastal Wetland Project, is a "project component" as defined in Section 373.1501(1), F.S., of the Comprehensive Everglades Restoration Plan (CERP). In addition, the Biscayne Bay Coastal Wetlands Project was identified as an Acceler8 project which the State of Florida is accelerating the funding, design, and construction of in order to realize immediate environmental benefits. The Biscayne Bay Coastal Wetlands Project is intended to aid in establishing a productive nursery habitat along the shoreline through redistribution of freshwater flow and the minimization of point source discharges. The overall project will enhance and improve quantity, quality, timing and distribution of freshwater to the Bay, including Biscayne National Park, and aid in the preservation, restoration, and spatial extent of natural coastal habitat.

On September 09, 2007, authorization for the construction and operation of the L-31E Culverts Project was issued through Department Permit No.: 0271729-001-GL. These improvements, in addition to the construction of the

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Deering Estate Flow-way (Deering Estate) Project are authorized in this permit. If any provision of this modification conflicts with the conditions in Comprehensive Everglades Restoration Plan (CERP) Permit No. 0271729-001-GL, then the provisions included within this modification shall prevail.

The L-31E Culverts project includes the installation of four flap-gated culverts, each consisting of 36" metal pipe, aluminum flap-gate, and concrete endwalls at each end of the pipe. In addition, installation of each culvert will also include the construction of a 10 foot wide canal excavated from the endwall at the upstream side of the culvert to the L-31E Canal and a 10-foot wide canal excavated from the endwall at the downstream side of the culvert to the eastern right-of-way of the L-31E Canal. This project is intended to restore a more natural flow of water by transporting freshwater through the culvert system to the coastal wetlands to the east, creating a more natural sheetflow and eliminating sudden releases of water through existing coastal structures. There are no State jurisdictional wetlands within the L-31E Culverts project area. Surface waters to be directly impacted by construction of this project component are Class III Waters, and Biscayne Bay National Park which is listed as an Outstanding Florida Water.

The Deering Estate Project includes an extension of the C-100A Spur Canal, construction, operation, and maintenance of a 100 cfs pump station, a conveyance feature that will discharge to Deering Estate via a spreader structure located east of Old Cutler Road and the creation of approximately 2-acres of educational wetland (See Figure 1). The project intends to improve freshwater and estuarine habitat, and salinity distribution within Biscayne Bay at the Deering Estate by re-directing runoff within the C-100 basin that is currently being discharged directly to tide and allowing this water to rehydrate the natural glade, via ground water and surface water, within the Deering Estate and the downstream estuary.

The South Florida Water Management District (District) is responsible for construction, operation, maintenance, repair, replacement, and rehabilitation of the L-31E Culverts and Deering Estate Projects. All conditions found herein apply to the District.

PROJECT LOCATION:
The L-31E Culverts Project is located in Miami-Dade County between the Goulds and C-103 Canal, Sections 4, 9, 28, 33 and Township 56 S Range 40 East and 57S Range 40 East. S-23B will be located north of SW 280 Street and south of the C-102/Princeton Canal on L-31E Canal. S-23A south of the C-102/Princeton Canal and north of S-23B on L-31E Canal. S-23D will be located between the C-103/Mowry Canal and Military Canal. S-23C will be located just north of the C-103/Mowry Canal.

The Deering Estate Project is located in Miami-Dade County about 1/2 mile north of the C-100 Canal at the S-123 Structure on the west side of Old Cutler Road Section 26, Township 55 south, Range 40 east. An off-site stockpile area will be located at the intersection of northeast corner of S.W. 232nd Street and S.W. 97th Avenue, Section 16, Township 56 South, Range 40 East.

DECLARATION OF REASONABLE ASSURANCES:
In issuing this permit, the Department finds that the District has given reasonable assurances sufficient to satisfy the requirements of the Comprehensive Everglades Restoration Plan Regulation Act, Section 373.1502, F.S. The Department bases this finding on the following documents, listed by Department document number:

1) South Florida Water Management District, L-31 E Culverts Permit Application and associated materials (December 2006);
2) South Florida Water Management District, Response to Request for Additional Information on L-31E Culverts (March 12, 2007); and,

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3) South Florida Water Management District, Pre-Final Design Plans, Specifications and Report for the L-31E Culverts (June 20, 2007)

4) South Florida Water Management District, Deering Estate Permit Application and associated materials (December 2006);

5) United States Fish and Wildlife, Letter of Concurrence under the Endangered Species Act (August 2007);

6) South Florida Water Management District, Stocking Piling Site Ownership, (November 2007);

7) South Florida Water Management District, Biological Assessment (December 2006);

8) South Florida Water Management District, Response to Additional Information 1 (May 2007);

9) South Florida Water Management District, Response to Additional Information 2 (August 2007)

10) South Florida Water Management District, Pre-Final Design Plans. Specifications and Report for the Deering Estate Flow-way (March 18, 2008)

Specifically, there are reasonable assurances, pursuant to Section 373.1502, F.S., that:

- "The project component will achieve the design objectives set forth in the detailed design documents submitted as part of the application." This finding is based on document 1 in its entirety, document 2, document 3 in its entirety, document 4 in its entirety, document 5 in its entirety, document 6 in its entirety;
- "State water quality standards, including water quality criteria and moderating provisions, will be met. Under no circumstances shall the project component cause or contribute to violation of state water quality standards." This finding is based on document 2 with emphasis on responses 8 and 9 and the Pilot Study Report, document 4, document 8 with emphasis on 7, 8, 10 and 14, and document 9 with emphasis on 2-5;
- "Discharges from the project component will not pose a serious danger to public health, safety or welfare." This finding is based on document 1 in its entirety, document 2 with emphasis on the Pilot Study, document 4 in its entirety, document 8 with emphasis on 2, 7, 8, 10 and 14, and document 9 with emphasis on 2-5;
- "Any impacts to wetlands or threatened or endangered species resulting from implementation of the project component will be avoided, minimized, and mitigated as appropriate." This finding is based on document 1 and document 2 with an emphasis on the Biological Assessment (BA) for the Biscayne Bay Coastal Wetlands project, the-Pre-Final Design Plans, Specifications and Report for the L-31E Culverts, document 4 in its entirety, document 5 in its entirety, document 7 in its entirety, document 4 with emphasis on 3, 7, 8, 10 and 12 and document 9 with emphasis on 2-5.

The District agrees to construct the project in accordance with the provisions of this permit, permit application, and the associated documentation on file with the Department.

GENERAL CONDITIONS:

In accordance with Subsection 373.1502(3)(e)(2) of the CERPRA, this permit may include any standard conditions provided by Department rule, which are appropriate and consistent with the CERPRA.

1. **Enforcement.** The terms, conditions, requirements, limitations and restrictions set forth in this permit, are "permit conditions" and are binding and enforceable pursuant to Chapters 373.129, 403.141, 403.727, 403.859 through 403.861 F.S. The permittee is placed on notice that the Department will review this permit periodically and may initiate enforcement action for any violation of these conditions.

2. **Scope of permit.** This permit is valid only for the specific processes and operations applied for and indicated in the approved drawings or exhibits. Any unauthorized deviation from the approved drawings, exhibits,

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specifications, or conditions of this permit may constitute grounds for revocation and enforcement action by the Department.

3. **Limitation of rights.** The issuance of this permit does not convey any vested rights or any exclusive privileges. Neither does it authorize any injury to public or private property or any invasion of personal rights, nor any infringement of federal, state, or local laws or regulations. This permit is not a waiver of or approval of any other Department permit that may be required for other aspects of the total project which are not addressed in this permit. However, this permit is in lieu of other permits under Chapter 373 or Chapter 403, F.S., except for permits issued under s. 403.0885, if applicable.

4. **Limitations upon title.** This permit conveys no title to land or water, does not constitute State recognition or acknowledgment of title, and does not constitute authority for the use of submerged lands unless herein provided and the necessary title or leasehold interests have been obtained from the State. Only the Trustees of the Internal Improvement Trust Fund may express State opinion as to title.

5. **Liability.** This permit does not relieve the permittee from liability for harm or injury to human health or welfare, animal, or plant life, or property caused by the construction or operation of this permitted source, or from penalties therefore; nor does it allow the permittee to cause pollution in contravention of Florida Statutes and Department rules, unless specifically authorized by an order from the Department. The permittee shall hold and save the Department harmless from any and all damages, claims, or liabilities which may arise by reason of the construction, alteration, operation, maintenance, removal, abandonment or use of any system authorized by the permit.

6. **Operation and maintenance responsibilities.** The permittee shall properly operate and maintain the facility and systems of treatment and control (and related appurtenances) that are installed and used by the permittee to achieve compliance with the conditions of this permit, as required by Department rules. This provision includes the operation of backup or auxiliary facilities or similar systems when necessary to achieve compliance with the conditions of the permit and when required by Department rules.

7. **Access Rights.** The permittee, by accepting this permit, specifically agrees to allow authorized Department personnel, upon presentation of credentials or other documents as may be required by law and at reasonable times, access to the premises where the permitted activity is located or conducted to:
   A. Have access to and copy any records that must be kept under conditions of the permit;
   B. Inspect the facility, equipment, practices, or operations regulated or required under this permit; and
   C. Sample or monitor any substances or parameters at any location reasonably necessary to assure compliance with this permit or Department rules.

   Reasonable time may depend on the nature of the concern being investigated.

8. **Noncompliance.** If, for any reason, the permittee does not comply with or will be unable to comply with any condition or limitation specified in this permit, the permittee shall immediately provide the Department with the following information:
   A. A description of and cause of noncompliance; and
   B. The period of noncompliance, including dates and times; or, if not corrected, the anticipated time the noncompliance is expected to continue, and steps being taken to reduce, eliminate, and prevent recurrence of the noncompliance. The permittee shall be responsible for any and all damages which may result and may be subject to enforcement action by the Department for penalties or for revocation of this permit.

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9. **Records as evidence.** In accepting this permit, the permittee understands and agrees that all records, notes, monitoring data, and other information relating to the construction or operation of this permitted source which are submitted to the Department may be used by the Department as evidence in any enforcement case involving the permitted source arising under the Florida Statutes or Department rules, except where such use is prescribed by Sections 403.111, F.S. and 403.73, F.S. Such evidence shall only be used to the extent it is consistent with the Florida Rules of Civil Procedure and appropriate evidentiary rules.

10. **Changes in Law.** The permittee agrees to comply with changes in applicable Department rules and applicable Florida Statutes after a reasonable time for compliance; provided, however, the permittee does not waive any other rights granted by Florida law.

11. **Transferability.** This permit is transferable only upon Department approval in accordance with Rules 62-4.120 and 62-343.130, F.A.C., as applicable. The permittee shall be liable for any non-compliance of the permitted activity until the transfer is approved by the Department.

12. **Permit at work site.** This permit or a copy thereof shall be kept at the work site of the permitted activity. For the purposes of this permit the work site shall be defined as the South Florida Water Management District Headquarters located at 3301 Gun Club Road in West Palm Beach, Florida.

13. **Records retention.** The permittee shall comply with the following:

    A. Upon request, the permittee shall furnish all records and plans required under Department rules. During enforcement actions, the retention period for all records will be extended automatically unless otherwise stipulated by the Department;

    B. The permittee shall hold at the facility or other location designated by this permit records of all monitoring information required by the permit, copies of all reports required by this permit, and records of all data used to complete the application for this permit. These materials shall be retained at least five years from the date of the sample, measurement, report, and application unless otherwise specified by Department rule; and

    C. Records of monitoring information shall include:

        1. the date, exact place, and time of sampling or measurements;
        2. the person responsible for performing the sampling or measurements;
        3. the dates analyses were performed or the appropriate code as required by Chapter 62-160, F.A.C.;
        4. the person responsible for performing the analyses;
        5. the analytical techniques or methods used, including but not limited to MDL; and
        6. the results of such analyses, including identification of potential outlier values.

14. **Requests for information.** When requested by the Department, the permittee shall within a reasonable time furnish any information required by law which is needed to determine compliance with the permit. If the permittee becomes aware that relevant facts were not submitted or were incorrect in the permit application or in any report to the Department, such facts or information shall be corrected promptly.

15. **External Agency Requirements.** Should any other regulatory agency require changes to the permitted system, the permittee shall notify the Department in writing of the changes prior to implementation so that a determination can be made whether a permit modification is required.

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16. **Sovereign Lands.** The permittee is hereby advised that Florida law states: No person shall commence any excavation, construction, or other activity involving the use of sovereign or other lands of the state, title to which is vested in the Board of Trustees of the Internal Improvement Trust Fund or the Department of Environmental Protection under Chapter 253, until such person has received from the Board of Trustees of the Internal Improvement Trust Fund the required lease, license, easement, or other form of consent authorizing the proposed use. Therefore, the permittee is responsible for obtaining any necessary authorizations from the Board of Trustees prior to commencing activity on sovereignty lands or other state-owned lands.

17. **Artifacts.** If historic or archaeological artifacts such as, but not limited to, Indian canoes, arrow heads, pottery or physical remains, are discovered at any time on the project site, the permittee shall immediately stop all activities which disturb the soil and notify the Department and the State Historic Preservation Officer.

SPECIFIC CONDITIONS:

1. **Instructions to Contractors.** The District shall ensure that the conditions contained within this permit are explained to all construction personnel working on the project and shall provide a copy of this permit to each contractor and subcontractor before the authorized work begins. Prior to construction, the District shall schedule a pre-construction meeting for attendance by the contractor(s), and representatives from the District, the Department, and other environmental regulatory agencies. The Department shall receive at least two weeks notice of the meeting. Within 30 days from the Notice-to-Proceed to the Contractor or upon District approval of a proposed construction schedule, whichever occurs first, the District shall provide the proposed construction schedule to the Department at the address identified in Specific Condition 2.

2. **Addresses.** Reports, schedules, and notices submitted to the Department in accordance with this permit shall be submitted to the Department's Division of Water Resource Management, Water Quality Standards and Special Projects Program, 2600 Blair Stone Road, MS 3560, Tallahassee, Florida, 32399-2400, telephone no. (850) 245-8416.

3. **Endangered Species.** The District shall avoid any actions that are likely to result in a take of any species listed by Fish and Wildlife Conservation Commission (FWC) in Chapter 68A-27, F.A.C or U.S. Fish and Wildlife Service, Department of the Interior (USFWS) in 50 CFR 17.11 or 50 CFR 17.12. In the event that either the Department or the District determine that the proposed activities will result in a take of a listed species, the District shall cease operations affecting the populations and closely coordinate with the FWC and the USFWS to obtain any necessary incidental take permits; Operations may continue if take authorization was granted for the affected species and all conditions accompanying that take are satisfied. If the District makes the above determination, it shall notify the Department at the address and telephone number in Specific Condition 2 within 24 hours of the date of such determination.

Construction

4. **Authorized Construction.** The District shall construct the Biscayne Bay Coastal Wetlands L-31E Culverts Project and Deering Estate Project in accordance with the plans and documentation submitted by the District as part of the permit application and any subsequent submittals that have been approved and are on file with the Department. Any substantial modifications to the construction plan, such as, but not limited to, hydrologic modifications or the addition/removal/modification of water control structures or changes to their location must be submitted for review and approval by the Department prior to construction and operation of such modifications. Substantial modifications shall be determined on a case-by-case basis by the Department in consultation with the District.

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5. **Future Phases.** This permit does not authorize any construction or operation activities associated with future portions of the Biscayne Bay Coastal Wetlands Project. Future phases will require separate review and approval by the Department.

6. **Construction Best Management Practices (BMPs).** At all times during the construction, the District shall use best management techniques for erosion and sedimentation control. All graded areas shall be stabilized and vegetated immediately after construction to prevent erosion. Prior to commencement of construction activities, the District shall submit the contractor's BMP plan, if different from the engineer's plan, which details the use of sediment controls to minimize the suspension and transport of soils, levee materials, and roadway materials into waters adjacent to or downstream of the construction site to the Department for review and approval. Once installation of the erosion controls identified through the BMP plan have been completed, the District shall contact the Department at the address listed in Specific Condition No. 2 to determine whether inspections of the installed controls are necessary.

7. **Adjacent Wetlands.** Wetlands adjacent to the construction activities shall be staked and fenced off with construction fencing or other effective physical barriers to prevent encroachment into wetlands prior to the commencement of construction. All areas of exposed soils shall be isolated from wetlands and surface waters to prevent erosion and deposition of sediments into these wetlands during permitted construction activities. All excavated or dredged material shall be placed strategically to prevent the transport of any material into wetlands and surface waters both during and after completion of the construction. Upon completion of the barrier installation, the District shall contact the Department at the address listed in Specific Condition No. 2 to determine whether inspections of the installed controls are necessary. The barriers shall remain in place until all adjacent construction activities are complete.

8. **Water Quantity and Flooding Impacts.** The District shall be responsible for ensuring that the project is constructed and operated so as to not adversely affect adjacent lands with regards to water quantity, water quality, and/or flooding. The District shall hold and save the Department harmless from any and all damages, claims or liabilities, which may arise from water quantity, water quality, and/or flooding impacts resulting from construction and operation of this project.

9. **NPDES Generic Permit for Stormwater Discharge from Large and Small Construction Activities.** The issuance of this permit does not constitute coverage under the National Pollutant Discharge Elimination System (NPDES) Generic Permit for Stormwater Discharges from Large and Small Construction Activities (CGP) pursuant to Rule 62-621.300(4)(a), F.A.C. Prior to the commencement of any construction, the District is advised to contact the Department's NPDES Stormwater Program at (850) 245-7522 or toll free at (866) 336-6312 or to download application information from the Department's website at http://www.dep.state.fl.us/water/stormwater/npdes/construction3.htm#permit

10. **Dewatering.** For any proposed discharge to occur as a result of construction dewatering activities, the District shall submit site-specific dewatering information to the Department for review and approval at least 30 days prior to commencement of dewatering activities. The plan shall include at a minimum: a site plan of the project component with the location of the proposed discharge point(s) and their associated water quality monitoring locations; the location and type of turbidity control devices and methods necessary to ensure state water quality standards will be met; calculations estimating the area of influence of dewatering, pumpage rates, duration and volumes; and any proposed methods of construction.

    If it is anticipated that dewatering will not be retained onsite, the District must also include documentation that the dewatering activities will meet the criteria contained in the "Basis of Review for Water Use Permit Applications within the South Florida Water Management District-April 23, 2007" with emphasis on Section 2.5.2(4).

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11. **NPDES Generic Permit for the Discharge of Produced Groundwater from any Non-Contaminated Site Activity.** The issuance of this permit does not constitute coverage under the NPDES Generic Permit for the Discharge of Produced Groundwater from any Non-Contaminated Site Activity pursuant to 62-621.300(2), F.A.C. If any offsite discharges will occur due to construction dewatering activities, then coverage under the aforementioned General Permit may be required and the District is advised to review Rule 62-621.300(2), F.A.C. Before discharge of produced groundwater can occur, analytical tests on samples of the proposed discharge water shall be performed to determine if contamination exists. If the analytical results comply with applicable criteria for use of the General Permit, then a short summary of the proposed activity and copy of the analytical tests shall be sent to the Department at the address identified in Specific Condition No. 2 within one week after discharge begins, and the District may proceed with the project component while abiding by all conditions of the Generic Permit.

12. **Site Inspections/Construction Meetings.** Throughout the construction phase of the L-31E and Deering Estate Projects, the Department may conduct periodic site inspections to ensure permit compliance and to monitor progress. The Department will coordinate with the construction manager or other District representatives prior to performing any on-site inspections. Representatives of the Department may be accompanied by a third-party inspector and/or consultant at any time. Upon, or prior to, receipt of the written statement of completion and certification, the Department shall conduct a final inspection of the Project(s). It is anticipated that this activity may be completed in conjunction with other regulatory agencies and may be accomplished in stages as the project progresses.

13. **As-Built Certification and Record Drawings.** Within 90 days after the completion of construction for each project phase, the District shall submit a written statement of completion and certification by a registered professional engineer or other appropriate individual as authorized by law. The statement of completion and certification shall be based on on-site observation of construction or review of as-built drawings for the purpose of determining whether or not the work was completed in compliance with permitted plans and specifications. Additionally, if deviation from the approved drawings is discovered during the certification process, the certification must be accompanied by a copy of the approved permit drawings with deviations noted. Both the original and revised specifications must be clearly shown. Plans submitted to the Department must be clearly labeled as "as-built" or "record" drawings with electronic copies provided in pdf format. A registered surveyor shall certify all surveyed dimensions and elevations.

14. **Manatee Protection During Construction:** The District shall comply with the following conditions intended to protect manatees from direct project effects:

    A. All personnel associated with the project shall be instructed about the presence of manatees and manatee speed zones, and the need to avoid collisions with and injury to manatees. The District shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act, the Endangered Species Act, and the Florida Manatee Sanctuary Act.

    B. All vessels associated with the construction project shall operate at "Idle Speed/No Wake" at all times while in the immediate area and while in water where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.

    C. Siltation or turbidity barriers shall be made of material in which manatees cannot become entangled, shall be properly secured, and shall be regularly monitored to avoid manatee entanglement or entrapment. Barriers must not impede manatee movement.

    D. All on-site project personnel are responsible for observing water-related activities for the presence of manatee(s). All in-water operations, including vessels, must be shutdown if a manatee(s) comes within 50 feet of the operation. Activities will not resume until the manatee(s) has moved beyond the 50-foot

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radius of the project operation, or until 30 minutes elapses if the manatee(s) has not reappeared within 50 feet of the operation. Animals must not be herded away or harassed into leaving.

E. Any collision with or injury to a manatee shall be reported immediately to the FWC Hotline at 1-888-404-FWCC. Collision and/or injury should also be reported to the U.S. Fish and Wildlife Service in Jacksonville (1-904-232-2580) for north Florida or Vero Beach (1-561-562-3909) for south Florida.

F. Temporary signs concerning manatees shall be posted prior to and during all in-water project activities. All signs are to be removed by the District upon completion of the project. Awareness signs that have already been approved for this use by the Florida Fish and Wildlife Conservation Commission (FWC) must be used. One sign measuring at least 3 ft. by 4 ft. which reads *Caution: Manatee Area* must be posted. A second sign measuring at least 81/2" by 11" explaining the requirements for "Idle Speed/No Wake" and the shut down of in-water operations must be posted in a location prominently visible to all personnel engaged in water-related activities.

Operations and Maintenance

15. **Operation of Passive Structures.** The L-31E Culverts Project shall be operated as passive structures. Any alteration of operations, including, but not limited to the installation of flashboard risers or increasing flow from source canals, must be submitted to the Department for review and approval. The District shall submit an operational plan at least 90 days prior to commencing modified operation of the culverts for Department review and approval.

16. **Pump Station Operation.** Prior to operation of the CD-20 Pump Station taking place, the District shall submit a final operations plan to the Department for review and approval. The District shall submit any modified operations plan at least 90 days prior to commencing modified operation of the pump station for Department review and approval.

17. **Pump Station Testing and Maintenance.** In order to ensure operational readiness, pump testing may be required by the permittee for the pump station authorized by this permit prior to commencing discharge activities. Operational readiness requirements for the pump station may include operation of the pump for approximately 2 to 4 hours per month or, as necessary, to maintain their mechanical integrity. Therefore, temporary operation of the pump station for testing and maintenance purposes is allowed and is not subject to the discharge criteria of the specific conditions of this permit. However, the permittee shall include all such discharge flows and loads as a part of the monitoring requirements of this permit.

18. **Culvert Testing and Maintenance.** In order to ensure operational readiness, testing and maintenance operations may be required by the construction contractor and/or District for the culverts authorized by this permit. The District shall submit a maintenance plan for the culverts for Department review and approval at least 30 days prior to initiation of operations.

19. **Public Health Safety and Welfare.** Pursuant to Subsection (3)(b)(3) of the CERPRA, discharges from the Biscayne Bay Coastal Wetlands Project shall not pose a serious danger to the public health, safety, or welfare.

Monitoring Requirements

20. **Water Quality Monitoring Program.** No later than 90 days prior to commencing flow through the culverts or the pump station, the District shall submit a final water quality monitoring plan to the Department for review and approval. Any modifications to the District's water quality monitoring plan shall be submitted to the Department for review and approval. The District shall conduct a water quality monitoring program in

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accordance with Table 1 for L-31E Culverts and Table 2 for the Deering Estate Pump Station and the approved water quality monitoring plan to characterize water quality spatially and seasonally, and to detect long term trends. Water quality monitoring shall commence upon the initiation of operations.

A. **Quality Assurance and Quality Control.** Sampling and monitoring data shall be collected, analyzed, reported and retained in accordance with Chapter 62-160, F.A.C. Any laboratory test required by this permit shall be performed by a laboratory that has been certified by the Department of Health (DOH) under Chapter 64E-1, F.A.C., where such certification is required by Rule 62-160.300, F.A.C. The laboratory must be certified for all specific method/analyte combinations that are used to comply with this permit. The analytical method used shall be appropriate so as to determine if the sample complies with Class I and Class III surface water quality standards as specified in Chapter 62-302, F.A.C., and groundwater standards as specified in Chapter 62-520, F.A.C., whichever is more stringent. All field activities including on-site tests and sample collection, whether performed by a laboratory or another organization, must follow all applicable procedures described in DEP-SOP-001/01 (February 1, 2004). Alternate field procedures and laboratory methods may be used if they have been approved according to the requirements of Rules 62-160.220, and 62-160.330, F.A.C.

B. **Method Detection Limits (MDLs).** The sample collection, analytical test methods and method detection limits (MDLs) applicable to this permit shall be performed and reported in accordance with Rule 62-4.246, F.A.C. a list of Department established analytical methods, and corresponding MDLs (method detection limits) and PQLs (practical quantification limits), which is titled "Florida Department of Environmental Protection Table as Required By Rule 62-4.246(4) Testing Methods for Discharges to Surface Water" dated April 25, 2006, is available from the Department on request. The MDLs and PQLs as described in this list shall constitute the minimum acceptable MDL/PQL values and the Department shall not accept results for which the laboratory's MDLs or PQLs are greater than those described above unless alternate MDLs and/or PQLs have been specifically approved by the Department for this permit. More stringent MDLs and PQLs may be necessary for specific parameters. If required, these will be identified in the permit monitoring table.

21. **Turbidity Monitoring.** Effective means of turbidity control, such as, but not limited to, turbidity curtains, shall be employed during all construction and maintenance activities that may create turbidity so that it shall not exceed 0 NTU's above background in the OFW and 29 NTU's above background in the Class III receiving waters. Turbidity curtains or other controls shall be placed and maintained around the work area to confine turbidity generated by construction within the work area. All screens, sheet pile, and other turbidity control devices shall remain in place until all turbidity has subsided and the turbidity level in the work cell meets state standards.

Turbidity monitoring equipment and personnel trained to use it shall be available on site at all times during construction activities that could result in project-generated turbidity levels beyond the work area. For monitoring purposes, the work area is that area defined by the turbidity curtained "cell(s)." The District shall monitor turbidity levels at least once every four hours during all activities that may create turbidity (unless monitoring data shows this to be excessive) during construction as follows.

A. Monitoring samples shall be taken at the surface at the following locations:

1. Background Sample(s): One background sample station, at least 250 feet upstream of the work area, outside any visible plume generated by the construction; and

2. Compliance Sample(s): Monitoring station located immediately downstream of the work area within the densest portion of any visible plume.

B. Turbidity monitoring results shall be compiled daily and summarized quarterly (every three calendar months) by project component. Beginning with the first calendar month that construction occurs that could generate turbidity in waters adjacent to the construction sites and continue until all construction is completed. Monitoring data with supporting documents shall be submitted to the Department

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quarterly during the period of actual construction. The reports shall clearly identify the following information:

1. Permit number;
2. Dates and time of sampling and analysis;
3. A statement describing the methods used in collection, handling, storage and analysis of the samples;
4. A clear description of project component activities taking place at the time of sampling;
5. A map indicating the sampling locations; and,
6. A statement by the individual responsible for implementation of the sampling program concerning the authenticity, precision, limits of detection and accuracy of the data.

C. Monitoring reports shall also include the following information for each sample that is taken:

1. Water depth
2. Depth of sample
3. Weather conditions
4. Water level stage and direction of flow.

22. **Mercury and Other Toxicants.** The District shall submit a proposed Mercury and Other Toxicants Monitoring Plan as a part of the Water Quality Monitoring Plan requirement in Specific Condition 20 for Department review and approval.

23. **Removal of Parameters.** Upon demonstration that a specific parameter(s) is not present or is found consistently in compliance with water quality standards, the District may request a modification to the monitoring program as appropriate. A minimum of one year's worth of data, for those parameters being sampled quarterly or more frequently, will be required prior to the Department approving any modification to the monitoring program. Parameters sampled semi-annually or annually will be examined on a case-by-case basis. The Department may approve a reduction of the monitoring frequency or waive the monitoring requirement for parameters that consistently are reported as in compliance with state water quality standards.

24. **Addition of Parameters.** If the Department has reason to believe that additional parameters exist that may cause or contribute to water quality violations in the project area, those parameters shall be added to the monitoring section of this permit as a permit modification.

Reporting

25. **Inspection Plan and Reports.** Within 180 days after completion of construction, the District shall submit to the Department, for review and approval, a L-31E Culverts and Deering Estate Inspection Plan to evaluate the integrity and functionality of all structures. Upon Department approval of the submitted plan, the District shall submit annual inspection reports. These reports shall be submitted to the Department in March each year and shall be prepared under the guidance of a professional engineer. The Inspection Report should include a summary of site conditions and the work that was completed in response to inadequacies that may have been found during regular inspections. Every five years, at a minimum, the permitted facilities shall be inspected by a Florida registered professional engineer and the subsequent Inspection Report shall be signed and sealed.

26. **Construction Status Reports.** Construction Status Reports or Construction Meeting Minutes for the project shall be available to the Department throughout the duration of construction activities and shall continue to be submitted until all disturbed areas are successfully stabilized. These Reports may be requested through the Project Manager, Construction Manager, or obtained at the construction meetings.

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27. **Annual Reports.** The District shall submit an "Annual Report" to the Department detailing the progress of the Biscayne Bay Coastal Wetland Project. In addition to the permit number and name of the permit administrator, the Annual Reports shall contain, at a minimum, the following information; the project name, permit number, discussion of project status, and conclusions regarding project success, problems encountered during the period covered, and actions taken to address problems encountered. The annual reporting requirements under this permit shall be incorporated into the South Florida Environmental Report (SFER) and/or as part of other reporting mechanisms which have been deemed acceptable by the Department. These reports shall be submitted to the Department no later than March 1st of each year. If additional reporting modifications are required, the District may request a modification of the Annual Report submission date, and upon approval by the Department, the District may modify the Annual Report submission date to coincide with other reporting requirements and time periods needed for data acquisition and analysis.

A. **Water Quality Data.** Records of monitoring information shall include:

1. Date, location, and time of sampling or measurements;
2. Person responsible for performing the sampling or measurements;
3. Dates analyses were performed or the appropriate code as required by Chapter 62-160, F.A.C.;
4. Person responsible for performing the analyses;
5. Analytical techniques or methods used, including MDL;
6. Results of such analyses, including appropriate data qualifiers;
7. Depth of samples;
8. Flow conditions and weather conditions at time of sampling; and,
9. Monthly flow volumes.

B. **Performance Evaluation.**

1. The operations status of the Project;
2. A comparison of quarterly water quality data using the student's t-test with a 95% confidence interval;
3. During operations, a statistical evaluation of whether the project is performing in a manner consistent with its design objectives/water quality performance estimates. In the event that the project is not performing in this manner, the Department may impose additional evaluation and reporting requirements;
4. Beginning with the second Annual Report, a comparison of performance of current reporting year with performance in previous years.
5. An evaluation of project performance based on ecological/biological monitoring efforts.

C. **Herbicide and Pesticide Tracking.** The District shall provide in each annual report information regarding the application of herbicides and pesticides used to exclude/eliminate undesirable vegetation and pests in the wetted area of the Project. Such reporting shall include the names, concentrations, locations, and quantities of all herbicides and pesticides used.

D. **Implementation Schedules.** When appropriate, the District shall include information on:

1. Comprehensive Everglades Restoration Plan Project implementation;
2. Project optimization;
3. Project design modifications; and,

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4. Implementation of remedial measures in the event of noncompliance with permit conditions.

Renewals and Modifications

28. **Permit Modifications.** The District shall submit proposed modifications to the Biscayne Bay Coastal Wetlands Project to the Department, prior to implementation of the modification, for review and approval.

29. **Permit Renewal.** At least 60 days prior to the expiration date of this permit, the District shall apply for renewal of this permit. Renewal may be for a period of up to 5 years in accordance with Subsection (3)(g) of the CERPRA.

30. **Department Review and Approval.** Where conditions in this permit require Department review of remedial actions or plan modifications to be implemented pursuant to this permit, the Department will consult with the District to ascertain whether a mutual agreement can be reached. If mutual agreement on the remedial actions or plan modifications cannot be reached, the action of the Department will be deemed final agency action and will be subject to judicial or administrative review, as appropriate.

Executed in Tallahassee, Florida.

STATE OF FLORIDA DEPARTMENT
OF ENVIRONMENTAL PROTECTION

Jerry Brooks 5/23/08
Jerry Brooks Date
Director
Division of Environmental Assessment and Restoration

JB/em/bb

FILING AND ACKNOWLEDGMENT

FILED, on this date, with the designated Department Clerk, receipt of which is hereby acknowledged.

Clerk 5/23/08
Clerk Date

ELECTRONIC COPIES FURNISHED TO:
Kenneth Ammon, SFWMD West Palm
Jorge Jaramillo, SFWMD West Palm Beach
Georgia Vince, SFWMD West Palm Beach
Nirmala Jeyakumar, SFWMD West Palm Beach

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Mary Ann Poole, FFWCC
Terri Stoutamire, Dept. of Community Affairs
Rebecca Elliott, Dept. of Agriculture and Consumer Services
Bill Irvine, Director Deering Estate at Cutler, Miami-Dade County
Katy Sorenson, Board of County Commissioners, Miami-Dade County

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TABLE 1: MONITORING REGIME FOR CANAL STATIONS

PARAMETER	UNITS	SAMPLE TYPE	SAMPLING FREQUENCY	SAMPLING LOCATION
Ammonia	mg/l	G	M	MI01, MW01, PR01, BB53
Salinity	mg/l (ppt)	G	M	MI01, MW01, PR01, BB53
TSS	mg/l	G	M	MI01, MW01, PR01, BB53
Color	PCU	G	M	MI01, MW01, PR01, BB53
Dissolved Oxygen	mg/l	G	M	MI01, MW01, PR01, BB53
pH	SU	G	M	MI01, MW01, PR01, BB53
Specific Conductance	uS/cm	G	M	MI01, MW01, PR01, BB53
Temperature	Deg C	G	M	MI01, MW01, PR01, BB53
Total Phosphorus	mg/l	G	M	MI01, MW01, PR01, BB53
Turbidity	NTU	G	M	MI01, MW01, PR01, BB53
NOX	mg/l	G	M	MI01, MW01, PR01, BB53
Flow	CFS	CAL	M	S23A, S23B, S23C, S23D
Stage	NGVD	CAL	M	S21A, S20G, S20F
Mercury	(See Specific Condition 19)			
Pesticides	(See Specific Condition 19)			

Table 1: Key

G – Grab sampling
M – Monthly
CAL - Calculated parameter

TABLE 2: MONITORING REGIME FOR PUMP STATION

PARAMETER	UNITS	SAMPLE TYPE	SAMPLING FREQUENCY	SAMPLING LOCATION
TKN	mg/l	C	Weekly (flow)	CD20
		G	Bi-Weekly (no flow)	
Dissolved Oxygen	mg/l	Insitu	Weekly (flow) or Bi-Weekly (no flow)	CD20

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Permittee: South Florida Water Management District
Project: Biscayne Bay Coastal Wetland Project-Deering Estate Flow-Way
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pH	SU	Insitu	Weekly (flow) or Bi-Weekly (no flow)	CD20
Specific Conductance	uS/cm	Insitu	Weekly (flow) or Bi-Weekly (no flow)	CD20
Temperature	Deg C	Insitu	Weekly (flow) or Bi-Weekly (no flow)	CD20
Total Phosphorus	mg/l	C	Bi-W	CD20
		G	Bi-Weekly (no flow)	
Turbidity	NTU	G	Weekly (flow) or Bi-Weekly (no flow)	CD20
NOX	mg/l	C	Bi-W	CD20
		G	Bi-Weekly (no flow)	
Flow	CFS	CAL	M	CD20
Stage	NGVD	CAL	M	CD20
Mercury	(See Specific Condition 22)			
Pesticides	(See Specific Condition 22)			

Table 2: Key

G – Grab sampling
C – Composite time proportional sampling
Bi-W – Bi - Weekly
Bi-WC – Bi - Weekly Composite
CAL - Calculated parameter

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Project: Biscayne Bay Coastal Wetland Project-Deering Estate Flow-Way
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Figure 1 Deering Estate Flow-way

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E.10.5.2 L-31E Permit

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT CORPS OF ENGINEERS
P. O. BOX 4970
JACKSONVILLE, FLORIDA 32232-0019

REPLY TO ATTENTION OF

MAY 15 2008

Regulatory Division
SAJ-1994-1327(IP-TKW)

Ms. Carol A. Wehle
Executive Director
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

Dear Ms. Wehle:

The U.S. Army Corps of Engineers (Corps) is pleased to enclose the Department of the Army permit, which should be available at the construction site. Work may begin immediately but the Corps must be notified of:

a. The date of commencement of the work,

b. The dates of work suspensions and resumptions of work, if suspended over a week, and

c. The date of final completion.

This information should be mailed to the U.S. Army Corps of Engineers, Regulatory Division, Enforcement Section, Post Office Box 4970, Jacksonville, Florida 32232-0019. The Enforcement Section is also responsible for inspections to determine whether Permittees have strictly adhered to permit conditions.

IT IS NOT LAWFUL TO DEVIATE FROM
THE APPROVED PLANS ENCLOSED.

Sincerely,

Paul L. Grosskruger
Colonel, U.S. Army
District Commander

Enclosures

-2-

Copies Furnished:

U.S. Fish and Wildlife Service, South Florida Ecological Services Office, 1339 20th Street, Vero Beach, Florida 32960
South Florida Office, U.S. Environmental Protection Agency, 400 North Congress Avenue, Suite 120, West Palm Beach, Florida 33401

DEPARTMENT OF THE ARMY PERMIT

RECEIVED
MAY 02 2008
JACKSONVILLE DISTRICT
USACE

Permitted: SOUTH FLORIDA WATER MANAGEMENT DISTRICT
3301 GUN CLUB ROAD
WEST PALM BEACH, FLORIDA 33406

Permit No: SAJ-1994-1327(IP-TKW)

Issuing Office: U.S. Army Engineer District, Jacksonville

NOTE: The term "you" and its derivatives, as used in this permit, means the Permittee or any future transferee. The term "this office" refers to the appropriate district or division office of the Corps of Engineers having jurisdiction over the permitted activity or the appropriate official of that office acting under the authority of the commanding officer.

You are authorized to perform work in accordance with the terms and conditions specified below.

Project Description: The project includes installation of flap-gated culverts at four locations along the L-31E Canal, connecting the canal with coastal wetlands along Biscayne Bay. Each culvert consists of 36" bituminous coated corrugated metal pipe with flashboard risers at the culvert intake and aluminum flap gates fixed to concrete end walls. Discharge culverts include a 10-foot wide, 4-foot deep canal excavated from the L-31E Canal to the end wall for each culvert and from the downstream end wall to the property limit. Following excavation, riprap will be placed throughout the excavated area in the canal bottoms. As a result of the project 0.33 acre of jurisdictional Waters of the United States will be impacted through excavation and subsequent fill. The work described above is to be completed in accordance with the following: (1) project plans and specifications (Attachment 1), (2) State Water Quality Certification (Attachment 2), and (3) seven additional attachments affixed at the end of this permit instrument.

Project Location: The proposed project is located along the L-31E Canal, east of the L-31E Levee, within coastal wetlands of Biscayne Bay, in Sections 28 and 33, Township 56 south, Range 40 east, and in Sections 4, 9, and 16, Township 57 south, Range 40 east, Miami-Dade County, Florida. The project site is bordered by Biscayne Bay to the east, the L-31E Levee and Canal to the west, C-102 Canal to the north, and the C-103 Canal to the south. The project is located within the U.S. Geological Survey's 8-

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digit Hydrologic Unit Code (HUC) 03090202, South East Florida Coast.

Culvert 1 (S-23B) Latitude 25° 30′ 40″ Longitude 80° 20′ 50″
Culvert 2 (S-23A) Latitude 25° 30′ 59″ Longitude 80° 20′ 49″
Culvert 3 (S-23D) Latitude 25° 28′ 37″ Longitude 80° 20′ 48″
Culvert 5 (S-23C) Latitude 25° 28′ 51″ Longitude 80° 20′ 49″

Permit Conditions

General Conditions:

1. The time limit for completing the work authorized ends on **November 13, 2012**. If you find that you need more time to complete the authorized activity, submit your request for a time extension to this office for consideration at least one month before the above date is reached.

2. You must maintain the activity authorized by this permit in good condition and in conformance with the terms and conditions of this permit. You are not relieved of this requirement if you abandon the permitted activity, although you may make a good faith transfer to a third party in compliance with General Condition 4 below. Should you wish to cease to maintain the authorized activity or should you desire to abandon it without a good faith transfer, you must obtain a modification of this permit from this office, which may require restoration of the area.

3. If you discover any previously unknown historic or archeological remains while accomplishing the activity authorized by this permit, you must immediately notify this office of what you have found. We will initiate the Federal and State coordination required to determine if the remains warrant a recovery effort or if the site is eligible for listing in the National Register of Historic Places.

4. If you sell the property associated with this permit, you must obtain the signature and the mailing address of the new owner in the space provided and forward a copy of the permit to this office to validate the transfer of this authorization.

5. If a conditioned water quality certification has been issued for your project, you must comply with the conditions

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specified in the certification as special conditions to this permit. For your convenience, a copy of the certification is attached if it contains such conditions.

6. You must allow representatives from this office to inspect the authorized activity at any time deemed necessary to ensure that it is being or has been accomplished in accordance with the terms and conditions of your permit.

Special Conditions: The terms used in these permits will have the same definition as those terms in 33 CFR Part 385.3, unless otherwise defined.

1. All submittals and reports required under this permit and all subsequent modifications must be provided to the following addresses in hard copy format:

U.S. Army Corps of Engineers (USACE)
South Florida Restoration Program Office
1400 Centrepark, Suite 750
West Palm Beach, Florida 33401
Re: Project No: SAJ-1994-1327(IP-TKW)

U.S. Army Corps of Engineers
Enforcement Section (CESAJ-RD-PE)
P.O. Box 4970
Jacksonville, Florida 32232-0019
Re: Project No: SAJ-1994-1327(IP-TKW)

These submittals may be provided in the single Consolidated Annual Report, i.e., the South Florida Environmental Report on March 1 of each year.

2. The Permittee shall conduct a pre-construction meeting a minimum of 5 days prior to commencement of construction in order to notify contractors of the requirements of the permit. The Permittee shall provide a minimum of 48 hours advance notification of the pre-construction meeting to the USACE, South Florida Restoration Program Office.

3. The Permittee shall notify the USACE, South Florida Restoration Program Office, in writing at least 48 hours prior to commencement of the work authorized by this permit.

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4. The Permittee must provide to the USACE as-built drawings of the authorized work and an As-Built Certification Form (Attachment 3). The drawings and Certification Form must be submitted to the USACE within 60 days of completion of the authorized work, or at the expiration of the construction window of this permit, whichever occurs first. The drawings must be signed and sealed by a registered professional engineer and include the following:

a. A plan view drawing of the location of the authorized work footprint (as shown on the permit drawings) with an overlay of the work as constructed in the same scale as the attached permit drawings (8½-inch by 11-inch). The drawing should show all "earth disturbance," including wetland impacts, water management structures, and any on-site mitigation areas.

b. List any deviations between the work authorized by this permit and the work as constructed. In the event that the completed work deviates, in any manner, from the authorized work, the Permittee shall describe, on the As-Built Certification Form, the deviations between the work authorized by this permit and the work as constructed. Clearly indicate on the as-built drawings any deviations that have been listed. *Please note that the depiction and/or description of any deviations on the drawings and/or As-Built Certification Form does not constitute approval of any deviations by the U.S. Army Corps of Engineers.*

c. The Department of the Army Permit number.

d. Include pre- and post-construction aerial photographs of the project site, if available.

5. Conditions for projects the Permittee plans to construct in furtherance of the Comprehensive Everglades Restoration Plan (CERP), but which are being constructed in advance of final authorization/approval of the associated CERP Project Implementation Report (PIR) and/or execution of a Project Cooperation Agreement (PCA):

a. The USACE' analysis of this permit application pursuant to applicable regulations and the National Environmental Policy

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Act (NEPA) may need to be supplemented as new information becomes available and/or to meet requirements for modifications of the permit.

b. The USACE' decision that this project has independent utility is made solely for the purpose of permitting and does not mean that it is or is not a separable project under CERP.

c. Issuing this permit does not constitute approval of any engineering or design for any future consideration of the project under CERP.

d. Future action on related portions of this project or other projects being implemented under CERP may require additional NEPA compliance analysis and documentation or other related analyses under the USACE' Civil Works Planning Process.

e. The issuance of this permit does not constitute a recommendation by the Chief of Engineers for congressional authorization of this project for construction or implementation as a feature or component of an authorized CERP project.

f. The issuance of this permit does not constitute approval of this project as being necessary, integral, and cost effective for consideration of cost sharing for the planning, design, engineering, construction or implementation of a feature of CERP.

g. Any work under an authorized federal project cannot be considered for any mitigation that may be required by issuance of this permit

h. The Permittee is required to design, construct, and operate the project consistent with the Central and Southern Florida Project as modified.

i. The permit specific conditions will be reevaluated if a PCA is executed on an authorized CERP project, which includes the Acceler8 project feature, in order to relieve the Permittee of specific conditions that are no longer applicable.

6. Environmental Commitments:

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a. The Permittee shall employ best management practices with regard to erosion and turbidity control and shall monitor water quality in accordance with the requirements of the Florida Department of Environmental Protection Permit No. 0271729-001-GL dated September 10, 2007 (Attachment 2). The Permittee shall ensure the project remains in compliance with State Water Quality Certification for the life of the project.

b. The contract specifications will prohibit the contractor from dumping oil, fuel, or hazardous wastes in the work area and will require that the contractor adopt safe and sanitary measures for the disposal of solid wastes in accordance with federal, state, and local requirements. The Permittee shall develop an environmental protection plan to address concerns regarding monitoring of equipment, maintenance and security of fuels, lubricants, and spill prevention.

c. Demolition debris will be disposed of in accordance with federal, state, and local requirements.

7. Wildlife/Listed Species Conditions:

a. Prior to construction, the Permittee shall inform contractor personnel of the potential presence of threatened and endangered species in the project area, the need for precautionary measures, and the ESA prohibition on taking listed species. All Construction contractors will be trained and briefed on how to identify and avoid harm and harassment to federally listed wildlife species as well as conditions under which the U.S. Fish and Wildlife Service (USFWS) should be notified. The USFWS shall be notified upon observation of nesting activity of any listed federal species. Both the Florida Fish and Wildlife Conservation Commission (FFWCC) and the USFWS will be consulted in the event that colonial or solitary wading bird nests are observed within the construction footprint. The USFWS will be notified upon locating a dead, injured, or sick wood stork or bald eagle before, during, and after construction of the project.

b. The following conservation measures will be incorporated into the project to minimize effects to any federally protected species that may be present:

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(1) *Standard Protection Measures for the Eastern Indigo Snake* (Attachment 4),

(2) *Clearance to Proceed with Construction Activities Adjacent to Bald Eagle Nests* available on the internet at http://www.fws.gov/verobeach/Programs/Permits/Section7.html and incorporated into the permit by reference,

(3) *Habitat Guidelines for the Wood Stork in the Southeast Region* available on the internet at http://www.fws.gov/verobeach/Programs/Permits/Section7.html and incorporated into the permit by reference,

(4) *Standard Manatee Conditions for In-Water Work, 2005* (Attachment 5),

(5) USFWS *Guidelines for Culverts Located in Manatee-Accessible CERP Projects* (Attachment 6),

(6) *Sea Turtle and Smalltooth Sawfish Construction Conditions* (Attachment 7)

(7) Protection measures for the American crocodile (Attachment 8)

8. Historic Properties:

a. No work is authorized by this permit on properties listed or eligible for listing in the National Register of Historic Places.

b. If prehistoric or historic artifacts, such as pottery or ceramics, stone tools or metal implements, dugout canoes, or any other physical remains that could be associated with Native American cultures, or early colonial or American settlement are encountered at any time within the project site area, the permitted project should cease all activities involving the subsurface disturbance in the immediate vicinity of such discoveries. The Permittee, or other designee, should contact the Florida Department of State, Division of Historical Resources, Review and Compliance Section at 850-245-6333 or 800-847-7278. Project activities should not resume without verbal and/or written authorization from the permitting agency.

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c. In the event that unmarked human remains are encountered during permitted activities, all work shall stop immediately and the proper authorities notified in accordance within Section 872.05, Florida Statutes.

9. Compensatory Mitigation:

a. The decision on this permit included consideration of environmental benefits expected to result from the construction of the work authorized herein. These environmental benefits are projected to offset the adverse effects of such works, as identified in the Unified Mitigation Assessment Methodology score sheet attached to this permit (Attachment 9). Specifically, wetland impacts as a result of the project are anticipated to be offset by project benefits which include enhancement to salinity concentrations, water stages, wetland vegetation, and algal composition within the wetland areas affected by culvert water deliveries. This area is estimated to be about one acre for each culvert and is hereby referred to as the "mitigation enhancement area".

b. The benefits provided by this Acceler8 project in and of itself have not currently been identified by the REstoration COordination and VERification (RECOVER) Assessment Team in the Monitoring and Assessment Plan (MAP). For this reason, project level ecological monitoring is required by the Permittee. If the Permittee is granted Department of the Army authorization to implement other components of the CERP BBCW Project that are not part of this permit action or if the project monitoring and assessment plans are updated, modified, or incorporated into other programs such as RECOVER's MAP, the permit conditions will be re-evaluated to incorporate additional monitoring requirements, and/or to relieve the Permittee of specific conditions that are no longer applicable, or to modify the specific conditions to avoid any duplicative monitoring.

10. Performance Standards: The Permittee shall submit an ecological and water quality monitoring plan to the USACE for approval prior to completion of construction. The monitoring plan shall include at least two of the culvert locations including the mitigation enhancement areas. The monitoring plan will define the performance measures, targets, and success

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criteria for the four mitigation enhancement areas. Based on the objectives of the project, the performance standards to be described in the monitoring plan are generally described below:

a. Improvement to the aquatic food web, including establishment of appropriate wetland periphyton communities that reflect an increasing salinity gradient from the culverts eastward to the shoreline. No increase in pollution tolerant plant species or elimination/reduction of existing desirable species.

b. Less than 5 percent cover of Category I and II invasive exotic plant species, pursuant to the most current list established by the Florida Exotic Pest Plant Council at http://www.fleppc.org particularly Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (*Casuarina* spp.) and including but not limited to the following nuisance species: primrose willow (*Ludwigia peruviana*), dogfennel (*Eupatorium capillifolium*), Bermudagrass (*Cynodon spp.*), Bahiagrass (*Paspalum notatum*), and cattail (*Typha* spp.) within the mitigation enhancement areas.

c. Hydrologic enhancement by redirecting flow from coastal canals to the coastal wetlands at the culvert delivery points. This permit acknowledges the project is anticipated to capture approximately 4% of the available water from the major conveyance canals (C-102 and C-103) and redistribute the water at the culvert locations thereby recreating/restoring remnant tidal creeks or portions thereof or associated wetland areas.

d. Salinity concentrations in coastal wetlands become more suitable and hypersaline zones are reduced. The direction and movement of the salinity gradient of restored tidal creeks in interior wetlands will be measured to ensure parameters more characteristic of an estuarine system.

The Permittee must achieve the above performance standards by the end of the 3rd year of monitoring within the mitigation enhancement areas, with no maintenance during the 3rd year of monitoring. In the event that the above performance standards have not been achieved the Permittee must undertake a remediation program approved by the USACE in accordance with Special Condition 13 of this permit.

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11. Monitoring and Reporting Timeframes: To show compliance with the performance standards the Permittee must complete the following:

a. Perform a time-zero monitoring event of two of the four culvert locations including the area anticipated to be enhanced by water deliveries within 60 days of completion of culvert installation.

b. Submit the time-zero report to the USACE within 60 days of completion of the monitoring event. The report will include a paragraph depicting baseline conditions of the site including information on wetland stage, vegetation, and algae.

c. Perform annual monitoring of at least two of the four culvert locations including areas affected by water deliveries for a period of no less than 3 years subsequent to completion of the project.

d. Submit annual monitoring reports to the USACE within 60 days of completion of the monitoring event.

e. Monitor at least two of the four culvert locations including areas affected by water deliveries and submit annual monitoring reports to the USACE until released in accordance with Special Condition 14 of this permit.

12. Reporting Format: Annual monitoring reports must follow a 10-page maximum report format for assessing mitigation sites. The Permittee must submit all documentation to the USACE on 8½-inch by 11-inch paper, and include the following:

a. Project Overview (1 Page):

(1) USACE Permit Number.

(2) Name and contact information of Permittee and consultant.

(3) Name of party responsible for conducting the monitoring and the date(s) the inspection was conducted.

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(4) A summary paragraph defining the purpose for the approved project, acreage and type of aquatic resources impacted, and acreage and type of aquatic resources authorized to compensate for the aquatic impacts. This includes an estimate of the wetland and/or remnant creek acres influenced as a result of each the culvert installations.

(5) Written description on the location and any identifiable information to locate the site perimeter(s).

(6) Directions to the project site (from a major highway).

(7) Dates project commenced and/or was completed.

(8) Short statement on whether the performance standards are being met.

(9) Dates of any recent corrective or maintenance activities conducted since the previous report submission.

(10) Specific recommendations for any additional corrective or remedial actions.

b. Requirements (1 page): List the monitoring requirements and performance standards, as specified in the ecological monitoring plan and special conditions of this permit, and evaluate whether the project site is successfully achieving the approved performance standards or trending towards success. Monitoring requirements include but are not limited to salinity, water quality, water stage, wetland vegetation, and algal composition.

c. Summary Data (maximum of 4 pages): Data must be provided to substantiate the success and/or potential challenges associated with the project. Any photo documentation must be dated and clearly labeled with the direction from which the photo was taken, and be identified on the appropriate maps.

d. Maps (maximum of 3 pages): Maps must be provided to show the location of the culverts and areas affected by water deliveries relative to other landscape features, habitat types,

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locations of photographic reference points, transects, sampling data points, and/or other features pertinent to the project.

e. Conclusions (1 page): A general statement must be included describing the conditions of the project and whether the net positive environmental benefits are being achieved. If performance standards are not being met, a brief explanation of the difficulties and potential remedial actions proposed by the Permittee, including a timetable, must be provided.

13. Remediation: If the project fails to meet the performance standards at the end of 3 years after completion of culvert installation, the project will be deemed unsuccessful. Within 60 days of notification by the USACE that the project is unsuccessful, the Permittee must submit to the USACE an alternate compensatory mitigation proposal to fully offset the functional loss that occurred as a result of the project. The alternate mitigation proposal may be required to include additional mitigation to compensate for the temporal loss of wetland function associated with the unsuccessful compensatory mitigation activities. The USACE reserves the right to fully evaluate, amend, and approve or reject the alternate compensatory mitigation proposal. Within 120 days of USACE approval, the Permittee will complete the alternate compensatory mitigation proposal.

14. Mitigation Release: Your responsibility to complete the required compensatory mitigation, as set forth in Special Condition of this permit will not be considered fulfilled until you have demonstrated mitigation success and have received written verification from the USACE or until a PCA for a CERP project that includes the project is executed and the USACE determines that these mitigation and monitoring conditions are superseded by PCA execution, in whole or in part. A mitigation area which has been released will require no further monitoring or reporting by the Permittee; however the Permittee, Successors and subsequent Transferees remain perpetually responsible to ensure that the mitigation area(s) remain in a condition appropriate to offset the authorized impacts in accordance with General Condition 2 of this permit.

15. None of the authorizations or conditions in this permit are intended to diminish or alter the governmental authority and

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powers of the Miccosukee Tribe of Indians and the Seminole Tribe of Florida (Tribes), or diminish or alter the rights of those tribes, including rights under any tribal agreement with the permittee or any agency of the U.S. Government. The permittee shall advise this office and the Tribes when the permittee becomes aware of issues implicating the powers or rights of the Tribes or other issues that may make necessary a modification to the permit.

16. The Permittee shall submit to this office any revisions and/or modifications to the underlying design documents and drawings for the enclosed project plans. The Permittee is advised that failure to provide complete requests for permit modifications or complete monitoring reports as required by any of the conditions above, may prevent this office from issuing future modifications to this permit and authorizations for further construction, even if the particular incomplete submittal is for a different portion of the project.

Further Information:

1. Congressional Authorities: You have been authorized to undertake the activity described above pursuant to:

(X) Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403).

(X) Section 404 of the Clean Water Act (33 U.S.C. 1344).

( ) Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. 1413).

2. Limits of this authorization.

a. This permit does not obviate the need to obtain other Federal, State, or local authorizations required by law.

b. This permit does not grant any property rights or exclusive privileges.

c. This permit does not authorize any injury to the property or rights of others.

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d. This permit does not authorize interference with any existing or proposed Federal projects.

3. Limits of Federal Liability. In issuing this permit, the Federal Government does not assume any liability for the following:

a. Damages to the permitted project or uses thereof as a result of other permitted or unpermitted activities or from natural causes.

b. Damages to the permitted project or uses thereof as a result of current or future activities undertaken by or on behalf of the United States in the public interest.

c. Damages to persons, property, or to other permitted or unpermitted activities or structures caused by the activity authorized by this permit.

d. Design or construction deficiencies associated with the permitted work.

e. Damage claims associated with any future modification, suspension, or revocation of this permit.

4. Reliance on Applicant's Data: The determination of this office that issuance of this permit is not contrary to the public interest was made in reliance on the information you provided.

5. Reevaluation of Permit Decision: This office may reevaluate its decision on this permit at any time the circumstances warrant. Circumstances that could require a reevaluation include, but are not limited to, the following:

a. You fail to comply with the terms and conditions of this permit.

b. The information provided by you in support of your permit application proves to have been false, incomplete, or inaccurate (see 4 above).

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c. Significant new information surfaces which this office did not consider in reaching the original public interest decision.

Such a reevaluation may result in a determination that it is appropriate to use the suspension, modification, and revocation procedures contained in 33 CFR 325.7 or enforcement procedures such as those contained in 33 CFR 326.4 and 326.5. The referenced enforcement procedures provide for the issuance of an administrative order requiring you comply with the terms and conditions of your permit and for the initiation of legal action where appropriate. You will be required to pay for any corrective measures ordered by this office, and if you fail to comply with such directive, this office may in certain situations (such as those specified in 33 CFR 209.170) accomplish the corrective measures by contract or otherwise and bill you for the cost.

6. Extensions: General Condition 1 establishes a time limit for the completion of the activity authorized by this permit. Unless there are circumstances requiring either a prompt completion of the authorized activity or a reevaluation of the public interest decision, the USACE will normally give favorable consideration to a request for an extension of this time limit.

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PERMITTEE: SOUTH FLORIDA WATER MANAGEMENT DISTRICT
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Your signature below, as Permittee, indicates that you accept and agree to comply with the terms and conditions of this permit.

(EXECUTIVE DIRECTOR) April 25, 2008
(DATE)
Carol A. Wehle
South Florida Water Management District

This permit becomes effective when the Federal official, designated to act for the Secretary of the Army, has signed below.

(DISTRICT ENGINEER) 12 May 2008
(DATE)
Paul L. Grosskruger
Colonel, U.S. Army
District Commander

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When the structures or work authorized by this permit are still in existence at the time the property is transferred, the terms and conditions of this permit will continue to be binding on the new owner(s) of the property. To validate the transfer of this permit and the associated liabilities associated with compliance with its terms and conditions, have the transferee sign and date below.

_____ _____
(TRANSFEREE-SIGNATURE) (DATE)

_____
(NAME-PRINTED)

_____
(ADDRESS)

_____
(CITY, STATE, AND ZIP CODE)

PERMIT NUMBER: SAJ-1994-1327(IP-TKW)
PERMITTEE: SOUTH FLORIDA WATER MANAGEMENT DISTRICT
PAGE 18 of 18

Attachments to Department of the Army Permit Number SAJ-1994-1327(IP-TKW)

1. L-31E CULVERTS BISCAYNE BAY COASTAL WETLANDS-PHASE 1 MIAMI-DADE COUNTY, FLORIDA PROJECT PLANS AND SPECIFICATIONS: 16 sheets dated September 7, 2007

2. WATER QUALITY CERTIFICATION: Specific Conditions of the water quality permit/certification in accordance with General Condition number 5 on page 2 of this DA permit; 14 pages dated September 10, 2007 (without attachments).

3. AS-BUILT CERTIFICATION FORM: 1 page

4. STANDARD PROTECTION MEASURES FOR THE EASTERN INDIGO SNAKE: 1 page.

5. STANDARD MANATEE CONSTRUCTION CONDITIONS: 2 pages dated June 2001

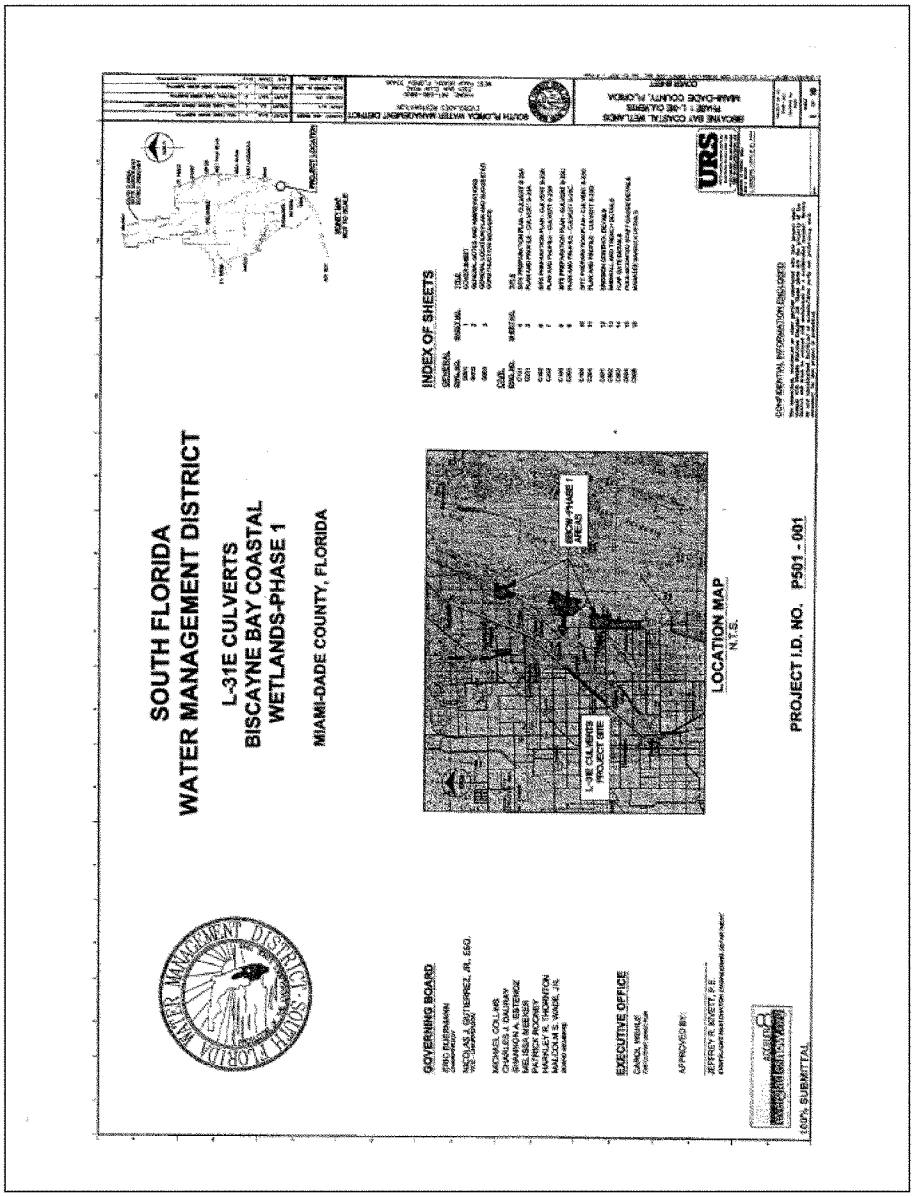
6. U.S. FISH AND WILDLIFE SERVICE GUIDELINES FOR CULVERTS LOCATED IN MANATEE-ACCESSIBLE CERP PROJECT: 1 page

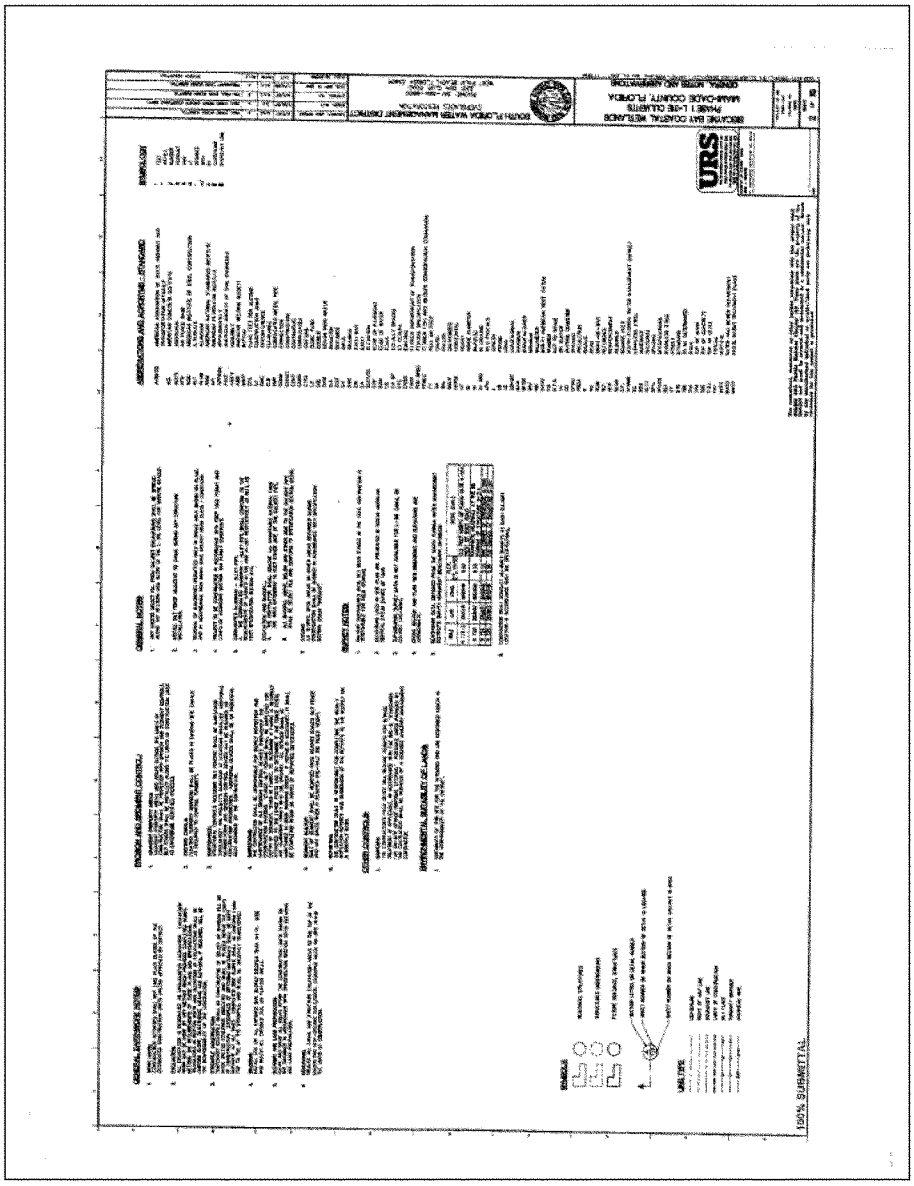
7. SEA TURTLE AND SMALLTOOTH SAWFISH CONSTRUCTION CONDITIONS: 1 page dated March 23, 2006

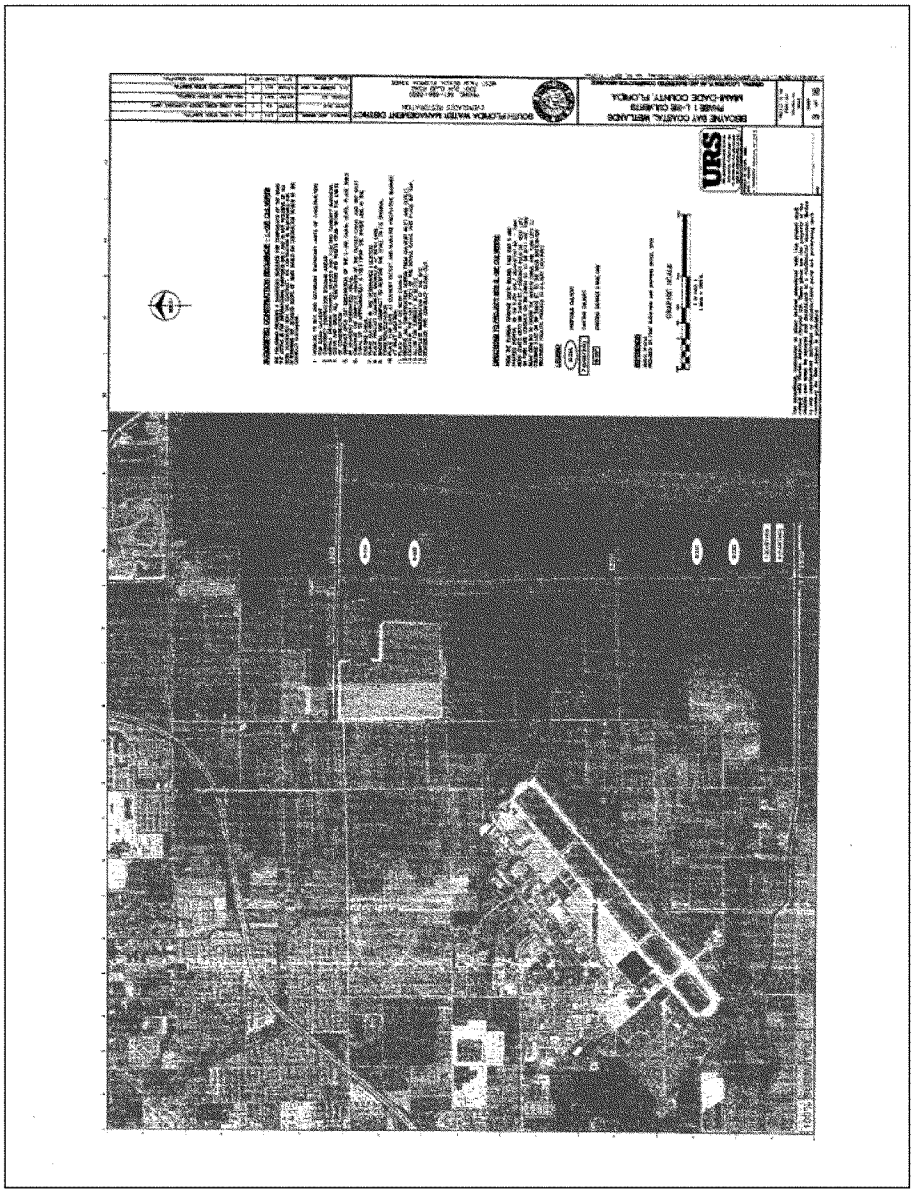
8. PROTECTION MEASURES FOR THE AMERICAN CROCODILE: 1 page dated June 12, 2007

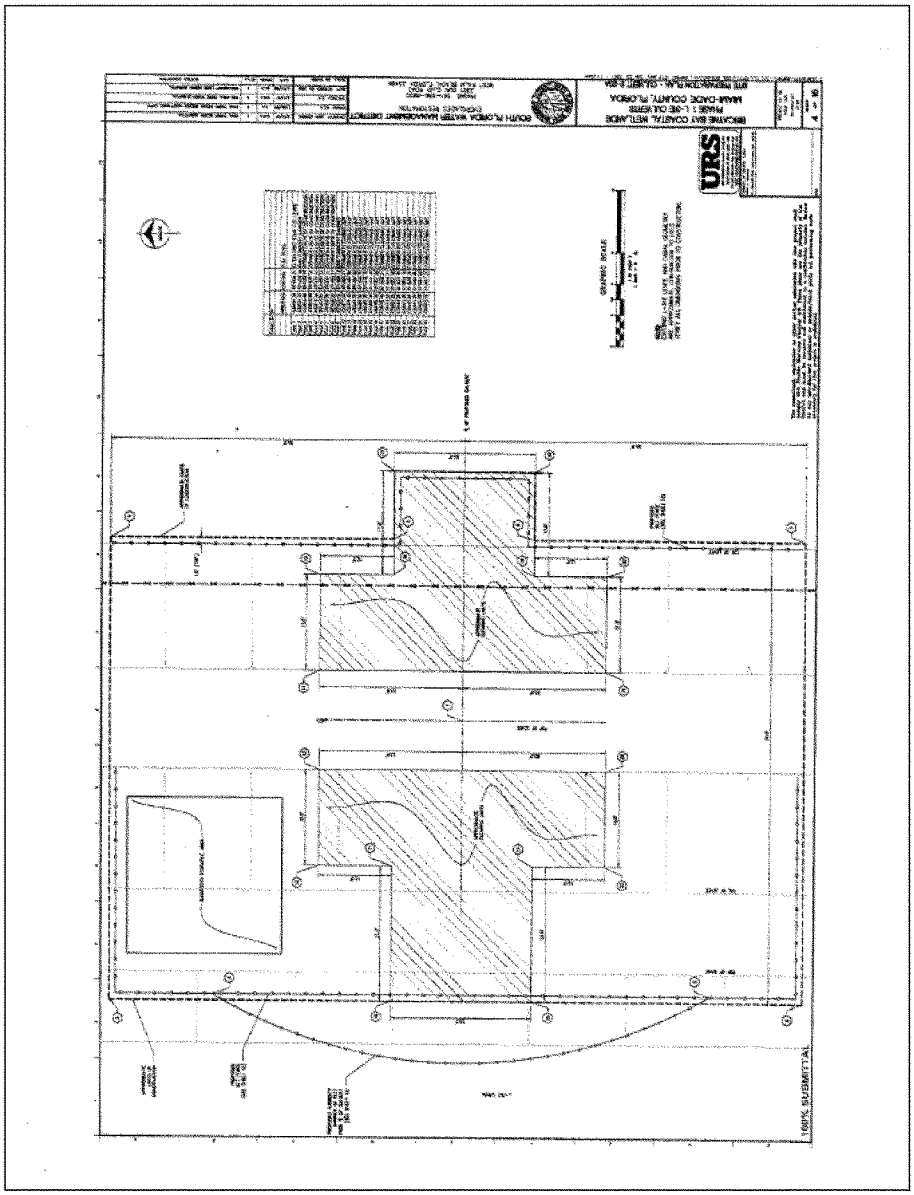
9. L-31E CUVLERTS UNIFIED MITIGATION ASSESSMENT METHODOLOGY SCORE SHEET: 1 page, dated November 5, 2007

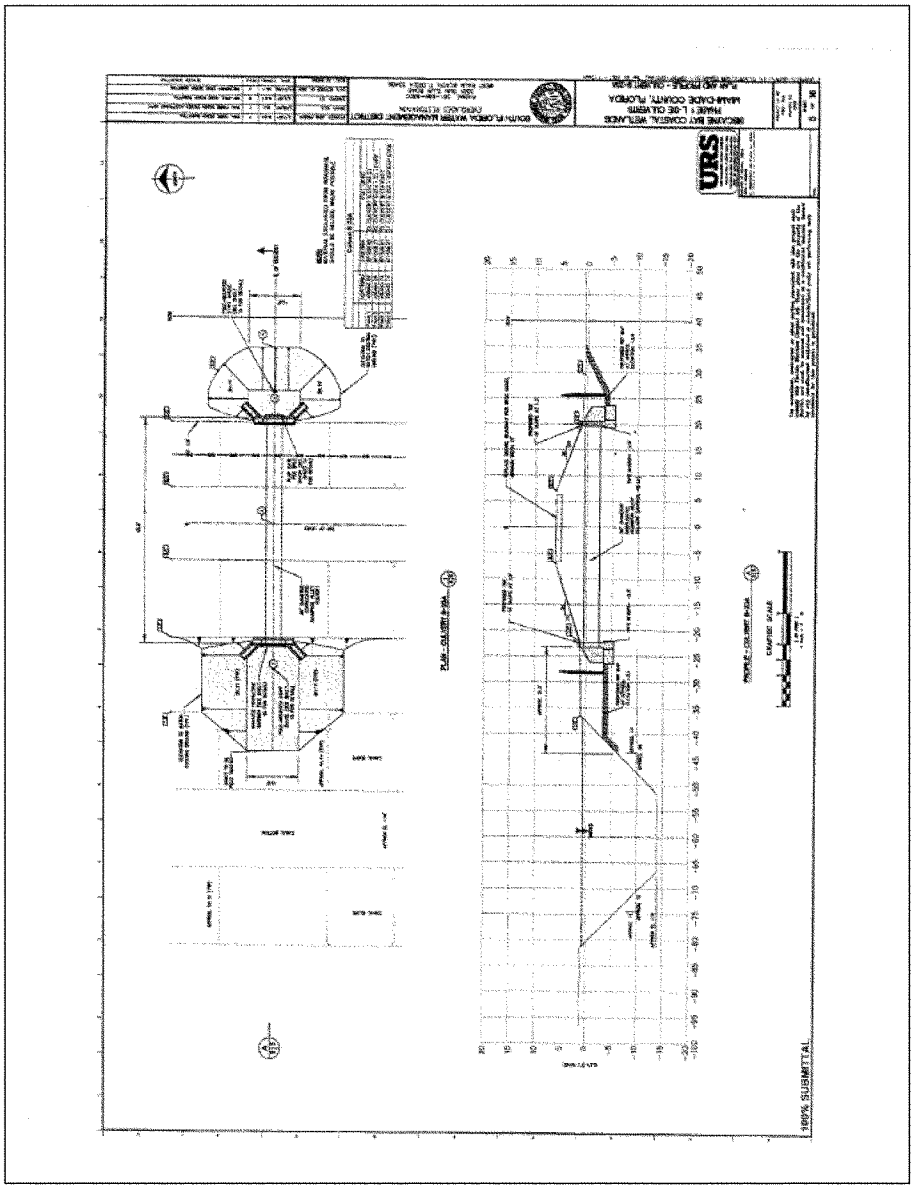
Attachment 1
Project Plans and Specifications


SOUTH FLORIDA
WATER MANAGEMENT DISTRICT
L-31E CULVERTS
BISCAYNE BAY COASTAL
WETLANDS-PHASE 1
MIAMI-DADE COUNTY, FLORIDA
INDEX OF SHEETS
GOVERNING BOARD
EXECUTIVE OFFICE
LOCATION MAP
N.T.S.
PROJECT I.D. NO. P501 - 001
URS
60% SUBMITTAL





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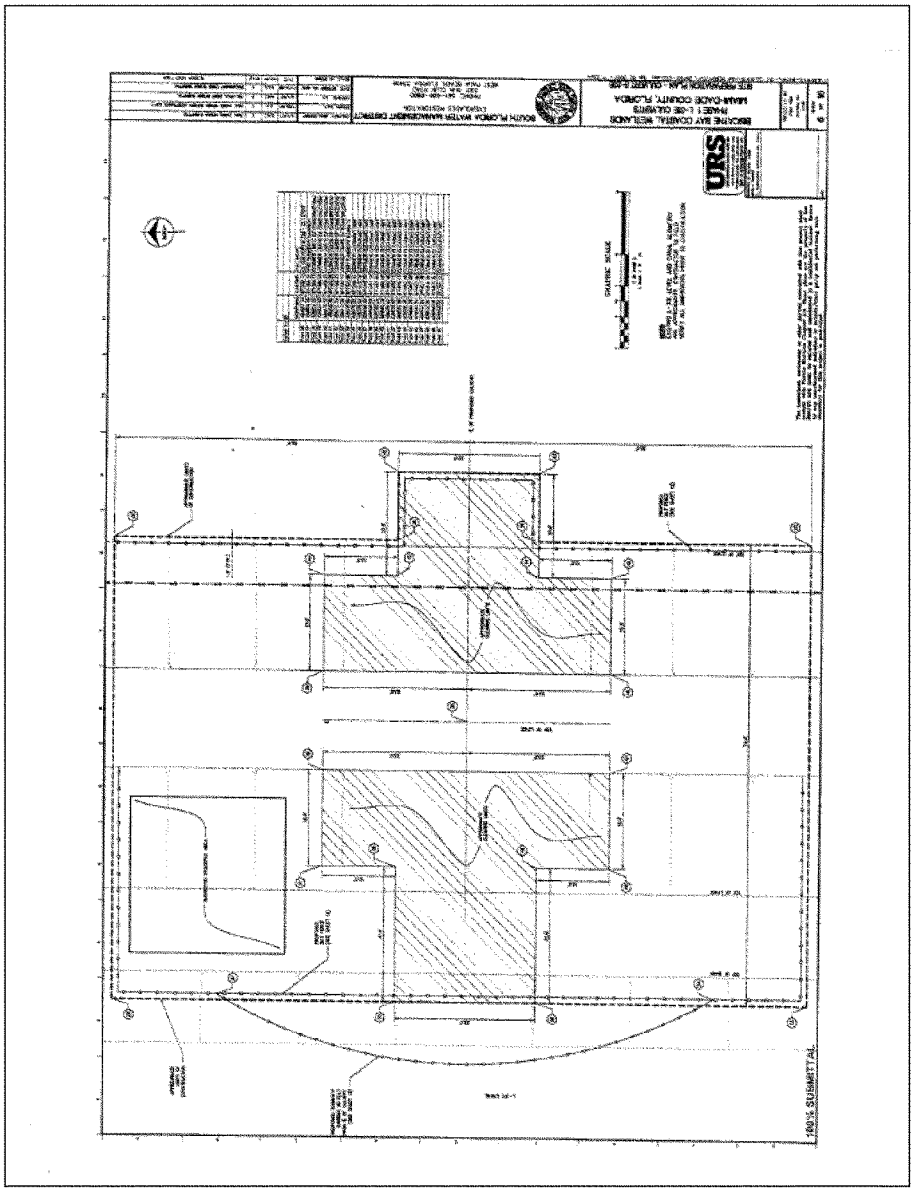

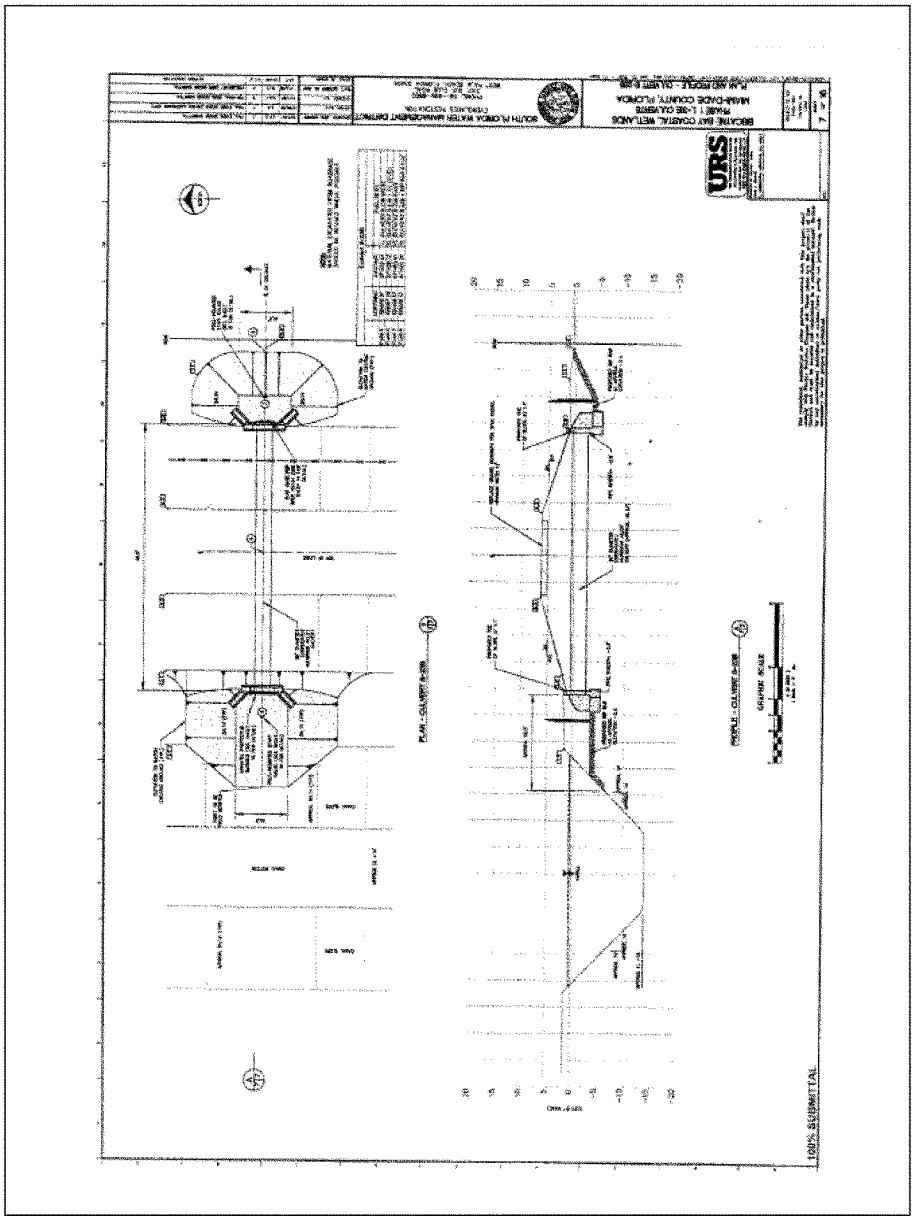
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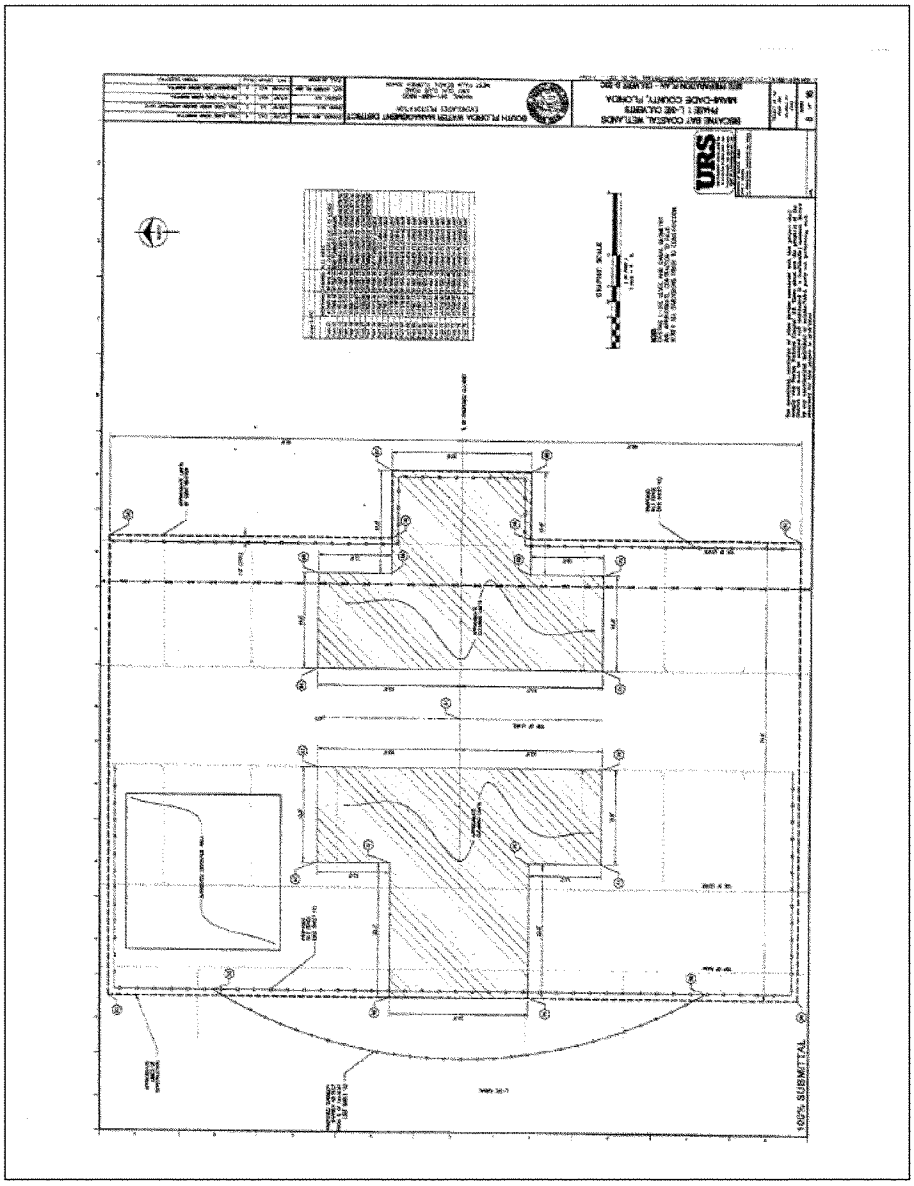

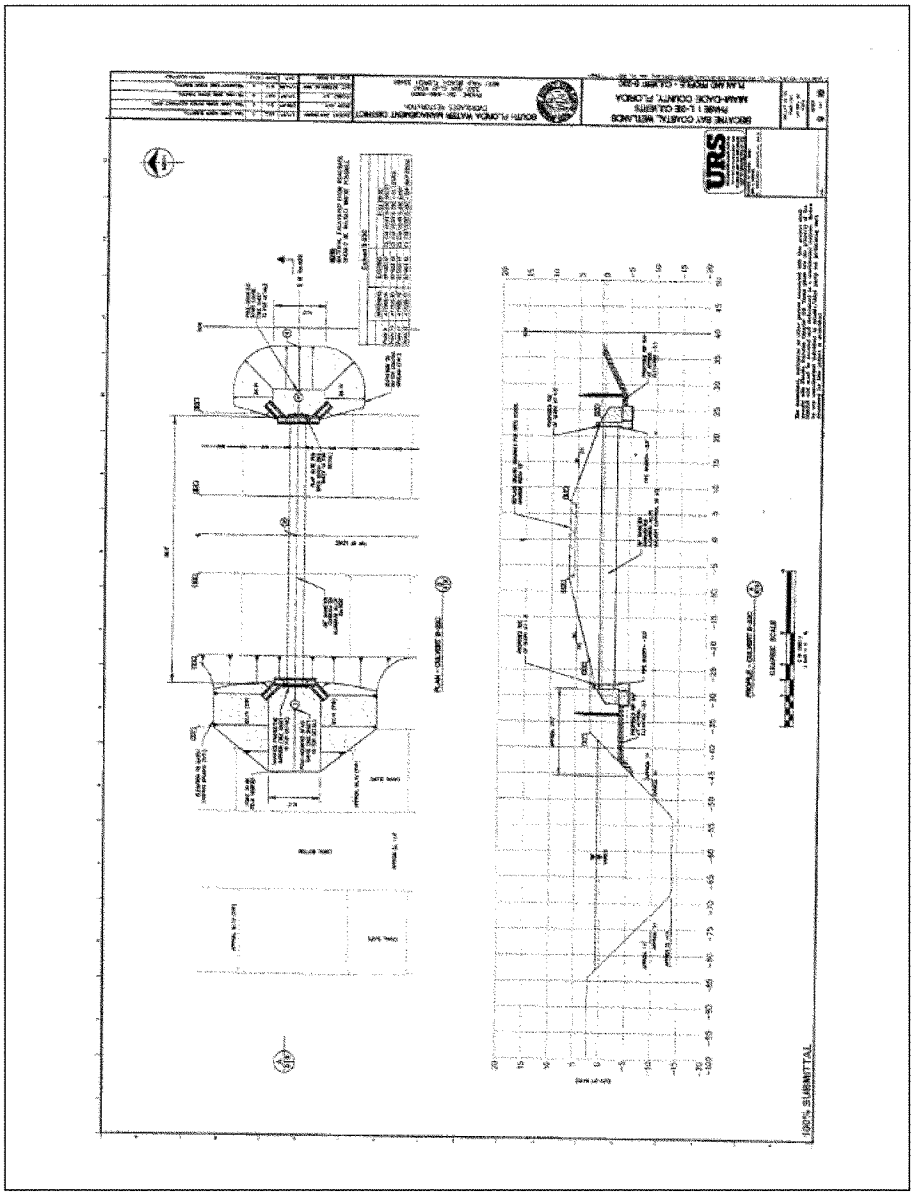

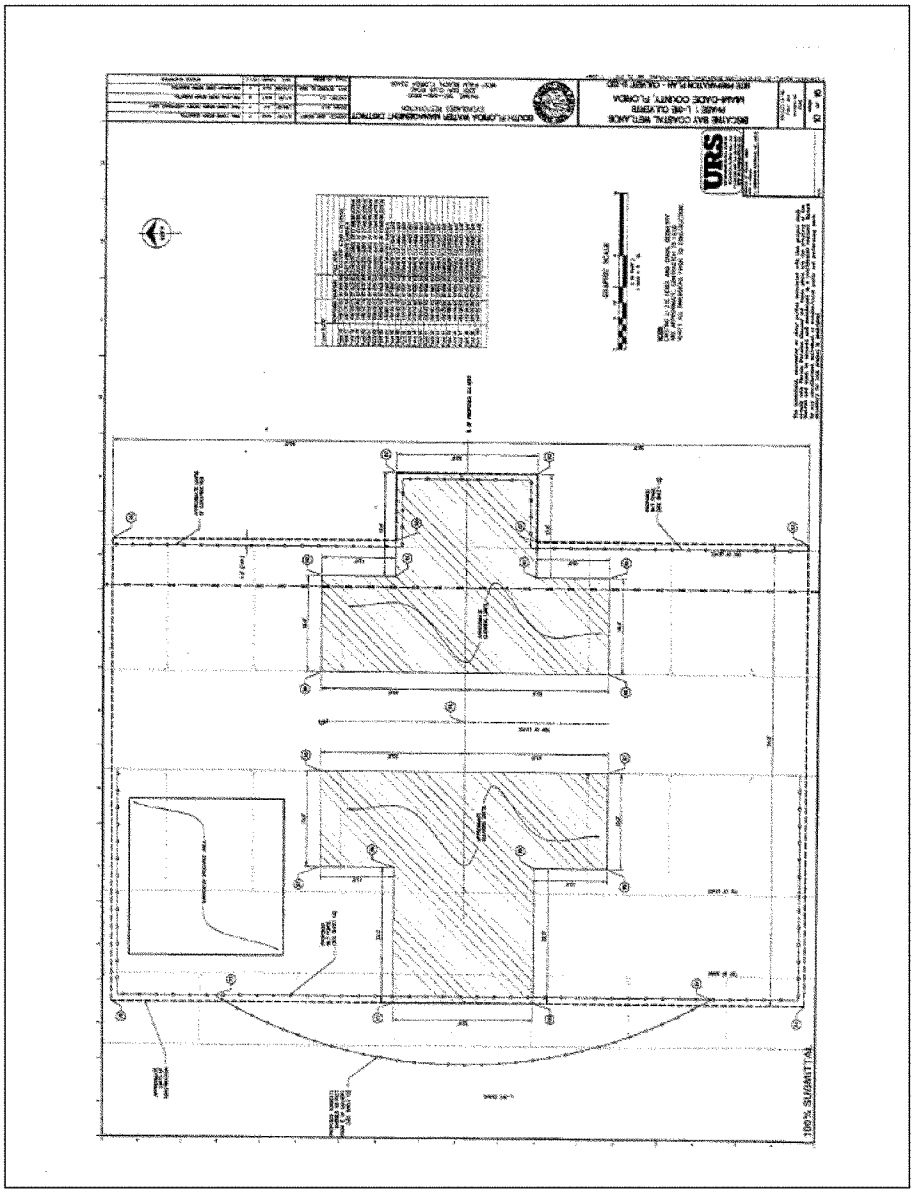

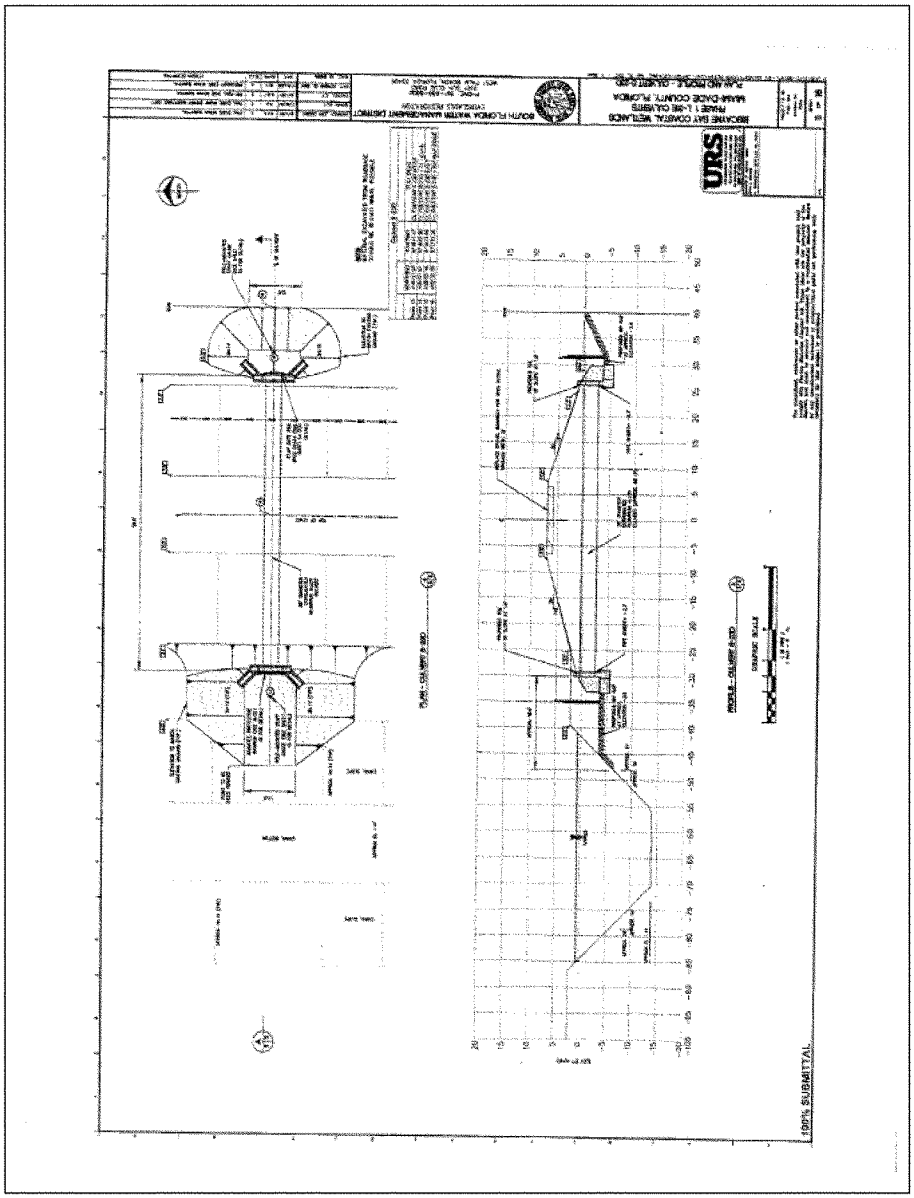

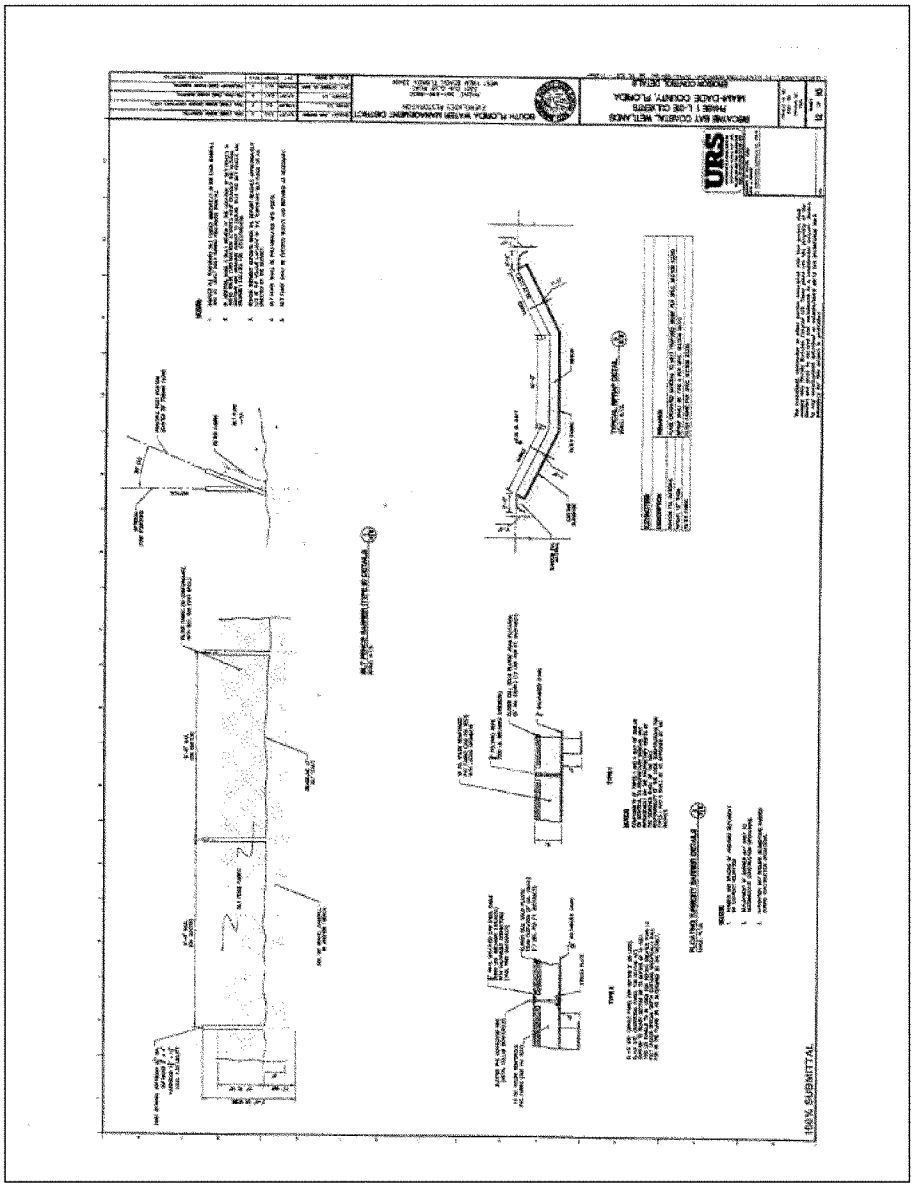
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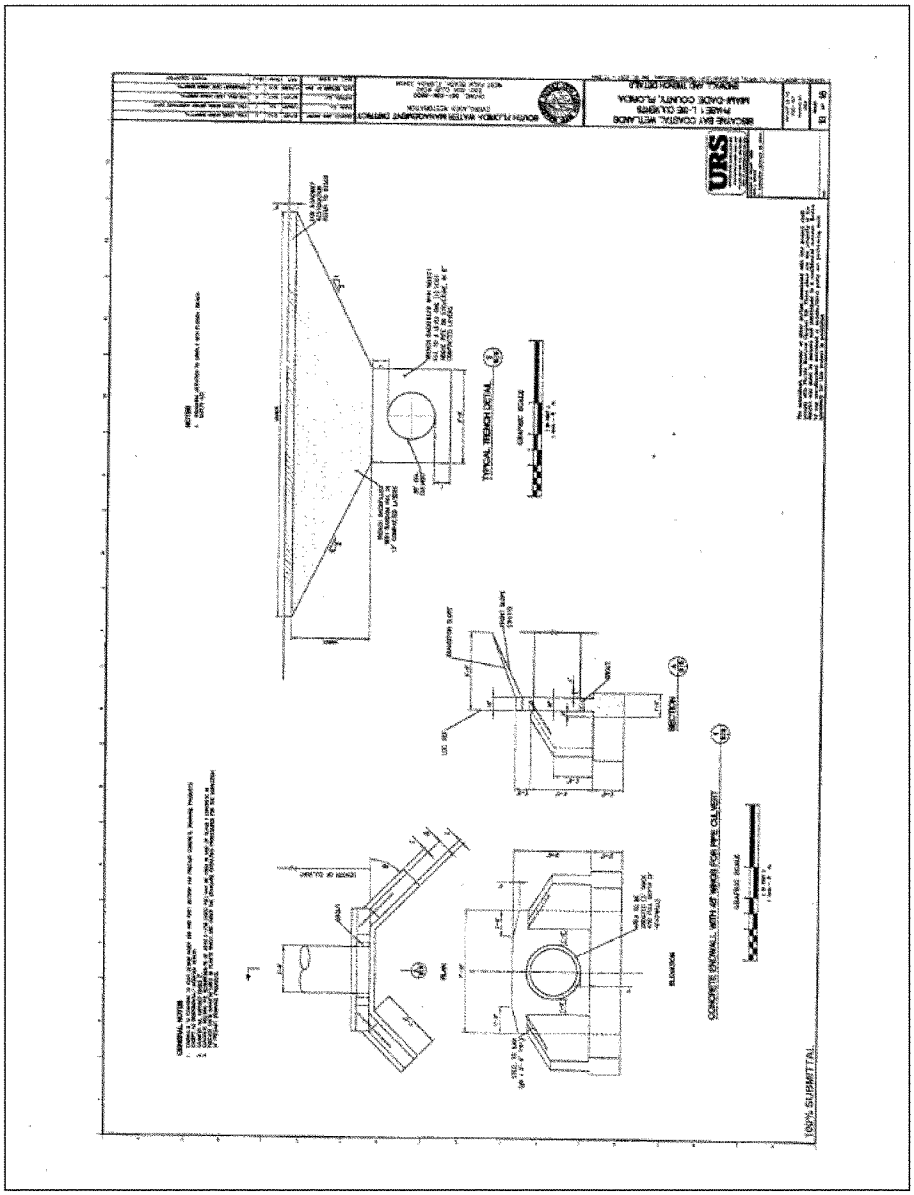
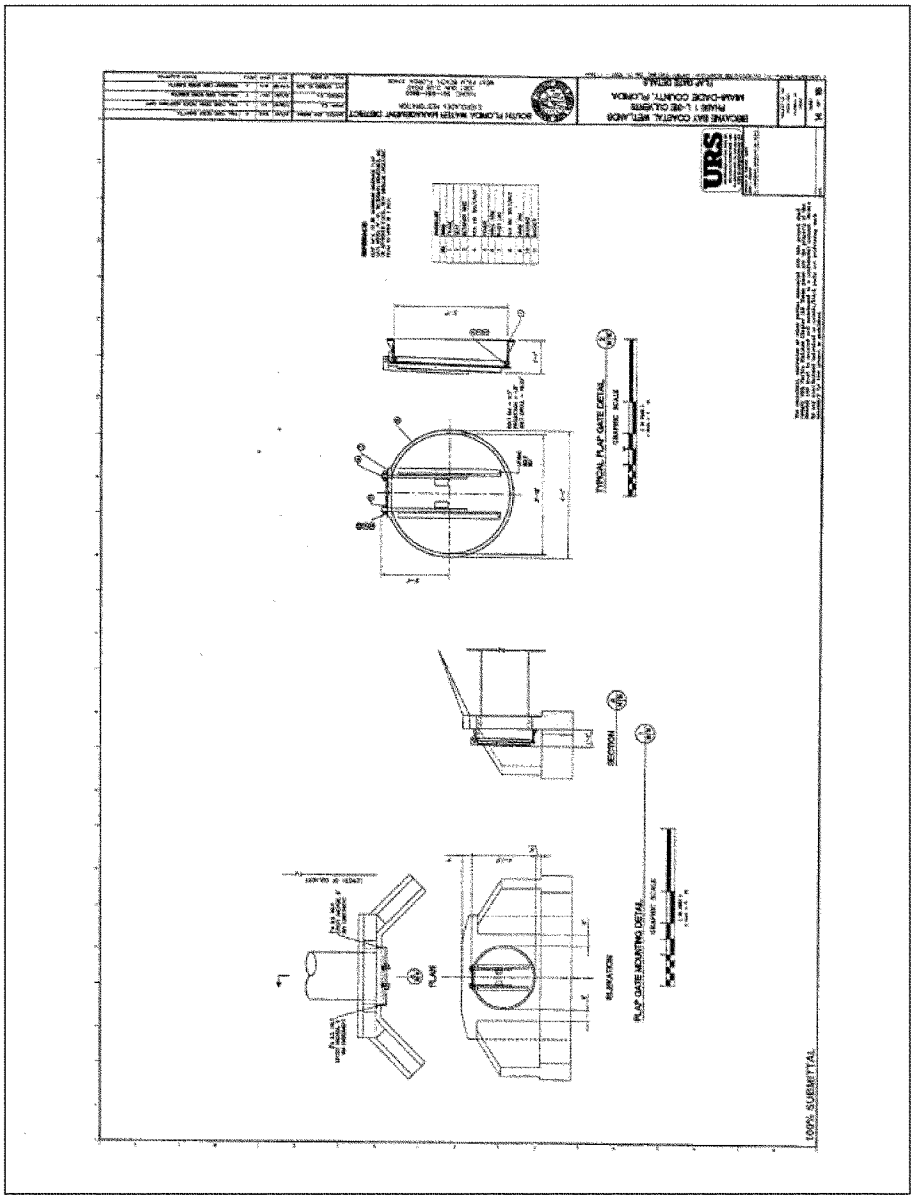
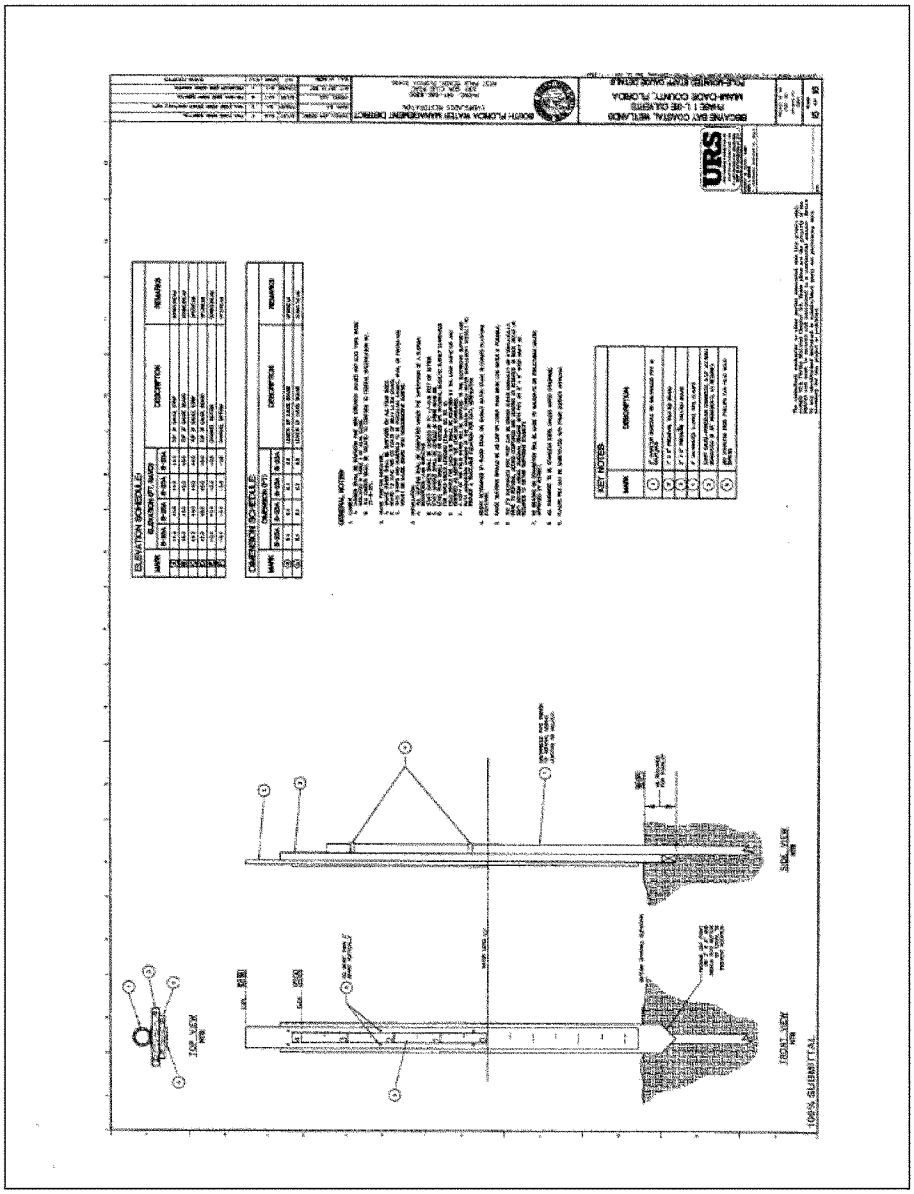
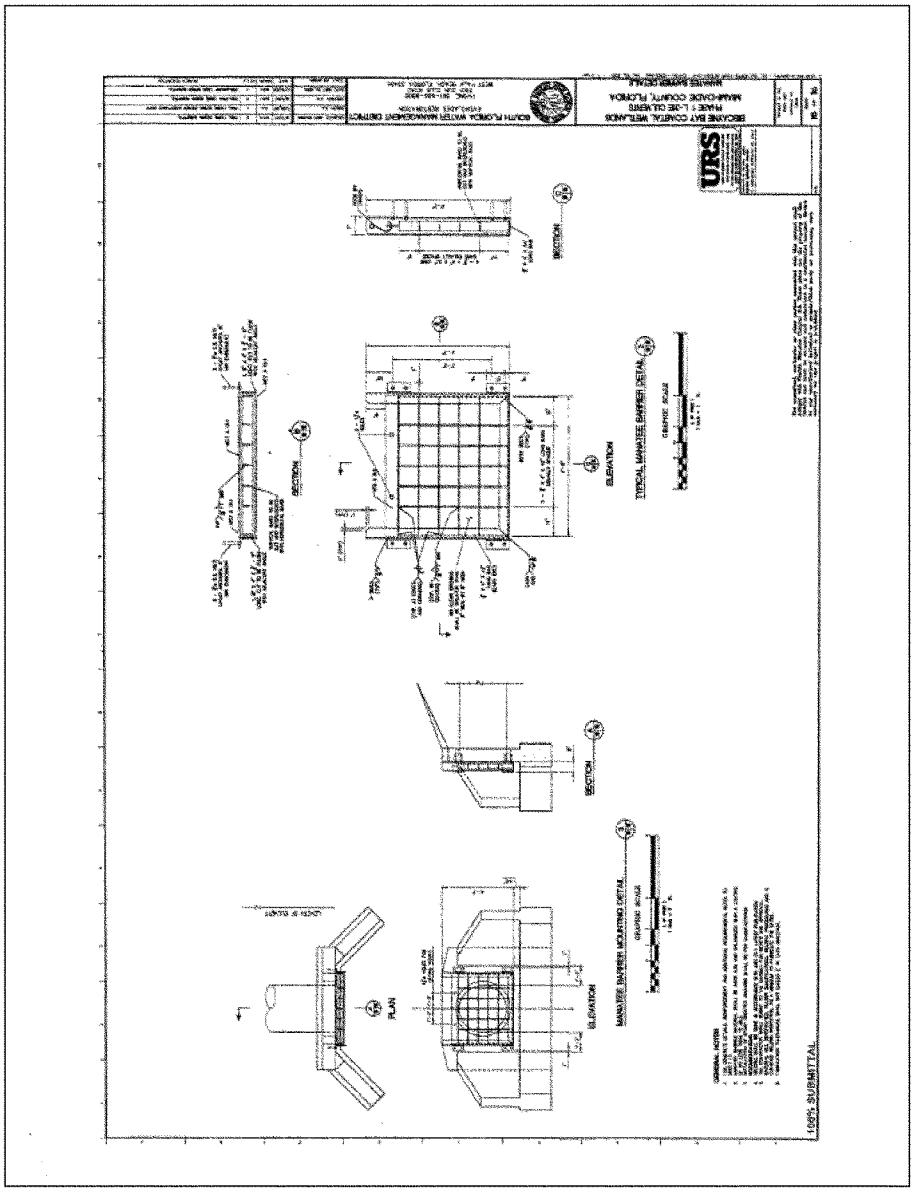

BISCAYNE BAY COASTAL WETLANDS
PHASE 1 - C-100 CULVERTS
MIAMI-DADE COUNTY, FLORIDA
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
DRAWING NO. - C-100 - 0002
DRAWING VERSION
SECTION - PIPE TRENCH DETAIL
URS
TYPICAL TRENCH DETAIL
GRAPHIC SCALE
SECTION
PLAN
ELEVATION
CONCRETE SNOWALL WITH 45° MITER FOR PIPE CULVERT
100% SUBMITTAL


URS
TYPICAL FLAP GATE DETAIL
SECTION
PLAN
ELEVATION
FLAP GATE MOUNTING DETAIL
100% SUBMITTAL


ELEVATION SCHEDULE
DIMENSION SCHEDULE
GENERAL NOTES
KEY NOTES
DESCRIPTION
REMARKS
URS
TOP VIEW
FRONT VIEW
SIDE VIEW
100% SUBMITTAL


SECTION
ELEVATION
TYPICAL MANATEE BARRIER DETAIL
GRAPHIC SCALE
SECTION
MANATEE BARRIER MOUNTING DETAIL
GRAPHIC SCALE
PLAN
ELEVATION
100% SUBMITTAL

Attachment 2
State Water Quality Certification

Florida Department of Environmental Protection

Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Charlie Crist
Governor

Jeff Kottkamp
Lt. Governor

Michael W. Sole
Secretary

COMPREHENSIVE EVERGLADES RESTORATION PLAN REGULATION ACT (CERPRA) PERMIT -CONSTRUCTION AND OPERATION AUTHORIZATION

PERMITTEE:
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

ATTENTION:
Ms. Carol Ann Wehle
Executive Director

Permit Number: 0271729-001
Project: Biscayne Bay Coastal Wetland Project: Phase I L-31E Culverts
County: Dade

Date of Issue: 09/10/2007
Expiration Date: 09/10/2012

This permit is issued under the authority of the Comprehensive Everglades Restoration Plan Regulation Act (CERPRA), Chapter 373.1502, Florida Statutes (F.S.); Title 62, Florida Administrative Code (F.A.C.); and pursuant to the Department of Environmental Protection (Department) authority under Chapter 373 and 403, F.S. The activity is not exempt from the requirement to obtain a CERPRA Permit.

The above named permittee is hereby authorized to initiate the activities described on the application, associated drawing(s), plans, and other documents attached hereto or on file with the Department and made a part hereof. The activities authorized by this permit must be conducted in conformance with all the provisions of this permit. Failure to comply with all permit conditions and documents referenced herein shall constitute grounds for revocation of the permit and appropriate enforcement action.

This permit constitutes a finding of consistency with Florida's Coastal Zone Management Program, as required by Section 307 of the Coastal Management Act, 14 U.S.C. § 1456, and constitutes certification of compliance with water quality standards under Section 401 of the Clean Water Act, 33 U.S.C. § 1341. Activities described in the related documents are not authorized until the project is determined to be in conformance with all applicable rules and with the general and specific conditions of this permit/certification/authorization, as specifically described below.

PROJECT DESCRIPTION:
The Biscayne Bay Coastal Wetland Project, is a "project component" as defined in Section 373.1501(1), F.S., of the Comprehensive Everglades Restoration Plan (CERP). In addition, the Biscayne Bay Coastal Wetlands Project was identified as an Accelerß project which the State of Florida is accelerating the funding, design, and construction of in order to realize immediate environmental benefits. The Biscayne Bay Coastal Wetlands Project will aid in establishing a productive nursery habitat along the shoreline through redistribution of freshwater flow and the minimization of point source discharges. The overall project will enhance and improve quantity, quality, timing and distribution of freshwater to the Bay, including Biscayne National Park, and aid in the preservation, restoration, and spatial extent of natural coastal habitat.

The L-31 E Culverts project, the first phase of the Biscayne Bay Coastal Wetlands Project, includes the installation of four flap-gated culverts, each consisting of 36" metal pipe, aluminum flap-gate, and concrete endwalls at each end of the pipe (See Figure 1). In addition, installation of each culvert will also include the construction of a 10 foot

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Permittee: South Florida Water Management District
Project: Biscayne Bay Coastal Wetland Project-L-31E Culverts
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wide canal excavated from the endwall at the upstream side of the culvert to the L-31E Canal and a 10-foot wide canal excavated from the endwall at the downstream side of the culvert to the eastern right-of-way of the L-31E Canal. This project is intended to restore a more natural flow of water by transporting freshwater through the culvert system to the coastal wetlands to the east, creating a more natural sheetflow and eliminating sudden releases of water through existing coastal structures. There are no State jurisdictional wetlands within the L-31E Culverts project area. Surface waters to be directly impacted by construction of this project component are Class III Waters, and Biscayne Bay National Park which is listed as an Outstanding Florida Water.

The South Florida Water Management District (District) is responsible for maintenance, repair, replacement, and rehabilitation of this project component. All conditions found herein apply to the District.

PROJECT LOCATION:
The L-31E Culverts Project is located in Miami-Dade County between the Goulds and C-103 Canal, Sections 4, 9, 28, 33 and Township 56 S Range 40 East and 57S Range 40 East. S-23B will be located north of SW 280 Street and south of the C-102/Princeton Canal on L-31E Canal. S-23A south of the C-102/Princeton Canal and north of S-23B on L-31E Canal. S-23D will be located between the C-103/Mowry Canal and Military Canal. S-23C will be located just north of the C-103/Mowry Canal.

DECLARATION OF REASONABLE ASSURANCES:
In issuing this permit, the Department finds that the District has given reasonable assurances sufficient to satisfy the requirements of the Comprehensive Everglades Restoration Plan Regulation Act, Section 373.1502, F.S. The Department bases this finding on the following documents, listed by Department document number:

1) South Florida Water Management District, L-31 E Culverts Permit Application and associated materials (December 2006);
2) South Florida Water Management District, Response to Request for Additional Information (March 12, 2007); and,
3) South Florida Water Management District, 90% Design Drawings (June 20, 2007)

Specifically, there are reasonable assurances, pursuant to Section 373.1502, F.S., that:

- "The project component will achieve the design objectives set forth in the detailed design documents submitted as part of the application." This finding is based on document 1 in its entirety, document 2, and document 3 in its entirety.
- "State water quality standards, including water quality criteria and moderating provisions, will be met. Under no circumstances shall the project component cause or contribute to violation of state water quality standards." This finding is based on document 2 with emphasis on responses 8 and 9 and the Pilot Study Report.
- "Discharges from the project component will not pose a serious danger to public health, safety or welfare." This finding is based on document 1 in its entirety and document 2 with emphasis on the Pilot Study;
- "Any impacts to wetlands or threatened or endangered species resulting from implementation of the project component will be avoided, minimized, and mitigated as appropriate." This finding is based on document 1 and document 2 with an emphasis on the Biological Assessment (BA) for the Biscayne Bay Coastal Wetlands project, and the 90% Design drawing.

The District agrees to construct the project in accordance with the provisions of this permit, permit application, and the associated documentation on file with the Department.

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Permittee: South Florida Water Management District
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GENERAL CONDITIONS:

In accordance with Subsection 373.1502(3)(e)(2) of the CERPRA, this permit may include any standard conditions provided by Department rule, which are appropriate and consistent with the CERPRA.

1. **Enforcement.** The terms, conditions, requirements, limitations and restrictions set forth in this permit, are "permit conditions" and are binding and enforceable pursuant to Chapters 373.129, 403.141, 403.727, 403.859 through 403.861 F.S. The permittee is placed on notice that the Department will review this permit periodically and may initiate enforcement action for any violation of these conditions.

2. **Scope of permit.** This permit is valid only for the specific processes and operations applied for and indicated in the approved drawings or exhibits. Any unauthorized deviation from the approved drawings, exhibits, specifications, or conditions of this permit may constitute grounds for revocation and enforcement action by the Department.

3. **Limitation of rights.** The issuance of this permit does not convey any vested rights or any exclusive privileges. Neither does it authorize any injury to public or private property or any invasion of personal rights, nor any infringement of federal, state, or local laws or regulations. This permit is not a waiver of or approval of any other Department permit that may be required for other aspects of the total project which are not addressed in this permit. However, this permit is in lieu of other permits under Chapter 373 or Chapter 403, F.S., except for permits issued under s. 403.0885, if applicable.

4. **Limitations upon title.** This permit conveys no title to land or water, does not constitute State recognition or acknowledgment of title, and does not constitute authority for the use of submerged lands unless herein provided and the necessary title or leasehold interests have been obtained from the State. Only the Trustees of the Internal Improvement Trust Fund may express State opinion as to title.

5. **Liability.** This permit does not relieve the permittee from liability for harm or injury to human health or welfare, animal, or plant life, or property caused by the construction or operation of this permitted source, or from penalties therefore; nor does it allow the permittee to cause pollution in contravention of Florida Statutes and Department rules, unless specifically authorized by an order from the Department. The permittee shall hold and save the Department harmless from any and all damages, claims, or liabilities which may arise by reason of the construction, alteration, operation, maintenance, removal, abandonment or use of any system authorized by the permit.

6. **Operation and maintenance responsibilities.** The permittee shall properly operate and maintain the facility and systems of treatment and control (and related appurtenances) that are installed and used by the permittee to achieve compliance with the conditions of this permit, as required by Department rules. This provision includes the operation of backup or auxiliary facilities or similar systems when necessary to achieve compliance with the conditions of the permit and when required by Department rules.

7. **Access Rights.** The permittee, by accepting this permit, specifically agrees to allow authorized Department personnel, upon presentation of credentials or other documents as may be required by law and at reasonable times, access to the premises where the permitted activity is located or conducted to:
   A. Have access to and copy any records that must be kept under conditions of the permit;
   B. Inspect the facility, equipment, practices, or operations regulated or required under this permit; and
   C. Sample or monitor any substances or parameters at any location reasonably necessary to assure compliance with this permit or Department rules.

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Reasonable time may depend on the nature of the concern being investigated.

8. **Noncompliance.** If, for any reason, the permittee does not comply with or will be unable to comply with any condition or limitation specified in this permit, the permittee shall immediately provide the Department with the following information:
   A. A description of and cause of noncompliance; and
   B. The period of noncompliance, including dates and times; or, if not corrected, the anticipated time the noncompliance is expected to continue, and steps being taken to reduce, eliminate, and prevent recurrence of the noncompliance. The permittee shall be responsible for any and all damages which may result and may be subject to enforcement action by the Department for penalties or for revocation of this permit.

9. **Records as evidence.** In accepting this permit, the permittee understands and agrees that all records, notes, monitoring data, and other information relating to the construction or operation of this permitted source which are submitted to the Department may be used by the Department as evidence in any enforcement case involving the permitted source arising under the Florida Statutes or Department rules, except where such use is prescribed by Sections 403.111, F.S. and 403.73, F.S. Such evidence shall only be used to the extent it is consistent with the Florida Rules of Civil Procedure and appropriate evidentiary rules.

10. **Changes in Law.** The permittee agrees to comply with changes in applicable Department rules and applicable Florida Statutes after a reasonable time for compliance; provided, however, the permittee does not waive any other rights granted by Florida law.

11. **Transferability.** This permit is transferable only upon Department approval in accordance with Rules 62-4.120 and 62-343.130, F.A.C., as applicable. The permittee shall be liable for any non-compliance of the permitted activity until the transfer is approved by the Department.

12. **Permit at work site.** This permit or a copy thereof shall be kept at the work site of the permitted activity. For the purposes of this permit the work site shall be defined as the South Florida Water Management District Headquarters located at 3301 Gun Club Road in West Palm Beach, Florida.

13. **Records retention.** The permittee shall comply with the following:
   A. Upon request, the permittee shall furnish all records and plans required under Department rules. During enforcement actions, the retention period for all records will be extended automatically unless otherwise stipulated by the Department;
   B. The permittee shall hold at the facility or other location designated by this permit records of all monitoring information required by the permit, copies of all reports required by this permit, and records of all data used to complete the application for this permit. These materials shall be retained at least five years from the date of the sample, measurement, report, and application unless otherwise specified by Department rule; and
   C. Records of monitoring information shall include:
      1. the date, exact place, and time of sampling or measurements;
      2. the person responsible for performing the sampling or measurements;
      3. the dates analyses were performed or the appropriate code as required by Chapter 62-160, F.A.C.;

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4. the person responsible for performing the analyses;
5. the analytical techniques or methods used, including but not limited to MDL; and
6. the results of such analyses, including identification of potential outlier values.

14. **Requests for information.** When requested by the Department, the permittee shall within a reasonable time furnish any information required by law which is needed to determine compliance with the permit. If the permittee becomes aware that relevant facts were not submitted or were incorrect in the permit application or in any report to the Department, such facts or information shall be corrected promptly.

15. **External Agency Requirements.** Should any other regulatory agency require changes to the permitted system, the permittee shall notify the Department in writing of the changes prior to implementation so that a determination can be made whether a permit modification is required.

16. **Sovereign Lands.** The permittee is hereby advised that Florida law states: No person shall commence any excavation, construction, or other activity involving the use of sovereign or other lands of the state, title to which is vested in the Board of Trustees of the Internal Improvement Trust Fund or the Department of Environmental Protection under Chapter 253, until such person has received from the Board of Trustees of the Internal Improvement Trust Fund the required lease, license, easement, or other form of consent authorizing the proposed use. Therefore, the permittee is responsible for obtaining any necessary authorizations from the Board of Trustees prior to commencing activity on sovereignty lands or other state-owned lands.

17. **Artifacts.** If historic or archaeological artifacts such as, but not limited to, Indian canoes, arrow heads, pottery or physical remains, are discovered at any time on the project site, the permittee shall immediately stop all activities which disturb the soil and notify the Department and the State Historic Preservation Officer.

SPECIFIC CONDITIONS:

1. **Instructions to Contractors.** The District shall ensure that the conditions contained within this permit are explained to all construction personnel working on the project and shall provide a copy of this permit to each contractor and subcontractor before the authorized work begins. Prior to construction, the District shall schedule a pre-construction meeting for attendance by the contractor(s), and representatives from the District, the Department, and other environmental regulatory agencies. The Department shall receive at least two weeks notice of the meeting. Within 30 days from the Notice-to-Proceed to the Contractor or upon District approval of a proposed construction schedule, whichever occurs first, the District shall provide the proposed construction schedule to the Department at the address identified in Specific Condition 2.

2. **Addresses.** Reports, schedules, and notices submitted to the Department in accordance with this permit shall be submitted to the Department's Division of Water Resource Management, Water Quality Standards and Special Projects Program, 2600 Blair Stone Road, MS 3560, Tallahassee, Florida, 32399-2400, telephone no. (850) 245-8416.

3. **Endangered Species.** The District shall avoid any actions that are likely to result in a take of any species listed by Fish and Wildlife Conservation Commission (FWC) in Chapter 68A-27, F.A.C or U.S. Fish and Wildlife Service, Department of the Interior (USFWS) in 50 CFR 17.11 or 50 CFR 17.12. In the event that either the Department or the District determine that the proposed activities will result in a take of a listed species, the District shall cease operations affecting the populations and closely coordinate with the FWC and the USFWS to obtain any necessary incidental take permits; Operations may continue if take authorization was granted for the affected species and all conditions accompanying that take are satisfied. If the District makes the above

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Permittee: South Florida Water Management District
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determination, it shall notify the Department at the address and telephone number in Specific Condition 2 within 24 hours of the date of such determination.

Construction

4. **Authorized Construction.** The District shall construct the L-31E Phase of the Biscayne Bay Coastal Wetlands Project in accordance with the plans and documentation submitted by the District as part of the permit application and any subsequent submittals that have been approved and are on file with the Department. Any substantial modifications to the construction plan, such as, but not limited to, hydrologic modifications or the addition/removal/modification of water control structures or changes to their location must be submitted for review and approval by the Department prior to construction and operation of such modifications. Substantial modifications shall be determined on a case-by-case basis by the Department in consultation with the District.

5. **Future Phases.** This permit does not authorize any construction or operation activities associated with future portions of the Biscayne Bay Coastal Wetlands Project. Future phases will require separate review and approval by the Department.

6. **Construction Best Management Practices (BMPs).** At all times during the construction, the District shall use best management techniques for erosion and sedimentation control. All graded areas shall be stabilized and vegetated immediately after construction to prevent erosion. Prior to commencement of construction activities, the District shall submit a BMP plan which details the use of sediment controls to minimize the suspension and transport of soils, levee materials, and roadway materials into waters adjacent to or downstream of the construction site to the Department for review and approval. Once installation of the erosion controls identified through the BMP plan have been completed, the District shall contact the Department at the address listed in Specific Condition No. 2 to determine whether inspections of the installed controls are necessary

7. **Adjacent Wetlands.** Wetlands adjacent to the construction activities shall be staked and fenced off with construction fencing or other effective physical barriers to prevent encroachment into wetlands prior to the commencement of construction. All areas of exposed soils shall be isolated from wetlands and surface waters to prevent erosion and deposition of sediments into these wetlands during permitted construction activities. All excavated or dredged material shall be placed strategically to prevent the transport of any material into wetlands and surface waters both during and after completion of the construction. Upon completion of the barrier installation, the District shall contact the Department at the address listed in Specific Condition No. 2 to determine whether inspections of the installed controls are necessary. The barriers shall remain in place until all adjacent construction activities are complete.

8. **Water Quantity and Flooding Impacts.** The District shall be responsible for ensuring that the project is constructed and operated so as to not adversely affect adjacent lands with regards to water quantity, water quality, and/or flooding. The District shall hold and save the Department harmless from any and all damages, claims or liabilities, which may arise from water quantity, water quality, and/or flooding impacts resulting from construction and operation of this project.

9. **NPDES Generic Permit for Stormwater Discharge from Large and Small Construction Activities.** The issuance of this permit does not constitute coverage under the National Pollutant Discharge Elimination System (NPDES) Generic Permit for Stormwater Discharges from Large and Small Construction Activities (CGP) pursuant to Rule 62-621.300(4)(a), F.A.C. Prior to the commencement of any construction, the District is advised to contact the Department's NPDES Stormwater Program at (850) 245-7522 or toll free at (866) 336-6312 or to download application information from the Department's website at http://www.dep.state.fl.us/water/stormwater/npdes/construction3.htm#permit

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10. **Dewatering.** For any proposed discharge to occur as a result of construction dewatering activities, the District shall submit site-specific dewatering information to the Department for review and approval at least 30 days prior to commencement of dewatering activities. The plan shall include at a minimum: a site plan of the project component with the location of the proposed discharge point(s) and their associated water quality monitoring locations; the location and type of turbidity control devices and methods necessary to ensure state water quality standards will be met; calculations estimating the area of influence of dewatering, pumpage rates, duration and volumes; and any proposed methods of construction.

    If it is anticipated that dewatering will not be retained onsite, the District must also include documentation that the dewatering activities will meet the criteria contained in the "Basis of Review for Water Use Permit Applications within the South Florida Water Management District-April 23, 2007" with emphasis on Section 2.5.2(4).

11. **NPDES Generic Permit for the Discharge of Produced Groundwater from any Non-Contaminated Site Activity.** The issuance of this permit does not constitute coverage under the NPDES Generic Permit for the Discharge of Produced Groundwater from any Non-Contaminated Site Activity pursuant to 62-621.300(2), F.A.C. If any offsite discharges will occur due to construction dewatering activities, then coverage under the aforementioned General Permit may be required and the District is advised to review Rule 62-621.300(2), F.A.C. Before discharge of produced groundwater can occur, analytical tests on samples of the proposed discharge water shall be performed to determine if contamination exists. If the analytical results comply with applicable criteria for use of the General Permit, then a short summary of the proposed activity and copy of the analytical tests shall be sent to the Department at the address identified in Specific Condition No. 2 within one week after discharge begins, and the District may proceed with the project component while abiding by all conditions of the Generic Permit.

12. **As-Built Certification and Record Drawings.** Within 90 days after the completion of construction for the L-31E Culverts, the District shall submit a written statement of completion and certification by a registered professional engineer or other appropriate individual as authorized by law. The statement of completion and certification shall be based on on-site observation of construction or review of as-built drawings for the purpose of determining whether or not the work was completed in compliance with permitted plans and specifications. Additionally, if deviation from the approved drawings is discovered during the certification process, the certification must be accompanied by a copy of the approved permit drawings with deviations noted. Both the original and revised specifications must be clearly shown. Plans submitted to the Department must be clearly labeled as "as-built" or "record" drawings with electronic copies provided in pdf format. A registered surveyor shall certify all surveyed dimensions and elevations.

13. **Manatee Protection During Construction:** The District shall comply with the following conditions intended to protect manatees from direct project effects:

    A. All personnel associated with the project shall be instructed about the presence of manatees and manatee speed zones, and the need to avoid collisions with and injury to manatees. The District shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act, the Endangered Species Act, and the Florida Manatee Sanctuary Act.

    B. All vessels associated with the construction project shall operate at "Idle Speed/No Wake" at all times while in the immediate area and while in water where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.

    C. Siltation or turbidity barriers shall be made of material in which manatees cannot become entangled, shall be properly secured, and shall be regularly monitored to avoid manatee entanglement or entrapment. Barriers must not impede manatee movement.

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D. All on-site project personnel are responsible for observing water-related activities for the presence of manatee(s). All in-water operations, including vessels, must be shutdown if a manatee(s) comes within 50 feet of the operation. Activities will not resume until the manatee(s) has moved beyond the 50-foot radius of the project operation, or until 30 minutes elapses if the manatee(s) has not reappeared within 50 feet of the operation. Animals must not be herded away or harassed into leaving.

E. Any collision with or injury to a manatee shall be reported immediately to the FWC Hotline at 1-888-404-FWCC. Collision and/or injury should also be reported to the U.S. Fish and Wildlife Service in Jacksonville (1-904-232-2580) for north Florida or Vero Beach (1-561-562-3909) for south Florida.

F. Temporary signs concerning manatees shall be posted prior to and during all in-water project activities. All signs are to be removed by the District upon completion of the project. Awareness signs that have already been approved for this use by the Florida Fish and Wildlife Conservation Commission (FWC) must be used. One sign measuring at least 3 ft. by 4 ft. which reads *Caution: Manatee Area* must be posted. A second sign measuring at least 81/2" by 11" explaining the requirements for "Idle Speed/No Wake" and the shut down of in-water operations must be posted in a location prominently visible to all personnel engaged in water-related activities.

Operations and Maintenance

14. **Operation of Passive Structures.** The L-31 Culverts Project shall be operated as a passive structure. Any alteration of operations, including, but not limited to the installation of flashboard risers or increasing flow from source canals, must be submitted to the Department for review and approval. The District shall submit an operational plan at least 90 days prior to commencing modified operation of the culverts for Department review and approval.

15. **Culvert Testing and Maintenance.** In order to ensure operational readiness, testing and maintenance operations may be required by the construction contractor and/or District for the culverts authorized by this permit. The District shall submit a maintenance plan for the culverts for Department review and approval at least 30 days prior to initiation of operations.

16. **Public Health Safety and Welfare.** Pursuant to Subsection (3)(b)(3) of the CERPRA, discharges from the Biscayne Bay Coastal Wetlands Project shall not pose a serious danger to the public health, safety, or welfare.

Monitoring Requirements

17. **Water Quality Monitoring Program.** No later than 90 days prior to commencing flow through the culverts, the District shall submit a final water quality monitoring plan to the Department for review and approval. Any modifications to the District's water quality monitoring plan shall be submitted to the Department for review and approval. The District shall conduct a water quality monitoring program in accordance with Table 1 and the approved water quality monitoring plan to characterize water quality spatially and seasonally, and to detect long term trends. Water quality monitoring shall commence upon the initiation of operations.

    A. **Quality Assurance and Quality Control.** Sampling and monitoring data shall be collected, analyzed, reported and retained in accordance with Chapter 62-160, F.A.C. Any laboratory test required by this permit shall be performed by a laboratory that has been certified by the Department of Health (DOH) under Chapter 64E-1, F.A.C., where such certification is required by Rule 62-160.300, F.A.C. The laboratory must be certified for all specific method/analyte combinations that are used to comply with this permit. The analytical method used shall be appropriate so as to determine if the sample complies with Class I and Class III surface water quality standards as specified in Chapter 62-302, F.A.C., and groundwater standards as specified in Chapter 62-520, F.A.C., whichever is more stringent. All field

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activities including on-site tests and sample collection, whether performed by a laboratory or another organization, must follow all applicable procedures described in DEP-SOP-001/01 (February 1, 2004). Alternate field procedures and laboratory methods may be used if they have been approved according to the requirements of Rules 62-160.220, and 62-160.330, F.A.C.

B. **Method Detection Limits (MDLs).** The sample collection, analytical test methods and method detection limits (MDLs) applicable to this permit shall be performed and reported in accordance with Rule 62-4.246, F.A.C. a list of Department established analytical methods, and corresponding MDLs (method detection limits) and PQLs (practical quantification limits), which is titled "Florida Department of Environmental Protection Table as Required By Rule 62-4.246(4) Testing Methods for Discharges to Surface Water" dated April 25, 2006, is available from the Department on request. The MDLs and PQLs as described in this list shall constitute the minimum acceptable MDL/PQL values and the Department shall not accept results for which the laboratory's MDLs or PQLs are greater than those described above unless alternate MDLs and/or PQLs have been specifically approved by the Department for this permit. More stringent MDLs and PQLs may be necessary for specific parameters. If required, these will be identified in the permit monitoring table.

18. **Turbidity Monitoring.** Effective means of turbidity control, such as, but not limited to, turbidity curtains, shall be employed during all construction and maintenance activities that may create turbidity so that it shall not exceed 0 NTU's above background in the OFW and 29 NTU's above background in the Class III receiving waters. Turbidity curtains or other controls shall be placed and maintained around the work area to confine turbidity generated by construction within the work area. All screens, sheet pile, and other turbidity control devices shall remain in place until all turbidity has subsided and the turbidity level in the work cell meets state standards.

Turbidity monitoring equipment and personnel trained to use it shall be available on site at all times during construction activities that could result in project-generated turbidity levels beyond the work area. For monitoring purposes, the work area is that area defined by the turbidity curtained "cell(s)." The District shall monitor turbidity levels at least once every four hours during all activities that may create turbidity (unless monitoring data shows this to be excessive) during construction as follows.

A. Monitoring samples shall be taken at the surface at the following locations:

1. Background Sample(s): One background sample station, at least 250 feet upstream of the work area, outside any visible plume generated by the construction; and
2. Compliance Sample(s): Monitoring station located immediately downstream of the work area within the densest portion of any visible plume.

B. Turbidity monitoring results shall be compiled daily and summarized quarterly (every three calendar months) by project component. Beginning with the first calendar month that construction occurs that could generate turbidity in waters adjacent to the construction sites and continue until all construction is completed. Monitoring data with supporting documents shall be submitted to the Department quarterly during the period of actual construction. The reports shall clearly identify the following information:

1. Permit number;
2. Dates and time of sampling and analysis;
3. A statement describing the methods used in collection, handling, storage and analysis of the samples;
4. A clear description of project component activities taking place at the time of sampling;
5. A map indicating the sampling locations; and,
6. A statement by the individual responsible for implementation of the sampling program concerning the authenticity, precision, limits of detection and accuracy of the data.

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C. Monitoring reports shall also include the following information for each sample that is taken:

1. Water depth
2. Depth of sample
3. Weather conditions
4. Water level stage and direction of flow.

19. **Mercury and Other Toxicants.** The District shall submit a proposed Mercury and Other Toxicants Monitoring Plan as a part of the Water Quality Monitoring Plan requirement in Specific Condition 17 for Department review and approval.

20. **Removal of Parameters.** Upon demonstration that a specific parameter(s) is not present or is found consistently in compliance with water quality standards, the District may request a modification to the monitoring program as appropriate. A minimum of one year's worth of data, for those parameters being sampled quarterly or more frequently, will be required prior to the Department approving any modification to the monitoring program. Parameters sampled semi-annually or annually will be examined on a case-by-case basis. The Department may approve a reduction of the monitoring frequency or waive the monitoring requirement for parameters that consistently are reported as in compliance with state water quality standards.

21. **Addition of Parameters.** If the Department has reason to believe that additional parameters exist that may cause or contribute to water quality violations in the project area, those parameters shall be added to the monitoring section of this permit as a permit modification.

Reporting

22. **Construction Status Reports.** Construction Status Reports or Construction Meeting Minutes for the project shall be available to the Department throughout the duration of construction activities and shall continue to be submitted until all disturbed areas are successfully stabilized. These Reports may be requested through the Project Manager, Construction Manager, or obtained at the construction meetings.

23. **Annual Reports.** The District shall submit an "Annual Report" to the Department detailing the progress of the Biscayne Bay Coastal Wetland Project. In addition to the permit number and name of the permit administrator, the Annual Reports shall contain, at a minimum, the following information; the project name, permit number, discussion of project status, and conclusions regarding project success, problems encountered during the period covered, and actions taken to address problems encountered. The annual reporting requirements under this permit shall be incorporated into the South Florida Environmental Report (SFER) and/or as part of other reporting mechanisms which have been deemed acceptable by the Department. These reports shall be submitted to the Department no later than March 1st of each year. If additional reporting modifications are required, the District may request a modification of the Annual Report submission date, and upon approval by the Department, the District may modify the Annual Report submission date to coincide with other reporting requirements and time periods needed for data acquisition and analysis.

A. **Water Quality Data.** Records of monitoring information shall include:

1. Date, location, and time of sampling or measurements;
2. Person responsible for performing the sampling or measurements;
3. Dates analyses were performed or the appropriate code as required by Chapter 62-160, F.A.C.;
4. Person responsible for performing the analyses;

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5. Analytical techniques or methods used, including MDL;
6. Results of such analyses, including appropriate data qualifiers;
7. Depth of samples;
8. Flow conditions and weather conditions at time of sampling; and,
9. Monthly flow volumes.

B. **Performance Evaluation.**

1. The operations status of the Project;
2. A comparison of quarterly water quality data using the student's t-test with a 95% confidence interval;
3. During operations, a statistical evaluation of whether the project is performing in a manner consistent with its design objectives/water quality performance estimates. In the event that the project is not performing in this manner, the Department may impose additional evaluation and reporting requirements;
4. Beginning with the second Annual Report, a comparison of performance of current reporting year with performance in previous years.
5. An evaluation of project performance based on ecological/biological monitoring efforts.

C. **Herbicide and Pesticide Tracking.** The District shall provide in each annual report information regarding the application of herbicides and pesticides used to exclude/eliminate undesirable vegetation and pests in the wetted area of the Project. Such reporting shall include the names, concentrations, locations, and quantities of all herbicides and pesticides used.

D. **Implementation Schedules.** When appropriate, the District shall include information on:

1. Comprehensive Everglades Restoration Plan Project implementation;
2. Project optimization;
3. Project design modifications; and,
4. Implementation of remedial measures in the event of noncompliance with permit conditions.

Renewals and Modifications

24. **Permit Modifications.** The District shall submit proposed modifications to the Biscayne Bay Coastal Wetlands Project to the Department, prior to implementation of the modification, for review and approval.

25. **Permit Renewal.** At least 60 days prior to the expiration date of this permit, the District shall apply for renewal of this permit. Renewal may be for a period of up to 5 years in accordance with Subsection (3)(g) of the CERPRA.

26. **Department Review and Approval.** Where conditions in this permit require Department review of remedial actions or plan modifications to be implemented pursuant to this permit, the Department will consult with the District to ascertain whether a mutual agreement can be reached. If mutual agreement on the remedial actions or plan modifications cannot be reached, the action of the Department will be deemed final agency action and will be subject to judicial or administrative review, as appropriate.

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Executed in Tallahassee, Florida.

STATE OF FLORIDA DEPARTMENT
OF ENVIRONMENTAL PROTECTION

Jerry Brooks 9/10/07
Jerry Brooks Date
Deputy Director
Division of Water Resource Management

JB/em/bb

FILING AND ACKNOWLEDGMENT

FILED, on this date, with the designated Department Clerk, receipt of which is hereby acknowledged.

Clerk 9/10/07
Date

ELECTRONIC COPIES FURNISHED TO:
Frank Nearhoof, FDEP
Shelley Yaun, FDEP
Kenny Hayman, FDEP
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Laura Kammerer, Dept. of State, Div. of Historical Resources
Linda McCarthy, Dept. of Agriculture and Consumer Services
Pam Repp, U.S. Fish and Wildlife Service
Joe Martinez, Board of County Commissioners, Miami-Dade County

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TABLE 1: MONITORING REGIME FOR CANAL STATIONS

PARAMETER	UNITS	SAMPLE TYPE	SAMPLING FREQUENCY	SAMPLING LOCATION
Ammonia	mg/l	G	M	MI01, MW01, PR01, BB53
Salinity	mg/l (ppt)	G	M	MI01, MW01, PR01, BB53
TSS	mg/l	G	M	MI01, MW01, PR01, BB53
Color	PCU	G	M	MI01, MW01, PR01, BB53
Dissolved Oxygen	mg/l	G	M	MI01, MW01, PR01, BB53
pH	SU	G	M	MI01, MW01, PR01, BB53
Specific Conductance	uS/cm	G	M	MI01, MW01, PR01, BB53
Temperature	Deg C	G	M	MI01, MW01, PR01, BB53
Total Phosphorus	mg/l	G	M	MI01, MW01, PR01, BB53
Turbidity	NTU	G	M	MI01, MW01, PR01, BB53
NOX	mg/l	G	M	MI01, MW01, PR01, BB53
Flow	CFS	CAL	M	S23A, S23B, S23C, S23D
Stage	NGVD	CAL	M	S21A, S20G, S20F
Mercury	(See Specific Condition 19)			
Pesticides	(See Specific Condition 19)			

Table 1: Key

G – Grab sampling
M – Monthly
CAL - Calculated parameter

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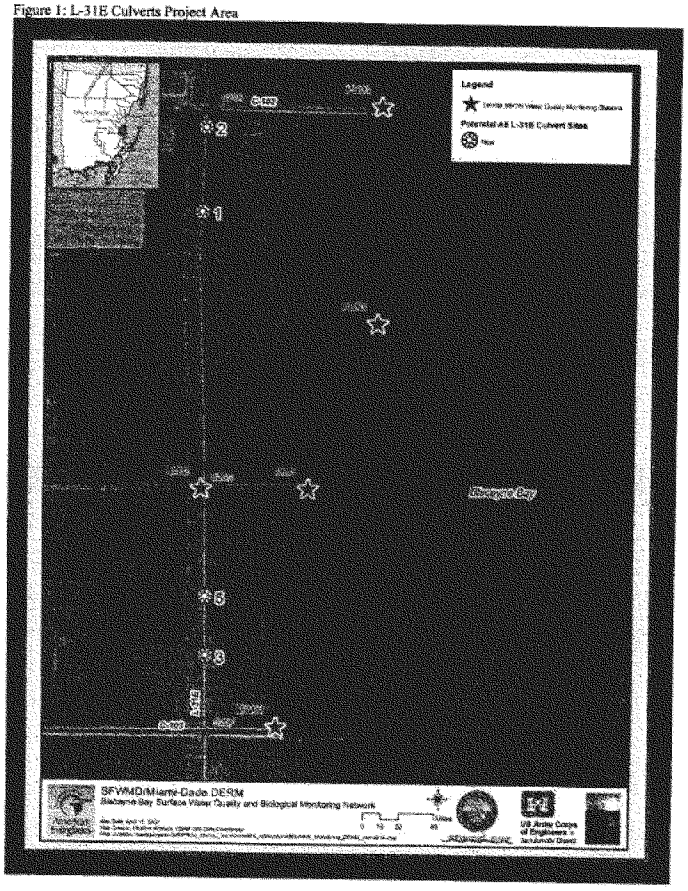
Figure 1: L-31E Culverts Project Area



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Attachment 3
AS-BUILT CERTIFICATION BY PROFESSIONAL ENGINEER

Submit this form and one set of as-built engineering drawings to the U.S. Army Corps of Engineers, Enforcement Section, Post Office Box 4970, Jacksonville, Florida 32232-0019. If you have questions regarding this requirement, please contact the Enforcement Section at 904-232-2907.

1. **Department of the Army Permit Number:**_____

2. **Permittee Information:**

   Name_____

   Address_____

3. **Project Site Identification:**

   Physical location/address_____

   _____

4. **As-Built Certification:**

I hereby certify that the authorized work, including any mitigation required by Special Conditions to the permit, has been accomplished in accordance with the Department of the Army permit with any deviations noted below. This determination is based upon on-site observation, scheduled and conducted by me or by a project representative under my direct supervision. I have enclosed one set of as-built engineering drawings.

Signature of Engineer	**Name (Please type)**
(FL, PR or VI) Reg. Number	**Company Name**

Address **City** **State** **ZIP**

(Affix Seal)

Date	**Telephone Number**

Attach additional pages as necessary to identify deviations from the approved permit drawings and special conditions.

Attachment 4

STANDARD PROTECTION MEASURES FOR THE EASTERN INDIGO SNAKE

(1) An eastern indigo snake protection/education plan will be developed by the applicant for all construction personnel to follow. The plan will be provided to the Service for review and approval at least 30 days prior to any clearing activities. The education materials for the plan may consist of a combination of posters, videos, pamphlets, and lectures (*e.g.*, an observer trained to identify eastern indigo snakes could use the protection/education plan to instruct construction personnel before and clearing activities occur). Informational signs should be posted throughout the construction site and contain the following:

a. a description of the eastern indigo snake, its habits, and protection under Federal law;

b. instructions not to injure, harm, harass or kill this species;

c. directions to cease clearing activities and allow the eastern indigo snake sufficient time to move away from the site on its own before resuming activities; and

d. telephone numbers of pertinent agencies to be contacted if a dead eastern indigo snake is found. The dead specimen should be thoroughly soaked in water, then frozen.

(2) Only an individual who has been authorized either by a section 10(a)(1)(A) permit issued by the Service, or authorized by the FWC for such activities, is permitted to come into contact with or relocate an eastern indigo snake;

(3) If necessary, eastern indigo snakes will be held in captivity only long enough to transport them to the release site; at no time will 2 snakes be kept in the same container during transportation; and

(4) An eastern indigo snake monitoring report must be submitted to the Service's South Florida Ecological Services Office, Vero Beach, Florida, within 60 days of clearing completion. The report should be submitted when any eastern indigo snakes are observed or relocated. The report should contain the following information:

a. results of the tortoise burrow and field surveys;

b. any sightings of eastern indigo snakes;

c. summaries of any relocation activities for the Project (*e.g.*, locations of where and when they were found and relocated); and

d. other obligations required by the FWC, as stipulated in their permit.

Attachment 5

STANDARD MANATEE CONSTRUCTION CONDITIONS

June 2001

The permittee shall comply with the following manatee protection construction conditions:

a. The permittee shall instruct all personnel associated with the project of the potential presence of manatees and the need to avoid collisions with manatees. All construction personnel are responsible for observing water-related activities for the presence of manatee(s).

b. The permittee shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act of 1972, The Endangered Species Act of 1973, and the Florida Manatee Sanctuary Act.

c. Siltation barriers shall be made of material in which manatees cannot become entangled, are properly secured, and are regularly monitored to avoid manatee entrapment. Barriers must not block manatee entry to or exist from essential habitat.

d. All vessels associated with the construction project shall operate at "no wake/idle" speeds at all times while in the construction area and while in water where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.

e. If manatee(s) are seen within 100 yards of the active daily construction/dredging operation or vessel movement, all appropriate precautions shall be implemented to ensure protection of the manatee. These precautions shall include the operation of all moving equipment no closer than 50 feet of a manatee. Operation of any equipment closer than 50 feet to a manatee shall necessitate immediate shutdown of that equipment. Activities will not resume until the manatee(s) has departed the project area of its own volition.

f. Any collision with and/or injury to a manatee shall be reported immediately to the FWC Hotline at 1-888-404-FWCC. Collision and/or injury should also be reported to the U.S. Fish and Wildlife Service in Jacksonville (1-904-232-2580) for north Florida or Vero Beach (1-561-562-3909) in south Florida.

g. Temporary signs concerning manatees shall be posted prior to and during all construction/dredging activities. All signs are to be removed by the permittee upon completion of the project. A sign measuring at least 3 ft. by 4 ft. which reads *Caution: Manatee Area* will be posted in a location prominently visible to water related construction crews. A second sign should be posted if vessels are associated with the construction, and should be placed visible to the vessel operator. The second sign should be at least 81/2" by 11" which reads *Caution: Manatee Habitat. Idle speed is required if operating a vessel in the construction area. All equipment must be shutdown if a manatee comes within 50 feet of operation. Any collision with and/or injury to a manatee shall be reported immediately to the FWC Hotline at 1-888-404-FWCC. The U.S. Fish and Wildlife Service should also be contacted in Jacksonville (1-904-232-2580) for north Florida or in Vero Beach (1-561-562-3909) for south Florida.*

CAUTION

MANATEE HABITAT

IDLE SPEED is required if operating a vessel
in the construction area.
All Equipment must be SHUT DOWN if a manatee
comes within 50 feet of operation.

Any collision with and/or injury to a manatee shall be reported immediately
to the **FWC** at:

1-888-404-FWCC

(1-888-404-3922)

Attachment 6

GUIDELINES FOR CULVERTS LOCATED IN MANATEE-ACCESSIBLE CERP PROJECTS

The following guidelines are developed to prevent manatee entrapment within culverts and to exclude manatees from unsuitable habitat. The guidance below applies only to free-flowing culverts. Structures with water control features (e.g., gates, flaps, etc.) and culverts that exceed the specifications below will require FWC and FWS review.

NEW AND EXISTING CULVERTS

1. Size requirements: All culverts 8 inches to 8 feet in diameter must be grated to prevent manatee entrapment. Grates must be spaced a maximum of 8 inches apart to effectively prevent manatee access. Diagonal, horizontal or vertical grates may be installed. Grates must be a permanent fixture and not part of a water control structure.

   Culverts less than 8 inches in diameter are exempt from this requirement, whereas, culverts greater than 8 inches may be subject to a case-by-case review, if necessary.

2. Length requirements: Based on documented manatee movement by FWC, the maximum recommended culvert length is 200 feet. Proposed culverts greater than 200 feet in length require consultation with the FWS and the FWC.

3. Case-by-Case Review: In consultation with FWS and FWC, all culverts may be reviewed. The decision to exclude manatees will be based on culvert length, water level, available habitat and other risk factors. If a decision is made to exclude manatees from access to culverts, the culvert should be grated, as described above.

   The benefit of access to important habitat (forage resources, calving sites, freshwater, travel corridors, warm-water refugia, refuge from watercraft or other forms of harassment) will be weighed against the potential risk of injury or death to manatees if the culvert were to remain accessible.

4. Additional Guidance:

   - Box culverts are preferred by FWS and FWC over round culverts. Bridges are the most preferred by FWS and FWC.

Manatees can become stranded in culverts during periods of low tide. Therefore, when planning for new culverts in tidal waters, a minimum 3-foot depth of water in the culvert at low tide stage is recommended.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
263 13th Avenue South
St. Petersburg, FL 33701

Attachment 7

SEA TURTLE AND SMALLTOOTH SAWFISH CONSTRUCTION CONDITIONS

The permittee shall comply with the following protected species construction conditions:

a. The permittee shall instruct all personnel associated with the project of the potential presence of these species and the need to avoid collisions with sea turtles and smalltooth sawfish. All construction personnel are responsible for observing water-related activities for the presence of these species.

b. The permittee shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing sea turtles or smalltooth sawfish, which are protected under the Endangered Species Act of 1973.

c. Siltation barriers shall be made of material in which a sea turtle or smalltooth sawfish cannot become entangled, be properly secured, and be regularly monitored to avoid protected species entrapment. Barriers may not block sea turtle or smalltooth sawfish entry to or exit from designated critical habitat without prior agreement from the National Marine Fisheries Service's Protected Resources Division, St. Petersburg, Florida.

d. All vessels associated with the construction project shall operate at "no wake/idle" speeds at all times while in the construction area and while in water depths where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will preferentially follow deep-water routes (e.g., marked channels) whenever possible.

e. If a sea turtle or smalltooth sawfish is seen within 100 yards of the active daily construction/dredging operation or vessel movement, all appropriate precautions shall be implemented to ensure its protection. These precautions shall include cessation of operation of any moving equipment closer than 50 feet of a sea turtle or smalltooth sawfish. Operation of any mechanical construction equipment shall cease immediately if a sea turtle or smalltooth sawfish is seen within a 50-ft radius of the equipment. Activities may not resume until the protected species has departed the project area of its own volition.

f. Any collision with and/or injury to a sea turtle or smalltooth sawfish shall be reported immediately to the National Marine Fisheries Service's Protected Resources Division (727-824-5312) and the local authorized sea turtle stranding/rescue organization.

g. Any special construction conditions, required of your specific project, outside these general conditions, if applicable, will be addressed in the primary consultation.

Revised: March 23, 2006
O:\forms\Sea Turtle and Smalltooth Sawfish Construction Conditions.doc

Attachment 8
Biscayne Bay Coastal Wetlands Acceler8 Project
Protection Measures for the American Crocodile
June 12, 2007

1. Prior to construction, an American crocodile survey will be conducted by a person with experience in performing American crocodile surveys. The survey should be adequate to ensure a high likelihood of detecting American crocodiles that maybe be using the project area for shelter, feeding and sunning. If construction is planned during the nesting season (March through September), the project area should also be surveyed for nesting and breeding activities. If American crocodiles or nests are detected, a protection plan will be developed in coordination with the Service and implemented prior to the initiation of construction.

2. The American crocodile survey report must be submitted to the Service prior to construction (using standard survey report format). The survey report shall be submitted whether or not a crocodile has been observed and contain information on any sightings of crocodiles or nests.

Attachment 9
L-31E Culverts
Unified Mitigation Assessment Methodology Score Sheet

L-31E Culverts UMAM
November 2007

Habitat Type	Landscape Support		Water Environment		Community Structure		Overall UMAM Score		Delta	Total Site				Functional
Enhancement	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Lift	Acreage	Subtotal	Time Lag	Risk	Gain
Mangrove (Wetland 22)	8	8	5	6	7	8	0.67	0.73	0.07	2	0.13	0.967	1	0.12571
Mangrove (Wetland 24)	8	8	6	8	7	8	0.70	0.80	0.10	2	0.2	0.967	1	0.1934
										4			Sum	[illegible]

Habitat Type	Landscape Support		Water Environment		Community Structure		Overall UMAM Score		Delta	Total Site				Functional
Impact	Pre	Post	Pre	Post	Pre	Post	Pre	Pre	Loss	Acreage	Subtotal	Time Lag	Risk	Gain
Mangrove (Wetland 22)	8	0	5	0	8	0	0.70	0.00	-0.70	0.15	-0.11	1	1	-0.11
Mangrove (Wetland 24)	8	0	6	0	7	0	0.70	0.00	-0.70	0.15	-0.11	1	1	-0.11
										0.3			Sum	[illegible]

ANNEX E
PROJECT MONITORING PLAN

PART III: ECOLOGICAL MONITORING PLAN

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E.0 ECOLOGICAL MONITORING PLAN

E.1 INTRODUCTION AND BACKGROUND

This document serves as a reference for ecological monitoring parameters and protocols for the Biscayne Bay Coastal Wetlands (BBCW) project. This project-level ecological monitoring plan has been designed to provide basic information needed to evaluate the Biscayne Bay Coastal Wetlands project's performance in meeting restoration goals and to facilitate effective, science-based management decisions concerning project design and operation. Specifically, the recommended ecological monitoring will determine if restoring historic patterns of freshwater flow, salinity, and water quality to nearshore waters and adjacent wetlands of southwestern Biscayne Bay will achieve the expected community structure, distribution, abundance, and viability of oyster bars, submerged aquatic vegetation (SAV), wetland vegetation, and associated biota. The ecological monitoring plan is designed to provide critical information for managing the project, which is consistent with the National Research Council's recent (2006) recommendation for the Incremental Adaptive Restoration approach for Comprehensive Everglades Restoration Plan. Because the selected project alternative, Alternative O Phase I, is the first phase of the larger Biscayne Bay Coastal Wetlands project, the ecological monitoring information will not only be used to manage the first phase of the project, but it can provide critical information for planning and constructing subsequent phases.

The guidance contained in this document will assist in maintaining consistency in sampling locations, parameter lists, and frequencies as well as providing documentation of the project scope. This monitoring plan has been aligned with the Comprehensive Everglades Restoration Plan, Restoration Coordination and Verification Monitoring and Assessment (RECOVER) Monitoring and Assessment Plan (MAP) to ensure that measures and targets selected by project teams are consistent with system-wide measures and that duplication of effort is avoided. Because the MAP was designed to detect system-wide or regional changes, only certain parameters are to be measured, and they will be measured across large spatial scales. The Biscayne Bay Coastal Wetlands Ecological Monitoring Plan will ensure temporal and spatial coverage of monitoring parameters that are appropriate to detect changes at the project level, which will likely mean filling gaps in the Monitoring and Assessment Plan monitoring parameters and adding additional project-level parameters not currently included in that plan. Thus, the project-level monitoring plan will likely have greater spatial and temporal resolution in its monitoring data. The Biscayne Bay Coastal Wetlands Ecological Monitoring Plan utilizes the protocols and results of the MAP whenever possible.

The project manager is responsible for maintaining the project monitoring plan and making sure that any changes are well documented and communicated to

team members and other parties as necessary. Prior to implementation of any aspect of this monitoring plan signature approval of the plan is required by the project manager and representatives of the monitoring departments or divisions of the sponsoring agencies.

E.1.1 Structure of the Plan

Because of the complexity of planned monitoring in the Biscayne Bay Coastal Wetlands project area, the ecological section of the monitoring plan is divided into two geographic components: (1) the nearshore area and (2) the wetlands area (including both the freshwater and saltwater wetlands). The nearshore bay component will monitor oysters, SAV, estuarine fishes, juvenile crocodiles, and salinity. The wetland component will include wetland macro vegetation, and wetland algae. Wetland hydrology monitoring has been included in ***Part 1 – Hydrometeorological Monitoring*** of this same Annex. Monitoring wetland algae serves primarily as a surrogate for detecting changes in salinity and water quality in the wetlands. Project objectives applicable to each component are identified, and the monitoring parameters that will evaluate the extent to which each objective is achieved are presented. For each monitoring parameter, the following information is provided: (1) justification for monitoring and relevance to performance measures, (2) project-level monitoring component, (3) Monitoring and Assessment Plan monitoring component, (4) comparison of project-level and Monitoring and Assessment Plan components, (5) data management and quality assurance and quality control, and (6) monitoring cost estimates.

E.1.2 Monitoring Application to Project Objectives

The five primary objectives that the Biscayne Bay Coastal Wetlands project is designed to achieve are provided in ***Table E-1***. Sections of the ecological monitoring plan that are designed to evaluate each objective are included in the table as a cross-reference.

TABLE E-1: CROSS-REFERENCE OF PROJECT OBJECTIVES AND APPLICABLE DOCUMENT SECTIONS

Project Objective	Applicable Document Sections
1. Re-establish productive nursery habitat along shoreline.	2.1 Oysters 2.2 SAV 2.3 Estuarine fish 2.4 Juvenile crocodiles
2. Redistribute freshwater flow to minimize point source discharges to improve estuarine habitat.	2.2 SAV 2.3 Estuarine fish 2.5 Nearshore salinity
3. Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.	2.1 Oysters 2.2 SAV 2.3 Estuarine fish 2.4 Juvenile crocodiles 2.5 Nearshore salinity 3.2 Wetland algae
4. Preserve and restore spatial extent of natural coastal glades habitat.	3.1 Wetland macro vegetation 3.2 Wetland algae
5. Re-establish connectivity between Biscayne Bay Coastal Wetlands, C-111 Basin, Model Land Basin, and adjacent basins.	3.2 Wetland macro vegetation 3.3 Wetland algae

Key: SAV submerged aquatic vegetation

E.1.3 Monitoring Duration

Project level monitoring for the Biscayne Bay Coastal Wetlands project should be conducted for at least five years, and then reassessed to determine if additional monitoring of specific parameters should be extended to ten years.

To understand the complexities of ecological changes over time, monitoring must remain flexible and adaptive. While it is likely that monitoring of certain parameters may be re-scaled both temporally and spatially after targets are attained for given parameters, some monitoring is needed to provide information on longer-term effects of the restoration project efforts. Moreover, additional parameters may be identified that qualify as requiring monitoring in order to gauge successes and failures within the project.

This Biscayne Bay Coastal Wetlands project monitoring plan was developed assuming that major, ongoing monitoring programs that are not funded by the Project would continue to supply data relevant to the Project. Should any of these programs (e.g. coastal water quality and seagrass monitoring) be discontinued or significantly curtailed, then Federal and local sponsors of the Project will reevaluate monitoring priorities and may redistribute funds for the benefit of the Project, even potentially not funding elements of this monitoring plan.

E.2 NEARSHORE

The local watershed is currently drained by a series of canals as part of the Central and Southern Florida (C&SF) Flood Control System dredged into the shallow aquifer and controlled by gated spillways. Runoff is discharged into Biscayne Bay via these canals at four locations within the Phase 1 project area. Prior to construction and operation of these canals, runoff discharged into Biscayne Bay through a series of small, natural channels or creeks distributed along the shoreline. All creeks in the project area have been significantly altered, and an estimated 20 to 30 creeks no longer function as freshwater conduits (Meeder et al.; 1999, 2000, 2001). In addition, the natural ability of the shallow Biscayne Aquifer to distribute water into the bay through seepage has been greatly reduced because of low water levels. Consequently, redirection of runoff into a few concentrated points and highly controlled releases has resulted in impacts to salinity within the nearshore bay environment in two primary ways. Habitat value within and immediately adjacent to canal mouths is poor because freshwater is released only to control stages upstream without regard to impacts to the estuary, and can be abrupt. Intermittent and sometimes intense discharges cause salinity near the canal mouths to vary widely within short periods of time. Many estuarine organisms are not adapted to manage abrupt and variable changes in salinity, therefore few organisms live within or very close to the canal discharges. Another way the redirection of runoff has affected the nearshore bay habitat is by generally altered patterns of salinity where salinity stays lower around the canal mouths and projects into the middle of the bay rather than being evenly distributed along shore. Modeling has shown that a more natural distribution of runoff into 21 creeks creates a broader area of lower salinity along the shoreline that does not extend out into the middle of the bay where sensitive coral and sponge habitat can be affected (Brown, 2003 and 2004). The primary restoration objectives of the Biscayne Bay Coastal Wetlands project in the nearshore area are:

Objective 1	Re-establish productive nursery habitat along the shoreline.
Objective 2	Redistribute freshwater flow to minimize point source discharges to improve estuarine habitat.
Objective 3	Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.

The purpose of this section of the monitoring plan is to provide information to adequately address the efficacy of achieving the above stated objectives. Thus, the monitoring plan must generate the types and frequencies of data necessary to adequately evaluate the following:

- The re-establishment of oyster habitat at creek mouths (indicator of nursery habitat and improvement of the quantity, timing, and distribution of freshwater to the bay; Objectives 1 and 3)

- The coverage of SAV along the shoreline; spatial extent and species composition (indicator of nursery habitat and reduction in point source discharges; Objectives 1 and 2)
- Fish composition and abundance more indicative of healthy estuarine nursery habitat (indicator of nursery habitat; Objective 1)
- Juvenile crocodile distribution and abundance (indicator of healthy nursery habitat, Objective 1)
- The salinity of water in the nearshore areas (indicator of reduced point source discharges and a measure of water quality, and directly affects the habitats and biota listed above; Objectives 2 and 3)

E.2.1 Oyster Monitoring

E.2.1.1 Justification and Relevance to Performance Measures

Relic Eastern (or American) oyster (*Crassostrea virginica*) reefs or bars have been found in association with most of the primary historic creek systems in the project area (Meeder *et al.*, 1999). With reduction and redirection of freshwater runoff (along with many other changes to the coastal wetlands), these historical oyster reefs or bars have been lost. New reefs have not formed in the mouths of canals presumably because of the poor habitat conditions. Restoration of a more natural overland flow, particularly the restoration of flow through coastal creeks, is expected to create conditions suitable for the reestablishment of Eastern oysters. The flat tree oyster (*Isognomon alatus*) is common in the project area, and possibly the Caribbean oyster, *Crassostrea rhizophorae* also occurs.

Monitoring oysters addresses project Objective 1 by evaluating the extent to which suitable nursery habitat is restored in the nearshore waters of the project area. Suitable nursery habitat includes oyster bars or reefs in the mouths of restored freshwater creek systems that have appropriate substrates in the project area. Historically, this included about 21 creek systems. The salinity regime that promotes establishment and maintenance of oyster reefs is the same regime that promotes an appropriate assemblage of estuarine fish. In south Florida this includes species such as red drum (*Sciaenops ocellatus*), once common in Biscayne Bay and found in association with oyster reefs (Smith, 1896). Black drum (*Pogonias cromis*), Atlantic croaker (*Micropogonias undulates*), snook (*Centropomis unidecimalis*), and spotted sea trout (*Cynoscion nebulosus*) are other estuarine species that were once more abundant in Biscayne Bay. Restoration of local conditions supportive of oysters in historical or equivalent oyster habitat is expected to lead to an increase in the number of characteristically estuarine fish and invertebrate species and their abundance more typically associated with oyster beds. Oyster monitoring will also address Objective 3 by evaluating the effects of improvement of the quantity, timing, and distribution of freshwater to the bay. Re-establishment of oyster habitat is an important component of two of the project's performance measures; Performance

Measure 1C (Salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat) and Performance Measure 2C (Viable Eastern oyster communities become established along the shoreline). This information will be used to support adaptive assessment efforts (see ***Part 4 Section E.5.1***).

E.2.2 Project-Level Component for Oysters

Data will be collected to monitor the rate of recruitment of new oysters to the population, distribution, abundance, reproductive status, and general health of adult oysters and growth and survival of young oysters until they join the adult size class. Project-level monitoring for oysters will consist of four primary components. Listed in order of priority, they include: (1) oyster spat recruitment, (2) oyster reef development, (3) juvenile growth and mortality, and (4) adult health and reproductive status. Monitoring will be conducted at eight sites along the shoreline in the project area (***Figure E-1*** and ***Table E-2***). Each site should be located at or near the mouths of historic or existing major freshwater creeks or at locations where significant freshwater flow to the bay is anticipated as a result of the project. Site selection should be flexible and should be a joint decision between the Biscayne Bay Coastal Wetlands project delivery team (PDT) monitoring sub-team and appropriate Restoration, Coordination and Verification (RECOVER) team. Factors such as the suitability of bottom substrate should also be considered in site selection. Monitoring for components 1, 3, and 4 should be conducted monthly for at least two years prior to project construction to establish a sufficient baseline. Oyster monitoring of these parameters will be reinitiated when nearshore salinity data show conditions more favorable for oyster re-colonization. Component 2 should be conducted annually for each year that the other components are monitored. Methods for monitoring each component are as follows.

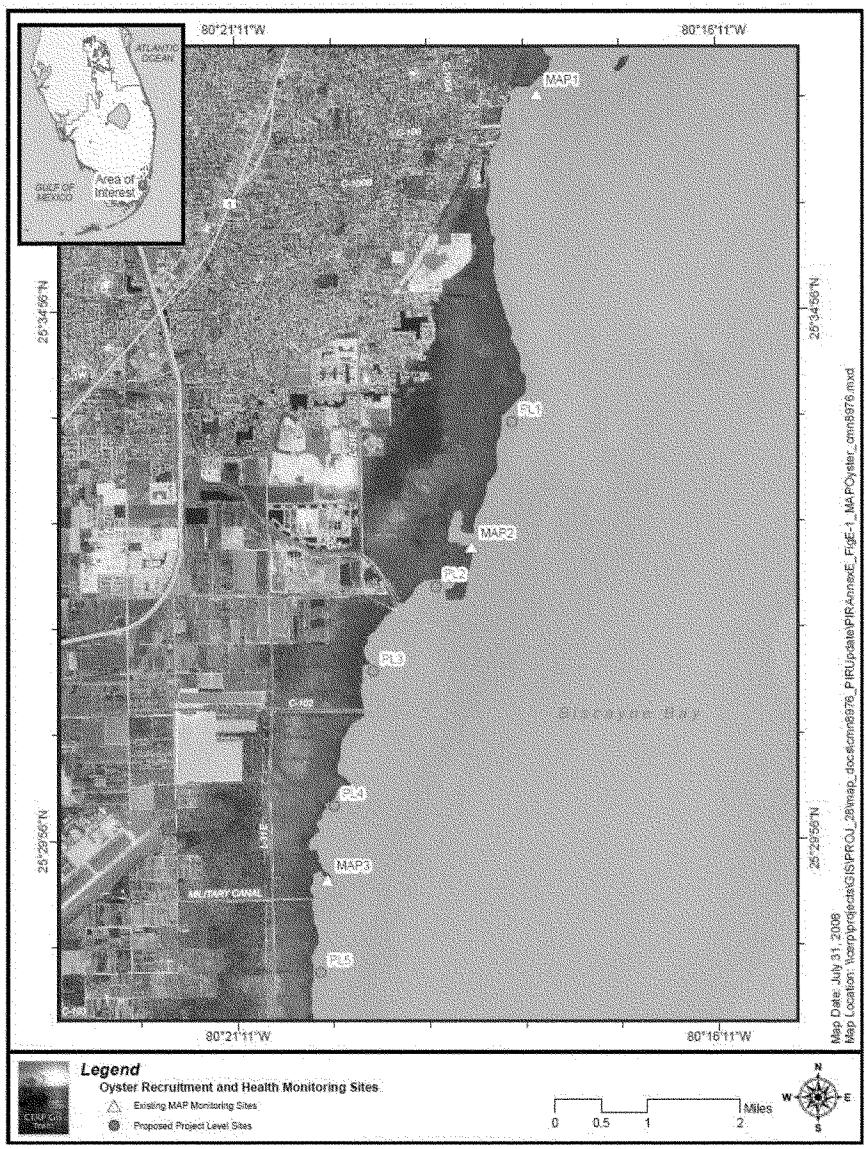


FIGURE E-1: APPROXIMATE LOCATIONS OF THE OYSTER RECRUITMENT AND HEALTH MONITORING SITES

Key: *Yellow triangles depict Monitoring and Assessment Plan sites; red dots depict project-level sites.

*Site selection is flexible and will be a joint decision between the Biscayne Bay Coastal Wetlands PDT monitoring sub-team and RECOVER. Some of the sites listed may not receive water until full implementation of Alternative O has been completed.

TABLE E-2: APPROXIMATE LOCATIONS OF MONITORING AND ASSESSMENT PLAN AND RECOMMENDED PROJECT-LEVEL OYSTER MONITORING SITES*

Site Name	Location Description	Latitude	Longitude
MAP1	Cutler Drain	25.61613	80.30075
MAP2	Black Point north embayment	25.54485	80.31240
MAP3	Creek North of Military Canal	25.49253	80.33765
PL1	Cutler Point Creek	25.56451	80.30533
PL2	Black Point south embayment	25.53862	80.31862
PL3	Nearshore north of C-102	25.52538	80.32952
PL4	Fender Point	25.50419	80.33643
PL5	Nearshore north of C-103	25.47799	80.33888

Key: MAP Monitoring and Assessment Plan
PL Project Level Oyster Monitoring Sites

*Site selection is flexible and will be a joint decision between the Biscayne Bay Coastal Wetlands PDT monitoring sub-team and RECOVER. Some of the sites listed would not receive water until full implementation of Alternative O has been completed.

Spat Recruitment (Priority 1)

Oyster spat recruitment monitoring at each site will be used to measure the availability of this life stage of oysters in the project area. This is considered the top monitoring priority because without spat recruits, oyster reefs cannot develop unless spat are artificially introduced. Three replicate spat monitoring arrays are deployed at each of the eight creek mouth sites facing the open water Identical arrays are deployed at one site and within two to three meters of the shoreline depending on location conditions. Upstream and one site downstream of each creek mouth site (i.e., a total of 24 sites will be monitored for spat). Exact locations of the upstream and downstream sites will be determined when monitoring begins. Each array consists of 12 axenic adult oyster shells strung together with a weighted galvanized wire. Oyster recruitment is estimated by counting the number of settled spat on the underside of the strung shells. Each array is deployed and recovered on a monthly schedule for the first year of the study. If the first year of data indicates that recruitment is limited to certain months of the year, deployments may be limited to those months during subsequent years. Spat recruitment monitoring should be conducted as soon as possible and before the project is constructed to establish a baseline and characterize interannual variability.

Oyster Reef Development (Priority 2)

The second priority for oyster monitoring is measurement of oyster reef development. This component is a direct indicator of the project's objective to restore estuarine nursery habitat along the shore of southwestern Biscayne Bay. Monitoring will involve thorough annual surveys of the shoreline for existing

oyster reefs or bars to provide a baseline of existing conditions. Subsequent surveys will be conducted annually after construction of the project to determine the extent that oysters have re-established in the project area. Surveys will document the number and distribution of live oyster bars. Surveys will be conducted along the shoreline between Shoal Point and Turkey Point, and focus on existing or historic creek mouths, or where freshwater is anticipated or known to be entering the bay (as determined by other monitoring parameters, e.g., salinity data). It is expected that annual surveys should only require one to two days working from a small boat. A critical aspect of this component is the definition of the size of an oyster clump that constitutes a reef or bar (*e.g.*, ¼ m^2, 1 m^2). The project team will make a decision regarding such qualifications of oyster reef development as the project progresses.

An important consideration of the monitoring for the current condition and reestablishment of oysters in the project area is the abundance and distribution of oysters on mangrove prop roots and other suitable substrate (*e.g.*, dock pilings or seawalls) in the project area. It is unknown how important the current distribution and abundance of oysters attached to prop roots is in the project area. Clearly, these individuals play a role in contributing to the filtering of bay water and in the deposition of feces and pseudo-feces that support a variety of organisms in the benthos. However, they likely play a limited role in providing structural habitat for estuarine fauna typically associated with well-developed oyster reefs. Considering the limited habitat contribution and labor intensive (and costly) assessment and monitoring of oysters attached to mangrove prop roots, the relative value of monitoring for these individuals was deemed insufficient to be included in the Biscayne Bay Coastal Wetlands Monitoring Plan. However, evaluating the relative importance of prop root oysters to the ecology of this system is of interest to the Biscayne Bay Coastal Wetlands project and would constitute a viable ecosystem initiative study.

The following procedure can be used to determine the status of live oysters on the reefs where oyster reefs become re-established. Initially, when reefs are small (~2 m^2), surveyors will count the number of live oysters comprising the reef. For larger reefs, one square meter (1-m^2) quadrats can be randomly deployed and all oysters within each quadrat are harvested for the counts of live and dead oysters, and the shell height of those oysters. Sampling is conducted twice per year (summer and winter). At each site, ten replicate one square meter quadrat samples or a statistically viable number of ¼-m^2 quadrat samples of live-dead adult oysters are collected. That sampling intensity allows detection of true changes in the density of oysters that is one and one-half times the standard deviation of oyster density at that site, with a 95 percent probability of detecting a true change when that change occurs. The above sampling intensity also allows a 20 percent probability of making a Type II error (no change was claimed when one actually occurred) for a change that is one and one-half times

the standard deviation. The probability of a Type II error goes down to five percent for a change that is two times the standard deviation. This replication scheme may be modified depending on the variance observed in the adult density data after the first year of sampling.

Juvenile Growth and Mortality (Priority 3)
While conditions at a given site may be suitable for spat recruitment and adult growth and survival, conditions may not be suitable for juvenile growth and survival. Thus, monitoring will be conducted to determine the suitability of the habitat for juvenile oyster growth and mortality. This parameter is an important assessment in the oyster monitoring scheme. Monitoring for this parameter is conducted by planting juvenile oysters at each site. Planted juveniles are cultured from parent brood stock collected from Biscayne Bay as close to the study site as possible. For example, adult oysters are readily available from the seawall at the Deering Estate, but it is unclear at this time if those oysters would be permitted to be harvested for brood stock. Spawning and rearing of oysters to the early post-settlement stage (two to five millimeter shell height) will be conducted offsite. Shells occupied by recent post-set oysters are planted into 12.5 millimeter mesh cages at each of the three sites, with periodic measurements of survival and growth taken. Each cage is composed of two compartments, with one compartment completely enclosed by mesh to exclude macrofaunal predators and the other compartment partially open to allow entry of such predators. This approach allows assessment of macrofaunal predation at each site.

Oyster Health (Priority 4)
Monitoring adult oyster health in the project area is important with respect to the prevalence of common oyster diseases that present significant problems to oysters. These diseases, including *Perkinsus marinus* (dermo) and *Haplosporidium nelsoni* (MSX), are known to be affected by salinity. Generally, salinity below 20 practical salinity units (psu) is unsuitable to these pathogens. Prevalence of these pathogens may indicate oysters will not develop robustly (Kennedy *et al.*, 1996; Woodward-Clyde, 1998). The prevalence and intensity of oyster diseases, primarily dermo and MSX, will be examined on a monthly basis by tissue analysis on fifteen Biscayne Bay oysters for each of the two diseases. Reproductive condition will also be determined from the gonadal condition on individuals examined for MSX. The results derived from the detailed sampling regime allows reproductive and disease patterns to be resolved at two spatial scales: within reef at each site and among sites.

Note that details of methods, including sampling design and statistical approaches, can be found in the Monitoring and Assessment Plan Statement of Work for Biscayne Bay oyster monitoring. These methods should be consistent with those provided in the Comprehensive Everglades Restoration Plan Quality

Assurance Systems Requirements Manual (RECOVER, 2004b). Also, the monitoring scheme described above should provide data that will be useful, if not critical, to an oyster habitat suitability index for south Florida.

E.2.3 Monitoring and Assessment Plan Component for Oysters

The Comprehensive Everglades Restoration Plan Monitoring and Assessment Plan team is currently conducting each of the four oyster monitoring parameters described above at three sites in the project area (black triangles in ***Figure E-1***, first three sites in ***Table E-2***.

E.2.4 Comparison between Preferred Project-Level Monitoring and the Monitoring and Assessment Plan for Oysters

Proposed baseline project-level monitoring for all four components listed in ***Section E.2.2*** has been completed by the Monitoring and Assessment Plan at three of the eight recommended sites. Fulfillment of recommended project-level monitoring will require conducting the monitoring of the four components at the additional five sites shown in ***Figure E-1*** (represented as red triangles) and the other five sites in ***Table E-2***. The three sites presently being monitored as defined by the Monitoring and Assessment Plan are not adequate for determining, to the extent required, whether or not oysters have been restored in the project area. The additional five site locations are consistent with the locations of historic major creek systems identified by Meeder et al. (1999). Ideally, the project will be managed to attain oyster re-colonization near as many major creek systems as possible. Therefore, restoration of oysters within these additional five creek systems, or appropriate alternate sites, should be attained. Details of methods and protocols can be found in the Monitoring and Assessment Plan Statement of Work for Monitoring and Assessment Plan Biscayne Bay oyster monitoring (under the Northern Estuaries component of the Monitoring and Assessment Plan; MAP Reference Number 3.3.3.6).

E.2.5 Data Management/Quality Assurance and Quality Control for Oysters

<u>Data Management</u>
Chapter 10 in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm) states that the Comprehensive Everglades Restoration Data Management Plan (February 26, 2002) provides for coordinated management and integration of all Comprehensive Everglades Restoration Plan information with a program-level strategy. The Comprehensive Everglades Restoration Plan Data and Information Management Team will interact with the Comprehensive Everglades Restoration Plan Quality Assurance Oversight Team, as necessary in order to:

1. Review and comment on all data-related technical specifications;
2. Ensure that a proper data quality assurance and quality control process will be in place, particularly for data-acquisition contracts; and
3. Review contract statement of work for environmental monitoring before they are issued.

Chapter 10 in the Quality Assurance Systems Requirements Manual further states that since data will be collected for a variety of uses within the Comprehensive Everglades Restoration Plan, including permits and other legal mandates, the data management system must follow standards and regulations, including:

- National Environmental Laboratory Accreditation Conference standards
- Florida Department of Environmental Protection standards, as specified in Chapter 62-160, Florida Administrative Code
- Comprehensive Everglades Restoration Data Management Plan requirements
- and, any other applicable regulations specific to the monitoring of different projects

In addition, data management should follow implementation guidelines being developed in the Restoration, Coordination and Verification Monitoring and Assessment Plan, which will provide more details on information and data management procedures. Other relevant Comprehensive Everglades Restoration Plan Guidance Memoranda references for Comprehensive Everglades Restoration Plan information and data management and standardization are as follows:

- Comprehensive Everglades Restoration Plan Guidance Memorandum #002 provides guidance for project names convention.
- Comprehensive Everglades Restoration Plan Guidance Memorandum #028 provides guidelines and recommendations covering all Comprehensive Everglades Restoration Plan GIS data sets standards. GIS documentation standards should be in compliance with the Federal Geographic Data Committee documentation for the data to be included in the Comprehensive Everglades Restoration Plan Enterprise GIS database.
- Comprehensive Everglades Restoration Plan Guidance Memorandum #041 provides guidance on agency responsibility and coordination for Comprehensive Everglades Restoration Plan data validation and management.

Chapter 10 in the Quality Assurance Systems Requirements Manual provides guidance and protocols on how to handle data types, elements, and standards;

project identifiers; field identifiers; laboratory identifiers; field data elements; data file format and content assessment; change control and tracking of issues; records management storage and access; records quality assurance measures; records custody, security, and access; documentation; and tracking revisions and corrections.

Quality Assurance and Quality Control for Oysters

Quality assurance and quality control for oyster monitoring in the Biscayne Bay Coastal Wetlands project should conform to the guidance and protocols provided in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm). ***Appendix L*** in the manual provides methods, references, and reporting units for conducting monitoring on oyster infection prevalence and intensity, reproductive status and health, juvenile oyster size and growth, spat recruitment, and gonadal index.

E.2.6 Cost Estimates for Oyster Monitoring

TABLE E-3: OYSTER MONITORING COST ESTIMATES

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$101,279	$17,973	$ 83,306
Years 1-5	$461,478	$101,424	$360,054
Years 6-10	$450,250	$101,424	$348,826
TOTAL	$911,728	$202,848	$708,880

Key: MAP Monitoring and Assessment Plan

The above estimates include costs for the oyster component in the Monitoring and Assessment Plan. If MAP funding for any of these projects terminates, the project level monitoring plan will be reevaluated to determine what if any of the monitoring should continue.

E.3 SUBMERGED AQUATIC VEGETATION (SAV) MONITORING

E.3.1 Justification and Relevance to Performance Measures

Seagrass and algal beds function as vital habitat to support critical life stages of a variety of ecologically important and commercially or recreationally valuable species. At least seven species of seagrasses occur in Biscayne Bay: turtle grass (*Thalassia testudinum* Banks & Soland ex Koenig), shoal grass (*Halodule wrightii* Aschers.), manatee grass *Syringodium filiforme* Kuetz, three species of *Halophila*, including *H. johnsonii* Eiseman, which is a federally-listed protected species, and widgeon (aka wigeon) grass (*Ruppia maritima* Linnaeus).

Distribution of seagrass species is generally related to water clarity and quality, substrate, salinity levels and salinity variability. Macroalgae also dominate some areas of the nearshore bottom habitat. The red alga *Laurencia poiteaui* Lamouroux in particular is common, but other species of green, red, and brown algae are frequently observed (Christian et al., 2004).

T. testudinum is most prominent in central and south Biscayne Bay where salinity is in the 30-36 psu range with low variability. Nutrient levels are also low compared to nearshore and northern areas. The distribution of seagrass species and other benthic flora and fauna in the western nearshore area of central and southern Biscayne Bay is influenced by both canal discharges and submarine groundwater seepage (Kohout and Kolipinski, 1967; Meeder et al., 1997 and 1999). Presence or absence of *T. testudinum* may indicate distinct zones where ground-water influence is substantial (*T. testudinum* absent) or insignificant (*T. testudinum* present). This is in part due to the salinity tolerance of *T. testudinum*, as it does not compete favorably in low and or highly variable salinity regimes (Lirman and Cropper, 2003). Both low salinity and high salinity variability can occur in nearshore regions where groundwater seepage has been documented, and surface water runoff occurs.

In the very nearshore regions (*e.g.* within 200 m of shoreline) *H. wrightii* is more prominent, as it can tolerate a broad range of salinity, and large salinity (and temperature) fluctuations (Lirman and Cropper, 2003). *R. maritima* and *S. filiforme* have sparse distributions in the Biscayne Bay Coastal Wetlands project area. *R. maritima* is uncommon and restricted to areas proximal to coastal embayments, while *S. filiforme* is more commonly found north and south of the project area. Although *R. maritima* is tolerant of a wide range of salinity, in Florida Bay and Biscayne Bay, it has been observed only in areas of persistent, low salinity regimes, and has been used as an indicator of freshwater input (Hunt et al., 2006).

The nutrient-enriched environment of the nearshore area promotes algae growth (Biber 2002), and salinity plays a role in its abundance and distribution. Nutrient concentrations in water management related canal discharges could be causing increased biomass of macroalgae and epiphytic growth on seagrass blades especially in the spring when salinity is higher, temperature is lower and irradiance is strong. During the summer, drifting macroalgae tends to die and decay thus liberating nitrogen and other nutrients captured during the spring.

The premise of the Biscayne Bay Coastal Wetlands and Comprehensive Everglades Restoration Plan is that restoring hydrology will improve the overall health of the various ecological communities in these estuaries. Because it is not practical to monitor every aspect of estuarine ecology, indicator species with direct links to system stressors were identified through the development of

Conceptual Ecological Models for southern Florida water-bodies (Rudnick et al., 2005; Browder et al., 2005). From those Conceptual Ecological Models, five hypothesis clusters for describing how the bay's ecology is linked to environmental drivers and stressors were identified, including water quality, benthic submerged aquatic vegetation, nearshore nursery function, nearshore community structure and toxins/contaminants.

The ecological premises behind SAV monitoring is that through the more diffused and prolonged delivery of freshwater to the bay (*i.e.*, more similar to conditions that existed prior to upstream water management), a more stable mesohaline salinity gradient, with fewer and less extreme variations, will be restored in the coastal environments of Biscayne Bay, and that excessive dissolved nutrients will be captured in wetlands upstream. Such conditions will enable development of more widespread coverage by a diverse SAV community. The Comprehensive Everglades Restoration Program hypothesis regarding seagrass is that the restoration of favorable flow and stable salinity regimes (especially mesohaline conditions) will result in the increased occurrence of *R. maritima* in the very nearshore and coastal embayments, and extension of the range of *H. wrightii* along shore with a broader coverage north to south. The seaward abundance of *H. wrightii* should retract somewhat as lower salinity is kept closer to shore and away from the coral and sponge habitats.

Redistribution of freshwater in the project area should affect SAV through changes in species distribution and relative abundance in the species composition in the nearshore regions (*i.e.*, within 1000 meters from shore). With the redistribution of freshwater, it is anticipated that the very nearshore (*i.e.*, less than 250 meters) and areas near mouths of historic creeks will show a gradual decrease in cover and abundance of *T. testudinum* and a concurrent increase in *H. wrightii* cover and abundance. It is also likely that *R. maritima* may become more established in coastal embayment areas. In addition, the abundance of macroalgae should decrease which will allow seagrasses to become more dense and productive.

Monitoring SAV addresses project Objective 1 by evaluating the extent to which suitable nursery habitat is restored in the nearshore waters of the project area. Suitable nursery habitat includes extensive seagrass coverage of appropriate species, as described above. The salinity regime that promotes establishment and maintenance of appropriate seagrass species along the shoreline (*i.e.*, *H. wrightii* and *R. maritima*) is the same regime that promotes an appropriate assemblage of estuarine fish, as described in ***Section 4.2***. Restoration of local conditions supportive of seagrass habitat is expected to lead to an increase in the diversity and abundance of characteristically estuarine fish and invertebrate species. SAV monitoring will address Objective 3 by evaluating the effects of improvement of the quantity, timing, and distribution of freshwater to the bay.

Expansion and appropriate species transition of SAV habitat is an important component of the project's Performance Measure 1D (The seagrass community at existing canal mouths will be similar in abundance and composition to the community in other areas nearshore). This information will support adaptive assessment efforts (see ***Part 4, Section E.5.2***).

E.3.2 Project-Level Component for SAV

The monitoring plan for the Biscayne Bay Coastal Wetlands SAV must be able to identify responses in both spatial and temporal scales. It is expected that with implementation of the project, there will be near-term and long-term responses, as well as localized and project-wide effects. Spatially, *H. wrightii* has been documented in the nearshore area at least one kilometer offshore, especially near Black Point (Christian et al., 2004). As the plume effect of flow from the C-1 Canal is mitigated through redistribution of flow to coastal wetlands, *H. wrightii* cover may be overtaken by *T. testudinum* in the areas furthest offshore. Temporally, seagrass colonization response is in the order of one to three years in Biscayne Bay based on unpublished monitoring data. Therefore, annual assessments should be adequate. Annual assessment of seagrass and macroalgal cover by species is recommended within a polygon extending from the shoreline to at least one kilometer offshore.

Random points with a density of about ten per square kilometer should be selected within a polygon nearshore of the project area that extends at least one kilometer from shore each year (***Figure E-2***). The monitored area should extend from Shoal Point to Turkey Point. At each station, five one-meter square areas of bottom will be analyzed using the Braun-Blanquet method (Fourqurean et al., 2001) for epibenthic vegetation. Observations can be collected either by divers or by imagery and later interpreted. Interpreters should be trained and calibrated with other projects in south Florida using the same approach.

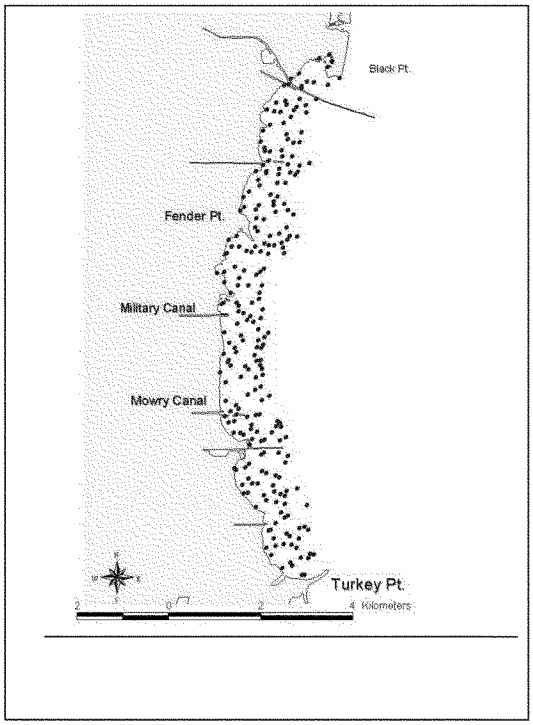


FIGURE E-2: EXAMPLE OF RANDOM SUBMERGED AQUATIC VEGETATION MONITORING POINTS IN AN AREA NEARSHORE THE PROJECT

It is difficult to predict, however, how rainfall patterns in particular may create year to year or longer term variation that could mask effects caused by the project. Although a broader scaled assessment sufficient to identify and document the regions SAV response to project activities will be required for the initial monitoring period (e.g., up to 5 years), subsequent monitoring can be targeted around areas of change (i.e., reduced distance from shore, or reduced regional coverage.

E.3.3 Monitoring and Assessment Plan Component for SAV

The Monitoring and Assessment Plan indicates that remote sensing will be used to evaluate spatial patterns of abundance and distribution of seagrass communities within Biscayne Bay. Color aerial photographs will be obtained and analyzed to create high-resolution digital benthic maps to:

1. Assess the present-day extent and distribution of seagrass communities.
2. Determine, through repetitive sampling, patterns of change in seagrass abundance and distribution as restoration efforts proceed.
3. Develop a suite of landscape-level indicators of seagrass condition as a monitoring tool to evaluate the effects of management decisions on seagrass resources in the region.

The Monitoring and Assessment Plan works to integrate on-going, long-term monitoring toward these landscape assessments. Presently, Miami-Dade County Department of Environmental Resources Management, through a contract with the South Florida Water Management District, samples 100 SAV stations in Biscayne Bay between Rickenbacker Causeway and Card Sound annually using Braun-Blanquet cover estimates. Additionally, ten-fixed stations, located between Haulover Inlet in North Biscayne Bay and Black Point in central Biscayne Bay are assessed annually, one of which (BH39) is within the specific nearshore project region of the Biscayne Bay Coastal Wetlands. The Monitoring and Assessment Plan is presently funding the "South Florida Seagrass Fish and Invertebrate Assessment Network", a project designed to integrate faunal sampling with the concurrent seagrass monitoring. This project includes an expansion of the South Florida Fish Habitat Assessment Program that will add seven SAV assessment areas in Biscayne Bay. Only two of those areas BB03–North Black Point and BB04-South Black Point are within the Biscayne Bay Coastal Wetlands project monitoring area.

A current MAP study evaluates epibenthic habitats from Rickenbacker Causeway to Turkey Point. The objective of this project is to document shallow epibenthic habitats within 500 meters of the western shoreline of the bay, and examine seasonal and long-term abundance of seagrass species and algae using high resolution digital imagery. The goal is to provide:

1. A comprehensive, spatially-explicit baseline database on the seasonal species composition, distribution, diversity, and abundance of benthic organisms that constitute the nearshore seagrass, macroalgal, and hard bottom communities of Biscayne Bay.
2. Detailed, high resolution environmental data (*i.e.*, temperature and salinity) that are essential to relate the current status and future changes of epibenthic communities to these physical parameters at a scale commensurate with the proposed surveys. An innovative benthic survey technology, the Shallow Water Positioning System (SWaPS) developed by scientists from National Oceanic and Atmospheric Administration's National Geodetic Survey (Lirman et al. 2006), is utilized to obtain observations that are geographically comprehensive. Since some historical data exists, changes in the distribution and abundance of key indicator species such as *H. wrighiie* and *R. maritima* may show effects of

modified water management patterns. The MAP Activity Title for this work is: Documenting Everglades Restoration Impacts on Biscayne Bay's Shallowest Benthic Habitats (MAP Activity Number: Southern Estuaries 3.2.3.3).

E.3.4 Comparison between Preferred Project-Level Monitoring and the Monitoring and Assessment Plan for Submerged Aquatic Vegetation

The scales of the projects mentioned above are appropriate to meet the objectives of the proposed studies. The proposed supplemental Biscayne Bay Coastal Wetlands SAV monitoring will provide information with additional resolution to allow assessment of the effects of the Biscayne Bay Coastal Wetlands project on the SAV. The proposed SAV monitoring plan for the Biscayne Bay Coastal Wetlands will provide explicit data that can be used in assessing how well both the Biscayne Bay Coastal Wetlands project and the overall Comprehensive Everglades Restoration Program are meeting their objectives through evaluation and documentation of the nearshore community structure and aquatic vegetation. New SAV monitoring stations in Biscayne Bay associated with the Biscayne Bay Coastal Wetlands SAV monitoring will be restricted to about the western most 1,000 meters of the bay, as this is the area in which demonstrable project effects are anticipated to occur. While the frequency of ongoing MAP and other efforts (*e.g.*, SF-FHAP and Miami-Dade County Department of Environmental Resources Management/South Florida Water Management District sampling) may be appropriate for assessing relations between faunal assemblages and regional changes in seagrass community composition and abundance on a broader regional scale, neither of these projects will provide the resolution needed in the nearshore zone (*e.g.*, in the 0-1000 meters) to allow evaluation of the anticipated project related responses in the SAV communities. Because the resolution provided by these other efforts is not adequate for the Biscayne Bay Coastal Wetlands project, these data will be of limited use by the project. The SWaPS project to collect high resolution digital imagery could be enhanced to include transects to the edge of the grass beds (one kilometer or more from shore) in some locations to determine how these mixed beds are responding to changed salinity. The increased coverage and level of resolution provided by the project-level SAV monitoring is imperative to provide the appropriate data density to allow determination of project effects.

E.3.5 Data Management/Quality Assurance Quality Control for SAV

Data Management
See ***Section E.2.5*** above

Quality Assurance/Quality Control for SAV Monitoring
Quality Assurance and Quality Control for SAV monitoring in the Biscayne Bay Coastal Wetlands project should conform to the guidance and protocols provided

in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements annual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm; RECOVER, 2004b). ***Appendix K*** in the document provides methods, references, and reporting units for conducting monitoring of SAV. Some of the parameters provided in ***Appendix K*** that may be relevant to the proposed project-level monitoring include SAV coverage using aerial photography interpretation and mapping; seagrass growth, production, biomass, coverage via fixed transects; and seagrass distribution and abundance using the Braun-Blanquet Cover Abundance method.

E.3.6 Estimated Monitoring Cost Estimates for Submerged Aquatic Vegetation

If it is assumed that the data collected by the shallow water positioning system (SWaPS) project can be used to assess the inshore area out to 500 meters, then the costs below would cover supplement monitoring to extend some transects in key areas (*e.g.* near Black Point) out to at least one kilometer.

TABLE E-4: ESTIMATED MONITORING COSTS FOR SUBMERGED AQUATIC VEGETATION

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$44,806	$39,037	$5,769
Years 1-5	$224,030	$195,185	$28,845
Years 6-10	$113,670	$56,835	$56,835
TOTAL	$337,700	$252,020	$85,680

Key: MAP Monitoring and Assessment Plan

Note that the above estimates are conservative as they imply that the specified level of effort will be required for the entire length of the project (which is a possibility). There are potential means for reducing costs through inclusion of multiple time scales for the monitoring, but this would be an 'adaptive' response. Further note that the year 6-10 estimate includes only targeted areas (e.g., reduced spatial coverage of the BBCA Assessment component, on an annually basis. Reduced areas are anticipated to be defined through the assessment of year 1-5 data, to those areas were flux in SAV can be tied to project related activities.

E.4 ESTUARINE FISH MONITORING

E.4.1 Justification and Relevance to Performance Measures

The faunal assemblages of western nearshore Biscayne Bay are made up of fishes and macro-invertebrates with both estuarine and marine affinities. An increase in diversity and abundance of the estuarine component of this assemblage (*i.e.*, the euryhaline fauna) would indicate progression toward the desired estuarine conditions in the western nearshore bay. As components of the nearshore food web, these species support the diet of recreationally and commercially important species that spend all or a part of their lives in the bay, especially in juvenile stages. Therefore, an increase in diversity and abundance of these fish and macro-invertebrates would indicate improved nursery habitat for juvenile fishes. This parameter applies to Biscayne Bay Coastal Wetlands Project Objectives:

1. Re-establish productive nursery habitat along the shoreline
2. Redistribute freshwater inflow to minimize point source discharges to improve estuarine habitat
3. Restore and improve quantity, quality, timing, and distribution of freshwater to the bay

Re-establishment of appropriate estuarine fish assemblages is an important component of three of the project's performance measures:

- Performance Measure 1A-(fish community assemblage within creeks and within one kilometer of the western shoreline will reflect that expected in a healthy, functioning estuary)
- Performance Measure 1C-(salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat)
- Performance Measure 3A-(nearshore salinity patterns exhibit a broader area and extended duration of mesohaline conditions)

This information will be used to support adaptive assessment efforts (see ***Part 4, Section E.5.3***).

E.4.2 Project-Level Component for Estuarine Fish Monitoring

The focus of this component of project-level monitoring is the shallow-open-water fish and macro-invertebrate assemblage in close proximity to the shoreline. Project-level monitoring will encompass the segment of shoreline between Shoal Point and Turkey Point that is the main area to be affected by the Biscayne Bay Coastal Wetlands Phase 1 project. At least 45 sites will be located between

Shoal Point and Turkey Point, with two sites located north of Shoal Point for comparison purposes. Three faunal samples will be collected at each site using one-square meter throw-trap gear described in Robblee et al. (1991) and also used in Monitoring and Assessment Plan projects 3.2.3.5 and 3.2.4.5 (Robblee and Browder, 2005). The number of sweeps of a seine through the throw-trap to collect each sample will be determined by the method described by Robblee and Browder (2005). Three Braun-Blanquet bottom cover estimates will be made at each site using standard methods described by Fourqurean et al. (2002). Salinity and temperature will be measured at each site in conjunction with faunal and bottom sampling. Water depth will be determined with a meter stick, and sediment depth will be estimated with a rod marked with a centimeter scale. Coordinates (digital latitude and longitude), date, and time of day will be noted.

Samples will be sorted, identified (fish to species, penaeid shrimp to species, crabs to major group, and carideans shrimps as a group), and counted. The resultant data will be summarized and analyzed to (1) quantify the composition of the faunal assemblages present; (2) determine spatial distributions in relation to environmental variables, especially salinity; and (3) track change over time in distributions, abundance, and species assemblages.

Previous work indicates that distinct species assemblages inhabit very shallow-open-water areas along the shoreline that is to be the focus of this project-level monitoring effort (Robblee and Browder, unpublished data). The Biscayne Bay Coastal Wetlands project monitoring will start from a foundation of two years of baseline data, collected at roughly the same locations (based on GPS coordinates) and with the same protocol as the new monitoring. A brief overview of the first year of data from this work (Browder et al., 2006) indicates a broad range of salinity occurs along the coastline (25 to 40 psu in February 2005 and 6 to 40 psu in August 2005), providing potential habitat for species with different salinity requirements. Redistribution of freshwater along the shoreline is expected to change the salinity pattern, re-establishing characteristic positive salinity gradients from coastal marshes into the nearshore bay and broadening the area of low-salinity water along the coastline. This should result in a change of faunal distributions, species abundances, and faunal assemblages. The area north of the Black Creek Jetty will receive more freshwater inflow than it currently receives. South of the Black Creek Jetty, some of the present point-source canal discharge will be redirected to coastal wetlands and will reach other parts of the coastline. Both of these changes will result in revised salinity patterns. The fauna may change in response to the change in salinity patterns in both of these areas. Changes on a smaller spatial scale also are expected. The Biscayne Bay Coastal Wetlands project monitoring sites are distributed along the coastline appropriately to capture both broad-scaled and detailed changes and assess them in relation to Biscayne Bay Coastal Wetlands project

objectives. Collection of three faunal samples at each sampling site will increase the chance of collecting at least one representative of each species or group present at the site, provide an "occurrence" estimate (0 to 3) for each site, and increase the ability to detect change brought about by Biscayne Bay Coastal Wetlands project. One advantage of this project-level monitoring scheme is that it will start from a foundation of two years of baseline data. These data will allow better characterization of pre-implementation spatial and temporal variability in the project area and more effective evaluation of monitoring results.

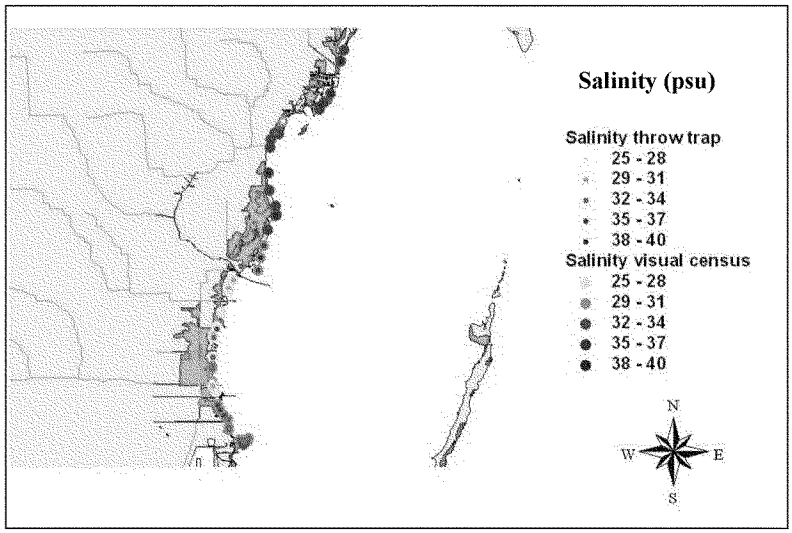


FIGURE E-3: SITES OF FEBRUARY 2005 ESTUARINE FISH (RED) AND VISUAL SURVEY (BLUE) MONITORING

Salinity in practical salinity units is shown by the size of the colored circles. Measured salinity was generally lower at visual survey sites.

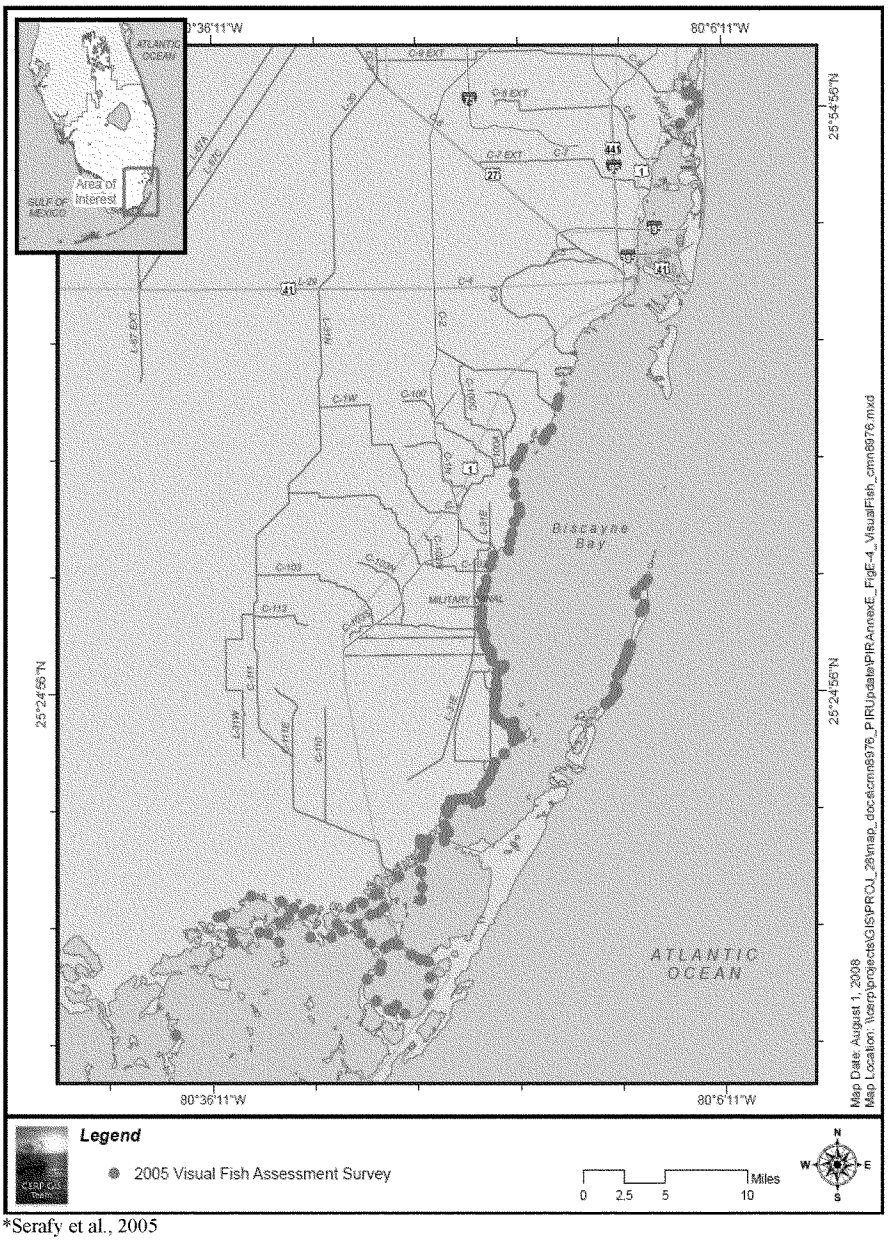
E.4.3 Monitoring and Assessment Plan Components for Estuarine Fish Monitoring

Monitoring that is currently funded under the Monitoring and Assessment Plan is described in ***Section E.3.2***. The Monitoring and Assessment Plan Activity Title for this project is: Epibenthic fauna adjacent to the South Biscayne Bay shoreline in relation to seagrass, shoreline fishes, and freshwater change in the Comprehensive Everglades Restoration Plan/Southern Estuaries Module Domain (Monitoring and Assessment Plan Activity Number: Southern Estuaries 3.2.4.7). Details for sampling protocols and sampling site locations

can be found in the statement of work for this project. This project is referred to below as epibenthic fauna monitoring.

The Monitoring and Assessment Plan has two additional existing monitoring components that relate to estuarine fishes in Biscayne Bay and complement the epibenthic fauna monitoring in Biscayne Bay. One is a visual survey of shoreline fishes conducted twice annually along the mangrove shoreline from Matheson Hammock to Manatee Bay (Serafy et al., 2005; ***Figure E-4***). The second is the Fish and Invertebrate Assessment Network, employing throw-trap gear, which includes two 30-cell sampling grids in western South Biscayne Bay (Robblee and Browder, 2005). The Fish and Invertebrate Assessment Network is sampled twice annually, at the end of the dry season (April-May) and at the end of the wet season (September-October). The grids extend from the shoreline to water depths of about two meters.

The Shoreline Fish Community Visual Assessment (Monitoring and Assessment Plan Module: 3.2.3.6) is conducted within the stretch of Biscayne Bay western shoreline from latitude 25° 16' N to latitude 25° 39' N. The visual fish assessment survey is conducted twice annually, during the wet season (July to September) and the dry season (January to March), on 30-meter transects located along the shoreline at sites that have been randomly selected in a stratified design. Each site is visited once each season. The same coordinates have been used to locate the site on each sampling date. Sampling has been conducted since 1998. At each site, a trained observer, using mask, snorkel, and water-proof paper, records the identity, number, and size-structure (minimum, mean, and maximum total length) of fishes within a two meter belt of inundated prop-root habitat (60-m^2 total transect area). After each transect is completed, water temperature and salinity are measured using a multi-probe water quality instrument, and water depth is determined using a two meter-long polyvinyl chloride pole marked off every two centimeters. Survey data are transferred to computer spreadsheets prior to analysis. See Serafy et al. (2003) for details of the fish survey and microhabitat measurement techniques. Results from the area indicated in ***Figure E-4*** between Shoal Point and Turkey Point will be applicable to the Biscayne Bay Coastal Wetlands Project Phase 1.



*Serafy et al., 2005

FIGURE E-4: MONITORING AND ASSESSMENT PLAN STUDY OF VISUAL FISH ASSESSMENT SURVEY SITES IN BISCAYNE BAY

The Fish and Invertebrate Assessment Network (FIAN) project (Monitoring and Assessment Plan 3.2.3.5 and 3.2.4.5) consists of a sampling regime organized by 30-cell sampling grids in each of 19 locations Biscayne Bay, Florida Bay, and the southernmost mangrove estuaries of southwest Florida. The Fish and Invertebrate Assessment Network project is designed in conjunction with the Monitoring and Assessment Plan seagrass monitoring and assessment project, FHAP-SF (Monitoring and Assessment Plan activity 3.2.3.3) and uses the same 30-cell grid sampling protocol. There are two grids in the area between Shoal Point and Turkey Point (one north and one south of Black Creek Jetty) and additional grids in Card Sound, Barnes Sound, and Manatee Bay (***Figure E-5***). There are two other sites in Biscayne Bay, both located north of the Rickenbacker Causeway. Sampling covers two periods, the late dry season (April-May) and the late wet season (September-October). The seasonal sampling began in April 2005. The sampling area applicable to Biscayne Bay Coastal Wetlands Project Phase 1 is indicated as North Black Point and South Black Point in ***Figure E-5***.

In the central and south Biscayne Bay area, grids extend from the western shoreline eastward into water depths of about two meters (***Figure E-5***). One randomly selected site is sampled in each of the 30 cells using a 1-m^2 throw-trap. The cells in each grid are the same size; however, cell sizes may differ among grids, depending on the size of the area to be covered. Approximately seven grid-cells fall on or adjacent to the shoreline north of the Black Creek Jetty and another seven grid-cells south of the jetty.

A 1-m^2 throw-trap is used to quantitatively sample epibenthic fish, shrimp and crabs in FIAN. The throw-trap was first developed by Kushlan (1974) for use in the freshwater Everglades. Using the throw-trap, or another enclosure type sampling device, has at least two significant strengths; (1) high capture efficiency for animals enclosed can be achieved by repeated sampling of the enclosed area and (2) resulting animal samples can be closely tied to habitat. Both strengths are critical when sampling fish and invertebrates in seagrass/algal beds.

The square fixed-frame 1-m^2 throw-trap was adapted to sampling in seagrass beds in Florida Bay (Sogard et al., 1987; Robblee et al., 1991). The basic throw-trap is an open-ended 1-m^2 aluminum box, 45-cm deep. It is covered by a 0.16-millimetes stretched mesh DELTA netting when used in water greater than 45-centimeters deep, which allows it to be used with self contained under-water breather apparatus (SCUBA) in water depths exceeding about one meter, as well as in shallower water. The throw-trap is thrown into undisturbed water, where it drops to the bottom, enclosing one square meter of area. A fixed-framed seine sized to fit snugly inside the throw-trap frame is used to repeatedly sweep the frame interior. Five sweeps have been determined to be adequate for use in

FIAN (Robblee and Browder, 2005), although a previous study (Browder and Robblee, 2005) determined that four sweeps were adequate for South Biscayne Bay. The throw-trap best captures those seagrass-associated species that seek shelter in benthic vegetation (seagrass, algal mat) when disturbed, but it also captures small fish species not primarily associated with the bottom. With five sweeps, the method has a capture efficiency of 100, 100, 97, and 86 percent for fish, pink shrimp, caridean shrimp, and crabs, respectively (Robblee and Browder, 2005).

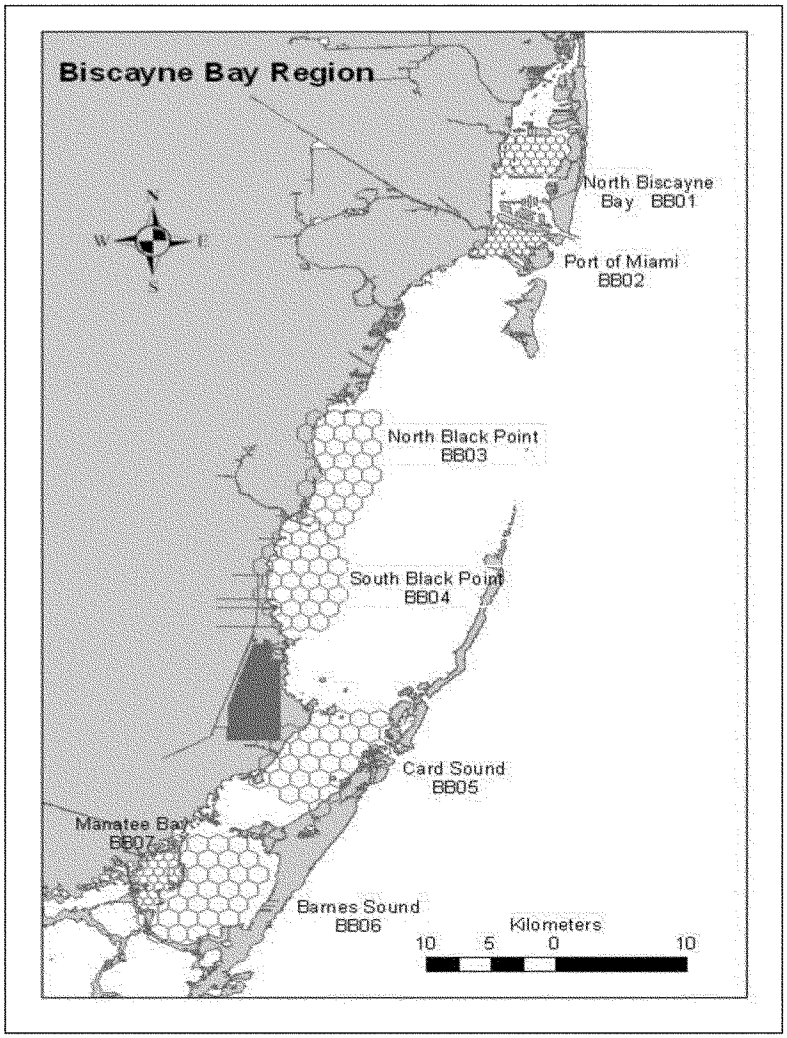


FIGURE E-5: BISCAYNE BAY REGION FIAN SAMPLING LOCATIONS INCLUDING ACTUAL 30-CELL SAMPLING GRIDS

E.4.4 Comparison between Preferred Project-Level Monitoring and the Monitoring and Assessment Plan for Estuarine Fish Monitoring

Ideally, epibenthic fauna monitoring would be added to the existing monitoring to fill gaps in monitoring coverage relative to Biscayne Bay Coastal Wetlands

implementation, and would complement both Restoration Coordination and Verification Monitoring, and Assessment Plan monitoring projects, enhancing their value to Biscayne Bay Coastal Wetlands. A recently funded Monitoring and Assessment Plan monitoring project provides more intensive coverage of the shallow-open-water area near to shore than Monitoring and Assessment Plan - FIAN. Initial effects of implementation are more likely to occur near to shore, where this new Monitoring and Assessment Plan monitoring is focused. Because of this focus, as well as the greater number of samples collected at each site (three instead of one), the epibenthic monitoring would be more sensitive to changes brought about by Biscayne Bay Coastal Wetlands implementation. Furthermore, any faunal changes detected so near to shore can be more easily related to implementation. Similarly, the epibenthic fauna monitoring should cover small, abundant species such as rainwater killifish (*Lucania parva*), pink shrimp, and caridean shrimp that are generally missed by visual surveys. These species may be important indicators of juvenile fish nursery habitat quality. Results of epibenthic fauna monitoring will help interpret any changes that might be suggested by the other Monitoring and Assessment Plan projects.

The Monitoring and Assessment Plan visual survey sites and the epibenthic fauna monitoring sites are located in close proximity to each other (each epibenthic fauna monitoring site is located in nearby open water at the same latitude as a visual survey site), facilitating the opportunity to look for commonality of responses and possible interactions among species found in mangrove prop-root habitat and the generally smaller species found in nearby open waters used as feeding grounds. The visual survey covers larger sized individuals and species than can be captured in throw-traps.

The Monitoring and Assessment Plan Fish and Invertebrate Network and epibenthic fauna monitoring use the same sampling gear (1-m^2 throw–trap) which will enhance the ability to integrate results of the two monitoring efforts. Monitoring and Assessment Plan - FIAN covers greater depth and distance-from-shoreline gradients and more area of south Biscayne Bay, but less of the sampling effort is located in nearshore shallow waters than in the epibenthic fauna monitoring (i.e., about 14 versus 42 sites from Shoal Point to Turkey Point). The epibenthic fauna monitoring tracks Biscayne Bay Coastal Wetlands effects near the shoreline, and FIAN expands monitoring coverage of epibenthic fishes and invertebrates to the outer limits of Biscayne Bay Coastal Wetlands effects.

E.4.5 Data Management/Quality Assurance Quality Control for Estuarine Fish Monitoring

Data Management
See ***Section 2.5*** above

Quality Assurance/Quality Control for Estuarine Fish
Quality assurance and quality control for estuarine fish monitoring in the Biscayne Bay Coastal Wetlands project should conform to guidance and protocols provided in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm). ***Appendix L*** in the document provides methods, references, and reporting units for monitoring estuarine fish abundance and distribution of faunal assemblages in relation to bottom habitat, salinity, and freshwater inflow.

E.4.6 Monitoring Cost Estimates for Estuarine Fish Monitoring

TABLE E-5: ESTIMATED MONITORING COST FOR ESTUARINE FISH MONITORING

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$473,367	$473,367	$0
Years 1-5	$2,466,327	$2,466,327	$0
Years 6-10	$2,491,200	$2,491,200	$0
TOTAL	$4,957,527	$4,957,527	$0

Key: MAP Monitoring and Assessment Plan

The above estimates include costs for the FIAN project (Monitoring and Assessment Plan Activity Numbers 3.2.3.5 and 3.2.4.5), visual assessment project (Monitoring and Assessment Plan Activity Number 3.2.3.6), and the new Biscayne Bay estuarine fish Monitoring and Assessment Plan project (Monitoring and Assessment Plan Activity Number 3.2.4.7). If MAP funding for any of these projects terminates, the project level monitoring plan will be reevaluated to determine what if any of the monitoring should continue.

E.5 JUVENILE CROCODILE MONITORING

E.5.1 Justification and Relevance to Performance Measures

Historically, Miami-Dade County was at the center of the American crocodile (*Crocodylus acutus*) geographic range in the United States (Kushlan and Mazzotti, 1989), with the coastal wetlands along the western shore of Biscayne

Bay providing important habitat. The shoreline, canals, and ponds of southern Biscayne Bay, Card Sound, and Barnes Sound provide essential habitat for juvenile and sub-adult crocodiles. Together with the nesting areas at the Florida Power and Light Turkey Point Power Plant and the U.S. Fish and Wildlife Service Crocodile Lakes National Wildlife Refuge, these habitats meet all of the life stage requirements to support the continued recovery of this endangered species.

The Turkey Point Power Plant and Crocodile Lakes National Wildlife Refuge contain the fastest growing component of the Florida population of American crocodiles. However, Biscayne Bay's nearshore areas and coastal wetlands north of Turkey Point have relatively high salinity that reduce the suitability of these areas for juvenile crocodiles, which require relatively low salinity for proper growth and development (Mazzotti et al., 2002). Restoration of oligohaline and mesohaline conditions along the mangrove shoreline of western Biscayne Bay should provide better quality hatchling and juvenile crocodile habitat.

Monitoring crocodiles addresses project Objective 1 by evaluating the extent to which suitable nursery habitat for hatchling and juvenile crocodiles is restored in the nearshore waters and mangrove wetlands of the project area. Suitable nursery habitat includes maintaining salinity regimes conducive to the growth and survival of these life stages. Crocodile monitoring will also address Objective 3 by evaluating the effects of improvement of the quantity, timing, and distribution of freshwater to the bay. Restoration of crocodile habitat in the project area is an important component of the project's Performance Measure 1C (salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat). Crocodile monitoring information will be used to support adaptive assessment efforts (see ***Part 4, Section E.6.2***).

E.5.2 Project-Level Component for Crocodile Monitoring

Diurnal and nocturnal surveys for crocodiles and nests will be conducted annually. All mangrove shorelines, creeks, and canals will be surveyed by spotlight during nocturnal hours from Shoal Point south and west along the coastline to Turkey Point. Spotlight surveys of the shoreline will be conducted from a small, shallow-draft skiff using a 200,000 candlepower blue spotlight. For canals, creeks, and smaller inland bodies of water, less powerful 50,000 candlepower head lamps will be used. The night spotlight count method was chosen because of its effectiveness in habitats where other survey methods are logistically impractical (Woodward and Moore, 1993). The reflective tapetum of a crocodilian's eye glows red in a spotlight and can be seen from a considerable distance (Magnusson, 1982; O'Brien, 1990). For consistency, surveys will be started at approximately the same time after sundown each sampling night whenever possible.

All crocodilians will be approached as closely as possible to identify the species, and to attempt capturing. Locations and times of sightings of crocodiles and crocodile activity (especially nesting activity) will be recorded along with a detailed description of the habitat (type of water body or wetland, substrate, vegetation, water depth and salinity, and air and water temperatures). Crocodiles will be captured, measured and marked (if necessary) whenever possible. Capture will be either by hand, with tongs, or with a self-locking wire noose. When possible, size estimates will be made for animals that cannot be caught. The following information will be recorded for captured animals: previous tail marking, total length, snout-to-vent length (measured from the tip of the snout to the posterior end of the vent), weight, and sex. If no previous tail marking is found the animal will be marked according to the system described by Mazzotti (1983).

Suitable nesting habitat within the study area will be searched on foot during daylight hours during the period of nest preparation (spring). Areas where signs of nests were reported, including a mound, eggshells, or digging activity, will also be investigated. Confirmed nest sites will be visited from July 15 until hatching. Hatchlings will be located at night by flashlight or during the day by searching the immediate vicinity of the nest. Hatchlings will be captured by hand or with tongs, and the same data will be recorded as for other captures described above.

E.5.3 Monitoring and Assessment Plan Component for Crocodile Monitoring

Presently, the Monitoring and Assessment Plan is conducting crocodile monitoring in the Biscayne Bay Coastal Wetlands project area that is consistent with the project-level monitoring parameters and protocols recommended in ***Section 5.2*** above.

E.5.4 Comparison between Preferred Project-Level Monitoring and the Monitoring and Assessment Plan for Crocodile Monitoring

Because Monitoring and Assessment Plan monitors for crocodiles in the Biscayne Bay Coastal Wetlands project area, monitoring for this endangered species will rely on this Monitoring and Assessment Plan component. Detailed descriptions of this monitoring can be found under Monitoring and Assessment Plan Activity Numbers 3.1.3.15 and 3.1.3.16 in the Greater Everglades Module of the Monitoring and Assessment Plan.

E.5.5 Data Management/Quality Assurance Quality Control for Crocodile Monitoring

Data Management
See ***Section 2.5*** above.

Quality Assurance and Quality Control for Crocodile Monitoring
Quality assurance and quality control for crocodile monitoring in the Biscayne Bay Coastal Wetlands project should conform to the guidance and protocols provided in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm; RECOVER, 2004b). ***Appendix O*** in the document provides methods, references, and reporting units for monitoring reptiles and amphibians. Metadata requirements associated with crocodiles nest searching includes: location coordinates (with projection), temperature, salinity (practical salinity units), habitat category, dominant vegetation, species, substrate, distance from water, nest dimensions, fertility, success/failure, sex, total length, snout-to-vent length, weight (grams or kilograms), head length (centimeters), and tail girth (centimeters) measured at the third scute row posterior of legs.

E.5.6 Monitoring Cost Estimates for Crocodile Monitoring

TABLE E-6: COST ESTIMATES FOR CROCODILE MONITORING

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$17,275	$17,275	$0
Years 1-5	$91,715	$91,715	$0
Years 6-10	$93,050	$93,050	$0
TOTAL	$184,765	$184,765	$0

Key: MAP Monitoring and Assessment Plan

The above estimates include costs for the American crocodile component in the Monitoring and Assessment Plan. If MAP funding for any of these projects terminates, the project level monitoring plan will be reevaluated to determine what if any of the monitoring should continue.

E.6 NEARSHORE SALINITY MONITORING

E.6.1 Justification and Relevance to Performance Measures

The Biscayne Bay Coastal Wetlands project is expected to result in altered salinity patterns that are similar to the patterns that existed prior to construction and operation of the Central and South Florida Flood Control system in the watershed. Currently, freshwater runoff is channeled into Biscayne Bay through five canals within the project area, and the system is operated for flood control and water supply purposes. This causes freshwater pulses that have resulted in highly variable fluctuations in salinity near the canal outfalls, and disrupted patterns spatially along the nearshore area. Reduced water storage in the watershed has also reduced the capacity of the watershed to detain runoff that used to seep into the bay during dry periods. Salinity is a primary driver of habitat suitability for a variety of estuarine organisms in Biscayne Bay including species of interest such as shoal grass, widgeon grass, Eastern oysters and American crocodiles. Spatially distributed salinity data will be required to detect whether the habitat becomes more favorable for the estuarine ecosystem. This parameter applies to Objective 3 above for the nearshore area. Salinity is a key monitoring parameter, and addresses Performance Measure 1C (Salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat), Performance Measure 3A (Nearshore salinity patterns exhibit a broader area and extended duration of mesohaline conditions), and Performance Measure 3B (Reduce areal extent of and frequency of hypersaline conditions in the bay). Salinity monitoring data will be used to support adaptive assessment efforts for oysters (***Section E.5.1***), SAV (***Section E.5.2***), estuarine fish (***Section E.5.3***), wetland algae (***Section E.6.1***), crocodiles (***Section E.6.2***), and wetland vegetation (***Section E.7.1***).

E.6.2 Project-Level Component for Nearshore Salinity Monitoring

Figure E-6 indicates location of the project level salinity monitoring sites using continuous recorders. A total of 30 sites should be monitored in the bay using continuous recording instruments moored near the bottom. Of these, 12 are located at creek mouths or along the shoreline; the remaining 18 are open water sites. ***Table E-7*** shows the approximate coordinates of the sites. Data will be recorded at a minimum of one-hour intervals at all sites for a minimum of ten years. Data are stored temporarily within the instruments and retrieved periodically. Data will be permanently stored and compiled in a master database at Park Headquarters.

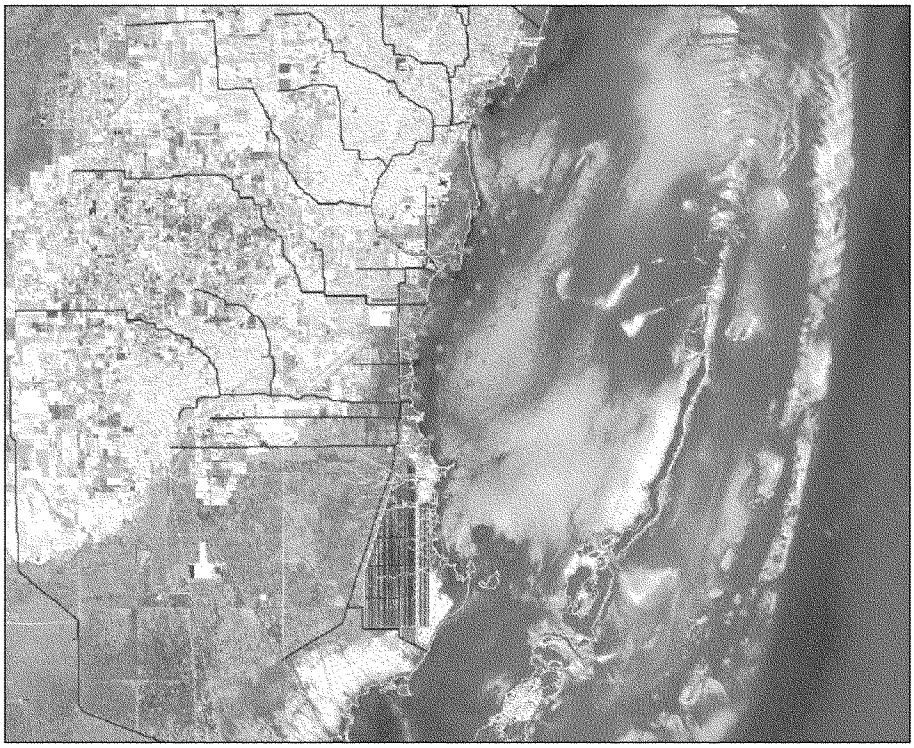


FIGURE E-6: APPROXIMATE LOCATIONS FOR PROJECT SALINITY MONITORING STATIONS IN BISCAYNE BAY
(Red Markers)

TABLE E-7: APPROXIMATE SALINITY MONITORING STATIONS

Site ID	Latitude	Longitude	Description
A	25.546	80.312	Mouth of Embayment N/O Black Point
B	25.537	80.318	Shoreline S/O Black Point
C	25.555	80.301	Open Water E/O Cutler Area
D	25.510	80.335	Shoreline N/O Fender Point
E	25.481	80.340	Shoreline between Military and C-103 Canals
F	25.616	80.302	Shoreline S/O Deering Estate
G	25.621	80.297	Shoreline E/O Deering Estate
J	25.610	80.303	Shoreline E/O C-100 Canal
K	25.534	80.324	Shoreline SE/O C-1 Canal
L	25.518	80.331	Shoreline S/O C-102 Canal
M	25.452	80.331	Shoreline S/O Convoy Point
12	25.436	80.301	Open water E/O Turkey Point
14	25.474	80.340	Shoreline N/O C-103 Canal
16	25.473	80.338	Shoreline NE/O C-103 Canal
18	25.479	80.309	Open water between Military and C-103 Canals
20	25.471	80.285	Turkey Point Channel (Head Pin)
22	25.492	80.339	Shoreline N/O Military Canal
26	25.487	80.326	Open water E/O Military Canal
28	25.498	80.339	Shoreline N/O Military Canal
32	25.496	80.325	Open water N/O Military Canal
34	25.494	80.309	Offshore N/O Military Canal
40	25.505	80.336	Shoreline S/O Fender Point
42	25.504	80.334	Shoreline S/O Fender Point
44	25.519	80.309	Open water E/O C-102 Canal
46	25.527	80.304	Open water in C-1 Channel
48	25.518	80.284	Offshore E/O C-102 Canal
52	25.545	80.309	Shoreline N/O Black Point
54	25.545	80.290	Open water E/O Black Point
56	25.564	80.305	Shoreline E/O Cutler area
60	25.564	80.284	Open water E/O Cutler area
62	25.612	80.306	Shoreline N/O C-100 Canal
66	25.604	80.289	Open water S/O C-100 Canal

Note: Site IDs subject to change.

Key: E/O East of
N/O North of
S/O South of

E.6.3 Monitoring and Assessment Plan Component for Nearshore Salinity Monitoring

Biscayne National Park has collected continuous (15-minute integrated) water quality data using bottom-mounted instruments at several sites in the bay for a few years. The Park currently operates 45 instruments at 34 stations near the project area. Some of the monitoring sites are set up with two instruments each for top and bottom salinity measurements. Monitoring and Assessment Plan includes all of the stations.

Miami-Dade County Department of Environmental Resources Management (DERM) has an established water quality monitoring network in the region of Biscayne Bay. DERM's network in this area consists of 23 stations sampled monthly for salinity. Since DERM has salinity results dating back to 1979, these data can be used to evaluate long-term trends and multi-decadal oscillations in salinity. The DERM data will augment the Biscayne National Park continuous data collection to assist in documenting and characterizing long-term modifications of conditions within the bay. Continuous recording conductivity, temperature, and depth instruments with both surface and bottom mounted sensors will be installed in critical regions of the bay (*i.e.*, shallow areas and those regions with projected modified conditions) to obtain conductivity, temperature, and depth data that will be used establish baseline conditions; monitor change in salinity patterns over time; determine whether and under what circumstances stratification exists; and, in combination with canal discharge data and other environmental data (*e.g.*, wind and rainfall), quantify the relationship between freshwater inflow volume and salinity patterns in the nearshore bay. In addition, these data will be used to define the habitat requirements (especially salinity and bottom type) of valued components of the epibenthic and planktonic communities in order to relate faunal changes to water management changes. Station locations have been selected and coincide with established, long-term water quality stations where possible.

Some specific sites are proposed in areas where there will be no anticipated Comprehensive Everglades Restoration Plan effect to provide comparison or control data. Spatially continuous fine-scale salinity data are obtained by National Oceanographic and Atmospheric Administration (NOAA) oceanographers on a monthly basis in Biscayne Bay (Figure 3-30 in the Monitoring and Assessment Plan) and will be important to interpreting these time series data.

E.6.4 Comparison between Preferred Project-Level Monitoring and the Monitoring and Assessment Plan for Nearshore Salinity Monitoring

It is expected that the existing, overall effort and resources expended for the MAP project will be the same as that required for Biscayne Bay Coastal

Wetlands project monitoring. The Biscayne Bay Coastal Wetlands project can also use the data collected by DERM and NOAA in a similar approach as MAP to verify and augment the primary salinity dataset. Since salinity is such a critically important parameter for evaluating the effectiveness of the project, any valid salinity results are likely to be of value.

E.6.5 Data Management/Quality Assurance Quality Control for Nearshore Salinity Monitoring

Data Management
See ***Section 2.5*** above.

Quality Assurance and Quality Control for Nearshore Salinity Monitoring
Quality assurance and quality control for nearshore salinity monitoring in the Biscayne Bay Coastal Wetlands project should conform to the guidance and protocols provided in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm; RECOVER 2004b). ***Chapter 3*** (Water Quality Field Sampling) is especially relevant to collecting salinity data. Special considerations for quality assurance and quality control for laboratory, field, and data management operations are necessary. A valuable reference for salinity data quality assurance and quality control is the annual report from Biscayne National Park to the U.S. Army Corps of Engineers (NPS 2006).

E.6.6 Monitoring Cost Estimates for Nearshore Salinity Monitoring

TABLE E-8: COST ESTIMATES FOR NEARSHORE SALINITY MONITORING

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$157,180	$157,180	$0
Years 1-5	$785,900	$785,900	$0
Years 6-10	$785,900	$785,900	$0
TOTAL	$1,571,800	$1,571,800	$0

Key: MAP Monitoring and Assessment Plan

E.7 WETLANDS COMPONENT

Historically, because of the low topography and year round water elevations that inundated the project area, nearly all of the land (perhaps more than 80 percent of the 60,000 acres within the original project study area) was covered by freshwater wetlands interspersed with small tree islands. Vegetation cover

maps created as recently as the 1940s indicate that freshwater wetlands extended from the coastal ridge toward the east and south close to the shoreline of Biscayne Bay. The importance of freshwater wetlands in the coastal regions of southern Florida has been documented, and it is known that undesirable changes and substantial losses have occurred over the last century (Egler, 1952). Freshwater wetlands are linked to:

1. Increased wildlife diversity and abundance
2. Improved water quality
3. Increased storage capacity
4. Groundwater and aquifer recharge
5. Enhanced downstream functions of the natural environment
6. Improved human interests

Fauna such as wading birds and alligators typically found in the Everglades toward the west also resided in this area. Nearer the shore, low salinity conditions were suitable for crocodiles and other estuarine wetland species.

Since the construction of the Central and South Florida system, most of the coastal wetlands, especially north of Card Sound, have become mostly saline rather than estuarine because the only freshwater inputs are rainfall and small amounts of groundwater that seep from the L-31E Borrow Canal. In addition, transitional habitats or ecotones that range in salinity from zero psu gradually to more marine salinity (35 psu) are almost non-existent in the area north of Card Sound. Generally, east of Levee 31E freshwater wetlands have been replaced with transitional or dwarf mangrove forest. A number of estuarine animals, such as American crocodiles and various wading bird species, including the state-listed roseate spoonbill, depend on lower saline conditions at different times in their life cycles. Currently, few juvenile crocodiles and wading birds utilize the south central area of Biscayne Bay between Shoal and Turkey Points. West of L-31E, marl marshes have been displaced by forested wetlands that are often dominated by water tolerant invasive non-native vegetation such as Brazilian pepper (*Schinus terebinthifolius*).

The primary objectives of the Biscayne Bay Coastal Wetlands project in the wetlands area are:

Objective 3	Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.
Objective 4	Preserve and restore spatial extent of natural coastal glades habitat.
Objective 5	Reestablish connectivity between Biscayne Bay Coastal Wetlands, C-111 Basin, Model Lands, and adjacent basins.

To provide information to adequately address the efficacy of achieving the above stated objectives, this monitoring component will evaluate the following:

- Changes in hydropattern (stage and hydroperiod); both east and west of L-31E (indicator of wetland vegetation habitat; Objectives 3 and 4)
- Changes in wetland vegetation (i.e., reduction in non-native vegetation coverage and transition to more natural vegetation community structure) will serve to preserve and restore coastal glades habitat; Objective 4)
- Changes in wetland algae (primarily diatoms) will serve as a surrogate for salinity and water quality in the wetlands, particularly east of L-31E. (Reduction in salinity in this area shows improved quality and distribution of freshwater to the bay, will aid in preserving and restoring coastal glades habitat, and shows improved connectivity; Objectives 3, 4, and 5). Wetland algae will also detect changes in nutrient levels (water quality); Objective 3)

E.7.1 Wetland Vegetation Responses

E.7.1.1 Justification and Relevance to Performance Measures

Major vegetation changes have occurred in the project area over the past century in response to hydrologic changes. These hydrologic changes include significant modifications to the hydropatterns and salinity regime in the coastal wetlands — both are major drivers of vegetation communities in the coastal wetlands of south Florida.

Historically, freshwater marl marsh extended across most of the project area and transitioned to a narrow band of mangroves at the shoreline of the Biscayne Bay. As a result of increased salinity in the wetlands along the coast, mangrove communities migrated inland, displacing the freshwater marl marsh community. Presently, mangrove forest, including extensive spatial coverage of dwarf mangroves, extends well inland from the shoreline, usually westward to levee, L-31E. On the western side of L-31E, wetlands have been severely impacted by drainage of the system. Water elevations are generally held close to or below land surface in the northern project area, or are starved of water as in the Deering Estate and Model Land basin where water is diverted by drainage structures toward other basins. In these areas, marl marshes have generally transitioned into a mixture of shrub and forested wetlands, sometimes with an understory of sawgrass or cattails (*Typha domingensis*). Non-native trees, particularly Brazilian pepper and Australian pine (*Casuarina equisetifolia*), are prevalent in these areas as a result of physical disturbance or hydrologic isolation.

By redistributing freshwater, the rehydration of the coastal wetlands should increase stages and hydroperiods in the freshwater wetlands and reduce salinity in the wetlands east of L-31E. Improved hydropatterns in the wetlands,

together with non-native vegetation controls, should result in significant changes to the coastal wetland vegetation communities. Improvements to the salinity regime should result in changes to the wetland vegetation east of L-31E. Herbaceous and graminoid species should increase in abundance in formerly salt-intruded areas. Results from a pilot project that diverted a limited amount of freshwater from L-31E eastward to the coastal wetlands have shown favorable changes in species composition (Ross et al., 2003). Sawgrass and spikerush, two freshwater species, appeared during the post-treatment period. Biscayne Bay Coastal Wetlands project performance measures that apply to wetland vegetation communities include Performance Measure 4A (Areal extent of freshwater wetlands and transverse glades vegetation increases), Performance Measure 4B (Enhance freshwater and oligohaline marsh habitat by restoring appropriate salinity, hydroperiod, water level), and Performance Measure 4F (The areal extent of non-native vegetation decreases). Monitoring wetland vegetation addresses project Objective 4 by evaluating the extent to which coastal glades habitat is restored. It also addresses project Objective 5 indirectly by providing information on the extent to which connectivity between basins has been restored.

E.7.1.2 Project-Level Monitoring for Wetland Vegetation

The project-level wetland vegetation monitoring will consist of two primary components: (1) large-scale changes in vegetation using aerial photo interpretation techniques, and (2) small-scale changes in vegetation from on-the-ground sampling of plots aligned along transects representative of important hydrologic gradients within the study area.

System-wide Aerial Photo Interpretation. Baseline (*i.e.,* pre-construction) and post-construction monitoring of wetlands will be conducted using aerial photo interpretation and mapping regular intervals for at least 20 years over the entire project area, using large-scale (1:24,000) stereo color infrared aerial photography. The Comprehensive Everglades Restoration Monitoring and Assessment Plan is conducting this monitoring for most of the Everglades ecosystem, including the Biscayne Bay Coastal Wetlands project area (***Figure E-8***). Details of methods to be used in the Monitoring and Assessment Plan effort are described in ***Section E.7.1.3*** below.

Vegetation Transects. The aerial photo interpretation monitoring conducted by the Comprehensive Everglades Restoration Monitoring and Assessment Plan will be augmented by supplementary analyses of vegetation changes in the project area for several reasons. First, the vegetation classification scheme utilized in the MAP study may not be particularly conducive to classifying the vegetation observed in the project area. Specifically, the wetlands vegetation in the Biscayne Bay Coastal Wetlands project area is comprised of various complex mixes of wetland species that do not fit easily into the MAP classification

scheme. Secondly, the quarter hectare minimum mapping unit may not provide the spatial resolution required to adequately document vegetation changes at the project level. Thus, more detailed analysis of vegetation changes will be conducted along a series of transects. Although the project area stretches 18 kilometers along the western shore of Biscayne Bay, it is relatively narrow (less than three kilometers) in the east-west direction, i.e., perpendicular to the coast. In most of the area, the change in vegetation in the east-west direction is of primary interest, as it is along this direction that restoration-derived changes in hydroperiod, salinity, or water quality will be manifested. Detailed evaluation of vegetation changes will therefore be conducted every three years in plots distributed along ten transects sited roughly as pictured in ***Figure E-7.*** One of the transects is located at the Deering Estate Flow-way; three are located within the Cutler Flow-way wetlands, and six distributed within the L-31E Flow-way. Where possible, the transects are to be located at existing vegetation monitoring sites for either the expedited project or past studies Wherever practical, transects will also be positioned as closely as possible to sites where any physical data (e.g., salinity or stage) will be collected. Given the limited access to some of the wetlands in the project area, especially those east of L-31E, the density of plots along each transect will be relatively sparse. Since vegetation plots are intended to provide ground representation of units identified from remote sensing, and replication is achieved across transects and not within them, sampling intensity of 4-5 plots or by the number of identifiable vegetation units crossed by the transect on each of the ten transects is recommended. Assuming an average of 5 plots, this would constitute a total sampling network of 40 plots. Exact plot locations will be fixed once the vegetation maps are available, with the aim of achieving higher sampling intensity near the borders separating adjacent vegetation types than in the centers of the mapping units. Thus, in addition to their independent value in assessing ecosystem change, the sampling plots will aid in calibrating the vegetation mapping component over time and in evaluating its spatial precision.

Vegetation sampling at the selected locations will be implemented within a nested, permanent-plot design. The largest unit will be a 10 x 10 meter tree plot, subdivided into four 5 x 5 meter cells, with corners marked by rebar driven into the bedrock. Trees (greater than five centimeters DBH) will be tagged, identified to species, their DBH measured, and their position estimated to the nearest meter. The cover of shrubs (greater than one meter in height) and lianas will be estimated by species in two of the 5 x 5 meter cells. Percentage cover of plants in the herb layer (less than one meter in height), as well as the density of tree seedlings, will be recorded for two randomly selected 1 x 1 meter quadrats within each cell (eight per plot). Herbs not present in the eight quadrats but surviving in the tree plot will be searched for and recorded. Plots should be 10 x 10 m, with four 1-m^2 seedling plots and four 3.14-m shrub plots nested within. Such plots have been used successfully in one MAP project (Southern Everglades Tree Island Condition), and are efficient to set up, sample,

and maintain over time. Compositional and structural sampling should be repeated at 3-year intervals.

The predominant dynamic in south Florida coastal wetlands during the last century has been a transition from low herbaceous marsh to forest of increasing height and density, under the combined influence of drainage and rising sea level. In order to monitor continuing structural change following restoration activities, plot sampling will be supplemented by structural sampling at the nine cell corners. A vertical line intercept method introduced by Ross et al. (2004) will be used to characterize the density of species occupancy of the canopy within one half meter height strata from the ground up.

Pore water conductivity is a critical driver addressed by the restoration, and should be monitored at all plots. Direct manual sampling from shallow wells at quarterly intervals is the most reliable and cost-effective method for the BBCW network.

Carbon and nitrogen isotopes of leaves, as well as leaf N:P ratios, reflect physiological stress and nutrient availability that may be affected by restoration efforts. One of the advantages of including such leaf measures, with their characteristically rapid response times, is how well they complement slower-to-change structural parameters in a monitoring program. Sampling could be quarterly, biannual, or annual, depending on the availability of funds. Extensive data on temporal variability is available from the L-31E Freshwater Rediversion Final Report (Ross et al. 2003).

Assessment of change in both compositional and structural data will incorporate the most recent developments in temporal data analysis, while building on methods used previously in south Florida (Armentano et al., 2006; Trexler et al., 2005). Emphasis will be on the dynamics of brackish and fresh water graminoids, mangroves, and invasive exotic species along the coastal gradient, especially with reference to observed changes in physical variables (*e.g.*, hydrology, salinity, water quality) associated with other components of the monitoring plan.

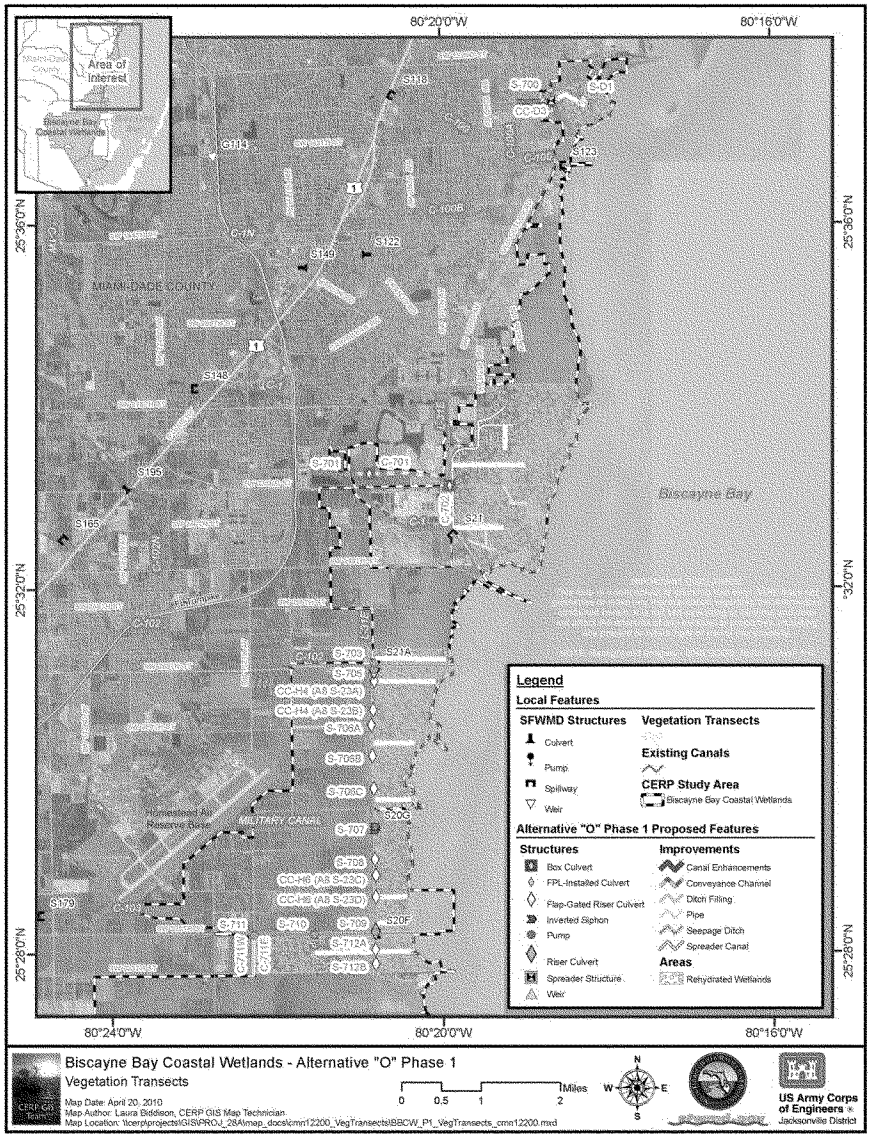


FIGURE E-7: APPROXIMATE LOCATIONS OF VEGETATION MONITORING TRANSECTS

E.7.1.3 Monitoring and Assessment Plan Component for Wetland Vegetation Monitoring

The objective of the Monitoring and Assessment Plan vegetation monitoring is to produce a spatially and thematically accurate vegetation map of the Everglades ecosystem. Vegetation mapping will monitor the spatial extent, pattern, and proportion of plant communities within major landscape regions of the greater Everglades wetlands. Areas to be mapped have been divided into five general zones (***Figure E-8***); the Biscayne Bay Coastal Wetlands project area lies within Zone 1. Specific landscape changes to be monitored in the Monitoring and Assessment Plan that pertain to the Biscayne Bay Coastal Wetlands project area include: (1) changes in the distribution and configuration of tidal creeks, salt marshes, and mangrove forests, and (2) changes in the extent and distribution of exotic plant communities.

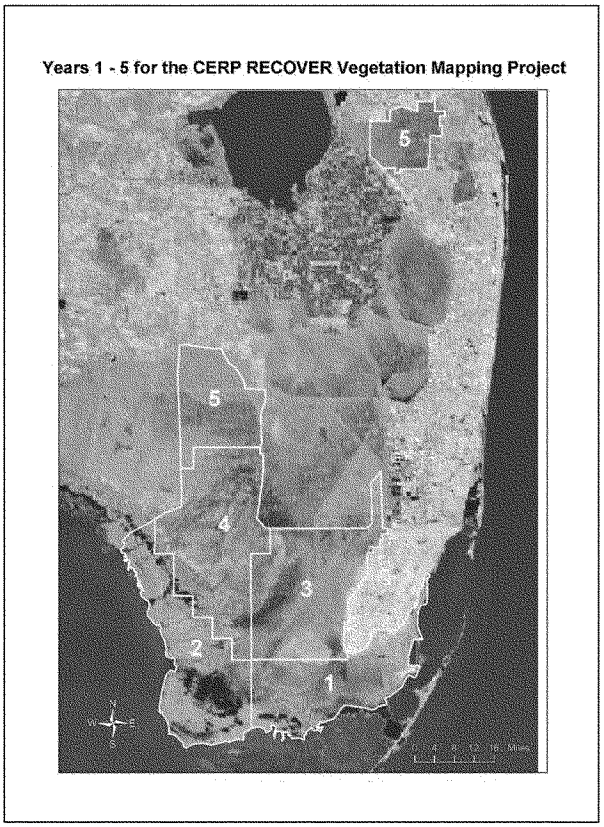


FIGURE E-8: MONITORING AND ASSESSMENT PLAN SHOWING SPATIAL EXTENT OF THE RESTORATION, COORDINATION AND VERIFICATION MONITORING AND ASSESSMENT PLAN VEGETATION MAPPING

Aerial photo-interpretation is currently the best tool available to produce dependable and accurate maps of the Everglades overall (Welch et al., 1995; Doren et al., 1999; Rutchey and Vilchek, 1999; Richardson and Harris, 1995). Full stereo aerial photography of the greater Everglades wetland system at a scale of 1:24,000 will be obtained at regular intervals. Photography will be interpreted and ground-truthed to produce vegetation maps at these intervals for the randomly selected cells. At this time, six years is the anticipated interval length (K. Rutchey, personal communication, September 13, 2006).

A baseline vegetation map will be established by filling in BBCW gaps not covered by Ruiz et al. 2008 BNP map. This will require about 1 month in Year 1.

A map of current canopy height will be incorporated for the entire area, applying softcopy procedures to existing aerial photography, and/or using recently flown LIDAR data for the BBCW. In these mangrove-dominated coastal wetlands, data on canopy height greatly facilitates vegetation mapping, improves its accuracy and spatial precision, and provides a variable that ties in directly to ecologically important variables such as biomass (and carbon sequestration). The map will take approximately one month to develop. Canopy height maps will be created every three years.

Vegetation communities will be mapped with a quarter hectare MMU grid from 1:24,000 scale color infrared aerial photography. Initial mapping will be performed using CIR aerial photography flown during December 2003 and January 2004 for the purpose of Comprehensive Everglades Restoration Plan Restoration, Coordination and Verification vegetation monitoring. Flights were made at an altitude of 12,000 feet above the mean terrain height, producing a photo scale of 1:24,000 or 1 inch = 2000 feet.

Each distinct vegetation community will be designated according to Rutchey et al. (2006). This hierarchal classification scheme will be used throughout the mapping project. Appropriate protocols and decision rules laid out in the classification system that are relative to the work will be followed. Each quarter hectare grid cell will be labeled, utilizing the most detailed level of classification possible to accurately portray the existing plant community. Color, tone, texture, shape, height, pattern, size, and location will be used to interpret the photographs. It is the intent of the Comprehensive Everglades Restoration Monitoring and Assessment Plan vegetation mapping effort to identify vegetation down to the species level wherever possible when that species is the dominant component of the grid cell being classified. Those grid cells containing exotic species of concern and cattail (*Typha* spp.) shall be classified accordingly as monotypic (> 90 percent), dominant (50–89 percent), or sparse (10-49 percent). It is possible for a grid cell to have more than one label, *e.g.*, when cattail or an exotic is less than 50 percent and the remaining vegetation can be classified as some other dominant species or community. Labeling will be based on determining the areal extent of the dominant classification through the best professional judgment of the photo interpreter. All decision-making rules and vegetation classifications are described in detail in the Vegetation Classification System for South Florida Natural Areas. The overall classification accuracy of each quarter section map must be greater than or equal to 90 percent in order to be accepted as a final map.

For details on deliverables, quality controls, accuracy assessments, and ground-truthing for the Comprehensive Everglades Restoration Monitoring and Assessment Plan vegetation monitoring, see the South Florida Water Management's Statement of Work for the Greater Everglades Wetlands Module

and Vegetation Mapping (Contract No. CP050413) and Project Work Plan for the Greater Everglades High Resolution Vegetation Interpretation (Avineon, December 20, 2005, Contract No. CP050413).

E.7.1.4 Comparison between Preferred Project-Level Monitoring and the Monitoring and Assessment Plan for Wetland Vegetation

System-wide Aerial Photo Interpretation
Vegetation monitoring planned for the Comprehensive Everglades Restoration Monitoring and Assessment Plan effort should be adequate for this component of the project-level monitoring. If the Monitoring and Assessment Plan effort is terminated or reduced in this region, the Biscayne Bay Coastal Wetlands project should continue the monitoring using the Monitoring and Assessment Plan protocols.

Vegetation Transects
The Monitoring and Assessment Plan has no existing or planned monitoring component for vegetation transects in the project area. This component as described in ***Section E.7.1.3*** above would be the responsibility of the project.

E.7.1.5 Data Management/Quality Assurance Quality Control for Wetland Vegetation Monitoring

Data Management
See ***Section 2.5*** above.

Quality Assurance and Quality Control for Wetland Vegetation Monitoring
Quality assurance and quality control for wetland vegetation monitoring in the Biscayne Bay Coastal Wetlands project should conform to guidance and protocols provided in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm; RECOVER 2004b). ***Appendix K*** in the document provides methods, references, and reporting units for conducting monitoring for various wetland vegetation parameters. Some of the parameters provided in ***Appendix K*** that may be relevant to the proposed project-level mapping include percent cover of herbaceous vegetation, stand density, tree diameter, plant community cover, wetlands vegetation mapping, canopy cover, and leaf area index.

E.7.1.6 Monitoring Cost Estimates for Wetland Vegetation Monitoring

System-wide Aerial Photo Interpretation
Because the Comprehensive Everglades Restoration Monitoring and Assessment Plan will be conducting the aerial photo interpretation component, no project-level costs are anticipated. However, if the Monitoring and Assessment Plan

effort is terminated or significantly reduced in this region, the Biscayne Bay Coastal Wetlands project will continue the effort at the level described in ***Section E.7.1.2*** above using the current Monitoring and Assessment Plan estimates for monitoring costs in Region 1.

Presently, the MAP effort is budgeted for $520 per square mile of project area surveyed. A rough approximation of the Biscayne Bay Coastal Wetlands wetland area of influence is 17,875 acres. This equals a cost of $14,524 for the first year of Monitoring and Assessment Plan monitoring.

Vegetation Transects
Because project-level vegetation transect monitoring will be conducted on a three cycle, costs vary from year to year.

TABLE E-9: ESTIMATED PROJECT-LEVEL VEGETATION TRANSECT MONITORING

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$99,670	$14,524	$85,146
Years 1-5	$335,766	$14,524	$321,242
Years 6-10	$307,250	$14,524	$292,726
TOTAL	$643,015	$29,048	$613,967

E.8 WETLAND ALGAE RESPONSES

E.8.1 Justification and Relevance to Performance Measures

Changes in hydrology and salinity resulting from water diversion and sea-level rise in the Biscayne Bay Coastal Wetlands have caused a landward displacement of coastal communities at a rate ranging from 3 to 30 meters per year over the last several decades (Ross et al., 2000; Gaiser et al., 2006a). Coastal development has further reduced acreage of wetland habitat and together these forces have diminished freshwater wetlands to ten percent of their original area with remaining undeveloped land being encroached by coastal as well as exotic vegetation (Gaiser et al., 2006a). One dominant community in coastal wetlands is benthic algae that form prolific growths on sediments, grasses and wet forest vegetation that inhabit the coastline. This benthic algal community has been shown to be one of the most sensitive ecological indicators of environmental change wetlands generally (Stevenson et al., 1996) and, particularly, coastal wetlands of south Florida (Gaiser et al., 2005).

Ideally, salinity would be measured directly in the coastal wetlands east of L-31E. However, the cost to conduct it would be high because of several challenges. Scientists are uncertain about the direction of overland flow in these wetlands. Topography is very flat with an extremely low slope. Established monitoring sites could possibly miss an effect altogether if the direction of flow bypasses a site. To counter this risk a large number of monitoring sites would be needed at least initially, greatly increasing start-up costs. Secondly, access is difficult. Soils are soft and often inundated so that servicing of sites would be time consuming. Lastly, small changes in topography such as could be caused by a footpath is likely to alter hydrology, therefore raised catwalks or boardwalks would need to be installed to access monitoring sites. To keep monitoring costs low, the Project Delivery Team is recommending that ecological variables be monitored as a surrogate for salinity and other physiochemical measures. Conclusions about environmental change interpreted from ecological variables are often more reliable than those drawn from physicochemical information because biota integrate the often wide and rapid variation experienced in their biogeochemical surroundings. In the context of the Biscayne Bay Coastal Wetlands project, the goals of rehydration through redistributing freshwater into coastal basins should result in shifts that are evident over months to years. Monitoring benthic algae, together with wetland and nearshore vegetation, provides a means of detecting these changes over multiple time-scales relevant to the restoration project. They can also be measured at a spatial scale that allows resolution beyond that provided by a small deployment of salinity recorders.

Diatoms are unicellular, glass-encased yellow algae that dominate benthic algal communities and have been shown in many studies to provide reliable indication of salinity. The resolution of salinity values inferred from diatom community composition is high enough to support their use in coastal monitoring programs as well as paleoecological investigations of sea-level rise and salt-water encroachment (Sullivan, 1999). Many models have been generated that relate diatom community composition to salinity in south Florida. Ross et al. (2001) mapped diatoms, vegetation and mollusks through a coastal Biscayne Bay wetland and showed that diatoms were most sensitive to the coastal gradient, and can be used to predict the distance from shore with 100 meter resolution. Gaiser et al. (2006a) surveyed diatoms throughout the Biscayne Bay Coastal Wetlands and found their communities to indicate pore-water salinity with an error of less than ten percent of the actual value. Surveys throughout Biscayne and Florida Bays found that diatoms could be used to predict salinity within two and five practical salinity units, respectively (Gaiser et al., 2005 and 2006a). Ample evidence now exists locally and globally to support the use of diatoms in salinity monitoring in wetlands and nearshore habitats. They respond at a time-scale appropriate to monitoring and adaptive management (months to years)

and can be sampled at a resolution adequate to detect spatial variation in environmental changes.

Monitoring algae primarily addresses project Objective 3 by evaluating the quality (salinity, nutrients), timing and distribution of water entering the wetlands. This parameter addresses Objective 4 by evaluating the extent to which periphyton species assemblages characteristic of coastal glades habitat are restored in the project area. The parameter also indirectly provides information on project Objective 5 by providing information on how well basins are reconnected within the project area. The Biscayne Bay Coastal Wetlands project performance measures that apply to wetland vegetation communities include Performance Measure 4A (Areal extent of freshwater wetlands and transverse glades vegetation increases), and Performance Measure 4B (Enhance freshwater and oligohaline marsh habitat by restoring appropriate salinity, hydroperiod, water level). Monitoring wetland algae also addresses project performance measures that apply to salinity in the wetlands and include Performance Measure 1C (Salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat). Wetland algae monitoring information will be used to support adaptive assessment efforts listed in ***Part 4, Section E.6.1***.

E.8.2 Project-Level Monitoring for Wetland Algae

Algae will be sampled at five sites along each of six vegetation of the monitoring transects shown in ***Figure E-7***, with the same justification as provided in ***Section E.8.1***. Transects will be located near where water is anticipated to enter the wetlands. Samples will be taken on a semi-annual basis (wet and dry season) to capture, and therefore exclude any seasonal variability from long-term trend detection. Quarterly sampling will be conducted for the first three years, then those data will be used to determine the time of year to sample when the variance is greatest. It is anticipated that after three years the sampling frequency can be reduced to a semi-annual sampling frequency. Exact plot locations will be fixed, and algal samples will consist of a composite of three-to-five $0.25m^2$ harvested quadrats of benthic substrate along or near the wetland vegetation monitoring transects. The samples will be homogenized, sub-sampled and brought back to the laboratory for analysis. Diatoms will be extracted from the samples, cleaned, identified and counted using standard techniques. Auxiliary data include a subsample of periphyton material that will be dried for nutrient analysis and salinity will be measured in the pore-water at each site.

Assessments of change from the compositional data will incorporate recent developments in temporal analysis (Trexler et al., 2005) with emphasis on producing interpretations of salinity from diatom composition using existing rigorous and regionally applicable calibration models (Gaiser et al., 2005).

Interpretations will be integrated with observed changes in other physical (hydrology, water quality) and biotic (vegetation) components of the monitoring plan.

E.8.3 Monitoring and Assessment Plan Component for Wetland Algae Monitoring

The CERP Monitoring and Assessment Plan does not include periphyton monitoring for this area. While it includes periphyton monitoring in the greater Everglades, the boundary of the mapping does not extend into the Biscayne Bay Coastal Wetlands Phase 1 project area.

E.8.4 Comparison of Preferred Project-Level and Monitoring and Assessment Plan Monitoring for Wetland Algae

Because the Monitoring and Assessment Plan does not include a periphyton component in the Biscayne Bay Coastal Wetlands project area, monitoring for this component will rely on a project-level design as described in ***Section E.8.2*** above.

E.8.5 Data Management, Quality Assurance and Quality Control for Wetland Algae Monitoring

Quality Assurance and Quality Control for wetland algae monitoring in the Biscayne Bay Coastal Wetlands project will conform to guidance and protocols provided in the Comprehensive Everglades Restoration Plan Quality Assurance Systems Requirements Manual (http://www.evergladesplan.org/pm/program_docs/qasr.cfm; RECOVER 2004b). ***Appendix I*** in the document provides methods, references, and reporting units for conducting monitoring for various wetland algae parameters, including diatoms.

E.8.6 Monitoring Cost Estimates for Wetland Algae Monitoring

Project-level wetland algae monitoring will be conducted quarterly every year for the first three years. After that time, it will be conducted semi-annually as it is anticipated that the first three years of results can be used to determine the best time of year to sample to catch the greatest variance, so sampling frequency can be reduced to semi-annual. The estimated cost for Year-1 monitoring is $70,000. The estimated cost for Year 4 is half the Year-1 cost plus annual inflation rate of 3% compounded annually, or $38,245. Each year includes this compounded inflation factor.

TABLE E-10: COST ESTIMATES FOR WETLAND ALGAE MONITORING

	Estimated Total Cost	Amount Funded by MAP	Remainder (Project Cost)
Year 1	$70,000	$0	$70,000
Years 1-5	$294,000	$0	$294,000
Years 6-10	$215,416	$0	$215,416
TOTAL	$509,417	$0	$509,417

Key: MAP – Monitoring and Assessment Plan

E.9 SUMMARY OF PLAN COST ESTIMATES

Table E-11 and ***Table E-12*** below provide a summary of cost estimates for project-level, Monitoring and Assessment Plan and other pertinent monitoring efforts in the Biscayne Bay Coastal Wetlands Project Phase 1 area for one, five- and ten-year time spans.

TABLE E-11: SUMMARY OF PROJECT-LEVEL AND MONITORING AND ASSESSMENT PLAN COST ESTIMATES FOR MONITORING PHASE 1 OF THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR ONE YEAR

Parameter	Total Costs	Amount Funded by MAP and Others	Remainder (Project Cost)
Oysters	$101,279	$17,973	$83,306
SAV	$44,806	$39,037	$5,769
Fish	$473,367	$473,367	$0
Crocodiles	$17,275	$17,275	$0
Nearshore Salinity	$157,180	$157,180	$0
Wetland Vegetation	$99,670	$14,524	$85,146
Wetland Algae	$70,000	$0	$70,000
Total	**$963,577**	**$719,356**	**$244,221**

Key: MAP Monitoring and Assessment Plan
SAV Submerged Aquatic Vegetation

Note: Cost estimates for the MAP monitoring efforts have been projected out five years based on the approved current three-year MAP monitoring projects (particularly for SAV and fish). This may over-estimate the actual funding that will be provided for the MAP component over the five-year time span, thus the MAP cost estimates above should be used with caution.

TABLE E-12: SUMMARY OF PROJECT-LEVEL AND MONITORING AND ASSESSMENT PLAN COST ESTIMATES FOR MONITORING PHASE 1 OF THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR TEN YEARS

Parameter	Total Costs	Amount Funded by MAP and Others	Remainder (Project Costs)
Oysters	$911,728	$202,848	$708,880
SAV	$337,700	$252,020	$85,680
Fish	$4,957,527	$4,957,527	$0
Crocodiles	$184,765	$184,765	$0
Nearshore Salinity	$1,571,800	$1,571,800	$0
Wetland Vegetation	$643,016	$29,048	$613,968
Wetland Algae	$509,416	$0	$509,416
Grand Total	**$9,115,952**	**$7,198,008**	**$1,917,944**

Key: MAP Monitoring and Assessment Plan
SAV Submerged Aquatic Vegetation

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ANNEX E
PROJECT MONITORING PLAN

PART IV: ADAPTIVE MANAGEMENT PLAN

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E.0 ADAPTIVE MANAGEMENT PLAN

ADAPTIVE MANAGEMENT PLAN FOR THE BISCAYNE BAY COASTAL WETLANDS PROJECT

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E.1 INTRODUCTION

E.1.1 Objectives of Adaptive Management Application

This document serves as a reference for how the Biscayne Bay Coastal Wetlands (Biscayne Bay Coastal Wetlands) project may apply adaptive management consistent with the 2006 Comprehensive Everglades Restoration Plan Adaptive Management Strategy for project-level application of adaptive management principles. The goal of applying adaptive management for the Biscayne Bay Coastal Wetlands is to generate learning that will address key questions about how the project will achieve its restoration goals and objectives, assess ecological response, and provide feedback and options to adjust management actions, as necessary, to ensure restoration goals are likely to be achieved. It is important to note that adaptive management is a type of process improvement, and the suggested management actions described herein are not self-executing. Moreover, any described operational or design changes would be implemented at the discretion of the leadership of the U.S. Army Corps of Engineers and the Governing Board of the South Florida Water Management District. Adaptive management actions will necessarily be implemented based on consideration of other agency restoration and water management priorities, and the availability of state and Federal funds.

The adaptive management options described would likely add value to each Biscayne Bay Coastal Wetlands project phase. Information gleaned from Phase 1 should greatly assist in improvement to the planning of Phase 2, and improving project operations and/or informing management of system-wide or regional performance issues that need to be addressed to help improve Biscayne Bay performance. Still to be addressed is management of the process itself with clearly identified roles, responsibilities, products and time frames. Management of the process will presumably be addressed by RECOVER.

The Biscayne Bay Coastal Wetlands Adaptive Management plan has been designed to utilize project-level and system-wide Ecological Monitoring results to

determine what changes or additions to management measures and operations are required to attain the project's intended restoration goals and objectives. Specifically, the suggested adaptive management measures should help ensure the restoration of beneficial patterns of freshwater flow, salinity, and water quality to nearshore waters and adjacent wetlands of southwestern Biscayne Bay to achieve the desired community structure, distribution, abundance, and viability of oyster bars, submerged aquatic vegetation, wetland vegetation, and associated biota. This plan facilitates the National Research Council's (2006) recommendation for the Incremental Adaptive Restoration approach for Comprehensive Everglades Restoration Plan.

E.1.2 Purpose of Adaptive Management Plan

The Biscayne Bay Coastal Wetlands project has made certain assumptions regarding ecosystem response (i.e., alteration of drivers and stressors that evoke beneficial responses) based on the Conceptual Ecological Model for Biscayne Bay (Browder et al. 2005a) that outlines the linkages between performance measures, targets, interim goals, and monitoring activities. Virtually all of the external drivers, stressors, ecological effects, and attributes described in the Conceptual Ecological Model are applicable to the Biscayne Bay Coastal Wetlands project. If these assumptions and hypotheses are correct, the Biscayne Bay Coastal Wetlands project has developed a plan to implement a set of constructed features that will test those hypotheses and generate the following environmental benefits: beneficial patterns of freshwater flow, salinity, and water quality to nearshore waters and adjacent wetlands of southwestern Biscayne Bay to achieve the desired community structure, distribution, abundance, and viability of oyster bars, submerged aquatic vegetation, wetland vegetation, and associated biota. The Biscayne Bay Coastal Wetlands Ecological Monitoring plan is intended to verify and ensure these benefits are realized, address unanswered questions about how the Biscayne Bay Coastal Wetlands will achieve desired restoration benefits, and inform management on what changes or additions to management measures and operations may be required to attain the project's intended restoration goals and objectives. This adaptive management effort will not only require that monitoring be sufficiently robust, but that stakeholders remain engaged in defining desirable system responses (project performance measure interim goals/targets), both spatially and temporally.

Failure to achieve desirable system responses (project performance measure interim goals/targets) should trigger an adaptive management decision-making process. However, this should not be construed as requiring immediate large scale remedial actions, but may be incremental steps in a series of adaptive management actions—the first step among which is to validate the restoration performance issue requiring action. A second logical step would be to question the validity of the performance measure. Assumptions about future ecological

conditions used to support planning, which are typically based on simplistic single-parameter a priori modeling and best professional judgment expectations, may not fully capture the intended complex multi-parameter goals of restoration. Decision frameworks are used to identify what management options are available depending on the actual restoration outcome (stressors/ecological attributes) being monitored and assessed. In some cases, remedial actions may be self-evident and readily executable following the decision framework and discussion amongst project stakeholders, e.g., optimizing operation of existing constructed features. In other cases, remedial actions may require elevation of the system-regional performance issue(s) to be evaluated and options developed that not-only address the restoration issue but also policy and management issues associated with taking the action. The adaptive management plan explains in further detail how the monitoring and assessment process will inform decision-making under different scenarios to improve project restoration performance.

E.2 BISCAYNE BAY COASTAL WETLANDS BACKGROUND AND OBJECTIVES

E.2.1 Project Background

The Biscayne Bay Coastal Wetlands Phase 1 project area encompasses a portion of south-central Biscayne Bay and extends roughly from Shoal Point south to Turkey Point. This area has been significantly altered by human activities that have degraded nearshore habitat along the south-central area of western Biscayne Bay, and the function and spatial extent of adjacent coastal wetlands. Detailed descriptions of historic conditions, anthropogenic affects, and anticipated project benefits can be found in the Problems and Opportunities section of the Project Implementation Report. A condensed version appears in the Introduction section of the Ecological Monitoring Plan (***Annex E – Part 3*** in the PIR).

The Biscayne Bay Coastal Wetlands project will be phased over time. For planning purposes, the U.S. Army Corps of Engineers will seek authorization for the project via two Project Implementation Reports. The Biscayne Bay Coastal Wetlands Project Implementation Report, Phase 1 will include components of the Biscayne Bay Coastal Wetlands SFWMD State Expedited Construction project, and additional management measures and features as described in the U.S. Army Corps of Engineer's 2007 Alternative Formulation Briefing document. This will affect how adaptive management will be conducted over the life of the project. The primary difference between Phase 1 and Phase 2 relative to adaptive management is geographic. Phase 1 does not have features that will affect the Model Land Basin or Barnes Sound in the southernmost part of the project area. At this time, it is not clear what features will be included in Phase 2, nor when Phase 2 might be constructed. However, information gained from

the Biscayne Bay Coastal Wetlands Phase 1 monitoring and adaptive management process should prove invaluable to helping guide the planning and implementation of Phase 2 of the project. It is likely that the adaptive management plan will evolve over time, as more information becomes available through the project-level and system-wide monitoring program that will, hopefully, allow the refinement of targets and reduce the level of uncertainty and risk regarding this restoration project. Ultimately, the decision to change adaptive management should be made by an adaptive assessment team that examines all the information available including risk tolerance of Type 1 (α) or Type 2 (ß) errors.

Key stakeholders have been identified (see ***Appendix E – Agency and Public Coordination***), who can be requested to continue to coordinate the development and implementation of this adaptive management plan. This will aid in ensuring that stakeholders and implementing agencies have a shared understanding of the adaptive management process, project goals and objectives, and the science generated and applied to the decision-making process. ***Appendix E*** also clarifies how stakeholders may be engaged, their input requested, and how stakeholder views and information may be considered in project decision-making.

E.2.2 Ecological Response

Restoration of the Biscayne Bay Coastal Wetlands and adjacent bay waters hinge on achieving five positive ecological responses. They are:

1. Re-establish productive nursery habitat along the shoreline.
2. Redistribute freshwater flow to minimize point source discharges to improve estuarine habitat.
3. Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.
4. Preserve and restore spatial extent of natural coastal glades habitat.
5. Re-establish connectivity between Biscayne Bay Coastal Wetlands, C-111 Basin, Model Land Basin, and adjacent basins.

E.2.3 Biscayne Bay Coastal Wetlands Project Restoration Vision

Historically, oyster beds and submerged aquatic vegetation beds provided important habitat for numerous organisms in south-central Biscayne Bay. These habitats, together with juvenile fishes and various macroinvertebrates, are indicators of a healthy estuary. Similarly, marl marshes and mangrove marshes provide important habitat for wetland species and are indicators of healthy south Florida coastal wetlands. Ecotones occurred along the coast where freshwater graded into saltwater habitats. The design of the Biscayne Bay Coastal Wetlands project and the Comprehensive Everglades Restoration Plan

focuses on re-directing flow from canals into the coastal wetlands to re-establish more natural overland flow regimes that will provide appropriate hydropatterns and salinity regimes to re-establish and maintain these key habitats along southwestern Biscayne Bay.

An objective of the Biscayne Bay Coastal Wetlands Adaptive Management Plan is to determine if restoring beneficial patterns of freshwater flow, salinity, and water quality to nearshore waters of southwestern Biscayne Bay will achieve the expected distribution, community structure and viability of oyster bars, submerged aquatic vegetation beds, and associated biota. The Biscayne Bay Coastal Wetlands Adaptive Management Plan will also evaluate ecosystem responses to changes in hydropatterns (water depth and hydroperiod) within the coastal wetlands (particularly the freshwater wetlands component) that are expected to provide ecological conditions suitable for expanded and intensified wildlife utilization through improvements in wetland habitat functional quality, and improvements in native plant and animal species diversity and abundance. There should be agreement on performance targets, and on the ecological changes that constitute improvements, as a prerequisite for determining which parameters in the system must be altered. Because of the uncertainties inherent in any effort to restore such a complex and altered system such as the Biscayne Bay Coastal Wetlands project area, the performance targets and the measures of success can only be broadly stated. Nevertheless, these targets and measures need definition to design an adaptive management plan that is well focused and efficient, thereby ensuring that it will provide the management adjustments necessary to achieve the restoration envisioned by the project team.

E.3 ADAPTIVE MANAGEMENT APPLICATION

E.3.1 Unanswered Questions

The ecological premise of restoring south-central Biscayne Bay and nearshore system lies in the Biscayne Bay Conceptual Ecological Model (Browder et al., 2005a). The following uncertainties relate to how the project will address the particular stressors affecting the decline of the system, as well as how the system's ecological attributes will respond to achieve restoration success based on the project goals and objectives.

Each of the following parameters must answer this question: Will there be enough water, especially during the dry season, to achieve established targets?

Additional uncertainties and questions include, but are not limited to:

Hydrology
- How do sea-level rise estimates affect these targets?
- Will there be enough freshwater available at the right times to establish the hydropatterns needed to achieve a coastal and nearshore wetland habitat response?

Salinity
- What are the nearshore and offshore salinity ranges and patterns desired for each ecological attribute?

Oysters
- What is the current and historical pre-canal distribution of oyster buildups in the Southern Estuaries? (Information would help set ecological attribute targets)

Seagrass
- What was the historical, pre- canal submerged aquatic vegetative species abundance and distribution?
- What salinity zone ranges and patterns are required for achieving diverse, abundant and stable seagrass communities in south-central Biscayne Bay?

Estuarine Macroinvertebrates and Fish
- What are the distribution and abundance of key faunal species and communities in relation to salinity patterns, habitat, and other major influencing factors? (Information would help identify predicted restoration response)

Crocodiles
- Will achieving a target salinity in the tidal wetlands ensure an increase in crocodile juvenile and adult numbers in the project area?
- Can adult crocodiles nest on the densely vegetated banks and berms of tidal creeks and drainage ditches in the project area?
- What is a desirable sustainable crocodile population and distribution within Biscayne Bay?

Periphyton
- How will the response by periphyton from project-induced salinity changes be isolated from water quality responses?

Water Quality

- Will hydrologic changes associated with the Biscayne Bay Coastal Wetlands project alone achieve oligotrophic nutrient concentrations that existed in the historical, pre-development system?

E.4 STRUCTURE OF ADAPTIVE MANAGEMENT PLAN AND PROCESS

E.4.1 Ecological Zones

The landscape of the Biscayne Bay Coastal Wetlands project area is characterized by three distinct ecological zones—nearshore bay, saltwater (tidal) wetlands, and freshwater wetlands. In some cases, management measures proposed by the project are being designed to address restoration objectives separately within each of those zones. In keeping with this process, the adaptive management plan has been structured by this geographic and ecological zonation. Adaptive management hypotheses, performance measures (indicators), monitoring parameters and associated management options are considered separately for each of the three zones in this document. The nearshore bay zone includes oysters, fish, and submerged aquatic vegetation as primary adaptive management indicators. Salinity is an important monitoring component utilized in the decision-making process of each of those indicators. The saltwater wetlands component includes periphyton and crocodiles as primary indicators. Again, salinity monitoring data are used in the decision-making process of each of the two indicators. The freshwater wetlands component has wetland vegetation as its primary indicator, with stage monitoring data as the most important supporting data to address wetland vegetation management.

E.4.2 Decision-Making Hierarchy

A preliminary decision-based hierarchy is suggested for the adaptive management plan based on resource objectives. This hierarchy defines the priorities for adaptive management operation action options should targets or monitoring results conflict. The first tier indicators include oysters (nearshore zone), periphyton (saltwater wetlands zone), and wetland vegetation (freshwater wetland zone). Submerged aquatic vegetation and crocodiles are in Tier 2 of the hierarchy. As noted above, salinity and water level monitoring data can be used to determine how to adaptive management adjustments to project plans/operations and or program plans/operations will achieve these indicator targets to reach optimum restoration.

E.4.3 Decision-Making Response

The decision-frameworks contained in each ecological zone section of this adaptive management plan are intended to help link performance measures to

monitoring, targets, and potential management options to ensure the Biscayne Bay Coastal Wetlands goals and objectives are reached. Project performance reports in the form of coordinated RECOVER module annual reports, biennial system status reports, or as needed depending on the timing of expected ecological response or unexpected responses requiring attention. RECOVER working with post BBCW project team members will present to managers, planners, engineers, and operations specialists the results of project performance reports and discuss potential options for management to consider at existing management forums (i.e., Design Coordination Team). It should be noted that this adaptive management plan is a guidance document intended to assist the CERP implementing agencies, the US Army Corps of Engineers and the South Florida Water Management District, and the Restoration, Coordination and Verification (RECOVER) staff in understanding project level ecological responses and the array of potential operational or design changes that might be employed to improve restoration response. As described previously, described management actions are not self-executing and any described operational or design changes would be implemented at the discretion of the leadership of the Corps of Engineers and the Governing Board of the South Florida Water Management District. Management actions would be implemented based on consideration of other agency restoration and water management priorities, and the availability of state and Federal funds.

The Biscayne Bay Coastal Wetlands Project Development Team also recognizes the need to request and receive regulatory approval for operational changes for adjusting the project, recommended by RECOVER or the Biscayne Bay Coastal Wetlands Project Development Team, that do not comply with the permitted operational plan. Other options, such as, adjustments to future project phases, Comprehensive Everglades Restoration Plan program plans and system operations, and/or non- Comprehensive Everglades Restoration Plan management options will require coordination with the appropriate agencies that have authority to make the suggested changes.

E.5 NEARSHORE ZONE

The local watershed is currently drained by a series of canals as part of the system dredged into the shallow aquifer and controlled by gated spillways created by the Central and Southern Florida Flood Control Project. Runoff is discharged into Biscayne Bay via these canals at seven locations within the Biscayne Bay Coastal Wetlands project area. Prior to construction and operation of these canals, stormwater runoff discharged into Biscayne Bay through a series of small, natural channels or creeks distributed along the shoreline. An estimated 20 to 30 creeks were destroyed in the project area. In addition, the natural ability of the shallow Biscayne aquifer to distribute water into the bay through seepage has been greatly reduced because of low water levels. Consequently, the redirection of runoff into a few points and highly

controlled releases has resulted in impacts to salinity within the nearshore bay environment in two primary ways. Habitat value within and immediately adjacent to the canal mouths is poor because freshwater is released only to control stages upstream without regard to impacts to the estuary, and can be abrupt. Intermittent and sometimes intense discharges cause salinity near the canal mouths to vary widely within short periods of time. Many estuarine organisms are not adapted to manage the abrupt and variable changes in salinity, therefore few organisms live within or very close to the canal discharges. The redirection of runoff has also affected the nearshore bay habitat by generally altered patterns of salinity.

Modeling has shown that a more natural distribution of runoff into 21 creeks creates a broader area of lower salinity along the shoreline that does not extend out into the middle of the bay where sensitive coral and sponge habitat can be affected (Brown, 2003 and 2004). The primary restoration objectives of the Biscayne Bay Coastal Wetlands project in the nearshore area are:

Objective 1	Re-establish productive nursery habitat along the shoreline.
Objective 2	Redistribute freshwater flow to minimize point source discharges to improve estuarine habitat.
Objective 3	Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.

The purpose of this section of the adaptive management plan is to provide information to adequately address the efficacy of achieving the above stated objectives. Thus, the adaptive management plan must generate the types of management measures and operational changes necessary to achieve the following:

- The re-establishment of oyster habitat at creek mouths (indicator of nursery habitat and improvement of the quantity, timing, and distribution of freshwater to the bay; Objectives 1 and 3)
- The coverage of appropriate coverage of submerged aquatic vegetation along the shoreline; spatial extent and species composition (indicator of nursery habitat and reduction in point source discharges; Objectives 1 and 2)
- Fish composition and abundance more indicative of healthy estuarine nursery habitat (indicator of nursery habitat; Objective 1)

E.5.1 Eastern Oyster Adaptive Management

E.5.1.1 Rationale

Relic Eastern (or American) oyster (*Crassostrea virginica*) reefs have been found in association with most of the primary historic creek systems in the project area

(Meeder et al., 1999). With reduction and redirection of freshwater Everglades discharge (along with many other changes to the coastal wetlands), these historical oyster bars and banks have been lost. Because of the abrupt episodic channelized discharge of redirected freshwater, new banks have not formed in other locations like the mouths of canals. Restoration of a more natural overland flow, particularly the restoration of flow through coastal creeks, is expected to create conditions suitable for the reestablishment of oysters.

Adaptively managing the project to restore eastern oysters in the project area addresses project Objective 1 by evaluating the extent to which suitable nursery habitat is restored in the nearshore waters of the project area. Suitable nursery habitat includes oyster bars or reefs in the mouths of restored freshwater creek systems that have suitable substrates in the project area. Historically, this included 21 creek systems. The salinity regime that promotes the establishment and maintenance of oyster reefs is the same regime that promotes an appropriate assemblage of estuarine fish. In South Florida this includes species such as red drum (*Sciaenops ocellatus*), once common in Biscayne Bay and found in association with oyster reefs (Smith, 1896). Black drum (*Pogonias cromis*), Atlantic croaker (*Micropogonias undulates*), and snook (*Centropomis unidecimalis*) are other estuarine species that were more abundant in Biscayne Bay in the past. Recreation of local conditions supportive of oysters in historical oyster habitat or equivalent oyster habitat is expected to lead to an increase in the number of characteristically estuarine fish and invertebrate species and their abundance. Re-establishment of oyster habitat is an important component of two of the project's performance measures; 1C (Salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat) and 2C (Viable Eastern oyster communities become established along the shoreline).

E.5.1.2 Adaptive Management Protocols of Oysters

A framework for how the project might be adaptively managed to restore oysters is shown in ***Table E-1***. The framework provides management action options based on five parameters that affect the establishment and maintenance of healthy eastern oyster populations. Information for four of those parameters (salinity, recruitment, juvenile growth and mortality, and disease) is provided by the Biscayne Bay Coastal Wetlands project-level ecological monitoring and RECOVER Monitoring and Assessment Plan oyster monitoring plan. Specifically, data will be collected to monitor the rate of recruitment of new oysters to the population, the distribution and abundance of adult oysters, the growth and survival of young oysters until they join the adult size class; and the reproductive and health status of those oysters. Monitoring will be conducted at eight sites along the shoreline in the project area (see Biscayne Bay Coastal Wetlands project monitoring plan see ***Part 3, Section E.2.1***). Each of these

sites is located at or near the mouths of historic or existing major freshwater creeks or at locations where significant freshwater flow to the bay is anticipated as a result of the project.

Note that any recommended operational changes are intended to be those that are allowed by the permitted operational plan; recommended operational changes that do not comply with the permitted operational plan will be required to receive regulatory approval.

TABLE E-1: POSSIBLE ACTION OPTIONS FOR ADAPTIVELY MANAGING THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR EASTERN OYSTERS

Stressor metric	Target	Management Action OPTION 1	Management Action OPTION 2	Management Action OPTION 3
Salinity	Stable salinity range of 10-25 psu at creeks	Change operations to meet flows	Review and revise (if appropriate) the salinity target	System-wide/ Regional Performance Issue Analysis (More water)
Recruitment	Presence/absence adults and larvae	Stock larvae	Stock adults	Change operations to avoid too much or too little flow in key months
Substrate	Acres of suitable habitat	Add oyster shell cultch	Try different substrate (e.g., concrete)	Dredge muck
Oyster reef development	Presence/absence of reefs at least 1 m2 in size	Add additional cultch		
Juvenile growth and mortality	Attain natural levels of growth and mortality	If flow/salinity events are affecting growth or mortality, adjust operations to eliminate or minimize events	Adjust flows to attain salinity similar to creeks where oyster growth is optimal	Excessive predation may require salinity adjustments through operations
Disease	Elimination	Operate flows to maintain salinity below maximum threshold	Lower salinity threshold and adjust operations accordingly	

The order of priority for action steps is also provided in ***Table E-1***. Listed in order of priority, they are:

(1) Salinity
(2) Oyster spat recruitment
(3) Substrate
(4) Oyster reef development

(5) Juvenile growth and mortality
(6) Adult health and reproductive status

Descriptions of how monitoring data may be used to determine adaptive management action steps for each parameter are provided below.

Salinity
Results from salinity monitoring can be used to determine if the appropriate salinity envelope is being achieved for oysters at or near the mouths of major tidal creeks. The target salinity envelope is about 10-25 psu. It will be important not only to ensure adequate flows during the dry season to maintain salinity at or below 25 psu. Eastern oysters can tolerate low salinity for short periods, but it will be equally important to limit freshwater flows such that salinity does not fall below 5 psu for more than five consecutive days. Flow to major creeks may be adjusted either by reduction of pumping rates into spreaders or through adjustments to flow rates at culverts.

Spat recruitment
Results from the spat recruitment monitoring will determine the availability of spat at the monitoring sites. If spat are available at all eight sites (***Figure E-1***) then no adaptive management measures for this parameter are necessary. However, if spat are unavailable at any of the eight sites, introduction of spat may be necessary. In this event, spat from local brood stock may be introduced to the site. The use of containment curtains may be required, to retain the spat at the site for one to two days until the spat have set on the available substrate. It should be noted that suitable substrate may not be present at the monitoring sites. Suitable substrate, preferably oyster clutch (oyster shells), may need to be distributed at the monitoring sites and other suitable sites (i.e., historic creek mouths or newly established outflow points). Costs for spat seeding or clutch placement will be covered by the adaptive management plan budget.

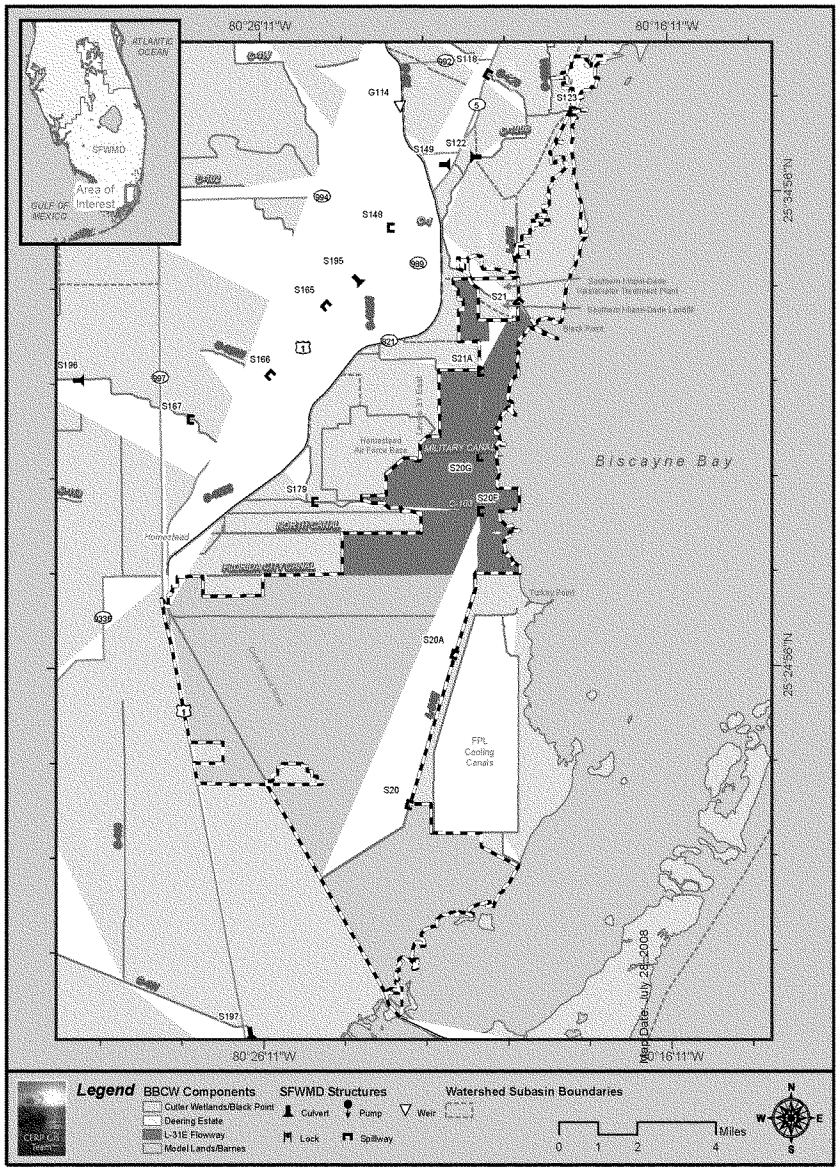

FIGURE E-1: BISCAYNE BAY COASTAL WETLANDS PROJECT AREA

Substrate

The eight primary creek mouths where oysters are targeted for restoration have been surveyed for the availability of suitable substrate, and it appears that suitable substrate is available at each site. However, if salinity is determined to be appropriate for oysters and spat are available but are not recruiting, then different substrates may have to be introduced to the sites (e.g., oyster cultch, fossilized cultch, concrete, etc.). It is unlikely that siltation will be an issue, but monitoring efforts should be able to determine this.

Oyster reef development

The adaptive assessment and management for this component could be greatly assisted by adapting the oyster Habitat Suitability Index (HSI; Volety et al., 2005; Mazzotti et al., 2005) model to Biscayne Bay. The model includes a larval component index (LCI) and an adult component index (ACI). Spat recruitment, mean salinity, temperature, and inflow of freshwater comprise the LCI. The ACI is comprised of densities of living oysters, disease intensity of dermo, spat recruitment, salinity, temperature and frequency of killing floods. Development of a HSI could help identify exact locations or areas that have the greatest potential to develop as reefs, extent of reef coverage assuming certain growth rates, and above all, reasonable predictive capability of oyster reef survival should conditions change in the future, as for example the amount of freshwater available.

Adapting the model to Biscayne Bay would require obtaining data from all four oyster monitoring components described above (spat recruitment, oyster reef development, juvenile growth and mortality, and oyster disease). The oyster HSI hinges on determining what is referred to as the "oyster accommodation space," which is the area of the water body that is suitable to support oysters based upon water quality. This concept does not mean that oysters would grow in all of the defined oyster accommodation space, but it quantifies how much suitable space is available. Oyster accommodation space does not take into account water depth, suitable settling habitat, etc. It provides information only on whether or not water quality is suitable to grow oysters. It should be noted that there may not be a very large accommodation space available in the Biscayne Bay Coastal Wetlands project area. However, if oyster reefs are restored at the appropriate locations, it can be assumed that salinity and other conditions are suitable for the desired estuarine biota along the shoreline.

If adapted for Biscayne Bay, the HSI model could be used to evaluate the oyster accommodation space in the project area. This will provide managers with the desired information about where in the project area water quality is suitable for oysters. Results of the evaluation should provide the information necessary for managers to adjust flow rates, and therefore, salinity regimes in the target areas.

The concept of establishing definitive timelines for the reestablishment of oyster reefs would be very difficult, if not impossible, to determine and would not be as important as using the oyster HSI model to evaluate the accommodation space. The HSI does not predict reef development on a timeline; it primarily determines whether or not the habitat is suitable. The most practical adaptive management action for minimizing the time for reestablishment of oyster reefs is through prompt assessments and response.

Juvenile growth and mortality

This monitoring will provide information for several facets of adaptively managing the project for oysters. First, it will help determine whether or not a physical event (e.g., significant water flow changes that affect salinity and other water quality parameters) affects juvenile growth and/or survival. If these events do cause juvenile mortality or significantly diminish growth, then the events should be minimized or eliminated through operations.

Second, the monitoring will determine how quickly oysters develop to maturity. These growth rates will likely vary by creek due to different salinity regimes occurring at the mouths of creeks. The adaptive management action would be to adjust flow rates and salinity regimes in creeks with poor oyster growth to conditions most similar to the creeks that have the most optimal oyster growth rates.

Third, the monitoring provides information on oyster mortality caused by macrofaunal predation. Predation pressure in the creeks may be very high, which may influence the restoration approach. For example, more juveniles may have to be planted than originally planned to overcome the local predator density affects. Larger juveniles may have to be planted to avoid a certain predator species that preys only on smaller juveniles. Another possible adaptive management technique for predator control would be the removal of predators, but this generally meets with very limited success. Also, the predator problem may be very time-specific in nature (i.e., it could be closely tied to seasonal occurrence of predator abundance). Adjusting flow rates and salinity regimes at the appropriate time of year may be an affective adaptive management action to thwart predators.

Finally, it is important to determine if there are oyster mortality events prior to achieving maturity status. One of the key milestones in reestablishing oyster reefs is to achieve progression of the life history process through to reproductive maturity status. If there are physical events that result in massive early life history mortality, then restoration of oyster reefs will not be realized.

Oyster health

Given that oyster diseases such as dermo are closely tied to salinity, results from disease monitoring would be a good indicator of the reestablishment of appropriate salinity ranges along the shoreline. For example, a lack of disease or low levels of disease should indicate that salinity is generally below 20 practical salinity units (the general salinity threshold, below which dermo and MSX do not thrive [Kennedy et al., 1996; Woodward-Clyde, 1998]). Prevalence of disease would indicate that salinity that is too high. In this case, the adaptive management action might be to introduce additional freshwater into the area where the disease is found to lower salinity below the preferred disease range (i.e., below 20 psu). These diseases are also closely tied to water temperature. The combination of high temperature and high salinity is ideal for disease proliferation. Even though the project will not directly affect water temperature, adaptively managing for water releases that keep salinity low during summer months should help keep disease levels under control.

E.5.2 Submerged Aquatic Vegetation Adaptive Management

E.5.2.1 Rationale

Seagrass beds function as vital habitat to support critical life stages of a variety of ecologically important and commercially or recreationally valuable species. Three species of seagrass commonly occur in the project area: turtle grass (*Thalassia testudinum),* shoal grass (*Halodule wrightii*), and wigeon grass (*Ruppia maritima*). Distribution of these species is generally related to water clarity and quality, substrate, salinity levels and salinity variability. The distribution in the western nearshore area of central and southern Biscayne Bay is influenced by both canal discharges and submarine groundwater seepage (Kohout and Kolipinski, 1967; Meeder et al., 1997 and 1999).

T. testudinum is most prominent in central and south Biscayne Bay where salinity is in the 30-36 psu range with low variability. Nutrient levels are also low compared to nearshore areas. Presence or absence of *T. testudinum* may indicate distinct zones where ground-water influence is substantial (*T. testudinum* absent) or insignificant (*T. testudinum* present). This is in part due to the salinity tolerance of *T. testudinum*, as it does not compete favorably in low and or highly variable salinity regimes (Lirman and Cropper, 2003). Both low salinity and high salinity variability can occur in nearshore regions where groundwater seepage has been documented, and surface water runoff occurs. In the very nearshore regions (e.g. within 500 meters of shoreline) *H. wrightii* is more prominent, as it can tolerate a broad range of salinity, and large salinity (and temperature) fluctuations (Lirman and Cropper, 2003). *R. maritima* is restricted to areas proximal to coastal embayments in the project area. Although *R. maritima* is tolerant of a wide range of salinity, in Florida Bay and Biscayne Bay, it has been observed only in areas of persistent, low salinity

regimes, and has been used as an indicator of freshwater input (Hunt *et al.*, 2006). One exception is a prolific growth in cooling canals associated with the Turkey Point Power Plant which is not connected to Biscayne Bay. Salinity in the cooling canals can range up to about 70 psu.

The ecological premise behind including seagrass as a parameter for adaptively managing the project is that through the more diffused and prolonged delivery of freshwater to the bay (i.e., more similar to conditions that existed prior to upstream water management), a more stable mesohaline salinity gradient, with fewer and less extreme variations, will be restored in the coastal environments of Biscayne Bay, and dissolved nutrients will be captured in wetlands upstream. Such conditions will provide a broader coverage of a more diverse submerged aquatic vegetation community. The Comprehensive Everglades Restoration Plan hypothesis regarding seagrass is that the restoration of favorable flow and stable salinity regimes (especially mesohaline conditions) will result in the increased occurrence of *R. maritima* in the very nearshore and coastal embayments, and extension of the range of *H. wrightii* along shore with a broader coverage north to south. The seaward abundance of *H. wrightii* should retract somewhat as lower salinity is kept closer to shore and away from the coral and sponge habitats.

Redistribution of freshwater in the project area should affect seagrass and submerged aquatic vegetation through changes in species distribution and relative abundance in the species composition in the nearshore regions (i.e., within 1000 meters from shore). With the redistribution of freshwater it is anticipated that the very nearshore (i.e., less than 250 meters) and areas near mouths of historic creeks will show a gradual decrease in cover and abundance of *T. testudinum* and a concurrent increase in *H. wrightii* cover and abundance. It is also likely that, *R. maritima* may become more established in the coastal embayment areas. In addition, the abundance of macroalgae should decrease which will allow seagrasses to be more dense and productive.

Adaptively managing for submerged aquatic vegetation addresses project Objective 1 by adjusting project features and operations to ensure that suitable nursery habitat is restored in the nearshore waters of the project area. Suitable nursery habitat includes extensive seagrass coverage of appropriate species, as described above. The salinity regime that promotes the establishment and maintenance of appropriate seagrass species along the shoreline (i.e., *H. wrightii* and *R. maritima*) is the same regime that promotes an appropriate assemblage of estuarine fish. Restoration of local conditions supportive of seagrass habitat is expected to lead to an increase in the number of characteristically estuarine fish and invertebrate species and their abundance. Expansion and appropriate species transition of submerged aquatic vegetation habitat is an important component of the project's Performance Measure 1D (The seagrass community at

existing canal mouths should be similar in abundance and composition to the community in other areas nearshore). Seagrass and submerged aquatic vegetation monitoring is listed in ***Part 3, Section E.3***.

E.5.2.2 Adaptive Management Protocols for Submerged Aquatic Vegetation

A framework for how the project may be adjusted as necessary to restore appropriate submerged aquatic vegetation coverage is shown in ***Table E-2***. The framework provides management action options based on two parameters that affect the establishment and maintenance of healthy submerged aquatic vegetation communities in the nearshore bay waters of the project area. Of primary importance for determining action steps will be the submerged aquatic vegetation monitoring data collected by the project and the Restoration, Coordination and Verification Monitoring and Assessment Plan (see Biscayne Bay Coastal Wetlands Ecological Monitoring Plan and the Monitoring and Assessment Plan). Also, the extensive salinity monitoring conducted by the MAP is important to determining adaptive management actions for submerged aquatic vegetation.

Hypothesis 1: The Biscayne Bay Coastal Wetlands project diffuse delivery of freshwater flows will achieve stable salinity regimes for increases in seagrass abundance and seagrass species tolerant of lower salinity levels.

TABLE E-2: POSSIBLE ACTION OPTIONS FOR ADAPTIVELY MANAGING THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR SUBMERGED AQUATIC VEGETATION

Stressor metric	Target	Management Action OPTION 1	Management Action OPTION 2	Management Action OPTION 3
Salinity Performance Measure	Wet Season: 20 psu in zone out to 500 meters Dry Season: 20 psu in zone out to 250 meters	Adjust Biscayne Bay Coastal Wetlands project operations	Revise salinity estimates	System-wide/Regional Performance Issue Analysis (More water)
Seagrass Species and Area (SAV performance measure)	Increase Halodule Sp. presence, and seagrass bed area	Adjust Biscayne Bay Coastal Wetlands operations		

Key: psu practical salinity units
sav submerged aquatic vegetation

Regarding seagrass in the Biscayne Bay Coastal Wetlands project, the adaptive assessment should consider:

Will the restoration of favorable flow and salinity regimes achieve restoration objectives for seagrass habitats, thereby increasing the distribution and density of representative estuarine fauna, including juvenile and adult stages of several economically important fisheries species?

The adaptive management question that follows is:

If objectives are not achieved, what additional changes in flow and salinity regimes are necessary?

E.5.3 Estuarine Fish Adaptive Management

E.5.3.1 Rationale

The faunal assemblages of western nearshore Biscayne Bay are made up of fishes and macro-invertebrates with both estuarine and marine affinities. An increase in the diversity and abundance of the estuarine component of this assemblage (i.e., the euryhaline fauna) would indicate progression toward the desired estuarine conditions in the western nearshore bay. As components of the nearshore food web, these species support the diet of recreationally and commercially important species that spend all or a part of their life in the bay, especially in juvenile stages. Therefore, an increase in the diversity and abundance of these fish and macro-invertebrates would indicate improved nursery habitat for juvenile fishes. This parameter applies to the Biscayne Bay Coastal Wetlands project's restoration objectives 1: re-establish productive nursery habitat along the shoreline; 2: redistribute freshwater inflow to minimize point source discharges to improve estuarine habitat; and 3: restore and improve quantity, quality, timing, and distribution of freshwater to the bay. Estuarine fish monitoring is listed in ***Section E.4***.

Redistribution of freshwater inflow from canals to many small creeks is expected to reestablish a positive salinity gradient along a greater portion of the shoreline and to reestablish estuarine conditions in these areas of the shoreline. This is expected to increase the diversity and abundance of estuarine fish and macro-invertebrates in very shallow nearshore waters. Re-establishment of more appropriate estuarine fish assemblages is an important component of three of the project's performance measures: Performance Measure 1A (fish community assemblage within creeks and within one kilometer of the western shoreline will reflect that expected in a healthy, functioning estuary); Performance Measure 1C (salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat); and Performance

Measure 3A (nearshore salinity patterns exhibit a broader area and extended duration of mesohaline conditions).

E.5.3.2 Adaptive Management Protocols for Estuarine Fish

A framework for how the project might be adjusted as necessary to restore estuarine fish is shown in ***Table E-3***. The framework provides management action options based on three parameters that affect the establishment and maintenance of healthy estuarine communities in the nearshore bay waters of the project area. Of primary importance for determining action steps will be the fish monitoring data collected by the project and the Restoration, Coordination and Verification Monitoring and Assessment Plan (see Biscayne Bay Coastal Wetlands Ecological monitoring plan and the Monitoring and Assessment Plan). Also, the extensive salinity monitoring conducted by the MAP is important to determining action steps for adaptively managing estuarine fish.

Hypothesis: The Biscayne Bay Coastal Wetlands project diffuse delivery of freshwater flows will achieve stable salinity regimes for increases in estuarine fish abundance.

Spotted seatrout can be used as an indicator of estuarine health and for the purposes of establishing a salinity target for estuarine fish. Regression equations from Serafy et al. (2008) were used to identify the ideal range of salinity for seatrout abundance (10 to 20 psu) during the wet season. This estimate is based on the best information available in the absence of laboratory-based osmoregulatory physiology and behavioral preference data.

TABLE E-3: POSSIBLE ACTION OPTIONS FOR ADAPTIVELY MANAGING THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR ESTUARINE FISH

Stressor metric	Target	Management Action OPTION 1	Management Action OPTION 2	Management Action OPTION 3
Salinity Range (Estuarine fish abundance requirements)	10 to 20 psu (wet season)	Adjust operations to achieve salinity range	Review and revise (if necessary) the performance measure	System-wide/Regional Performance Issue Analysis (More water)
Seagrass (SAV performance measure)	Increase Seagrass Bed Area			

Key: psu practical salinity units
sav submerged aquatic vegetation

Adaptive assessments should be conducted in which periodic quantitative determinations are made of the number and abundance of species in the estuarine assemblage, i.e., those species known to occur in the oligohaline (0-5 psu) and mesohaline (5-18 psu) coastal waters of southeast Florida. The assessment will take two approaches (1) the frequency, distribution, and abundance of key indicator species (presently sheepshead minnow (*Cyprinodon variegatus),* clown goby (*Microgobius gulosus),* and others that may be added based on baseline sampling), and (2) measuring the proportion of the potential estuarine assemblage present in the collection. The potential estuarine community most broadly includes those species known to occur in the oligohaline (0-5 psu) and mesohaline (5-18 psu) coastal waters of southeast Florida. Based on extensive study, Gilmore (1995) listed the top 25 species occurring in the marginal tidal wetlands of the Indian River Lagoon area. Six additional species occurring in oligohaline tributaries of the Sebastian River (Gilmore, 1995) can be added to that list. Based on their presence in these areas and other aspects of their biogeographical distribution pattern, all 31 of these species appear to be potential residents of the future nearshore estuarine habitat of a fully implemented Biscayne Bay Coastal Wetlands project. Locally, 18 of these species already occur in mangrove wetlands adjacent to Biscayne Bay (Lorenz et al., 2006). Another five species associated with oligohaline habitat of Biscayne Bay (Lorenz et al., 2006), but not listed by Gilmore, represent additions to the potential estuarine assemblage of at least 36 species for the nearshore Biscayne Bay Coastal Wetlands area. At least six of these were found in the very nearshore sampling of Browder et al. (2006), and an additional two were found in South Biscayne Bay in the more spatially extensive throw-trap sampling of Robblee et al. (unpublished). An increase in approaches (1) and (2) over baseline conditions would be indications of progress toward the desired condition. Estuarine species available locally would be expected to expand into the nearshore zone in the short-term. The timing and duration of low-salinity conditions, as well as the intensity and rapidity of salinity change resulting from the project, will help determine the specific species that colonize the area. The establishment of a substantive number of new species from among the potential estuarine assemblage would provide strong evidence for successful implementation of Biscayne Bay Coastal Wetlands project. The list of potential estuarine species may undergo further refinement on the basis of the baseline monitoring and the developing literature. Supporting approaches are briefly described below.

Distribution and abundance of individual species

Abundance can be determined using methods of abundance estimation previously applied to Biscayne Bay faunal data (Browder et al., 2005b; Johnson et al., 2006; Serafy and Valle, 2006; Browder et al., 2006).

Distribution of faunal assemblages
Cluster analysis and other multi-variate techniques may be used to help refine our understanding of faunal assemblages in relation to salinity and other environmental variables. Based on previous work, at least two main clusters are expected to form along the shoreline. Sites assigned to each cluster or species composition within clusters may change once Biscayne Bay Coastal Wetlands project is implemented and freshwater is redirected from canals to various wetland routes to the bay. An expansion of the assemblage associated with more estuarine-like conditions would be a positive sign of the expansion of estuarine habitat.

Relationships to bottom habitat, salinity, and freshwater inflow
Simple plots and fitted curves of occurrence and density by 5 psu bands will be prepared in acknowledgment of the Delta distribution of the data (i.e., removing non-detects from the dataset). Delta-based methods are appropriate for patchy faunal distributions and have been shown to uncover patterns and suggested relationships of faunal distributions to salinity (Serafy and Valle, 2006; Browder et al., 2006; Serafy et al., 2008). Grouping of sites by salinity-bin will further contribute to addressing patchy distributions and reducing the proportion of zeros in the analysis. Weighted mean salinity will be determined for each species during each sample collection (Lorenz and Serafy, 2006; Browder et al., 2006).

Distributional shifts and trends over time
Distributions of some species along the shoreline may change in response to changes brought about by Biscayne Bay Coastal Wetlands project implementation. The distribution along the shoreline of various key species and dominant species will be followed by plotting number caught at each site as a function of latitude. Frequency and abundance will be calculated for comparison over time, and specific changes, by location, will be evaluated. General additive modeling (Johnson et al., 2006) will be used to help determine the factors associated with the faunal changes.

The above and other possible approaches to analysis and assessment of project-level data are described in Robblee and Browder, (2005); Browder et al., (2006); Johnson et al., (2006); Lorenz and Serafy, (2006); and Serafy and Valle, (2006).

E.6 SALTWATER WETLANDS ZONE

Since the construction of the Central and Southern Florida system, most of the coastal wetlands east of the L-31E Canal have become mostly saline rather than estuarine because the only freshwater inputs are rainfall and small amounts of groundwater that seep from the L-31E Borrow Canal. In addition, transitional habitats or ecotones that range in salinity from 0 psu gradually to more marine salinity (35 psu) are almost non-existent in the area between Shoal Point and

Turkey Point. Generally, east of Levee 31E freshwater wetlands have been replaced with transitional or dwarf mangrove forest. A number of estuarine animals depend on the lower saline conditions at different times in their life cycles such as American crocodiles and various wading bird species, including the state listed roseate spoonbill. Currently, few juvenile crocodiles and wading birds utilize the south central area of Biscayne Bay between Shoal Point and Turkey Point. The primary objectives of the Biscayne Bay Coastal Wetlands project in the tidal (or salt water) wetlands are:

Objective 1	Re-establish productive nursery habitat along the shoreline.
Objective 3	Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.

The purpose of this section of the adaptive management plan is to provide information to adequately address the efficacy of achieving the above stated objectives for the saltwater wetlands. Thus, the adaptive management plan must generate the types of management measures and operational changes necessary to achieve the following:

- Periphyton communities that reflect desired salinity gradients across the saltwater wetlands (indicator of appropriate salinity conditions in the tidal wetlands and tidal creeks, restoration objectives 1 and 3).
- Juvenile crocodile distribution and abundance (indicator of healthy nursery habitat, restoration objective 1).

E.6.1 Wetland Algae Adaptive Management

E.6.1.1 Rationale

Benthic algae is a dominant community in coastal wetlands of the project area. It forms prolific growths on sediments, grasses and wet forest vegetation that inhabit the coastline, and it has been shown to be one of the most sensitive ecological indicators of environmental change wetlands generally (Stevenson et al., 1996) and, particularly, coastal wetlands of south Florida (Gaiser et al., 2005). Many models have been generated that relate diatom community composition to salinity in south Florida. Ross et al. (2001) mapped diatoms, vegetation and mollusks along a transect through a coastal Biscayne Bay wetland and showed that diatoms were sensitive to the coastal gradient, and can be used to predict the distance from shore with 100 meter resolution. Gaiser et al., (2006a) surveyed diatoms throughout the Biscayne Bay Coastal Wetlands and found their communities to indicate pore-water salinity with an error of less than 10 percent of the actual value. Surveys throughout Biscayne Bay and Florida Bay found that diatoms could be used to predict salinity within 2 psu and 5 psu, respectively (Gaiser et al., 2005 and 2006a). Benthic algae responds at time-scales appropriate for adaptive management purposes (months to years)

and can be sampled at a resolution adequate to detect spatial variation in environmental changes. Benthic algae monitoring is discussed in ***Part 3, Section E.8***.

Changes in hydrology and salinity resulting from water diversion and sea-level rise in the Biscayne Bay Coastal Wetlands have caused a landward displacement of coastal communities at a rate ranging from 3-30 meters per year, over the last several decades (Ross et al., 2000; Gaiser et al., 2006a). Together with urban and agricultural development, these forces have diminished freshwater wetlands to ten percent of their original area (Gaiser et al., 2006a). In the context of the Biscayne Bay Coastal Wetlands project, the goals of rehydration through redistributing freshwater into coastal basins should result in desirable shifts in vegetation due to salinity changes that are evident over months to years. Adaptively managing the saltwater wetlands using benthic algae as a parameter would provide a means of detecting these changes over multiple time-scales relevant to the restoration project.

Adaptively managing the saltwater wetlands part of the project area using algae primarily addresses project Objective 3 by evaluating the quality (salinity, nutrients), timing and distribution of water entering the wetlands. This parameter addresses Objective 4 by evaluating the extent to which the periphyton species assemblages characteristic of coastal glades habitat are restored in the project area. The parameter also indirectly provides information on project Objective 5 by providing information on the how well basins are reconnected within the project area. Biscayne Bay Coastal Wetlands project performance measures that apply to wetland vegetation communities include performance measure 4A (Areal extent of freshwater wetlands and transverse glades vegetation increases), performance measure 4B (Enhance freshwater and oligohaline marsh habitat by restoring appropriate salinity, hydroperiod, water level). Adaptively managing for wetland algae also addresses project performance measures that apply to salinity in the wetlands and include performance measure 1C (Salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat).

E.6.1.2 Adaptive Assessment and Management Protocols for Wetland Algae

A framework for how the project might be adaptively managed to restore appropriate periphyton communities is shown in ***Table E-4***. The framework provides management action options based on three parameters that affect the establishment and maintenance of appropriate periphyton communities in the saltwater wetlands of the project area. Of primary importance for determining action steps may be the periphyton monitoring data collected by the project (see Biscayne Bay Coastal Wetlands Ecological Monitoring Plan). Also, the extensive

salinity monitoring conducted by the Monitoring and Assessment Plan is important to determining action steps for adaptively managing for periphyton.

TABLE E-4: POSSIBLE ACTION OPTIONS FOR ADAPTIVELY MANAGING THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR PERIPHYTON

Stressor Metric	Target	Management Action OPTION 1	Management Action OPTION 2	Management Action OPTION 3
Diatom community composition	Community composition reflects salinity gradient of 0-20 psu from west to east	Change operations to meet salinity target	Plug or fill mosquito or drainage ditches as needed to obtain desired freshwater distribution	System-wide/Regional Performance Issue Analysis (More water)
Water quality	Nutrient and contaminant concentrations at targets as described in project performance measures	Adjust operations to improve water quality	Improve and enforce Best Management Practices	
Wetland macro vegetation	Narrow mangrove fringe along shoreline; graminoid marsh inland from mangrove	Provide a more natural fire regime to promote and maintain graminoid marsh community	Physically remove forested wetland vegetation to promote growth and establishment of graminoids	

Key: psu = practical salinity units

Early aerial photos, paleoecological data and anecdotal reports show that prior to drainage and compartmentalization, the majority of the Biscayne Bay Coastal Wetlands was freshwater marsh, while the fringing mangrove zone was restricted to a narrow band along the coast. Benthic periphyton within most of the Biscayne Bay Coastal Wetlands was similar to graminoid-dominated areas of the interior Everglades and colonized by freshwater species of diatoms and invertebrates (Gaiser et al., 2006a). Now the entire area to the east of the L-31E has been encroached with mangroves and other woody vegetation, including exotics; and, the benthic floral and faunal communities are dominated by marine forms (Gaiser et al., 2006a; Ross et al., 2001). Construction of a small culvert through the L-31E draining into the wetland unit north of the Mowry Canal

(C-103) was studied to determine the impact of a small increase in freshwater delivery to an area encroached by dwarf mangrove forest (Ross et al., 2003). While the volume of water delivered to the marsh through the culvert was minimal and confined to times when stage in the L-31E Borrow Canal was abnormally high, the slight decrease in salinity allowed for a rapid replacement of hypersaline algae by oligohaline forms and a slower and weak response in the plant community.

These studies support the contention that re-hydration of wetland units east of the L-31E with freshwater should be rapidly detectable in the diatom community, and therefore diatoms can be used as an early sign of a cascade of desirable changes in the future. This is important with respect to adaptive management as it provides indication that things are moving in the right direction; the fact that no responses are detected in conspicuous features (i.e., the vegetation) does not necessarily mean that management plans should change, but perhaps merely that more time is needed for the response cascade to be noticed at larger scales. If diatoms do not show a transition toward the desired assemblage along a given transect within the first three years of post-construction monitoring, then operations may have to be adjusted to provide more freshwater to that area. However, while the diatom community may quickly reflect a return to less saline conditions after rehydration, the diatom community will also reflect other environmental conditions including the surrounding plant community type and quality of the new water supply. As mentioned above, replacement of a woody forest by graminoid marsh will occur slowly and perhaps only when coupled with other manipulations, which include manual removal and fire. Diatom communities may not resemble counterparts in the freshwater Everglades marsh until this graminoid community is restored, and therefore the project may need to be altered to include other means of encouraging this replacement.

Diatom community composition may be the only proposed metric for detecting adverse changes in water quality with re-hydration. Depending on the source of rehydrating water, it is possible that nutrients or other contaminants are present in unnatural concentrations. Diatoms respond to nutrient availability as strongly as salinity (Gaiser et al., 2005 and 2006b); therefore, any ecological changes due to water quality alterations will be rapidly detected. This may be the most likely utility of the diatom metric in adaptive management. It may provide the only signal of contamination in source water and as such, can be used to change delivery sources and volumes accordingly before the community transitions to an undesirable and unmanageable state (i.e., cattail marsh, exotic expansion). If, in the first three years of post-construction monitoring, diatom communities demonstrate a transition toward eutrophic taxa, then operations may have to be adjusted to ensure a cleaner water supply.

A lack of change in diatom community composition with rehydration may result when, and if, the rate of sea-level rise exceeds the magnitude of freshwater delivery, or if mosquito ditches and other modern surface features redirect water from natural conveyance in this system. A decompartmentalization process has been recommended as a first step in facilitating the management and hydrologic reconnection of these wetlands (Ruiz and Ross, 2004; Meeder and Harlem, 2004; Ross et al., 2003; Ruiz et al., 2002), although hydraulic analyses indicate that some of the ditches may be necessary to move freshwater toward the coast. By having sampling locations spatially distributed throughout the Biscayne Bay Coastal Wetlands, the diatom community monitoring should allow for detection of places where rehydration is not eliciting the desired ecosystem response because water is following undesired flow paths. Once detected, these locations can be managed through other means to increase the potential for maximum response to the hydrologic change.

E.6.2 Juvenile Crocodile Adaptive Management

E.6.2.1 Rationale

Historically, Miami-Dade County was at the core of the American crocodile geographic range in the United States (Kushlan and Mazzotti, 1989), with the coastal wetlands along the shore of Biscayne Bay providing important habitat. The shoreline, canals, and ponds of southern Biscayne Bay, Card Sound and Barnes Sound still provide essential habitat for juvenile and sub-adult crocodiles. Together with the nesting areas at the Florida Power and Light Turkey Point Power Plant and the U.S. Fish and Wildlife Service Crocodile Lakes National Wildlife Refuge, these habitats meet all of the life stage requirements to support the continued recovery of this endangered species.

The Turkey Point Power Plant and Crocodile Lakes National Wildlife Refuge contain the fastest growing component of the Florida population of American crocodiles. However, Biscayne Bay's nearshore areas and coastal wetlands north of Turkey Point have relatively high salinity that reduce the suitability of these areas for juvenile crocodiles, which require relatively low salinity for proper growth and development (Mazzotti et al., 2002). Restoration of oligohaline and mesohaline conditions along the mangrove shoreline of western Biscayne Bay should provide better quality hatchling and juvenile crocodile habitat.

Adaptively managing the saltwater wetlands within the project area using crocodile information would address the project's restoration objective 1 by evaluating the extent to which suitable nursery habitat for hatchling and juvenile crocodiles is restored in the nearshore waters and mangrove wetlands of the project area. Suitable nursery habitat includes maintaining salinity regimes conducive to the growth and survival of these life stages. Crocodile monitoring (see ***Part 3, Section E.5***) will also address restoration objective 3 by evaluating

the effects of improvement of the quantity, timing, and distribution of freshwater to the bay. Restoration of crocodile habitat in the project area is an important component of the project's performance measure 1C (Salinity concentrations in coastal wetlands, in particular creek mouths and nearshore areas to 100 meters offshore, become more suitable as oyster, estuarine fish, and juvenile crocodile habitat).

E.6.2.2 Adaptive Assessment and Management Protocols for Crocodiles

A framework for how the project can be adaptively managed to restore crocodile habitat is shown in ***Table E-5***. The framework provides management action options based on two parameters that affect the establishment and maintenance of healthy crocodile habitat in the saltwater wetlands of the project area. Of primary importance for determining action steps will be the crocodile monitoring data collected by the RECOVER MAP. The extensive salinity monitoring conducted by the MAP is important to determining action steps for adaptively managing estuarine fish.

TABLE E-5: POSSIBLE ACTION OPTIONS FOR ADAPTIVELY MANAGING THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR AMERICAN CROCODILES

Stressor Metric	Target	Management Action OPTION 1	Management Action OPTION 2	Management Action OPTION 3
Salinity	0-20 psu	Change operations to meet salinity target	Plug or fill mosquito or drainage ditches as needed to obtain desired freshwater distribution	System-wide/ Regional Performance Issue Analysis (More water)
Nesting habitat	Nesting density similar to natural areas (e.g., Crocodiles Lakes National Wildlife Refuge)	Remove dense woody vegetation on the berms associated with drainage ditches and creeks	Increase berm elevation using fill (marl or sand)	

Key: psu = practical salinity unit

A primary objective for restoring crocodile habitat in the project area is to provide suitable conditions for the survival and growth of hatchlings and juveniles. To that end, re-establishing optimal salinity conditions is the most

important stressor metric that can be addressed by the project. Hatchling and juvenile crocodiles require low salinity for growth and survival presumably because they have limited physiological capability to osmoregulate. The ideal salinity range for crocodiles is 0–20 psu (Mazzotti et al., 2002). As salinity levels increase above 20 psu, habitat suitability decreases. Redirecting freshwater from conveyance canals into the coastal wetlands should lower salinity in the area, which should increase suitable habitat for juvenile crocodiles. Salinity values in the saltwater wetlands should be maintained within the 0–20 psu range throughout the wet season and at least the first part of the dry season. Adaptive management options for meeting the salinity target include adjusting operations of pumps and culvert flow, as well as, plugging or filling mosquito and drainage ditches to improve the distribution of freshwater flow across the tidal wetlands.

Re-establishing nesting habitat in the project area is also desirable. Natural nesting habitat includes sites with sandy shorelines or raised marl creek banks adjacent to deep water (Service, 1999). Crocodiles also nest on elevated man-made structures, such as canal berms and other places where fill has been introduced. It is likely that suitable nesting habitat existed historically along the banks of the major creeks upstream of the mangrove fringe in the project area. Today, those creeks have dense woody vegetation (mostly red mangroves) growing along their banks. Also, the major east-west drainage ditches in the tidal wetlands have dense woody vegetation proliferating in the ditch bed and along the berms adjacent to the ditches. Adaptive management options to improve nesting habitat include providing more open and elevated creek bank areas, which may require removal of woody vegetation, and increasing the elevation of the berms through introduction of fill of suitable soil type (i.e., marl or sand).

E.7 FRESHWATER WETLANDS ZONE

Historically, because of the low topography and year round water elevations that inundated the project area, nearly all of the land (perhaps more than 80 percent of the 60,000 acres) was covered by freshwater wetlands interspersed with small tree islands. Vegetation cover maps created even as late as the 1940s indicate that freshwater wetlands extended from the coastal ridge toward the east and south, close to the shoreline of Biscayne Bay (Davis, 1943). The importance of freshwater wetlands in the coastal regions of Southern Florida has been documented, and it is known that undesirable changes and substantial losses have occurred over the last century (Egler, 1952). Freshwater wetlands are linked to: (1) increased wildlife diversity and abundance; (2) improved water quality; (3) increased storage capacity; (4) groundwater and aquifer recharge; (5) enhanced downstream functions of the natural environment; and (6) improved human interests. Fauna such as wading birds and alligators typically found in the Everglades toward the west also resided in this area.

Nearer the shore, low salinity conditions were suitable for crocodiles and other estuarine wetland species.

Since the construction of the Central and Southern Florida system, most of the freshwater wetlands north of Turkey Point have become confined to areas located immediately west of L-31E, and the marl marshes have been displaced by forested wetlands that are often dominated by water tolerant invasive non-native vegetation such as Brazilian pepper (*Schinus terebinthifolius*). The primary objectives of the Biscayne Bay Coastal Wetlands project in the wetlands area are:

Objective 3	Restore and improve quantity, quality, timing, and distribution of freshwater to the bay.
Objective 4	Preserve and restore spatial extent of natural coastal glades habitat.
Objective 5	Reestablish connectivity between Biscayne Bay Coastal Wetlands, C-111 Basin, Model Lands, and adjacent basins.

The purpose of this section of the adaptive management plan is to provide information to adequately address the efficacy of achieving the above stated objectives for the freshwater wetlands. Thus, the adaptive management plan must generate the types of management measures and operational changes necessary to achieve the following:

- Establishment of hydropatterns (stage and hydroperiod) appropriate for graminoid freshwater marshes; mostly west of L-31E (indicator of freshwater wetland vegetation habitat; restoration objectives 3, 4)
- Transition of forested wetlands to graminoid freshwater marshes, including reduction in non-native vegetation coverage and transition to more natural vegetation community structure (will serve to preserve and restore coastal glades habitat; restoration objective 4)

E.7.1 Wetland Vegetation Adaptive Management

E.7.1.1 Rationale

As noted under ***Part 3, Section E.7.1.1*** major vegetation changes have occurred in the project area over the past century in response to hydrologic changes. These hydrologic changes include significant modifications to the hydropatterns and salinity regime in the coastal wetlands—both are major drivers of vegetation communities in the coastal wetlands of south Florida. Historically, freshwater marl marsh extended across most of project area and transitioned to a narrow band of mangroves at the shoreline of the Biscayne Bay. As a result of increased salinity in the wetlands along the coast, mangrove communities migrated inland, displacing the freshwater marl marsh community. Presently,

mangrove forest, including extensive spatial coverage of dwarf mangroves, extends well inland from the shoreline, usually westward to L-31E. On the western side of L-31E, wetlands have been severely impacted by drainage of the system. Water elevations are generally held close to or below land surface in the northern project area, or starved of water as in the Deering Estate and Model Land basin areas where water is diverted by drainage structures toward other basins. Marl marshes have generally transitioned into a mixture of shrub and forested wetlands, sometimes with an understory of sawgrass or cattails (*Typha domingensis*). Non-native trees, particularly Brazilian pepper and Australian pine (*Casuarina equisetifolia*), are prevalent in these areas as a result of physical disturbance or hydrologic isolation.

The rehydration of the coastal wetlands by redistributing freshwater should increase stages and hydroperiods in the freshwater wetlands and reduce salinity in the wetlands east of L-31E. Improved hydropatterns in the wetlands, together with non-native vegetation controls, should result in significant changes to the coastal wetland vegetation communities. Improvements to the salinity regime should result in changes to the wetland vegetation east of L-31E. Dwarf mangrove coverage should decrease while the abundance of herbaceous and graminoid species should increase. Results from a pilot project that diverted a limited amount of freshwater from L-31E eastward to the coastal wetlands have shown changes in species composition (Ross *et al.*, 2003). Sawgrass and spikerush, two freshwater species, appeared during the post treatment period. Biscayne Bay Coastal Wetlands project performance measures that apply to wetland vegetation communities include PM 4A (Areal extent of freshwater wetlands and transverse glades vegetation increases), 4B (Enhance freshwater and oligohaline marsh habitat by restoring appropriate salinity, hydroperiod, water level), and 4F (The areal extent of non-native vegetation decreases). Monitoring wetland vegetation addresses the project's restoration objective 4 by evaluating the extent to which coastal glades habitat is restored. It also addresses the project's restoration objective 5 indirectly by providing information on the extent to which connectivity between basins has been restored.

E.7.1.2 Adaptive Management Protocols for Wetland Vegetation

A framework for how the project might be adaptively managed to restore wetland vegetation is shown in ***Table E-6***. The framework provides management action options based on four parameters that affect the establishment and maintenance of healthy wetland vegetation in coastal wetlands within the project area. Of primary importance for determining action steps will be the wetland vegetation monitoring data collected by the project and the RECOVER MAP (see Biscayne Bay Coastal Wetlands Ecological Monitoring Plan and the MAP). Also, the water level monitoring conducted by the project-

level monitoring plan is important to determining action steps for adaptively managing estuarine fish.

TABLE E-6: POSSIBLE ACTION OPTIONS FOR ADAPTIVELY MANAGING THE BISCAYNE BAY COASTAL WETLANDS PROJECT FOR WETLAND VEGETATION

Stressor Metric	Target	OPTION 1 Management Action	OPTION 2 Management Action	OPTION 3 Management Action
Water level	-0.5 to +2.0 feet	If target not met, change operations to meet target (i.e., redirect more water into wetlands)	Change operations to meet a different point of the target range	System-wide/ Regional Performance Issue Analysis (More water)
Hydroperiod	28 to 32 weeks	If target not met, change operations to meet target (i.e., redirect more water into wetlands)	Change operations to meet a different point of the target range	System-wide/ Regional Performance Issue Analysis (More water)
Salinity	0 psu west of L-31E; 0-20 psu east of L-31E (with gradient)	Increase or decrease diversions to attain target	Fill or plug drainage and mosquito ditches	System-wide/ Regional Performance Issue Analysis (More water)
Fire or other disturbance	Natural fire frequency	Modify fire frequency to meet target	Increase or decrease fire frequency	

Key: psu = practical salinity units

Hydropattern (water level and hydroperiod)

Adaptive management actions for the wetland vegetation should tie together, to the extent possible, the information gained from monitoring vegetation (see ***Section E.7***), hydropattern (see ***Part 3, Section E.6.8***), and salinity. An adaptive management action to improve wetland vegetation response, and therefore project performance, would involve adjustments in structure operations (pumps, culverts) to modify the hydropattern. Specifically, if graminoids do not become established or are slow in colonizing an area, water levels and/or hydroperiod can be increased or decreased to a more optimum level. For example, the performance measure for restoring marl prairies specifies an ideal hydroperiod of 28-32 weeks annually. If the observed post-construction hydroperiod is much above or below that optimum, then operations could be adjusted to produce a hydroperiod closer to the 28-32 week window. Similarly, if stage data indicated that the wetlands are at the upper end of the currently

specified range (+ 2 feet above ground), without evidence of graminoid establishment, then water level could be lowered to fall closer to the mid point of the range. These adjustments, of course, may affect performance downstream. Also, there will likely be tradeoffs for wetland areas that are responding well versus areas that are not responding well. That is, there may not be enough water to restore the entire project area, and success may be represented by restoration of portions of it. Adaptive management for the wetland vegetation may end up being tied very closely to specific monitoring transects.

Salinity

Changes in wetland vegetation east of L-31E in response to hydrologic alteration are less easily predicted. For instance, it is unclear how the dwarf and transitional mangrove communities will respond to increased freshwater flow. In these areas, the anticipated decreases in salinity associated with increased freshwater flows may not be realized due to acceleration in sea level rise. Also, rendering the north-south oriented mosquito ditches and east-west agricultural ditches hydrologically inert may be as important a restoration activity as redirecting water from major conveyance canals into the coastal wetlands. This decompartmentalization process has been recommended as a first step in facilitating the management and hydrologic re-connection of these wetlands (Ruiz and Ross, 2004; Meeder and Harlem, 2004; Ross et al., 2003; Ruiz et al., 2002). However, as with the freshwater wetlands west of L-31E, hydrologic restoration alone may not immediately re-establish the desired gradient of halophilic and non-halophilic graminoid and shrub communities. The vegetation management program noted above should include management measures for this area. Specifically, controlled burning would be effective in maintaining and perhaps stimulating expansion of the graminoid community (black needlerush and saltgrass) just south of C-102, by eradicating existing mangroves and impeding further encroachment of mangroves and non-native vegetation. With or without fires, vegetation change is most likely to occur in the re-created creek systems and small basins, where redirected freshwater will have the greatest impact.

Fire or other Disturbance

Because of the prevalence of woody vegetation in this area, it is unclear how changes in hydrology will affect vegetation community structure, because hydrologically-initiated vegetation change may require a disturbance event to be set in motion. It is likely that hydropattern changes will have a stronger effect on seedlings than adult trees.

It is possible, even likely, that changes in vegetation structure in response to modified hydropatterns will be relatively slow in the absence of some initial active measures intended to expedite the response. For example, if the woody vegetation were removed by some method, then graminoids should respond

relatively quickly (i.e., less than ten years), given appropriate hydropattern and salinity conditions. One option for removing the woody plants would be well-planned and well-implemented controlled burning in certain regions of the project area during or just after project construction. Prior to such an operation, the area in wetland forest cover prior to drainage should be delineated. Along some of the western portion of the Biscayne Bay Coastal Wetlands project area, it is possible that a line of forested wetlands bordered the pine uplands and provided a transition to the coastal marsh. In such areas, woody vegetation other than non-native species should not be removed or controlled. It should be noted that some graminoids (e.g., sawgrass) may take decades to recolonize an area after disturbance. Even after graminoids become established, it is likely that a management program will need to be implemented to control the woody plants. Historically, fire has been the natural control on woody plant invasion in much of the Everglades (Egler, 1952).

E.8 DURATION AND COST OF BISCAYNE BAY COASTAL WETLANDS PROJECT ADAPTIVE MANAGEMENT

Monitoring and assessment that drives the adaptive management should be reviewed and revised periodically. A suggested frequency of two years is reasonable. It is highly likely that certain parameters can be scaled back both temporally and spatially after a few years of initial post-project monitoring. Once targets are attained for given parameters, then monitoring for those parameters can be reduced or possibly discontinued. However, the extent of a monitoring reduction cannot be determined until pre-construction, during-construction, and several years of post-construction monitoring have been conducted. Timing of the adaptive management program should consider baseline monitoring needed to generate an appropriate confidence level, when the project is constructed, and timing of ecological response. Table 3-11 in the Biscayne Bay Coastal Wetlands Alternative Formulation Briefing document gives the timeframe for when benefits are expected in each zone: 0-15 years, with most benefits realized between five to ten years.

E.8.1 Adaptive Management Costs (Non-Monitoring Costs)

Section 2031 of the Water Resources Development Act of 2007 (WRDA 2007) appears to support the "use of contemporary water resources paradigms, including integrated water resources management and adaptive management". Although the suggested management actions described herein are not self-executing, they can only be implemented at the discretion of the leadership of the USACE and the Governing Board of the South Florida Water Management District, and will necessarily be implemented based on consideration of other agency restoration and water management priorities, and the availability of state and Federal funds. It is fully expected that the costs associated with implementation of any adaptive management measures will be

borne equally by the USACE and the non-Federal sponsor. ***Table E-7*** provides a summary of possible costs associated with the employing various adaptive management options.

As shown in Table E-7, total costs for adaptive management are estimated to be between $486,200 and $727,200. These costs are both within the cost cap specified in Engineering Regulation (ER) 1105-2-100 (3% of total project costs excluding monitoring costs). The low end estimate ($486,200) is approximately 0.35% of the total project costs, and the high end estimate ($727,200) is approximately 0.53%.

TABLE E-7: POSSIBLE ADAPTIVE MANAGEMENT COSTS

Management Option	Cost
Oyster shell (cultch)[1]	$160,000
Oyster larvae stocking[2]	$21,200
Oyster spat-on-shell stocking[2]	$16,000
Operational Adjustments	$0
Plug or fill mosquito and drainage ditches[3]	$100,000
Fire[4]	$19,000 (Aerial Ignition) / $180,000 (WUI Burning)
Berm vegetation removal[5]	$160,000 (heavy equipment grubbing) / $240,000 (hand grubbing)
Total Cost AM Actions	**$486,200 / $727,200**

Key: WUI Wildland Urban Interface

[1]Oyster cultch estimate based on needing shell to cover 0.5 acre of bay bottom for each of 8 creeks at a cost of $40,000 per acre. Estimate provided by Kathy Fitzpatrick (Coastal Engineer with Martin County Government).

[2]The stocking of oysters at the 8 major creek mouths will occur as two separate methods to determine which is most viable for the project area. Ready-to-settle larvae (pediveliger stage) can be stocked within a 31-foot diameter enclosure (~800 ft^2) at each creek mouth and 1 million larvae distributed within each enclosure at a cost of:

8 million larvae	= $5,000	
8 enclosures	= $11,200	($14 per linear foot for turbidity barriers)
Labor	= $3,000	
Total	= $21,200	

Given the uncertainties of settlement conditions, an alternative stocking method should be performed for each creek, which is referred to as spat-on-shell stocking

(SOS). SOS stocking means that oyster spat that have newly settled onto oyster shell are placed onto the bay bottom at the mouths of major creeks. The SOS are in bags that contain about 300 oyster shells with an average of 5 spat on each shell at a cost of $20 per bag. Based on an estimate of using 100 bags per creek mouth means that one stocking effort would cost:

8 sites (i.e., creek mouths) x 100 bags/site x $20/bag = $16,000

For either method, if conditions are favorable it will take about a year for the spat to reach sexual maturity and begin producing larvae. The BBCW ecological monitoring will determine the level of success of each stocking method. The estimate of using 100 bags per site is a best professional judgment estimate by the USFWS. Information for the cost estimate for the pediveliger larvae stocking was provided by Bay Shellfish Company (Terra Ceia, Florida) and for the spat-on-shell stocking by Dr. John Scarpa at Harbor Branch Oceanographic Institution. Turbidity barrier quote provided by Geotechnical Supply Incorporated.

[3]Filling and plugging of drainage ditches based on length estimates of 34 major drainage ditches in the Phase 1 project area (including North Canal freshwater wetland) and used Ruiz and Ross (2004) data on ditch dimensions. Plug estimates are based on a 30-yd long plug for each ditch. Cost estimates provided by the U.S. Army Corps of Engineers (Jacksonville Office).

[4]The fire management estimate is based on a controlled burning of 3,000 acres of graminoid marsh once over a 5-year span. This assumes that graminoid marsh has replaced forested wetland in the target area. Cost for aerial ignition of sawgrass with no holding concerns (i.e., no issues with urban or agricultural development nearby) is $6.50 per acre (or $19,000 for 3,000 acres). Cost for wildland/urban interface (WUI) burning is $60.00 per acre (or $180,000 for 3,000 acres). Cost estimates provided by Roger Onstad (Prescribed Fire Specialist, Everglades National Park).

[5]Berm vegetation removal is based on clearing and grubbing of 8 acres of spoil berm associated with 8 east-west drainage ditches. According to Ruiz and Ross (2004) and Ruiz (personal communication 2008) the excavation of these ditches resulted in the creation of spoil berms that are approximately 15 feet wide. According to their surveys the average length of ditches in the Cutler Wetlands and the wetlands east of L-31E between C-1 and C-103 is 2940 feet. Thus, there would be on average about 1 acre of spoil berm on each side of each ditch (15 ft x 2940 ft = 44,100 ft^2 = 1.01 acres). The cost for clearing and grubbing using heavy equipment is ~$20,000 per acre. However, site conditions may preclude using heavy equipment due to a number of reasons (elevation, environmentally sensitive land, etc.) and may require using manual labor at a cost of ~$30,000

per acre for clearing and grubbing. To clear and grub spoil berms on one side of 8 ditches (3 ditches in Cutler Wetlands, 1 ditch between C-1 and C-102, 2 ditches between C-102 and Military Canal, and 2 ditches between Military Canal and C-103) would require clearing about 8 acres (total for all ditches) and would cost $160,000 using heavy equipment (8 x $20,000) or $240,000 clearing and grubbing by hand (8 x $30,000). It should be noted that the cleared berms will likely required long-term, periodic maintenance to keep them cleared of vegetation. Also, it may be more practical and cost effective to scrape down some of the spoil peninsulas associated with C-102, Military Canal, and C-103 to provide crocodile nesting habitat. Cost estimates were provided by Gary Milano and Steve Blair (Miami-Dade County Department of Environmental Resources Management).

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ANNEX E
PROJECT MONITORING PLAN

PART V: NUISANCE AND EXOTIC VEGETATION CONTROL PLAN

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Biscayne Bay Coastal Wetlands Phase 1 Western Project
Nuisance and Exotic Vegetation Control Plan

November 2009

E PART V: NUISANCE AND EXOTIC VEGETATION CONTROL PLAN

E.1 INTRODUCTION

The purpose of this document is to provide a framework for making decisions related to nuisance and exotic vegetation control on project lands associated with the Biscayne Bay Coastal Wetlands Phase 1. While the plan presents specific *Management Objectives*, these objectives were developed in large part to assist in estimating the costs associated with optimal land management practices with respect to current known exotic and nuisance vegetation threats. While the plan represents its authors' best attempts to capture anticipated costs, the costs presented herein could escalate due to numerous reasons including unanticipated spread of exotic and/or nuisance species, increased labor costs, increased chemical costs. Conversely, the overall cost associated with implementation of this plan could also be reduced for similar reasons. Costs might also be reduced if the agencies are successful at partnering, and/or establishing other means to accomplish the plan, thereby lessening the Federal and Non-Federal Sponsors' financial obligation for exotic and nuisance vegetation management.

This plan should be considered a living document and should be periodically updated to reflect changes occurring and/or anticipated to occur over the project lands. More importantly, it needs to be noted that the suggested management actions described herein are not self-executing, and the decision to implement a given action would be at the discretion of the leadership of the U.S. Army Corps of Engineers, and the Governing Board of the South Florida Water Management District, and will necessarily be made based on consideration of other agency restoration and water management priorities, and the availability of state and Federal funds.

It will be important to manage, under this project, those areas over which benefits were contemplated. ***Figure E-1*** depicts the location of the Biscayne Bay Coastal Wetlands Phase 1 project features

E.2 MANAGEMENT OBJECTIVES

Establishment of conditions, which are favorable to long-term maintenance control of non-native species, and the re-establishment of native flora represent the primary objectives of this effort. To achieve these goals, this work plan is proposed to complete both initial and long-term invasive plant control efforts

necessary to achieve maintenance control levels of invasive vegetation within the project area. In the initial phase, multiple passes of herbicide treatments are required. Aerial and/or ground-based treatments will be employed in an effort to reduce invasive species cover to levels at or below five percent cover. Following this initial, intensive phase, periodic sweeps are performed by ground crews to spot treat smaller infestations. In many cases, prescribed fire can be utilized to help keep exotic or nuisance species in check.

It is important to note that some areas with past substrate disturbance, such as the freshwater wetlands located between the C-103 and North Canals, will most likely require substrate removal in order to re-establish biogeochemical conditions necessary for native plant communities to recover. Without substrate removal, many invasive species would have a competitive advantage over native flora and very frequent herbicide applications would be required. It is anticipated that this substrate removal, if required, would be accomplished as part of the overall construction contract.

Monitoring for nuisance and exotic vegetation is an important component of this plan. Without detailed information concerning the type and spatial extent of invasive plant populations, strategic planning for their control is likely to be ineffectual. Maps based on current surveys will improve decision making and planning during initial control efforts while longer term monitoring efforts are needed to maintain populations at the lowest feasible levels.

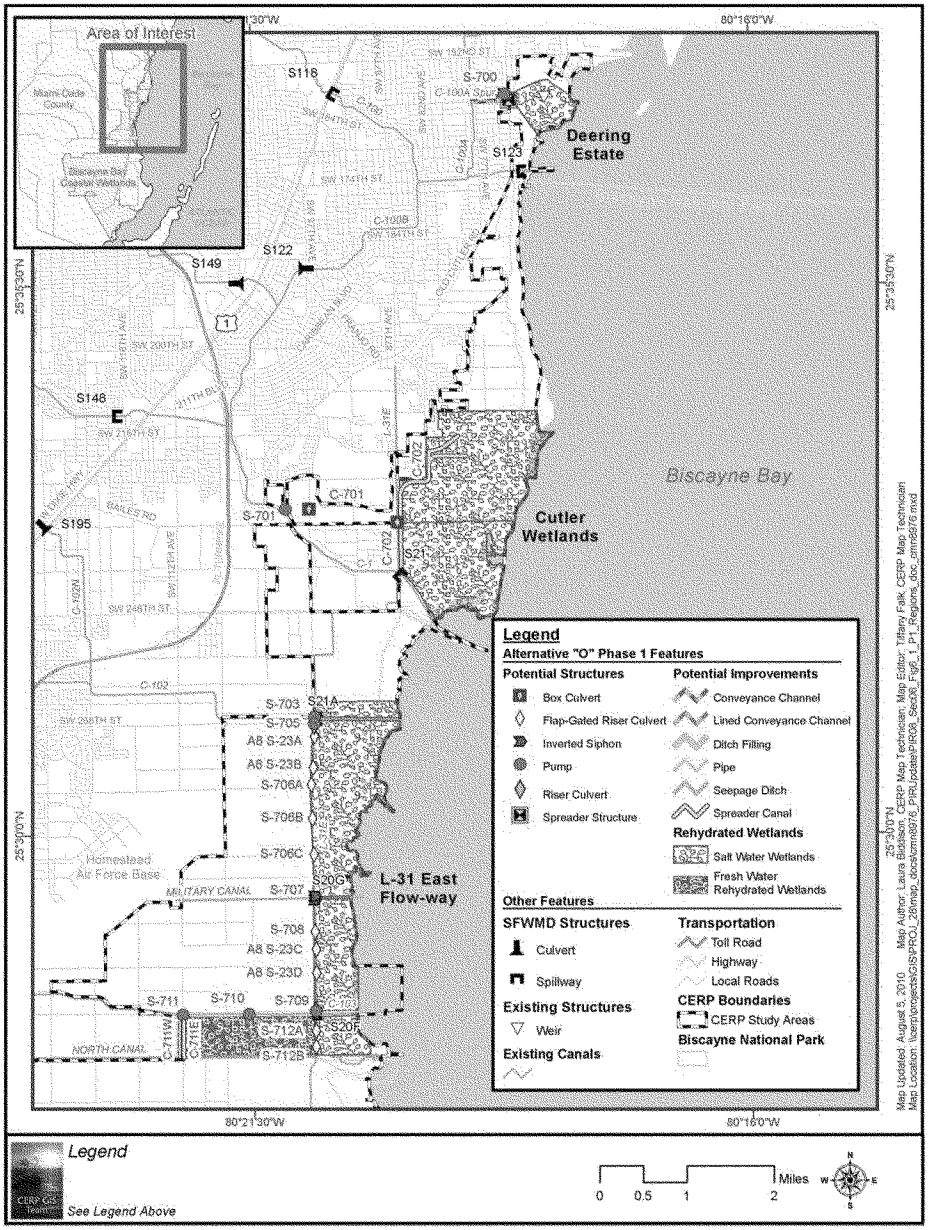

FIGURE E-1: BISCAYNE BAY COASTAL WETLANDS PHASE 1 PROJECT FEATURES

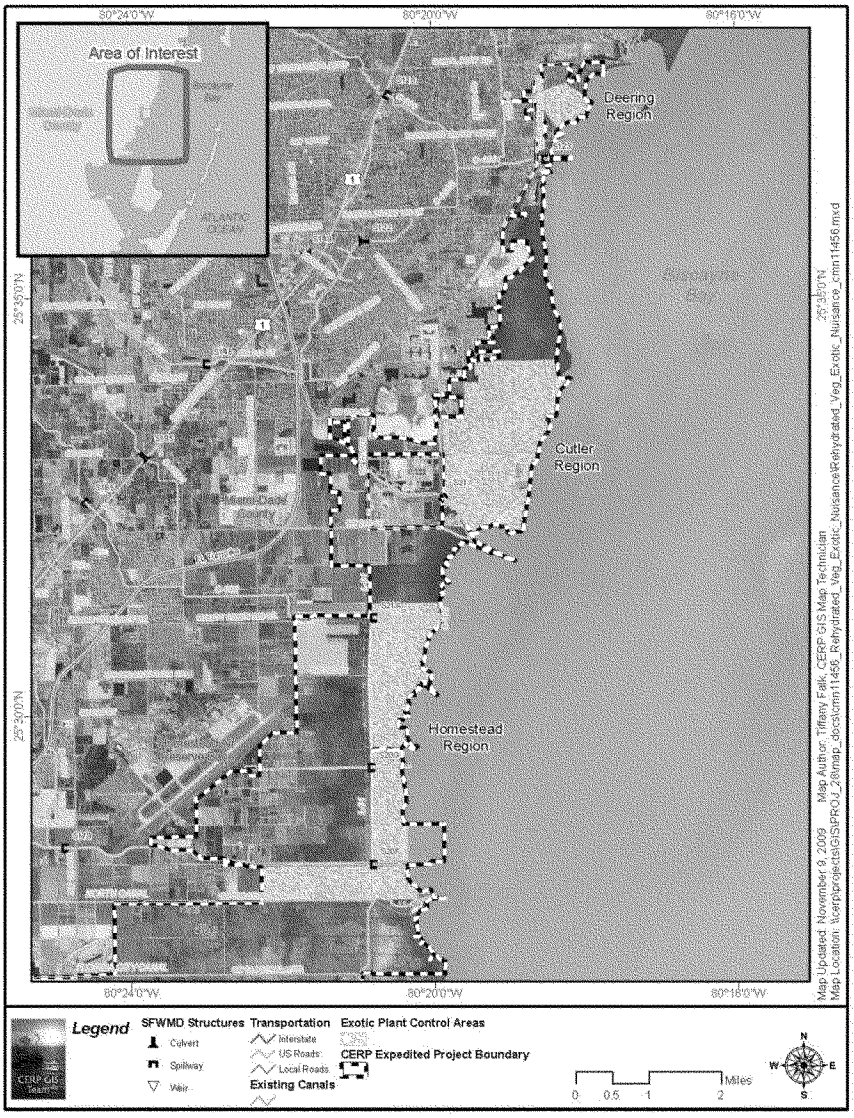

FIGURE E-2: LOCATIONS OF VEGETATION MANAGEMENT AREAS IDENTIFIED FOR THIS PLAN

E.3 EXISTING VEGETATIVE COMMUNITIES

Generally, five habitat types dominate the project area. They include submerged aquatic vegetation (SAV) (primarily seagrasses and macro-algae), mangrove forests, saline emergent wetlands, freshwater wetlands and non-native dominated wetlands, typically dominated by Australian pine (*Casaurina* spp.) or Brazilian pepper (*Schinus terebinthifolius*). Mangrove forest covers the majority of the project area north of Turkey Point and east of L-31E, whereas non-native dominated forested wetlands dominate the area west of L-31E. Herbaceous flats occupy the majority of the project area south of Turkey Point in the area known as the Model Lands, except for the coastal fringe, which is dominated by mangroves. ***Figure E-2*** displays the major vegetative types within the management areas identified for this plan.

The primary factors influencing the distribution of vegetation in this region are hydropattern, salinity, previous disturbance, invasion by non-indigenous plant species, and to a lesser extent, nutrient loading and soil type. As a consequence of past and current water management practices and land development, freshwater wetlands in the project area have been reduced in aerial extent, altered and degraded. Currently much of this area is drained. The current operation of the systems has resulted in an inland migration of saline conditions in both the groundwater and surface waters such that the expansion of moderate to high salinity zones have diminished the spatial extent of freshwater wetland habitats, and have allowed the landward expansion of saltwater and mangrove wetlands.

Some wetlands have been impacted by invasive exotic vegetation, sometimes as a result of physical disturbance and/or hydrologic isolation. The type of non-native species that dominates a given area is generally related to the topography of the wetland. The majority of the Australian pine dominated wetlands occur in artificially elevated mangrove areas. Often the pines occur as linear features along berms created by the digging of drainage and mosquito ditches. Scattered Australian pine mixed with shrubs (usually mangrove) and/or sawgrass occurs in much of the project area north of Turkey Point and on both sides of L-31E. Brazilian pepper dominated wetlands are generally located at intermediate elevations and hydroperiods, between wetland and upland areas in the project area (EPA, 1994). Brazilian pepper can occur as dense mono-specific stands that are difficult to penetrate or as stands mixed with willow, buttonwood and/or other mangrove species.

A variety of other invasive, non-native flora can be found scattered throughout the project area. Shoebutton ardisia (*Ardisia elliptica*) is often found associated with the extensive stands of Brazilian pepper. Small isolated stands of Bishopwood (*Bischofia javanica*) occur along the western edge of the project

area, usually adjacent to urban development. Other exotic species known to exist in the project area include Napier grass (*Pennisetum purpureum*), seaside mahoe (*Thespesia populnea*), melaleuca (Melaleuca quinquefolia), wild taro (*Colocasia esculenta*), Peruvian primrose willow (*Ludwigia peruviana*), lead tree (*Leucaena leucocephala*), woman's tongue (*Albezia lebbeck*), and Australian umbrella tree (*Schefflera actinophylla*). The project area should be closely monitored for kripa (*Lumnitzera racemosa*), an exotic shrub/tree that was recently observed escaping captivity nearby. Spatial information for exotic plant species distribution in the BBCW project area rely primarily on 2004 mapping efforts conducted during early planning for this project.

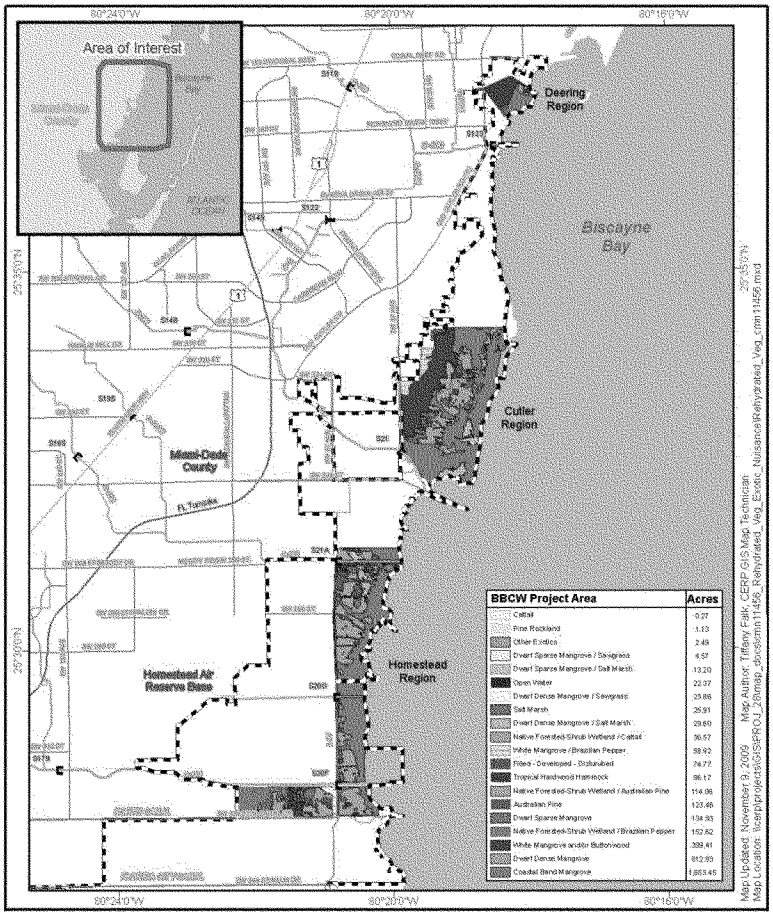

FIGURE E-3: VEGETATION COVER TYPES WITHIN PLAN PROJECT AREAS

E.4 ANTICIPATED EFFECTS OF HYDROLOGIC RESTORATION ON NUISANCE AND EXOTIC PLANT POPULATIONS

Restored hydroperiods, and the restoration of more natural sheet flow are changes that will benefit native vegetation and in some cases reduce the "invasiveness" of exotic species. Many of the invasive, non-indigenous species present in the project area will be less capable of dominating native plant communities as hydroperiods are restored, primarily due to intolerance of prolonged inundation. However, hydroperiod is not always the major driver of an exotic species' potential invasiveness. Species with wide tolerances of environmental conditions, which overlap pre- and post-restoration conditions, may continue to spread or maintain populations despite efforts to reverse hydrologic disturbances. The predicted effects of hydrologic restoration on invasive exotic species in the BBCW project area are summarized in ***Table E-1*** below.

TABLE E-1: EFFECTS OF HYDROLOGIC RESTORATION ON COMMON NUISANCE AND EXOTIC PLANT SPECIES IN THE BBCW PROJECT AREA

Species	Restoration Effect	Management Impacts
Australian Pine (*Casuarina* spp.)	Minimal Decrease	Casuarina does not tolerate prolonged flooding, but it will continue to invade canal banks, spoil piles, and other elevated soils
Brazilian Pepper (*Schinus terebinthifolius*)	Minimal decrease	Mature plants may survive wetter conditions, but growth rates and seedling survival would likely decrease.
Bishopwood (*Bischofia javanica*)	Decrease	Cannot tolerate flooding. However, likely to persist in disturbed areas with shorter hydroperiods.
Burma Reed (Neyraudia reynaudiana)	Decrease	Tolerant of a wide range of environmental conditions, but is most invasive in open, dry, and sunny sites.
Lead Tree (*Leucaena leucocephala*)	Decrease	Cannot tolerate flooding. However, likely to be found in disturbed, upland areas near the construction footprint.
Melaleuca (*Melaleuca quinquenervia*)	None Expected	This species would continue to be a serious threat in all areas of the project area, regardless of changes in hydrology.
Napier Grass (*Pennisetum purpureum*)	Increase	Has created problems in flood-control systems by blocking access to canals and reducing water flows.
Primrose Willow (*Ludwigia peruviana*)	Increase	Tolerant of sustained flooding and very competitive in nutrient-rich soils.

E.5 SPECIFIC PLAN GOALS

While this plan's broad objectives are described in Section 2, the specific focus of this plan must necessarily focus on the following specific goals;

1. Implement a "Quarantine Strategy" for the natural areas of the project area, which focuses initial control efforts in areas with light infestations and move systematically towards areas with heavy infestations.

2. Maintain low infestation levels where initial control efforts have succeeded in reducing invasive plant populations at maintenance control levels. Maintenance control will be defined as less than five percent total cover of all invasive species.

Implementation of a quarantine strategy will begin on the southern and eastern boundaries at the border of Biscayne National Park Boundary (BNP) and proceed to the northwest toward the heavily infested non mangrove forested fringe areas. Where practical, efforts should also be taken to reduce heavy infestations away from shared borders of both private and other public managed lands within the project footprint. The quarantine approach is a proven strategy for halting the spread of invasive plants and reducing overall impacts from invasive species (as well as unavoidable impacts associated with vegetation management activities in densely infested areas). Control efforts are expected to move more quickly in these areas and the removal of targeted species can be accomplished with fewer impacts to native plant species.

The project construction footprints are particularly vulnerable to invasion by undesirable plant species as a result of their proximity to adjacent lands which may not be receiving vegetation managementIt is important that land managers deal with nuisance native and exotic plant species as they invade the construction footprint, before infestations become well-established. For this reason, there should be an emphasis on frequent monitoring and low-level control efforts of establishing invasive plants.

E.6 CONTROL METHODS

There are three primary methods of that will be employed for nuisance and exotic control in the Biscayne Bay project area: (1) mechanical/manual control, (2) herbicidal control, and (3) biological control. Biological control efforts will not be specifically funded through this project as it is a system-wide tool and is proposed for full implementation by CERP through the Melaleuca and Other Exotic Plants Implement Biological Control Project.

Mechanical/manual control methods will be used primarily in the western forested fringe area, and freshwater wetlands between the C-103 and North

Canals, where invasive plant densities are high and standing biomass will limit accessibility and the ability to restore fire to the system. Mechanical methods can include substrate removal, mowing, chopping, feller bunching, chipping, sawing, and other physical removal techniques. In natural areas, the advantages of using machines include immediate removal of unwanted biomass, selective removal of noxious tree species, creation of access trails, ease of follow-up maintenance events, and opening the canopy for increased light penetration and recruitment of native understory species. Disadvantages include increased cost of operations compared with using herbicidal methods, soil disturbance, slow progress through a site, and accessibility and logistical problems.

Herbicidal control involves the judicious application of chemicals to the targeted plants or underlying soil. This practice is a complex, training-intensive, sometimes controversial, but economically effective technique. Some advantages of this type of control are that herbicides can be selectively used to remove only targeted species; applied more uniformly without producing viable plant fragments; achieve longer lasting control; are easier and less costly to apply than other controls; and more area can be treated per day. Disadvantages include a period of unsightliness in the treated area; treated areas may be temporarily restricted from certain uses by the public; access may become limited in dense areas, and applicators must be thoroughly trained. When used in accordance with all label statements and all applicable federal and state regulations, the risk to the environment as well as the applicator is minimal.

Herbicides used for vegetation management activities are generally available in three formulations: water soluble, oil soluble, and dry, such as pellets of wettable powders. There are different methods of applying these products based partly on the formulation used, composition of the community of vegetation in which the target plants are growing (selective treatment) and efficiency of covering a given treatment site. For aquatic applications the primary methods include spraying with a handgun or a boom apparatus mounted on a truck, boat or helicopter. Dry formulations can be applied through a spreader device or blower. In terrestrial applications, herbicides may be applied with handgun mounted on a truck (or even a boat), aerial application, backpack sprayer, or from a squirt bottle.

Biological control refers to the use of living organisms which will feed upon, kill, or interfere with the target organism's life processes resulting in the decline of the target species population. Many nuisance plants are not native to the state and therefore have no natural enemies to check their growth and reproductive capabilities. Advantages of using biocontrol agents are that they potentially need only one introduction to provide long-term control. The primary disadvantages are that it requires a significant commitment of initial funding over many years to gain approval for release, it takes a long time for control to

be effected and control may not be realized. More information on biological control and its use in the South Florida environment can be found at the CERP website Melaleuca Eradication and Other Exotic Plants Implement Biological Controls - Draft Project Implementation Report - February 2009 (http://cerp.info/pm/projects/proj_95_melaleuca.aspx).

The SFWMD uses a combination of these methods in order to maintain nuisance invasive exotic species at the lowest feasible levels. Work will be carried out by SFWMD contractors following the Vegetation Management Division's Contractor Standard Operating Procedures.

E.7 SURVEY FOOTPRINT AREAS AND MAP EXOTIC/NUISANCE VEGETATION

Monitoring and mapping of nuisance and invasive plant species is a key component of this plan. An effective monitoring program will be cost-efficient, relatively rapid, and contain sufficient spatial information direct vegetation management crews to infestations. To meet these needs, a combination of aerial and ground surveys will be conducted on a two-year cycle during initial plan implementation. The SFWMD and other regional land managers currently utilize an aerial mapping technique known as digital aerial sketch mapping (DASM) to locate invasive plant infestations over large, remote areas. DASM involves "mapping on the fly" with GPS-linked computers on board low-flying aircraft, typically a helicopter. Flights are conducted on east/west transects on one kilometer intervals, allowing for a complete census of the land management area. This relatively inexpensive mapping technology (approximately $0.07/acre) is currently utilized throughout the Greater Everglades, so inclusion of the BBCW project area would be a logical extension of this regional, biennial mapping effort.

DASM is not an effective method for detecting small, incipient populations, especially when the invasive plant occupies under-stories of forested plant communities. Therefore, ground-based monitoring will also be utilized to locate less visible infestations. Given the large size of the management area, a complete census is not feasible for ground-based monitoring. Instead, land managers must implement a strategic sampling protocol which integrates other data sources (e.g., DASM) knowledge of weed infestation patterns, and priority regions. Land managers should also coordinate with vegetation management crews, field biologists, and others who frequently traverse the landscape to promote efficient communication regarding invasive species locations.

All spatial data for invasive plant infestations will be maintained in a geo-database and will be linked to the SFWMD's WEEDAR database, which tracks invasive plant treatment activities. A user-friendly map (ArcGIS geo-database format) using points, lines and polygons of exotic and nuisance

vegetation recorded during survey efforts will be produced to facilitate control efforts. Point data will be utilized for less commonly observed species while polygon and polyline data will be presented for more extensive infestations.

E.8 ASSESS EFFECTIVENESS OF EXOTIC CONTROL EFFORTS

Spot assessments will be conducted roughly three to four months following treatments to generally evaluate control methods on target species. Contractor Daily Progress Reports, notes on treatments, and the map of exotic/nuisance species will be used to conduct follow-up evaluation of treatment efforts in a qualitative manner. Emphasis will be on identifying problems and successes in order to better strategize for future control efforts.

E.9 ESTIMATED PLAN COSTS

Based on the infestation levels shown in ***Figure E-3***, it is estimated that approximately 40 acres will require intensive initial and follow-up treatments to reach maintenance level conditions. The estimated unit cost for these intensive control efforts is $3000/acre. The remaining 485 acres containing scattered infestations will also require initial and follow up treatment, but at lower per acre costs. An estimated unit cost of $2000/acre will be required for these areas. Dense vegetation, deep muck, and protected mangrove communities make ground-based herbicide and mechanical control logistically difficult, and therefore costly, but these methods are the only available option for control. Based on current resource capabilities, it is estimated that the initial control effort will take five years at a total cost of $1,090,000, or $218,000 per year. After the first five years, the 3,778-acre management area will require annual inspections and low-intensity herbicidal controls to keep invasive plants at maintenance control levels. Based on an estimated unit cost of $500/acre for this level of treatment, it is estimated that the annual maintenance costs (after the first five years) will be $190,000/year. This estimate also includes monitoring costs, which are necessary to identify and prioritize management needs, and primarily consists of flight services for digital aerial sketch-mapping (discussed in Section 7). It is recommended that the first three years of the initial control effort be completed during the period of construction, and its $654,000, costs be shared as a project construction cost. It is recommended that remainder of the five year initial effort, be completed after the project becomes operational, and its $218,000 annual costs be shared as a project OMRR&R cost, along with the subsequent annual management costs of $190,000 per year. Although developed for this project, these unit costs are based largely on historical invasive plant management conducted by SFWMD and other management entities in the region.

The SFWMD and other agencies have conducted numerous management trials in the area to develop more financially-efficient methods for invasive plant

control. For example, mechanical shredding of dense, monotypic stands of invasive species may substantially reduce long-term control costs and achieve management goals in less time. The SFWMD will continue to evaluate management approaches to reduce costs as the project moves forward.

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TO SUPPORT THE
PROJECT IMPLEMENTATION REPORT

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F.0 RECOVER REGIONAL EVALUATION REPORT: TRANSMITTAL LETTER

REstoration COordination and VERification (RECOVER)
Evaluation Team, Regional Evaluation Report

TRANSMITTAL LETTER

April 5, 2006,

Project Managers and Planning Technical Leads
Biscayne Bay Coastal Wetland Project
Comprehensive Everglades Restoration Plan

Dear Project Team Managers and Planning Technical Leads,

RECOVER has completed its regional evaluation of the Biscayne Bay Coastal Wetland Project (BBCW) alternative plans and our final report is attached.

RECOVER's evaluation of project alternatives fulfills the following requirements as prescribed by the Programmatic Regulations:

1. Support project teams to achieve consistency with the CERP's goals and objectives;
2. Document the performance of the project alternative plans using RECOVER approved system-wide performance measures, project performance measures (when appropriate), and best professional judgment. RECOVER determines the ability of each alternative plan to meet the targets established for each performance measure and describes the resulting effects upon the natural system. When appropriate, RECOVER evaluations include a qualitative analysis on how the project fulfills CERP goals and objectives;
3. Suggest improvements to the project, which if pursued could improve project performance or enhance benefits to the natural system;
4. Provide insight, if possible, and alert the project teams of any inconsistent modeling assumptions for the project as originally modeled in the CERP.

Recommendations discussed within the RECOVER regional evaluation report generally fall into one of three categories:

1. Recommendations that can easily be incorporated into the plan formulation process;
2. Recommendations that are more conceptual in nature, which the Project Team may select to incorporate into preliminary designs to improve project performance; and
3. Recommendations that are crucial to the project, but cannot be addressed prior to the AFB meeting.

Concerning the latter category, RECOVER provided its regional evaluation to satisfy the need for timely reporting, while bringing forward as much science as possible. As a result, this report may not constitute the entirety of RECOVER's review as specified in

the Programmatic Regulations. Therefore, RECOVER may provide additional information supporting and refining the original regional evaluation, with the expectation that those additional evaluation comments be considered by the project team.
The following list highlights RECOVER's comments to the project team.

- Both spreader canal path length and potential natural areas restored provide important water quality benefits that should be considered by the project team
- Current project nitrate estimates underestimate potential water quality benefits
- The BBCW project should consider interactions with the C-111 spreader canal project to enhance rehydration of the Model Lands. This includes the potential for a hybrid alternative (see section 4.2.6)
- Reservoir and STA operations should be conducted to minimize dry down in the project area thereby minimizing oxidation of sediments and corresponding potentially high sediment nutrient fluxes
- Additional water quality and biological tools/models which will yield performance measures should be developed both at the system and project level for this area of the system.
- When the project monitoring plan is developed it should incorporate both short and long-term response water quality and biological indicators and the data should be collected in a manor that could generate additional evaluation and assessment tools
- The planning process is iterative and should be treated that way. Normally a couple of rounds of modeling are needed to optimize the alternatives. RECOVER recommends that future projects incorporate these iterations into the planning process.
- This Biscayne Bay area could use additional water to achieve restoration targets. The ET recommends that future system-wide planning and adaptive management efforts incorporate a review of the system to determine if additional water is available for Biscayne Bay for both the BBCW and the C-111 spreader canal projects.

Best regards,

Evaluation Team Chairs
(Orlando Ramos-Ginés, Kim Chuirazzi, and Steve Traxler)

F.1 BISCAYNE BAY COASTAL WETLANDS (BBCW) PROJECT SYSTEM-WIDE EVALUATION REPORT PREPARED BY RECOVER

F.1.1 Introduction and Purpose of the Evaluation

The Biscayne Bay Coastal Wetlands project team has identified their final array of alternative plans and requested that Restoration, Coordination and Verification (RECOVER) conduct a system-wide evaluation of the alternative plans being considered. The role of RECOVER is to organize and apply scientific and technical information in ways that are most effective in supporting the objectives of the Comprehensive Everglades Restoration Plan (CERP or Comprehensive Plan). One of the primary missions of RECOVER is to work with the project team to evaluate and maximize the contribution made by each project to the system-wide performance of the CERP. The RECOVER Evaluation Team (ET) is charged with the responsibility of conducting system-wide evaluations (previously termed regional evaluations).

The ET is an interagency and interdisciplinary scientific and technical team charged with developing and using performance measures for evaluating alternative plans developed for Project Implementation Reports (PIRs). The purpose of the ET evaluation is to ensure that alternative plans are consistent with the goals and purposes of the CERP. For its evaluations, the ET has developed a suite of approximately 40 ecological performance measures and eight water supply and flood protection performance measures. Output from the South Florida Water Management Model (SFWMM version 5.4), which is the primary hydrologic simulation model for the CERP, is used to produce performance measure output. The SFWMM is a regional-scale model that provides simulations of hydrologic conditions at a two-mile by two-mile spatial resolution. Because of the large-scale resolution of the model and the relatively small hydrologic influence of some CERP projects, ET performance measures may not always reveal differences in system-wide performance of project alternative plans. In these cases, RECOVER uses other scientific information to evaluate the potential performance of project alternatives on the system.

The purposes of regional evaluations are to (1) inform the project team of the compatibility of proposed project alternative plans with regional CERP restoration goals and performance expectations; (2) determine the performance of each alternative plan toward meeting system-wide goals and objectives through the use of system-wide performance measures, project performance measures, and best professional judgment; (3) identify improvements for project performance that would improve its regional performance, and (4) provide decision-makers required information regarding regional performance expectations of specific projects.

The type of RECOVER evaluations may vary depending on the applied tools, new information that may have become available, the project's relationship to the Central and South Florida (C&SF) Project, or the project implementation schedule. In the case of hydrologically isolated projects, RECOVER may not be able to rely on regional modeling results for their evaluations. For these projects, the scope of RECOVER's evaluations may be limited to reviewing project-level model results and applying best professional judgment.

F.1.2 Project Background and General Description of Alternative Plans

F.1.2.1 Project Goals and Objectives

The Biscayne Bay Coastal Wetlands project is part of the CERP as authorized by the Water Resources Development Act (WRDA) 2000 (U.S. Congress, 2000). The goal of the Biscayne Bay Coastal Wetlands project is to restore or enhance freshwater wetlands, tidal wetlands, and nearshore bay habitat. The objectives of this project, as identified in the Biscayne Bay Coastal Wetlands Feasibility Scoping Meeting Document (USACE and SFWMD, 2004) are as follows:

- Re-establish productive nursery habitat along the shoreline.
- Redistribute freshwater flow to minimize point source discharges to improve freshwater and estuarine habitat.
- Restore and improve quantity, quality, timing, and distribution of fresh water to the bay, including Biscayne National Park (BNP).
- Preserve and restore the spatial extent of natural coastal glades habitat.
- Reestablish connectivity between Biscayne coastal wetlands, C-111 Basin, Model Lands, and adjacent basins.

F.1.2.2 Project Background

In the pre-drainage Everglades, water flowed to Biscayne Bay through near-surface groundwater, overland flow through sloughs, freshwater upwellings in the bay, and overland sheet flow (Ruiz and Ross, 2004). Groundwater levels have been lowered by several feet since the 1920s in order to provide flood protection to nearby populated areas. Lower groundwater levels have resulted in substantial decreases in groundwater flow into Biscayne Bay. Stormwater runoff in canals has replaced the much more gradual dispersal of water provided by overland sheet flow. These canals now discharge at a few points along the shoreline increasing the intensity of freshwater discharges and precluding stormwater flows through coastal wetlands. Levee 31 East (L31E) was constructed about 30 years ago near the coast of southern Biscayne Bay to help control the damaging effects of salt water intrusion on the Biscayne Aquifer. A drainage system is currently operated to provide flood protection drainage for agricultural land uses, and to maintain adequate freshwater supply for groundwater withdrawals by private and public wells.

The issues and opportunities for restoration in southern Miami-Dade County have been discussed for many years. This project began to take form under the Biscayne Bay Surface Water Improvement and Management (SWIM) Plan administered by the South Florida Water Management District (SFWMD). Certain issues and solutions were proposed in the early 1980s and investigated under Miami-Dade County's Biscayne Bay Management Plan. The SFWMD has been operating a pilot project, L-31E Culvert and Weir Project, in the study area and conducting research for several years. Much of the land in the project area remains open, therefore restoring and using wetlands near the coast is recommended to slow runoff and redistribute flow away from the canal outfalls into a more natural estuarine system. The major benefits of restoring more natural drainage would be to restore estuarine conditions, as well as improve inland freshwater habitats. Other benefits may include improved water quality and enhanced water supply protection.

The CERP includes a brief conceptual description of the Biscayne Bay Coastal Wetlands project. It was identified as an "Other Project Element", meaning that the effect of the proposed project could not be modeled with the SFWMM. The SFWMM was designed to predict and quantify broad, regional changes in hydrology in the inland portions of south Florida. The hydrologic impact of the Biscayne Bay Coastal Wetlands project is near the minimum spatial resolution of the SFWMM, and lies along the southeastern boundary of the model domain, increasing model uncertainty and reducing the utility of model results. Consequently, the Biscayne Bay Coastal Wetlands project team used a combination of regional model output and best professional judgment to evaluate their suite of project alternatives. RECOVER used this limited model output to the extent feasible, as well as best professional judgment to review the project's analysis of local benefits and to provide the system-wide perspective of the performance of proposed alternative plans.

F.1.2.3 General Description of Alternative Plans

The Biscayne Bay Coastal Wetlands project identified their final array of five project alternative plans. Alternative plans being considered include management measures such as stormwater treatment areas (STAs), reservoirs, and spreader canals. The five alternatives that make up the final suite of alternative plans are as follows:

- Alternative E
- Alternative J
- Alternative M2
- Alternative Q
- Yellow Book (YB) Alternative

Documentation for the management measures associated with each alternative plan was provided by the BBCW Project Team and can be found in Appendix A of this report.

F.1.3 Evaluation Methodology and Information Considered

This section outlines the methodology used by RECOVER to conduct its system-wide (regional) evaluation of alternative plans. It also describes the modeling and technical information considered by RECOVER to evaluate the potential system-wide effects of the Biscayne Bay Coastal Wetlands project. RECOVER's analyses of the information and its evaluation of the implications to the system are presented in later sections of this report.

F.1.3.1 Methodology

Because the Biscayne Bay Coastal Wetlands project is essentially outside the spatial resolution and domain of the SFWMM, the Watershed Systems of 1-D Stream-River Networks, 2-D Overland Regimes, and 3-D Subsurface Media (WASH123D) and TABS-Multi-Dimensional Sediments (TABS-MDS) sub-regional models were used by the project team to simulate canal, groundwater, and surface water flows in the project footprint. Some model output data from these sub-regional models warranted further investigation, prompting the project team to consider additional available data, Geographic Information System (GIS) tools, and best professional judgment to describe potential performance of the alternative plans at the project area. The Biscayne Bay Coastal Wetlands project team provided RECOVER with the following information for consideration during the system-wide evaluation of alternative plans:

- WASH123D and TABS-MDS output for an average water year (1998-1999)
- Ecological Benefits Analysis Methodology (Appendix B)
- "Quantifying Ecological Benefits and Evaluating Alternatives for the Biscayne Bay Coastal Wetlands Project" Draft Report

RECOVER typically uses CERP system-wide performance measures to evaluate alternative plan performance; however, these performance measures are dependent on SFWMM output. Because the project area is on the boundary of the SFWMM domain and because at this boundary the SFWMM does not perform as expected, RECOVER evaluated the alternative plans performance using the following methodology:

- RECOVER reviewed salinity output from the TABS-MDS sub-regional model for each alternative, and where feasible compared results to the

CERP system-wide performance targets established for different regions of Biscayne Bay.

- RECOVER reviewed WASH123D hydrologic output to determine if there were any expected benefits or impacts to the wetlands and freshwater marshes upstream of the project. Due to concerns over modeling RECOVER did not use this output for analysis. Rather, the review team provided comments on model formulation to help future model efforts.
- RECOVER reviewed the ecological benefits analysis methodology and matrix provided by the project team (Appendix B and C) and provided any additional considerations or expected benefits/impacts of each alternative plan for the Project Team to consider.
- RECOVER reviewed the management features information to qualitatively determine the project effects on water quality, water supply, flood protection, and saltwater intrusion.
- RECOVER reviewed the modeling assumptions and proposed changes to the alternative plans, and/or operational features that may improve alternative plan performance. The project team should consider the proposed changes when refining their tentative selected plan (TSP).

F.1.3.2 Hydrologic Modeling Considered

RECOVER reviewed the WASH123D and TABS-MDS model results. As noted earlier RECOVER did not use the WASH123D output due to concerns over model conceptualization and formulation. Where possible, TABS-MDS output was compared to RECOVER salinity targets.

F.1.3.3 Water Quality Information Considered

Because RECOVER currently lacks existing water quality tools for the region within which the project is located, RECOVER considered non-model hydrologic information that could be assessed in term of their potential water quality effects on the system. Such information included structural flows, frequency of STA drydowns, creation/restoration of natural areas, and canal operations. Additionally, RECOVER has considered non-model information for water quality parameters evaluated by the project team as presented in the ecological benefits analysis matrix.

F.1.3.4 Additional Pending Modeling Results

Additional model results may be pursued by the Biscayne Bay Coastal Wetlands project team. When available, RECOVER will review these additional model results and provide modified and/or additional comments to the Biscayne Bay Coastal Wetlands project team on alternative plan performance, where appropriate.

F.1.4 Consistency of Project Goals and Objectives and System-wide Performance of Alternatives Plans

F.1.4.1 Project Goals and Objectives - Consistency with the Comprehensive Plan

The planning objectives developed for the Biscayne Bay Coastal Wetlands project are generally consistent with the objectives of the Comprehensive Plan (USACE and SFWMD, 1999). The planning goal of this project is to restore or enhance freshwater wetlands, tidal wetlands, and nearshore bay habitat. It will primarily contribute to CERP environmental benefits to Biscayne Bay by improving the quantity, quality, timing and distribution of freshwater deliveries to the bay. The planning objectives for this project were developed using both the broad CERP goals and objectives and the more defined regional and site-specific restoration objectives. The five objectives developed for the Biscayne Bay Coastal Wetlands project presented below (***Table F-1***) directly correspond to specific CERP objective(s) contained in the C&SF Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement (USACE and SFWMD, 1999).

TABLE F-1: PROJECT AND CERP OBJECTIVES

Project Objective	Corresponding CERP Objective(s)
Reestablish productive nursery habitat along the shoreline.	Improve habitat and functional quality. Improve native plant and animal species abundance and diversity.
Redistribute freshwater flow to minimize point source discharges to improve freshwater and estuarine habitat.	Improve habitat and functional quality. Improve native plant and animal species abundance and diversity.
Restore and improve quantity, quality, timing, and distribution of fresh water to the bay, including Biscayne National Park.	Improve habitat and functional quality. Improve native plant and animal species abundance and diversity.
Preserve and restore the spatial extent of natural coastal glades habitat.	Increase spatial extent.
Reestablish connectivity between Biscayne coastal wetlands, C-111 Basin, Model Lands, and adjacent basins.	Increase availability of fresh water. Improve habitat and functional quality. Increase spatial extent.

F.1.4.2 System-wide Performance of Alternative Plans

The following sections summarize performance of the project alternatives using the methodology described in ***Section 3.1*** of this report. Given the underlying issues with the model tools used by the project team, RECOVER decided to provide additional, relevant evaluation on how the models were conceptualized for the project area. RECOVER identified major concerns with how models were conceptualized to represent the hydrologic system in the project area. The

comments made by RECOVER on the conceptualization are intended to help with future project model refinement efforts. RECOVER opted to use physical/structural and operational features of the project, or any other available information, to provide a system-wide evaluation of the alternative plans.

F.1.4.2.1 Review and Evaluation of WASH 123D Hydrologic Model and TABS-MDS Model Conceptualization and Output

The hydrologic system for the wetlands portion of the project area was simulated using the WASH123D model. The model's western boundary condition utilizes output from the SFWMM southeastern boundary, as modeled under Alternative 7R5 (SFWMM v5.4.1). The WASH123D model is a fully coupled groundwater/surface water model. Output from the eastern boundary of the WASH123D model provides input data to the TABS-MDS model. The TABS-MDS model is the hydrodynamic model that is used by the project team to quantify the salinity based performance measures in the nearshore bay region of the project area. Although both models have been used successfully to simulate natural environments, their conceptualization and construction to represent the hydrologic system in the Biscayne Bay Coastal Wetlands project area is of continued concern to the project team and to RECOVER.

The Biscayne Bay Coastal Wetlands project team members brought concerns to the Engineering Research and Development Center (ERDC) of the US Army Corps of Engineers (USACE) concerning how the WASH123D model represents/simulates the hydrologic system in the project area. ERDC has attempted to rectify these issues. However, as currently constructed, the model continues to show unrealistic flows in some basins. For example, historical data and SFWMM output, including the future with and without CERP, indicate that the C-103 Canal provides a relatively large fraction of water to the bay, varying from about 17 to 33 percent of the total surface flows for 1998-1999 (average rainfall conditions). WASH123D output indicates that percentage of total surface flows through C-103 Canal for existing conditions, future without CERP, and the Yellow Book alternative is only 6, 1, and 0.01 percent, respectively. The opposite trend appears to be true for the C-100 Basin, which has too much flow compared to historical conditions.

Also of concern are the differences observed between WASH123D output and that of a U.S. Geological Survey (USGS) regional groundwater model that includes the project area. WASH123D indicates very high groundwater fluxes to the bay and a very large percentage (approximately about 70 to 80 percent) of the total fresh water entering the bay arrives as groundwater. Groundwater flux across the project area, according to the WASH123D output, is on the order of 700,000 acre-feet per year. In contrast, the USGS Regional Groundwater Model indicates that the groundwater discharge rate along the entire western bay coastline is probably only about six percent of the measured surface water

discharge (Langevin, 2001). The USGS model suggests that nearly 100 percent of the fresh groundwater discharge to the bay occurs through the northern half of the bay, north of the C-100 Canal. The coastal lowlands south of C-100 Canal prevent the water table from rising high enough to drive groundwater to the bay and almost all of the Biscayne Bay Coastal Wetlands project area lies south of the C-100 Canal.

The WASH123D simulations of surface flows and the large groundwater transfer from the eastern model boundary to the western boundary of the TABS-MDS model explains the much lower than expected salinity values along the coast as simulated by TABS-MDS model. This led the project team to believe that the performance of project alternatives is unreasonably high for salinity-based performance measures for virtually all alternatives. RECOVER has similar concerns over the western boundary conditions provided to TABS-MDS by WASH123D.

According to ERDC modelers, the concerns with the WASH123D output stem from a combination of the western boundary conditions obtained from the SFWMM CERP0 simulations (v5.4) and the fact that the SFWMD often did not follow the operating rules for water control structures in the model domain. The latest version of the WASH123D simulation includes adjustments to the opening and closing triggers of the water control structures in the model domain in an attempt to "work around" the above identified issues. These latest adjustments have produced more reasonable groundwater flows to Biscayne Bay along the coastline in the C-100 and C-103 basins; however, the simulated groundwater flows remain much higher than estimated groundwater flows. Because of these apparent problems with the constructed WASH123D model for the project area, the Biscayne Bay Coastal Wetlands project team has been reluctant to include results from this model in its benefits analysis and evaluations of the alternative plans. The Interagency Modeling Center (IMC) provided review of previous WASH123D model version for the Biscayne Bay project area and has agreed with project team concerns (December 2004 and October 2005). RECOVER concurs. In the current state, the constructed model does not reasonably represent the hydrologic system of the project area.

In an effort to utilize output from the TABS-MDS model constructed for Biscayne Bay, ERDC recently conducted additional runs of the model using the latest WASH123D output for the TABS western boundary condition, reducing groundwater flux data from the WASH123D outputs by 300,000 acre-feet/year for all alternative plans prior to being input to TABS-MDS. This adjustment provides more reasonable total freshwater input to the TABS-MDS model, which results in more realistic performance of the alternative plans as compared with salinity performance measures. It provides more realistic differences between alternatives. At the time this report was prepared, these latest TABS-MDS data

were being included in the multi-criteria decision matrix agreed-upon by the project team. RECOVER expects to review this new output and any additional model results and will provide comments to the project team where relevant.

F.1.4.2.2 Evaluation of Ecological Effects

Background

Historically, the Biscayne Bay Coastal Wetlands and nearshore areas supported a diverse assemblage of estuarine faunal communities, including oyster reefs, estuarine fish and crocodiles. The remains of oyster reefs have been found in association with remnant coastal creeks that once dispersed fresh water to the bay through coastal wetlands (Meeder et al., 1999). Historic photographs, satellite imagery and soil analyses show that, prior to construction of the South Dade Conveyance System, estuarine conditions in lower Biscayne Bay were maintained by the flow of fresh water through the series of creeks within the project area (Meeder et al., 1999). As many as 48 historic creek beds have been identified between Shoal and Convoy Points (Meeder et al., 2001). Major creeks drained surface water passing through the transverse glades of the coastal ridge and were distinct from the shorter, more numerous tidal creeks and creeks that originated at local springs. Redfish and other species of sciaenids that rely upon estuarine areas were "abundant at all seasons" during the late nineteenth century (Smith, 1896). Prior to the early part of the twentieth century, Miami-Dade County was at the core of the American crocodile geographic range in the United States (Kushlan and Mazzotti, 1989) and coastal wetlands along the western shore of Biscayne Bay provided important crocodilian habitat.

Estuarine fishes and shellfish have precipitously declined in abundance due to the loss of estuarine habitat along the bay's southwestern edge (Serafy et al., 2001). The diversity of estuarine species is very low in southern Biscayne Bay at this time. Historic oyster beds are presently inactive due to habitat changes associated with the loss of freshwater discharge into the wetlands through creek systems. Attempts to restore red drum to the bay through stocking failed largely because juveniles were released into areas that were no longer consistently estuarine (Serafy et al., 1996).

Abrupt canal-driven salinity fluctuations are damaging to aquatic plants and fish populations (Montague and Ley, 1993; Serafy et al., 1997). In the southwestern part Biscayne Bay, the salinity of marine waters, downstream of canal water control structures, usually 30-35 parts per thousand (ppt), frequently drops 20 ppt within 60 minutes and returns almost as rapidly (Chin and Wang, 1987). As the system is currently operated, these dramatic salinity fluctuations can occur several times per day during the wet season (June-October) when water is released through control gates. The higher salinities that now characterize the western bay and adjacent wetlands have

severely reduced the suitability of this area for juvenile crocodiles, which require relatively low salinities for proper growth and development.

Salinity requirements for oysters, estuarine fishes and crocodiles are very similar. For oysters, ideal salinity ranges in south Florida are 5-15 ppt during the wet season and 10-19 ppt during the dry season (RECOVER, 2006) 5-15 ppt from June through October, with higher salinities during the remainder of the year. Ideal salinity for juvenile crocodiles is 0-20 ppt in the mangrove wetlands and coastal creeks during the wet season and several months into the dry season (approximately June through January; Mazzotti et al., 2002).

Evaluation

The combination of storage, STA treatment capacity and spreader canals is expected to help address project goals by providing flexibility in distributing water at more appropriate spatial and temporal distributions.

The RECOVER performance measure SE-6 for South Biscayne Bay provides estimates from Meeder et al. (2002) that 321,912 and 145,595 acre-feet of water in the wet season and dry season, respectively, is required to re-establish and maintain the freshwater wetlands and establish a positive salinity gradient, with an average bottom salinity of 20 ppt, 500 meters into the bay from the shoreline during the wet season and 250 meters into the bay from the shoreline during the dry season. If the project is successful at providing sufficient fresh water at the appropriate temporal and spatial scales, reestablishing a broader, more stable polyhaline zone in shallow waters further offshore should provide more suitable nursery habitat for pink shrimp. Shrimp densities in the northern part of the restoration area (between Shoal Point and Black Point) appear robust. However, shrimp densities in the southern area (between Black and Convoy points) are very low, possibly because of the widely fluctuating salinities that now prevail in the southern area.

An analysis of the RECOVER performance measures for Biscayne Bay, using the project information provided and available to us, shows that maximum benefits could be obtained when the performance measure targets are met through the delivery of adequate quantities of water. The Initial CERP Update (RECOVER, 2005b) reported that the modeled CERP alternative (CERPA) provides approximately 60 percent of the wet season flow and 77 percent of the dry season flow required to meet the target for the Biscayne Bay Coastal Wetlands area. The CERP Monitoring and Assessment Plan (MAP) (RECOVER, 2004) and the Draft 2005 Assessment Strategy for the MAP (RECOVER, 2005a) contain hypotheses and supporting research directly addressing nearshore community structure. As research on the MAP elements continues, community response within the project area will be better understood and developed.

F.1.4.2.3 Evaluation of Water Quality Effects

Water Quality Approach by Project Team

In the estimation of benefits, the project team focused on the various proposed STAs upstream of the spreader canals and estimated water quality benefits based upon load reduction expected from the STAs. This was based on projected future land uses, estimates of rainfall, runoff coefficients, estimates of possible implementation of best management practices (BMPs), and changes in runoff due to project components. These calculations produced runoff volumes and concentrations necessary for benefits quantification. They were obtained for the existing conditions, the future with project conditions and for each of the alternative plans. Estimates of the expected quality of water to reach the proposed spreader canals and, ultimately, the wetlands were derived from first order wetland decay equations for total phosphorus and nitrate. The project team did not estimate other water quality benefits beyond nitrate load reduction.

RECOVER Analysis

RECOVER recommends the project team consider the following approach in quantifying additional water quality benefits. The project's forecast of future water quality conditions herein presented assumes planned land use changes and BMP implementation. However, RECOVER cautions that those are current plans that may not necessarily be implemented in the future. The project team estimates of (existing) concentrations of total phosphorus characterized existing Miami-Dade Department of Environmental Resource Management (DERM) water quality data accurately (***Table F-2***). The estimates of existing nitrate concentrations, however, significantly underestimated DERM water quality data (***Table F-3***) (http://www.sfwmd.gov/org/ema/envmon/wqm/bisc/biscs.html). The predicted future water quality conditions are significantly lower than existing conditions (***Table F-2*** and ***Table F-3***).

Table F-2: TOTAL PHOSPHORUS CONCENTRATIONS IN MG/L
(Derm Water Quality Stations)

			Predicted Future Total Phosphorus Concentration:		
Canal	**Existing DERM**	**Predicted Existing based on Land Use**	**Future Based upon Land Use**	**Less BMPs + STAs**	**Future Estimated**
C-102	0.007 (PR03)	0.007	0.007	Not estimated	Not estimated
C-103	0.007 (MW04)	0.007	0.007	Not estimated	Not estimated

Table F-3: NITRATE + NITRITE-N CONCENTRATIONS IN MG/L
(DERM Water Quality Stations)

			Predicted Total Nitrate Concentration:		
Canal	**Existing DERM**	**Predicted Existing based on Land Use**	**Future Based upon Land Use**	**Less BMPs + STAs**	**Future Estimated**
C-102	1.49 (PR01) to 4.017 (PR03)	0.8	1.0595	0.4786	0.5809
C-103	2.2 (MW04)	0.67	0.8774	0.2115	0.6659

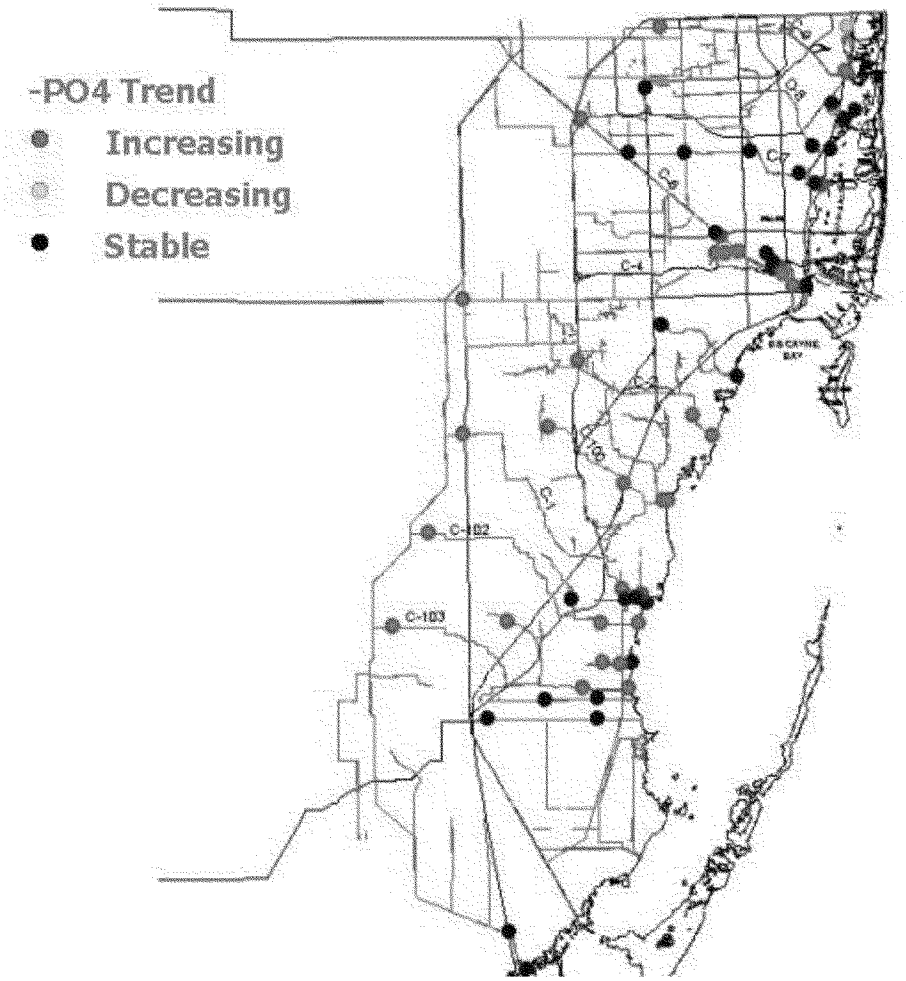

FIGURE F-1: DERM DATA ON TPO4 TRENDS IN BISCAYNE BAY COASTAL WETLANDS PROJECT AREA

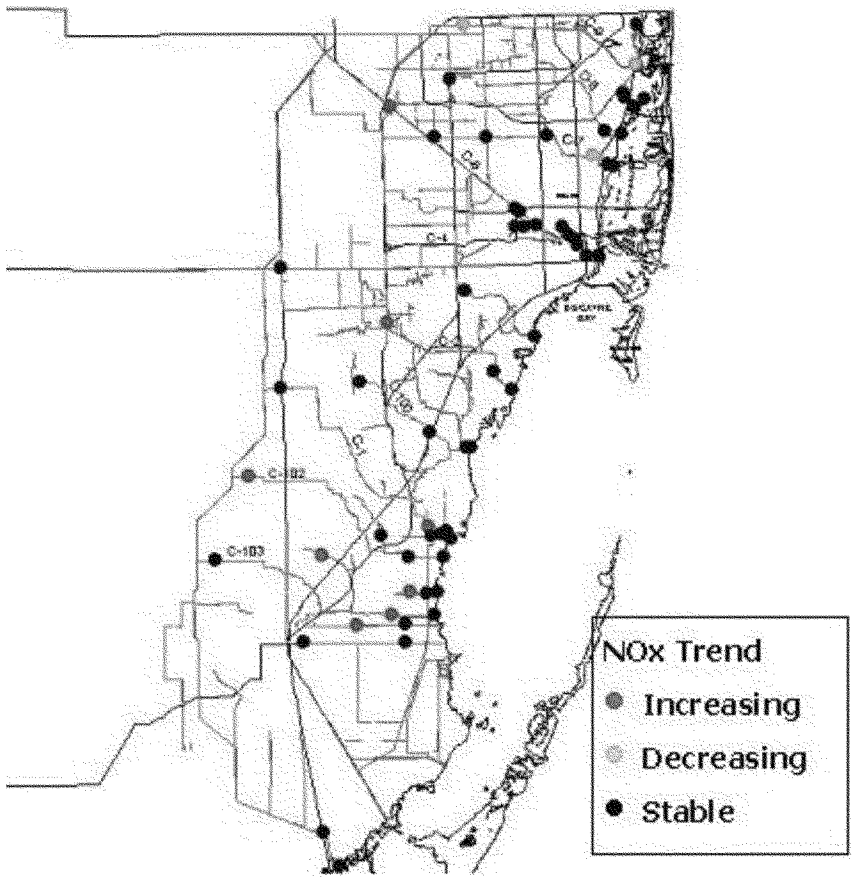

FIGURE F-2: DERM DATA ON NOX (NITRATE/NITRITE) TRENDS IN THE BISCAYNE BAY COASTAL WETLANDS PROJECT AREA

The project water quality (WQ) estimates forecast future conditions as stable for total phosphorus and improving for nitrate. These estimates do not include the effect of using reuse water which will likely have different (higher) concentrations than canal water estimates. DERM forecasts TPO4 conditions in the area degrading and nitrate/ nitrite conditions degrading or stable.

Figure F-1 and ***Figure F-2*** Miami-Dade DERM, Natural Resource Division, Numeric Nutrient Criteria Technical Advisory Committee presentation;

February 19, 2004. The project team's optimistic forecast reduces the potential WQ benefits obtained by the project alternatives. RECOVER recommends that the project consider projected nitrate and phosphorus concentrations provided by Miami-Dade DERM.

The project has significant water quality benefits in addition to those offered by the STAs. Canal path length itself and the potential for various spreader canals to help rehydrate and restore significant areas of wetlands may produce benefits that exceed that of the STAs by an order of magnitude. RECOVER suggests that water quality benefits provided by the spreader canal and rehydrated natural areas, which are beyond those provided by the proposed STAs, be included in the benefits quantification by the project team.

Rehydrating Natural Areas

Increased spatial extent of natural areas by rehydrating inland marshes and estuarine habitats not only directly benefits biota by restoring previously degraded habitats, but also provides important water quality benefits not previously included by the project team in its benefits quantification. The ability to maintain more natural timing and distribution of water in the coastal wetlands allows periphyton and other native vegetation to flourish. This provides additional phosphorus uptake capacity beyond that of the proposed STAs. Increasing the spatial extent of natural areas along with available carbon production (CO_2) leads to increased de-nitrification, thereby benefiting the system further. In a study conducted by Rudnick et al. (1999) on the Taylor Slough, dissolved inorganic nitrogen (DIN) decreased from 240 $\mu g\ l^{-1}$(17 mM) to 36 $\mu g\ l^{-1}$ (2.6 mM) along a three kilometer flow path. Although this was a peat based system and some of the project area is more of a mineral-based (marl) system, similar (slightly lower) de-nitrification benefits can be expected. Rehydrating the Model Lands through coordination of C-111 and Biscayne Bay Coastal Wetlands projects can potentially provide long-term water quality and habitat benefits.

The project will offer substantial water quality benefits to the downstream areas of the project footprint. This will affect loads conveyed to southern Biscayne Bay. The rapid loading that occurs via the C-1, C-102, and C-103 Canals will be spread across a flow path several miles long (http://www.sfwmd.gov/org/ema/envmon/wqm/bisc/biscs.html). This will likely provide significant system-wide benefit to the southern estuaries. This will improve the status of or conditions for several southern estuaries performance measure indicators including nutrient concentrations, nutrient loading, algal blooms, water clarity, and toxins.

Stormwater Treatment Areas and Reservoirs

The current alternatives provide flexibility in STA and reservoir design and operations that can maximize benefits for water quality or potential for restored or enhanced natural areas. STAs can be extremely efficient if designed and operated to promote periphyton and emergent and submergent vegetation, as well as particulate settling. The 2,997 and 3,615 acres proposed under Alternatives E and J, respectively, provide important acreage for phosphorus reduction. Similarly, Alternatives E and J provide the most storage flexibility to optimize the timing of water deliveries. The potential to make water available in the dry season can help reduce nutrient fluxes associate with sediment oxidation. These alternatives provide more STA acreage than the Yellow Book design. Additionally, the Yellow Book design did not call for reservoir construction. The project team recognizes the water quality benefits provided by the STAs and reservoirs. RECOVER stresses the importance of adaptive management to help projects obtain their objectives (and goals) in the face of current uncertainties.

Spreader Canal

The spreader canals are key features of the restoration provided by this project. Spreader canals distribute water across flow paths, providing significant areas of inundation, which translates into restored or enhanced wetlands. The current alternatives provide flexibility and demonstrate a range of benefits by using spreader canals. The differences in spreader canal length amongst the alternatives provide variation in the flow path. Considering inundated acreages with hydroperiod between 0.5- to 3.5 -feet stage could provide an indication of this benefit. Given 1999-2000 was a statistically dry period, it would be reasonable to expect that the acreage determined was a conservative estimate of the wetland restoration/creation capacity of the proposed spreader canals. During dry periods, water stages would be at or near their lowest and the foot print created by spreader canals would be at or near its smallest. The flow path from the spreader canal to the mangrove areas is approximately three and a half miles (18,000 feet). The range of wetlands created (compared to the without project condition) during the 1999-2000 dry period varied from 2,192 to 4,420 acres for Alternatives J and Q, respectively (***Table F-4***).

An idealized 5,000-foot spreader over the 18,000-foot flow path would potentially create about 2,100 acres of wetlands. This is consistent with the range of inundated acreages is presented ***Table F-4***. Accordingly, load reduction would vary between alternatives due to differences in spreader canal length. Water quality effects due to the spreaders would be magnified as these wetlands are less likely to endure dry out. Project components would not dry out and additional inundated areas would be available to provide relief to nutrient loading to southern Biscayne and Florida Bay. The Project Delivery Team (PDT)

recognized the importance of the spreader canals in relation to connectivity and spatial extent, but RECOVER recommends noting the potential water quality benefits associated with the spreader canal and the rehydration of natural areas.

TABLE F-4: WATER QUALITY FLOW PATHS AND WETLANDS

Alternative	Deering and Black Creek	South and Florida City Canal	Wetlands South of Florida City Canal	Total Inundation Acreages	Net Difference between Future Without Project and Alternatives
Yellow Book	0	702	4,699	9,988	2,287
Future Without Project	0	371	4,348	7,701	0
E	0	797	5,332	10,222	2,521
J	0	371	4,798	9,893	2,192
M	0	1,076	4,563	11,395	3,694
Q	0	837	4,028	12,121	4,420

F.1.4.2.4 Evaluation of Effects on Water Supply, Flood Damage Reduction, and Saltwater Intrusion

Background

The Biscayne Bay Coastal Wetlands project is located directly above the Biscayne Aquifer, which covers most of Miami-Dade and Broward counties. Water in the Biscayne Aquifer is unconfined and the aquifer has high hydrologic conductivity, exceeding 300,000 feet/day in eastern Miami-Dade County (Fish and Stewart 1991). Consequently, water levels respond rapidly to recharge or groundwater withdrawals, including drainage and recharge from canals, recharge from rainfall, evapotranspiration, and pumpage from supply wells (Sonenshein, 1995). The large reservoirs and STAs planned in some of the project alternatives, and the more stable flow of fresh water to the coast especially during the dry season, are expected to deter saltwater intrusion in southeastern Miami-Dade County. The ability to deliver water to the coast during the dry season is likely dependent upon several assumptions, including the availability of reuse water.

Under pre-drainage conditions, large volumes of low dissolved-solids water formed seasonally and flowed eastward forcing the saltwater-freshwater interface toward the coast. Since the development of canal and flood protection systems in south Florida, the saltwater-freshwater interface has moved westward. Saltwater intrusion has been a concern in Miami-Dade County;

coastal well fields began showing evidence of increasing salinity more than 65 years ago. A history of saltwater intrusion in Miami-Dade County through 1984 is reported by Klein and Waller (1985). In 1995, Sonenshein (1995) placed the saltwater-freshwater interface line west of the Biscayne Bay Coastal Wetlands project footprint (***Figure F-3***).

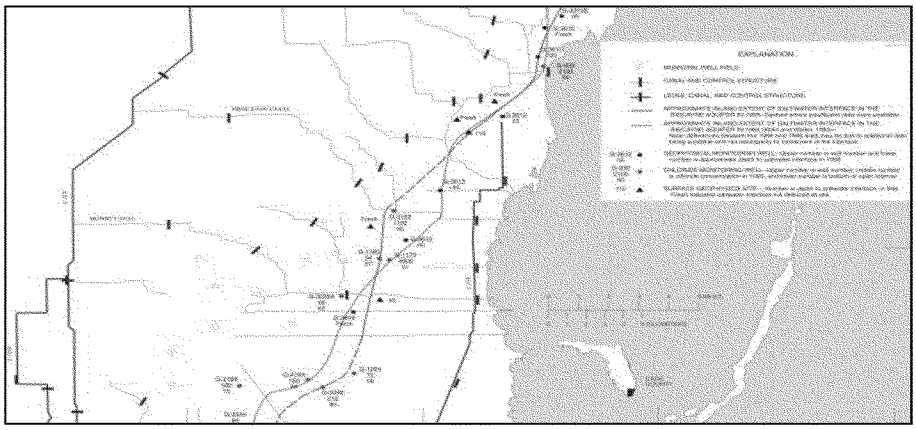

FIGURE F-3: SALTWATER-FRESHWATER INTERFACE IN 1984 (GRAY) AND 1995 (GREEN)

Evaluation

The problem of saltwater intrusion in the Biscayne Bay Coastal Wetlands area has a seasonal component that the project is, in part, expected to address. Recharge by rainfall is greatest during the wet season, from June to November, and recharge by canal seepage is greatest during the dry season, from December to May. Consequently, average water levels and the water-level gradients are lower in the dry season than in the wet season. In southeastern Miami-Dade County, water level declines during the dry season range from 0.5 to one foot. Within Everglades National Park (ENP) and along Tamiami Trail, declines range from 0.7 to 1.6 feet. The largest declines, about two to three feet, occur from the area east of ENP to just east of Krome Avenue (Fish and Stewart, 1991). It is expected that the Biscayne Bay Coastal Wetlands project will aid in maintaining freshwater flow to the coast during the dry season through water storage features like reservoirs and STAs, thereby potentially providing necessary aquifer recharge to limit further saltwater intrusion during this time period. An evaluation of the alternatives considered for the Biscayne Bay Coastal Wetlands project shows that Alternatives E and J would provide the most storage to supplement dry season flows and improve aquifer recharge

during this time of the year. While inter-basin operation of the reservoirs and STAs (including supplemental reuse water) will ultimately determine the success in restricting movement of the saltwater-freshwater interface, these two alternatives provide the most potential for providing a nearly constant supply of fresh water to the coast during both the wet and dry seasons in the northern and central regions of the project.

TABLE F-5: ACREAGES OF RESERVOIRS AND STORMWATER TREATMENT AREAS TO BE PROVIDED BY EACH ALTERNATIVE

	Existing Condition	2050 Without Project Condition	Yellow Book	E	J	M	Q
Reservoir (acre-feet)	0	0	0	32,270	3,000	0	0
STA (acre-feet)	0	80	2,327	2,997	3,615	80	80

F.1.4.2.5 Evaluation of Effects on Spatial Extent and Habitat Connectivity

Background

Spatial extent is one of the defining characteristics of the Everglades ecosystem. Worldwide losses of wetlands to agriculture and other development have left behind poor water quality, loss of wetland species, loss of recreational and commercial opportunities, increased salinities, and lowered productivity in downstream estuaries and bays. In the Everglades ecosystem, half of the spatial extent of wetlands was lost by the time USACE and SFWMD began to take a second look at the C&SF project impacts.

In addition to a large spatial extent, the connectedness of Everglades wetlands is critical to the ability of the comparatively nutrient-poor system to support the tremendous abundance of biota it was naturally capable of supporting. Smaller, more isolated wetlands of various types, including short-hydroperiod wetlands, provide critical support for the Everglades from the sidelines by providing additional habitat for many Everglades species, particularly birds. Additionally, these habitats have been disproportionately impacted by development compared to remaining habitat types, ultimately degrading needed buffer zones.

During the Restudy, increasing the spatial extent and connectivity of wetlands was described as a "precursor" to restoring the Everglades ecosystem (USACE and SFWMD, 1999). Wetland restoration adjacent to all projects was expected to increase the overall acreage of wetlands throughout the system. This would not only increase the amount of habitat available to wetland species, but provide free water storage and improve water quality. The Biscayne Bay Coastal Wetlands in particular are important for reconnecting overland flow with the marine ecosystem. If all the planned water is delivered to the area, a series of

stable potentially year-long freshwater habitats will be created to provide nursery grounds for estuarine fish. The establishment of these stable freshwater environments is consistent with the CERP goal of increasing the spatial extent of natural habitat, increasing the connectivity, and improving species abundance and diversity.

Evaluation

An evaluation of the Biscayne Bay Coastal Wetlands alternatives shows that Alternative E provides the most opportunity to establish connectivity with approximately 47 miles of levees, roadways, and canals removed. Alternatives J and Q provide substantial reductions in the miles of roadways, canals, and levees over the future without project condition. RECOVER agrees with the project team's decision to use spreader canal length and removal of levees, canals and roadways as a means to estimate project benefits (spatial extent and connectivity).

TABLE F-6: MILES OF LEVEES, CANALS AND ROADWAYS REMOVED BY EACH ALTERNATIVE

	Existing Condition	2050 Without Project Condition	Yellow Book	E	J	M	Q
Miles Levees, Canals, and Roadways Removed	0	0	10.66	36.73	28.53	5.28	21.05
Miles L31N Removed	0.01	2.24	3.05	10.57	3.31	5.28	5.28
Total	0.01	2.24	13.71	47.30	31.82	10.56	26.33

Improved spatial extent is more difficult to quantify, since land related to each alternative has not yet been determined by the project team. Given south Florida's projected population growth, however, any lands not included in the project alternatives or maintained as public lands will likely be developed consistent with surrounding land use patterns. Those implementing CERP must make a concerted effort to recognize and, where possible, protect the wetlands within and between project boundaries throughout the south Florida ecosystem. Otherwise, the cumulative effect of losses, each of which may appear small and isolated to single projects, will likely accumulate over time and add up to serious losses for the system as a whole. Spatial extent has been one of the characteristics of the greater Everglades ecosystem that has proven difficult to quantify.

F.1.4.2.6 Interaction with Other Projects

The Biscayne Bay Coastal Wetlands and the C-111 Spreader Canal projects overlap in their goals and the area (and habitat types) they are expected to affect. Because CERP was formulated as a set of interactive, interdependent projects, optimizing the linkages between these projects will likely result in increased performance. At this point, some alternatives can provide linkages between the projects. Maximum operation flexibility for the region will provide the projects the most opportunity to optimize ecological benefits and create project linkages where possible. By formulating and operating projects in a complementary fashion, there will be greater potential to create and sustain the freshwater head to rehydrate larger acreage in the Model Lands, to increase freshwater discharge to the estuaries, and to increase spatial connectivity in the areas. As noted earlier in the report, rehydrating natural areas not only provides habitat benefits, but also provides corresponding water quality benefits.

The Biscayne Bay Coastal Wetlands Alternative J would interact better with the central alignment of C-111 Spreader Canal or a more northern variation of this alignment. Depending on which alternative is selected, the Model Lands may miss out on potential acreage of rehydration. Exploration of a hybrid alternative including the flexibility provided by features in either Alternatives E or J, combined with the C-111 Spreader Canal to the south in Alternative Q likely has the greatest potential to actualize and optimize the desired benefits. It is important to note that both the C-111 Spreader Canal and the Biscayne Bay Coastal Wetlands projects need additional, clean water either from the system or from some other means such as reuse water cleaned to a proper level. Because of the interaction and interdependency of the two projects, Biscayne Bay Coastal Wetlands and C-111 Spreader Canal should have a combined project-level monitoring plan developed that compliments the MAP, but goes into greater detail to determine success and shortcomings in the projects future and effected habitats and indicators.

F.1.5 Ability of Project Alternatives to Address Planning and Scientific Uncertainties (Comprehensive Everglades Restoration Plan Adaptive Management)

As with other ecosystem restoration projects throughout the nation, every potential restoration action carries with it an amount of uncertainty and risk. There are five key principles that are fundamental to this approach:

1. Anticipating possible contingencies during planning and exploring qualitatively different options for responding
2. Employing science-based approaches to build knowledge over time, including development of "safe-to-fail" project designs and assessment procedures

3. Designing "robust" projects that can be adapted to uncertain or changing future conditions
4. Building shared understanding through collaboration and conflict resolution
5. Reconciling competing objectives to benefit both nature and society

The first three key principles as they relate to the Biscayne Bay Coastal Wetlands project are addressed in the following two subsections. Although the project team has already identified uncertainties and formulated plans to address and alleviate these uncertainties, they should consider some additional uncertainties mentioned throughout this report. In general, uncertainties related to large-scale restoration can be categorized as scientific uncertainties and planning uncertainties.

F.1.5.1 Scientific Uncertainty

Scientific uncertainty is the uncertainty regarding the environmental response corresponding to a specific action. With regard to the Biscayne Bay Coastal Wetlands project, there is little uncertainty that decreased salinities in Biscayne Bay will improve populations of desirable indicator species including submerged aquatic vegetation (SAV), oysters, estuarine fishes, and crocodiles. CERP system-wide performance measures for Biscayne Bay detail the expected freshwater flows required to reach these salinity targets during both the wet season and dry season. RECOVER finds that the project team has addressed some of the uncertainties, but the project team also needs to consider those additional uncertainties presented in this report.

F.1.5.2 Planning Uncertainties

Planning uncertainties for the Biscayne Bay Coastal Wetlands project center on the amount of water that can be made available that will directly affect the potential level of restoration accomplished by the project. In Restudy modeling, the C-111 Spreader Canal project and Modified Water Deliveries to Everglades National Park (MODWATERS) project redirected flows from Biscayne Bay. To compensate for this decrease in freshwater deliveries, wastewater reuse was added to the CERP to provide supplemental flows to the bay. At this time, however, significant uncertainty remains regarding (1) the volumes of freshwater flows delivered to the Biscayne Bay Coastal Wetlands project, and (2) the timing and availability of wastewater reuse as a CERP component to provide supplemental water, of reasonable quality, to Biscayne Bay. The Initial CERP Update conducted by RECOVER in 2005 (RECOVER, 2005b) showed that the modeled CERP alternative (CERPA) provides approximately 60 percent of the wet season flow and 77 percent of the dry season flow required to meet the target. The future without CERP (2050B3) only supplies approximately 41 percent of the wet season or dry season target.

F.1.5.2.1 Water Available to Biscayne Bay Coastal Wetlands Project

The volumes of water identified for Biscayne Bay Coastal Wetlands project during the Restudy were inadequate to meet restoration goals for the bay. Although Congress authorized Alternative D13R, it allowed for updates of the plan to "seek continuous improvement...based on new information, improved modeling, new technology, and changed circumstances" (Senate Report No.106-362). Given this adaptive management approach, it will be the responsibility of the System Planning and Operation Team (SPOT), in coordination with the Biscayne Bay Coastal Wetlands project team, to address whether additional water can be made available through existing CERP projects and whether such water could be delivered to the Biscayne Bay Coastal Wetlands project to address the Restudy performance shortfall. Because these are long-term activities related to system-wide performance, solutions cannot be proposed before selection of a TSP by the project team.

The Biscayne Bay Coastal Wetlands project team needs to consider the best means of accomplishing restoration of Biscayne Bay given different inflow volumes when comparing alternatives. Alternatives E and J provide the most flexibility in moving and storing water for wet/dry season operational flexibility. While Alternative Q provides for inter-basin transfers of water, it does not have the storage capacity to regulate and equalize water flows into the bay. RECOVER suggests a hybrid alternative be considered in the final alternative plan design.

TABLE F-7: WATER AVAILABILITY SCORES FOR ALTERNATIVES

	Existing Condition	2050 Without Project Condition	Yellow Book	E	J	M	Q
Inter-basin Transfer Capability	1	1	4	5	4	2	5
Lined Canal(s)	0	0	1	0	0	1	2
Reservoirs to the West	0	0	0	6	4	0	0

F.1.5.2.2 Supplemental Wastewater Reuse

The two wastewater reuse facilities proposed in the Biscayne Bay Coastal Wetlands area are the West Miami-Dade Reuse Facility and the South Miami-Dade Reuse Facility, which are expected to produce 100 and 131 million gallons per day, respectively. The South Miami-Dade Reuse Facility would provide supplemental water to Biscayne Bay via groundwater recharge adjacent to the project, and therefore provide saltwater intrusion benefits. The West Miami-Dade Reuse Facility, however, is planned primarily to contribute water to

the Bird Drive Recharge Area which is well west of Biscayne Bay. This project will potentially provide some project benefit through groundwater flow. The West Reuse project is planned far in the future with full 100 million gallons per day (mgd) capacity being in 2050.

A sensitivity analysis conducted by the SFWMD and presented at the Greater Everglades Ecosystem Restoration (GEER) Conference in 2000 investigated what impacts would occur if wastewater reuse components were removed from D13R (Santee et. al., 2000). The sensitivity analysis found that removal of the West Miami-Dade Reuse water resulted in approximately 20,000 acre-feet reduction to flows in Biscayne Bay over D13R and additional water supply cutbacks (five to six months) in all Lower East Coast Service Areas (LECSAs). Removal of the South Miami-Dade Reuse Facility resulted in an approximately 120,000 acre-feet flow reduction of flows to Biscayne Bay over D13R, and additional water supply cutbacks (ten months) in LECSA 3. From these results, it can be inferred that the presence of wastewater reuse to supplement flows to Biscayne Bay significantly influences the ability of the project to meet restoration goals, and the ability of the region to meet water supply needs. As with the water availability issue, it is incumbent upon the Biscayne Bay Coastal Wetlands project team to consider how their alternative plans will operate until wastewater reuse is available to provide supplemental water to the bay. It is important to recognize that reuse will not be fully implemented in the early stages of CERP and therefore the associated water quality and hydrologic benefits will not be actualized during this time.

Alternatives E and J provide the most storage and operational flexibility, as previously discussed; however, until wastewater reuse is utilized, fewer water quality improvements may be possible under these alternatives. The supplemental water supplied by reuse, especially during the dry season, would keep reservoirs and STAs from drying down, thereby increasing nutrient assimilation and reducing potential nutrient fluxes. Although reuse provides needed water for seasonal hydration, reuse water brings along with it a water quality expense (***Table F-8***).

TABLE F-8: EXAMPLES OF EFFLUENT CONCENTRATIONS REQUIRED FOR DIFFERENT LEVELS OF REUSE TREATMENT AND AVERAGE EFFLUENT CONCENTRATIONS FOR THE SOUTH DADE WASTE WATER TREATMENT PROJECT* FROM 1999-2004. (CDM 2004)

Parameter	Reuse	Wetlands Application	Class III / OFW
Total Suspended Solids (mg/ L)	5[1]	5	3.5
CBOB-BOD5 (mg/ L)	20[2]	5	
Total Nitrogen (mg/l as nitrogen)		3	0.27
Total Phosphorous (mg/L as phosphorus)	1.09*	1	0.005
Fecal Coliform (# /100 ml)	<1.0	<1.0	<1.0
Total Ammonia-Nirogen (mg/L)			0.02 –0.05
Nitrite/Nitrate-Nitrogen (mg/L)	.87*		0.01 mg/L
Total Kjeldahl Nitrogen (mg/L)	17.55*		0.22 mg/L
Ortho-Phosphorus (mg/L)			0.002 mg/L
Dissolved Oxygen (mg/L)			5.0-7.3
Turbidity (NTU)			0.5 NTU
Salinity			Shall not change salinity in test site by more than 5 ppt
pH			6.5-7.5[3]
Heavy Metals			See Table 3.4 (citation)
EPOC			Lowest possible levels[4]
Cryptosporidium and Giardia			Lowest possible levels[4]

[1]Single sample maximum
[2]Annual average
[3]Appropriate limits for pH in the estuarine zone will require further evaluation
[4]Even though, currently there are no established numerical criteria or anti-degradation targets for these parameters, available information shall be gathered on removal efficiency of various treatment technologies and detectable levels after advanced treatment for these parameters for comparative assessment. In practical terms, the objective would be to identify the technology that reduces such contaminants to the lowest level.

Source: Final Report: South Dade Advanced Wastewater Alternatives

F.1.6 Opportunities for Alternative Plan Improvements and Other Considerations

RECOVER provides insight, if possible, and alerts the project team to any inconsistent modeling assumptions for the project. As part of the responsibilities given to RECOVER, this section presents suggested improvements to the alternative plans, which, where possible, are intended to improve the project's

performance or enhance benefits to the natural system. These suggested improvements to the alternative plans should be considered by the project during the design of the final plan or reevaluation of alternative plans. The project manager or designee is required to notify RECOVER in writing if any of these suggested improvements to the alternative plans were incorporated in the final design. Additionally, RECOVER provides suggestions on how the project may analyze data or modeling output that may provide the project with greater system-wide benefits than recognized under the current analysis. The following bulleted list highlights opportunities for alternative plan improvement as well as notes alternative benefit not recognized by the project team:

- Both spreader canal path length and potential natural areas restored provide important water quality benefits that should be considered by the project team
- Current project nitrate estimates underestimate potential water quality benefits
- The Biscayne Bay Coastal Wetlands project should consider interactions with the C-111 Spreader Canal project to enhance rehydration of the Model Lands. This includes the potential for a hybrid alternative (see ***Section 4.2.6***)
- Reservoir and STA operations should be conducted to minimize dry down in the project area thereby minimizing oxidation of sediments and corresponding potentially high sediment nutrient fluxes
- Additional water quality and biological tools/models which will yield performance measures should be developed both at the system and project level for this area of the system.
- When the project monitoring plan is developed it should incorporate both short and long-term response water quality and biological indicators and the data should be collected in a manner that could generate additional evaluation and assessment tools
- The planning process is iterative and should be treated that way. Normally a couple of rounds of modeling are needed to optimize the alternatives. RECOVER recommends that future projects incorporate these iterations into the planning process.
- This Biscayne Bay area could use additional water to achieve restoration targets. The ET recommends that future system-wide planning and adaptive management efforts incorporate a review of the system to determine if additional water is available for Biscayne Bay for both this and the C-111 Spreader Canal projects.

F.1.7 Conclusions

RECOVER's review of relevant project-level and system-wide information mentioned in the report indicates that the project is likely to meet the following goals:

- Redistribute freshwater flow to minimize point source discharges to improve freshwater and estuarine habitat
- Preserve and restore the spatial extent of natural coastal glades habitat
- Potentially restore and improve quantity, quality, timing, and distribution of fresh water to the Biscayne Bay, including Biscayne National Park (BNP)
- Aid in reestablishing connectivity between Biscayne coastal wetlands, C-111 Basin, Model Lands, and adjacent basins
- Potentially help reestablish productive nursery habitat along the shoreline

Redistributing current canal flow through spreader canals will provide benefits by minimizing point source discharges. This will minimize the number of extreme salinity fluctuations occurring in the estuarine habitat. Redistribution of canal flow will also benefit the system by helping to restore previously hydrologically-isolated habitats as well as help restore previously desiccated habitats.

As noted in the report, the level of benefits achieved will be directly related to the ability to rehydrate natural areas. These natural areas have the potential to provide water quality benefits to both the freshwater marshes and the coastal estuaries. The reuse assumption and issues associated with reuse will need to be addressed. This is not only an issue at the Biscayne Bay Coastal Wetlands Project level but for other projects, such as the C-111 Spreader Canal project, as well. This is included in the regional evaluation to recognize constraints on the planning assumptions. The SPOT team is currently working on issues surrounding availability of water for the Biscayne Bay Coastal Wetlands and C-111 Spreader Canal projects.

As noted in the ***Section 4.2.2*** "Evaluation of Ecological Benefits", water deliveries to Biscayne Bay will help ameliorate the effect of high salinities. Maintenance of lower salinities via these freshwater deliveries is critical to reducing the effect of *Perkinus marinus* predation effects on oysters. Freshwater deliveries similarly moderate the effect of high salinities on neonate *Crocodylus acutus* and effect survival.

In addition to the water quality benefits provided by rehydration, STA and reservoir operational flexibility will provide the project the ability to respond to changes in land use and corresponding water availability and water quality. These benefits will be leveraged by the wetlands created by spreader canals in the southerly flow path. Alternatives E and J provide the most flexibility in design and operations and both provide benefits beyond the Yellow Book and Base (existing) alternatives. A hybridized alternative, such as Alternatives E or J with the south spreader from Alternative Q, will likely help attain the greatest

benefits. If the project team pursues this option, RECOVER will review any additional project materials.

The RECOVER ET recognizes that the project team has requested additional modeling runs that have not yet been run by ERDC. RECOVER expects to review this additional output and will provide the project with additional comments where necessary. In addition to the system-wide evaluation of the Biscayne Bay Coastal Wetlands project, RECOVER evaluated the benefits matrix used by the project. Appendices A and B contain the alternative structural information and multi-criteria decision matrix summary, respectively, considered by the RECOVER ET review team.

RECOVER's comments are not bound by many of the same constraints (including costs) that the project team faces. RECOVER understands the balanced view the project team undertakes when developing their alternatives and in many instances may have already screened out some of the recommendations made by RECOVER.

RECOVER's recent adoption of the "values triangle" recognizes the need to balance science, timely reporting, and inclusiveness. For this RECOVER evaluation, significant efforts were undertaken to satisfy the need for timely reporting while bringing forward as much science as possible. This report may not constitute the entirety of RECOVER's review of this project as specified in the Programmatic Regulations (DOD, 2003). RECOVER may provide the project additional information supporting and refining the original evaluation.

F.1.8 Appendix A: Biscayne Bay Coastal Wetlands Alternative Matrix for All Alternatives, December 2005

Alternative / Management Measure	Yellow Book	Alternative M2	Alternative Q	Alternative E	Alternative J
Reservoir (acres)	N/A	(1) DA-C1 375 ac-ft	N/A	(5) Reservoirs @ 35,925 ac-ft	(5) Reservoirs @ 32,450 ac-ft
STA in acre-feet (acres @ depth)	(4) STAs @ 13,950 acre-feet	(1) STA – C1 Lennar flow way 600 acre-feet (?)	(1) FW-C1 Lennar flow way@ 600 acre-feet	(5) STAs @ 8370 acre-feet	(5)STAs @ 8991acre-feet
Pump(s)/sizes (cfs)	(10) Pumps = 1550 cfs	(2) Pumps = 640 cfs	(10) Pumps = 1480 cfs	(10) Pumps = 2045 cfs	(8) Pumps = 1395 cfs
Levees (feet/cyd)	(1) L-C1 4 miles long	(1)L-C1 4 miles long	(4) levees @ 29,500 feet long	(2) levees 8,000+ feet	(1) L-C1 3-feet height x 8000-feet length
Canals (feet/cyd)	(5) new canals	(5) new canals	(4) new canals	(7)new canals/bypass canals	(5) new canals
Spreader canals	(4) spreader canals	(3) spreader canals	(4) spreader canals	(2) spreaders	(2) spreaders
Plugs vs. backfilling canals	(23) plugs Backfill mosquito ditches Backfill North Canal	(1) plug	(22) plugs Plug mosquito ditches an let fill naturally	(2) plugs Backfill mosquito ditches Backfill L-31E	(3) plugs Backfill mosquito ditches Backfill L-31E Remove Tallahassee Road 200-foot sections removed every 1000 feet
Culverts weirs & pipes	(56)+ culverts (1) weir	(2) culverts	(7) culverts (1) weir	(10+) culverts (1) weir (3) pipes	(17) culverts (1) weir
Unique measures					

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F.1.9 Appendix B: Biscayne Bay Coastal Wetlands Multi-Criteria Decision Method

Ecological benefits were determined by combining some components of the TABS-MDS model output with a suite of evaluation metrics that did not rely on model output. This method, referred to as the Multi-Criteria Decision Method (MCDM), evaluated benefits for each of the three project sub-regions and within three ecological zones. The MCDM performance measures and evaluation metrics address each of the original five project objectives as defined above. An additional objective was added to underline the importance of restoring the nearshore area, and is referred to as: "Restore nearshore salinity regimes."

The team utilized 15 performance measures and 19 evaluation metrics to address the six project objectives. For each performance measure, there is at least one evaluation metric by which the performance measure is scored. Of these, only one performance measure relies on output from the TABS-MDS model. The others are based primarily on best professional judgment by the team regarding how management measures or operations inherent to a given alternative would improve habitat. Some of the evaluation metrics employ GIS measurements to determine scores. Each alternative was scored for all 19 evaluation metrics in each of the three geographic sub-regions of the project, and within each of the three ecological zones into which the project can be divided. It should be noted that not all project objectives apply to a given ecological zone. For the nearshore zone, objectives 1, 2, 3, and 6 are applicable. For the salt water wetlands zone, objectives 1, 2, 3, and 5 are applicable. For the freshwater wetlands, objectives 2, 3, 4, and 5 are applicable.

Numeric targets for evaluation metrics were established whenever possible. For these metrics, the scores were converted to percent target achieved to compare and contrast between and among evaluation metrics. Establishing targets for some metrics was not possible. In these cases, scores were normalized against the alternative with the highest score. Normalizing or converting scores to percent target achieved resulted in transforming scores to a scale of 0 to 1, which allows evaluation metrics to be averaged to produce an ecological benefits index for each ecological zone. These indices can then be applied to the total spatial extent of each zone to produce habitat units.

The following outlines the evaluation matrix and describes how each performance measure and evaluation metric relates to the project objective (i.e., how the metrics benefit habitat):

I. Re-establish shoreline nursery habitat

A. Performance Measure-Linear extent of coastal spreaders (1 evaluation metric). This performance measure assumes that the ability to restore

nearshore habitat to an appropriate salinity regime is a function of the capability to redistribute water along as much of the shoreline as possible (i.e., the longer the coastal spreaders, the more nearshore habitat will be restored).

II. Objective-Redistribute freshwater to improve habitat

A. Performance Measure-Reduce direct canal discharge (one evaluation metric). This performance measure assumes that diverting water from canals into the wetlands improves habitat by reducing harmful point source discharges to the nearshore areas and rehydrates the wetlands into which the water is diverted.

B. Performance Measure–Flexibility to move water (three evaluation metrics). The flexibility to move water in the project area is assumed to be a function of: 1) the capability to transfer water between project sub-regions, 2) the use of lined canals to eliminate seepage of water to be transferred, and 3) the capability to store water for use when needed (i.e., availability of water during the dry season).

   i. Evaluation Metric–Inter-region transfer capability. This metric is evaluated by qualitatively scoring the transfer capability on a scale of 0 to 3 for each region (0 = no transfer capability, 1 = little transfer capability, 2 = moderate, 3 = high).
   ii. Evaluation Metric–Lined canals (seepage reduction). This metric assumes that lined canals provide better capability to transfer water than unlined canals because no water will be lost to seepage.
   iii. Evaluation Metric–Reservoirs. This metric assumes that the larger the reservoir, the better the capability to transfer water, and thus is scored based on the relative sizes of reservoirs by alternative and region.

C. Performance Measure–Hydrate freshwater wetlands (one evaluation metric). The performance measure assumes that the ability to restore freshwater wetlands is based at least partly on the capability to redistribute water into as much of the freshwater wetland habitat as possible (i.e., the longer the freshwater spreaders, the more freshwater wetland habitat will be restored).

III. Objective–Restore and Improve Quality and Timing of Freshwater to the Bay

A. Performance Measure–Reduce nutrient concentration (two evaluation metrics). Water quality is evaluated based on the presence or absence of reservoirs and STAs, and on the volume of water diverted into those features.

i. Evaluation Metric–Reduce nitrogen concentrations. This metric is scored using a spreadsheet model that is driven by Kadlec (2004) equations for nitrate removal by STAs and wetlands.
ii. Evaluation Metric–Reduce phosphorus concentrations. Reduction in phosphorus is calculated in a similar manner, except removal efficiencies were estimated for different flow paths rather than using the Kadlec equations for nitrate.

B. Performance Measure-Storage Capacity (two evaluation metrics). The ability to store water is assumed to provide the capability to improve the timing of freshwater delivery to the bay. For this analysis, reservoirs and STAs are considered the only storage features. The greater the storage capacity, the higher the score.

i. Evaluation Metric–Reservoirs
ii. Evaluation Metric–STAs

IV. Objective–Preserve and Restore Coastal Glades Habitat

A. Performance Measures–Reduction in Exotic Vegetation (one evaluation metric). This metric assumes that displacement of non-native vegetation by STAs or reservoirs improves coastal glade habitat.
B. Performance Measure–Reduction in Good Quality Habitat (one evaluation metric). This metric assumes that displace of high quality wetlands by STAs or reservoirs contribute to the degradation of coastal glades habitat.
C. Performance Measure–Spatial Extent of Existing Public Wetlands Restored (one evaluation metric). This metric assumes that the greater the area restored that is already in public hands, the better.

V. Objective–Re-establish Water Basin and Wetland Connectivity

A. Performance Measure–Length of Obstructions Removed (one evaluation metric). This metric assumes that removal of physical obstructions, like roads and levees, will increase wetland and basin connectivity.
B. Performance Measure–Increase Connection between Fresh and Salt Water Wetlands (one evaluation metric). This metric assumes that

removal of L-31E will increase the connectivity between salt and freshwater wetlands.

VI. Objective–Nearshore Salinity

A. Performance Measure–Storage Available (one evaluation metric). This measure assumes that the greater the storage capacity, the more likely that the desired salinity target will be maintained.
B. Performance Measure–Use of Additional Water for Environmental Benefit (Reuse) (one evaluation metric). This metric gives credit to all alternatives relative to Future Without Project provided by waste water reuse.
C. Performance Measure–Ability to Redistribute Water in the Coastal Zone (one evaluation metric, incorporates TABS-MDS output). This metric assumes that the ability to distribute water to the nearshore area is a function of the volume of water diverted from canals and the proportional length of the coastal spreader (i.e., combines I.A. and II.A. above).
D. Performance Measure–Ability to Establish Ecologically Desirable Salinity Ranges (TABS-MDS output, one evaluation metric). This metric relies on the scoring of Performance Measure 3.A.2 by the TBS-MDS model.

The team considered several options for weighting the evaluation metrics and performance measures, prior to applying ecological benefits indices to the acreages in the various ecological zones of the project. However, treating the evaluation metrics with equal weighting provided the best separation between alternatives. This eliminated the need to justify weighting. After scoring, all evaluation metrics applicable to a given ecological zone were averaged to provide a single index value that could then be applied to the acreage within that zone.

Using the evaluation method described above, the project alternatives were ranked according to the habitat units (HU's) of ecological lift provided above the future without project condition as follows:

1. Alternative E 39,314 HUs
2. Alternative J 27,845 HUs
3. Alternative Q 24,003 HUs
4. Yellow Book 22,399 HUs
5. Alternative M 12,330 HUs

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F.2 Biscayne Bay Coastal Wetlands-RECOVER Consistency Review of Project-Level Monitoring-And Recommendations for Inclusion into the Monitoring and Assessment Plan (January 25, 2008)

F.2.1 Introduction and Purpose of the Evaluation

RECOVER has been charged with evaluating project level monitoring plans as regards consistency with RECOVER's Monitoring and Assessment Plan (MAP, 2004) and other relevant guidance (e.g., CGL 12/06), and to determine the need for additional ecological monitoring above and beyond what is already contained in the MAP. As projects are typically not at the construction stage when this review is prepared, and that a variety of changes may possibly occur between the above date and operational readiness of the project, this review should be considered an interim document. Future developments may require modification of monitoring plans and/or revision of this review. This document provides RECOVER's recommendations to the PDT regarding incorporation of proposed monitoring into the MAP. Processes are in place through the RECOVER Leadership Group (RLG), DCT or QRB to resolve outstanding issues.

Adequate monitoring is needed in order to effectively carry out RECOVER's adaptive management mission (see AM strategy: http://www.evergladesplan.org/pm/program_docs/adaptive_mgmt.aspx). MAP related monitoring generally has as its goal the generation of long-term datasets of sufficient temporal and spatial scope to permit valid interpretation(s) and consequently facilitate effective adaptive management of system-wide restoration over the long-term. The proposed MAP as envisioned by the project teams is ambitious and the reality of finite resources and rising costs are additional considerations that must be included when prioritizing monitoring needs. The degree to which proposed monitoring elements can be implemented, phased in, or ranked, cannot be fully defined outside the holistic MAP perspective and the prudent balance between cost and science. This review should not be construed as assessing the relative merit of monitoring elements proposed by the projects. The objectives of the review are to ensure holistic system-wide consistency, and to identify monitoring elements appropriate and necessary to be incorporated into the MAP to drive adaptive management and evaluate progress toward Interim Goals.

Project-level monitoring typically involves monitoring that is: 1) required by permit (implemented by the project), 2) directly related to project operations (e.g., stage and flow), and 3) to be used for assessing CERP performance and to adaptively manage individual projects and groups of projects into the future. Project-level monitoring plan elements which address system level responses, and which are amenable to drive the adaptive management process would, as necessary and appropriate, be initiated and assessed under the aegis of

RECOVER via incorporation into the MAP. Regulatory requirements may become part of the MAP only if they are consistent with MAP objectives; otherwise they would remain with and be funded by the project. Incorporation of additional monitoring into the MAP presupposes that appropriate RECOVER funding is available at the time of the required inception of any such monitoring.

F.2.2 Objectives of the Monitoring and Assessment Plan

1. Provide data necessary and appropriate to detect and document restoration-induced change, including the evaluation of progress toward Interim Goals.
2. Provide data necessary and appropriate to implement effective Adaptive Management.

F.2.3 Background

Historically, Biscayne Bay served as the eastern outlet of the Everglades, with freshwater flowing overland to the bay through broad channels (transverse glades), which drained through a system of 20-30 tidally influenced creeks and/or as groundwater through the Biscayne Aquifer. Regional drainage, canal construction and operation (particularly C-100, C-1, C-102, C-103, and C-111), lowered groundwater levels, urban development, construction of roads, levees, and other hydrologic barriers to surface flow has altered this drainage pattern resulting in a much changed estuarine system. The objective of the Biscayne Bay Coastal Wetlands Ecological and Water Quality Monitoring Plan is to: 1) recreate a natural pattern of freshwater flow to the estuary via the rehydration of coastal wetlands, 2) improve nearshore salinity patterns, 3) enhance water quality (both nearshore and offshore), and 4) improve structure and viability of associated floral and faunal communities.

F.2.4 Consistency with the Monitoring and Assessment Plan

An overview of MAP monitoring elements pertinent to the Biscayne Bay Coastal Wetlands project is presented as an appendix to this document. The project level monitoring plan is consistent with, and complimentary to the MAP, neither duplicating nor replacing this program. The plan acknowledges the guidance present in CERP Guidance Manual (CGM) 40, CGM42, and the QASR. The plan details relevance to the performance measures developed by the PDT.

TABLE F-9: RECOVER ASSESSMENT TEAM CHAIR APPROVALS

AT Chair	Concur	Do Not Concur	Comments
Greg Graves, SFWMD	☒	☐	None.
Steve Traxler, FWS	☒	☐	None.
Elmar Kurzbach, USACE	☒	☐	None.
Patti Sime, SFWMD	☒	☐	None.

F.2.5 RECOVER Recommendations: Incorporation of Project Delivery Team-Proposed Monitoring into the Monitoring and Assessment Plan

Note: Monitoring not recommended for inclusion in the MAP does not imply a technical disagreement with the proposed monitoring element.

F.2.5.1 Project Proposal-Duration

Monitoring duration for 20 years:
three (3) years pre-project
seven (7) years during construction
ten (10) years post-project

- **RECOVER Response**
  Monitoring design, initiation date, intensity of effort and duration should reflect construction schedules, parameters measured, and a periodic assessment of each monitoring element's data with the ultimate goal of monitoring until stable conditions occur (i.e., in RECOVER's System Status Report).

- **Additional Cost to Monitoring and Assessment Plan**
  Monitoring scheduling will appropriately reflect the phasing of the Project.

F.2.5.2 Project Proposal-Oysters

Five (5) additional sites need to be monitored for recruitment, reef development, juvenile growth and mortality, and health.

- **RECOVER Response**
  Historically, oyster beds were not extensive within Biscayne Bay. Institution of annual presence-absence/extent surveys along the marsh where salinity monitoring data indicates potential habitat exists should

have value to document improvements, and cost to do so would be reasonable.

- **Additional Cost to Monitoring and Assessment Plan**
  None at this time. As salinity monitoring indicates improved conditions, RECOVER will enlist the help of the PDT to explore advisability and location of additional oyster monitoring.

F.2.5.3 Project Proposal–Submerged Aquatic Vegetation

16 transects where greatest change of freshwater flow likely to occur (9 transects at canal mouths, 2 at Deering, 2 at Cutler wetland, 3 nearshore between C102 and C103).

- **RECOVER Response**
  1. The largest changes are expected to occur near existing canal mouths as the frequency of canal discharges decrease due to diversion; however, as flood control may demand, point discharges may continue as a function of the frequency of storms which varies year to year.
  2. A vibrant SAV community currently dominates southern Biscayne Bay. The SAV community along the nearshore is likely to undergo a shift in speciation in response to altered salinity as a result of the redirection of freshwater flows, but the areal expanse of change is likely to be limited.

- **Additional Cost to Monitoring and Assessment Plan**
  Substantial funding is currently being expended to evaluate seagrass condition in the MAP. The Assessment Team (AT) Chairs will work with the PDT and the southern estuaries module scientists to explore optimizing existing efforts to better focus on expected changes, especially Phase I induced changes. [1]

F.2.5.4 Project Proposal–Nearshore Estuarine Fish and Invert Community

More intensive coverage than current MAP affords (three times more samples) focused on the shallow open water area near to shore.

- **RECOVER Response**
  Changes in fish and invertebrate community composition following changes in salinity regime are well-documented; therefore, modifications to the existing salinity regime by the project is expected to result in a corresponding community change, with communities experiencing the

[1] Potential revision to current SAV mapping methodology may be advised.

largest salinity change most likely to have a detectable signal. However, the charge of the MAP is to detect system-level changes, and is specifically precluded from documenting habitat unit related responses. Significant benefits in the fish community should be detectable at the currently monitored system-level.

- **Additional Cost to Monitoring and Assessment Plan**
  Existing MAP fish monitoring is sufficient if maintained at current level for this area. If existing MAP monitoring is sufficiently changed such that this area is no longer captured, or if project-generated salinity changes do not meet project objectives and no concomitant response is seen in MAP fish monitoring, then this recommendation should be revisited.

F.2.5.5 Project Proposal-Juvenile Crocodiles

Continue existing MAP monitoring.

- **RECOVER Response**
  MAP crocodile monitoring in the Biscayne Bay Coastal Wetlands project area is consistent with project-level monitoring parameters and recommended protocols.

- **Additional Cost to Monitoring and Assessment Plan**
  Existing MAP monitoring sufficient if maintained at current level for this area.

F.2.5.6 Project Proposal-Nearshore Salinity Monitoring

Ten new continuous monitoring sites.

- **RECOVER Response**
  Salinity is a key monitoring parameter. MAP currently supports BNP to operate 45 instruments at 34 stations in the project area. These data provide insight as to where water diverted from canals is actually entering Biscayne Bay, and may guide adaptive management of the project to focus restorative flows on areas where ecological benefit is most promising and sustainable.

- **Additional Cost to Monitoring and Assessment Plan**
  None. The current MAP salinity network will be re-configured based on data from the existing nearshore salinity monitoring network, expected implementation dates of Phase I and II, and zones of most probable impact. Possible cessation of seasonal drawdown may also factor in network re-configuration.

F.2.5.7 Project Proposal–Wetland Stage

Hourly stage at six new monitoring wells and at four existing (ten in all).

- **RECOVER Response**
  Changes in hydroperiod and stage will be a consequence of quantity and timing of water deliveries, as well as the extent of hydraulic connectivity to the underlying, extremely permeable, Biscayne Aquifer. There is little likelihood that pre-development quantities and timing of water delivery will be available (i.e., mid-Bay freshwater boils), and thus changes in vegetation will reflect the degree stages are in fact increased. Where stage can be significantly improved, vegetation changes should occur. Restoring appropriate wetland vegetation is being addressed via vegetation mapping in MAP.

- **Additional Cost to Monitoring and Assessment Plan**
  Stage and water level monitoring are properly part of project monitoring, and not appropriate for inclusion in the MAP.

F.2.5.8 Project Proposal–Wetland Algae

40 sites quarterly, since 1) re-hydration rapidly detectable in diatom community, therefore early sign of desirable change; 2) Diatoms respond to nutrient availability as strongly as salinity, most likely utility to provide signal to change sources and volumes.

- **RECOVER Response**
  1. The benthic algal community is a sensitive indicator of changing salinity and nutrient regime; however, likely shifts in algal community structure as a result of addition of freshwater is not the most direct and applicable driver to adaptively manage project water deliveries. The nearshore salinity monitoring is clearly responsive to seasonal water availability (***Figure F-4***) and provides obvious guidance on both quantity as well as timing of water necessary to sustain viable nearshore nursery habitat. Re-establishing estuarine function poses a much greater ecological lift than the coastal wetlands *per se*, and accordingly prudent management of water delivery should focus on determining the optimum way to establish the greatest possible ecological benefit. Ecological lift is expected to occur in the coastal wetlands, and the algal community therein will undoubtedly be transformed in areas where additional water is made available, but those responses will not initially drive adaptive management decisions. Changes in coastal wetland stage and salinity regime will be reflected in vegetation, albeit slowly, and thus ultimately detectable in existing MAP vegetative mapping efforts. Unlike the well-documented faunal lift afforded by viable estuarine conditions, the link

between detectable algal community shifts and optimizing predator-prey function for wading birds, etc., is weak.

2. Redirected water is known to contain nitrate nitrogen nutrient concentration higher than that present in rainwater. These waters currently enter the Biscayne Bay directly with no mediating treatment. A nutrient response in the algae is therefore expected if not desired. Nitrate is readily denitrified in wetlands, while phosphorus is recycled and removed through burial, thus nitrate nitrogen alone is unlikely to induce the types of changes in the coastal wetland plant community commonly associated with phosphorus since the wetlands perched atop the Biscayne formation are P-limited. A nutrient response in the wetland algae would indicate a beneficial not a detrimental impact on the ecosystem, when the ecosystem is considered as a whole, and would not as such constitute a need to take adaptive management. Addressing elevated nutrients in canal water is the responsibility of the Total Maximum Daily Load process.

- **Additional Cost to Monitoring and Assessment Plan**
  No additional monitoring proposed for inclusion in the MAP.

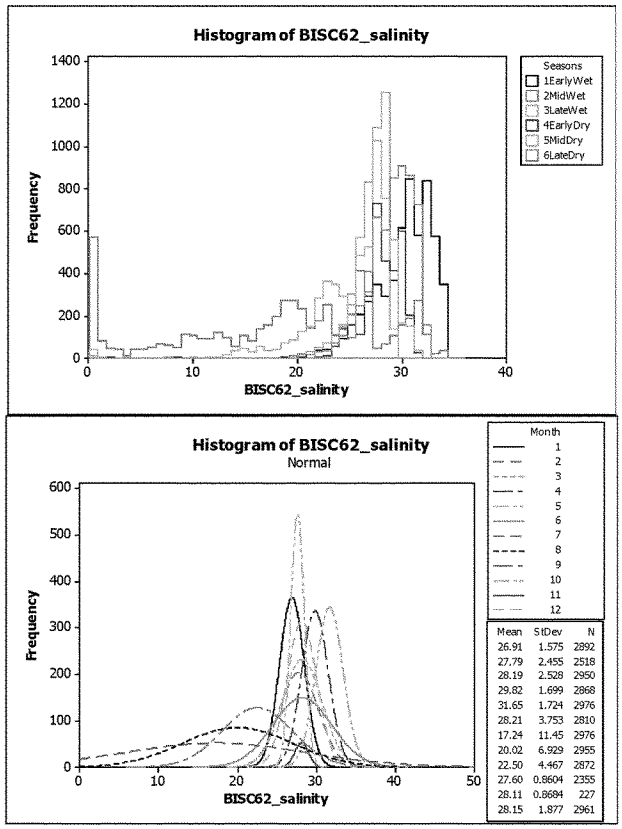

FIGURE F-4: NEARSHORE SALINITY MONITORING DATA IS DIRECTLY AMENABLE TO ADAPTIVE MANAGEMENT OF PROJECT OPERATIONS TO OPTIMIZE QUANTITY AND TIMING OF WATER DELIVERIES

F.2.5.9 Project Proposal-Wetland Macro Vegetation

Detailed analysis of vegetation changes will be conducted along a series of transects.

- **RECOVER Response**
  MAP aerial photography is ground-truthed to about 90 percent accuracy. Vegetative changes will occur slowly, and aerial photography of the area is currently taken on a five-year basis.

- **Additional Cost to Monitoring and Assessment Plan**
  Explore feasibility of using Miami-Dade aerials.

F.2.5.10 Project Proposal-Water Quality Monitoring Network

Six new near shore water quality monitoring sites.

- **RECOVER Response**
  Flow and water quality monitoring associated with canals, pumps, and other project features are either permit or operationally related; however, six new water quality monitoring sites proposed for inclusion in the MAP. Sites located in Biscayne Bay immediately adjacent to discharge points would likely detect changes from decreased flows and loads; but decreased flows and load data are already available at the structures from which the response in the Biscayne Bay may be reliably deduced. The purpose of MAP's water quality monitoring network in the Biscayne Bay is to assess system-wide responses; if the changes in water quality are not detectable on the system-level scale then either those changes were insignificant or did not occur.

- **Additional Cost to Monitoring and Assessment Plan**
  None. Maintain or optimize existing monitoring network.

- **Summary:**
  Additional cost to MAP may arise from need to reconfigure existing salinity network to better reflect spatial extent of potential impacts; however, the project implementation schedule may offset or delay these costs. All monitoring will need to be re-evaluated over time to determine if it is working as intended, if additional monitoring is advisable, if monitoring should be expanded or reduced in scope, or terminated or replaced by another monitoring element as the data and the changing landscape of restoration priorities so warrant. Processes are in place through the RLG, DCT or QRB to resolve outstanding issues.

F.2.5.11 Project-Level Monitoring Plan Review Team Members

- Dr. Gretchen Ehlinger, Everglades Partners Joint Venture, USACE Contractor
- Greg Graves, RECOVER, SFWMD
- Dr. Brad Robbins, Coastal Ecosystems Division, SFWMD
- Patti Sime, RECOVER, SFWMD

F.2.6 Appendix–Overview of Existing Monitoring and Assessment Plan Monitoring Relevant to Biscayne Bay Coastal Wetlands

The following monitoring elements are currently being addressed in the MAP:

- Biscayne Bay Salinity Monitoring Network (MAP Activity Number 3.2.3.3)
- Shoreline Fish Community Visual Assessment (MAP Activity Number 3.2.3.6)
- Biscayne Bay Coastal Wetland Fish Communities (MAP Activity Number 3.2.3.3)
- South Florida Seagrass Fish and Invertebrate Assessment Network (MAP Activity Number 3.2.3.5 and 3.2.4.5)
- Epibenthic fauna adjacent to the south Biscayne Bay shoreline in relation to seagrass, shoreline fishes, and freshwater change in the CERP/Southern Estuaries Module Domain (MAP Activity Number 3.2.4.7)
- Documenting Everglades Restoration Impacts on Biscayne Bay's Shallowest Benthic Habitats (Map Activity Number 3.2.3.3)
- Biscayne Bay WQ monitoring network (DERM-SFWMD contract)
- Canal WQ monitoring network (DERM-SFWMD contract)
- Structure flows and loads (SFWMD)
- High Resolution Vegetation Photo Interpretation Mapping (MAP Activity Number 3.1.3.04)

F.2.6.1 Biscayne Bay Salinity Monitoring Network (Monitoring and Assessment Plan Activity Number 3.2.3.3)

The Biscayne Bay Salinity Monitoring Network's (BBSMN) primary purpose is to provide the quality and quantity of data sufficient for determining the effects of CERP on salinity regimes within the Bay. The objectives of this project are to: 1) continue monitoring salinity, conductivity, temperature and depth at all existing stations, 2) provide these data to other scientists and managers via the SFWMD's online database dbHydro, 3) establish reference conditions (document temporal and spatial variability of salinity in the near shore region of Biscayne Bay), 4) determine the status and trends of a key variable of the Conceptual Ecological Model (CEM), 5) provide data to evaluate MAP performance measures. This project expanded the existing salinity monitoring network to nearshore shallow areas of Biscayne Bay, which are considered to be important sentinel sites for monitoring changes in salinity that result from CERP project implementation (***Figure F-5***). Salinity measurements in the shallow nearshore zone are particularly important because 1) a long-term salinity dataset (baseline) does not exist for this region, 2) salinity is thought to be extremely dynamic nearshore, 3) this region is the focus of multiple performance measures by the southern estuaries team, and 4) this region has the greatest potential of being affected by CERP.

There are 38 existing sites where data are collected within Biscayne Bay. The northernmost site is located south of the Snapper Creek Canal. Sites continue south through the estuary to Manatee Bay and Barnes Sound. The sampling sites are arranged as a series of east-west transects that radiate outward from canals or other interesting hydrological features. These transects are meant to document a progression of estuarine conditions from nearshore to offshore. Fourteen sites are located within the mangrove zone, which is expected to be the first area affected by changes in fresh water delivery to the bay. Twenty sites are located in the central area of the bay. Sites were chosen as special interest areas, such as Black Point and Turkey Point, and Barnes Sound and Manatee Bay because of their hydrology and proximity to key environmental concerns and changes in water flow. Site locations were chosen by a working group from the Biscayne Bay Coastal Wetlands project and the southern estuaries Regional Evaluation Team including personnel from National Park Service (NPS), Miami-Dade County DERM, National Oceanographic and Atmospheric Administration (NOAA)-Atmospheric Oceanographic and Meteorological Laboratory (AOML), NOAA-National Marine Fisheries Service (NMFS), USACE, University of Miami Rosenstiel School of Marine and Atmospheric Sciences (UM-RSMAS), and Florida International University (FIU). YSI 6600 Data sondes are used to collect continuous conductivity, temperature and depth. These instruments are deployed on a three-week rotation schedule.

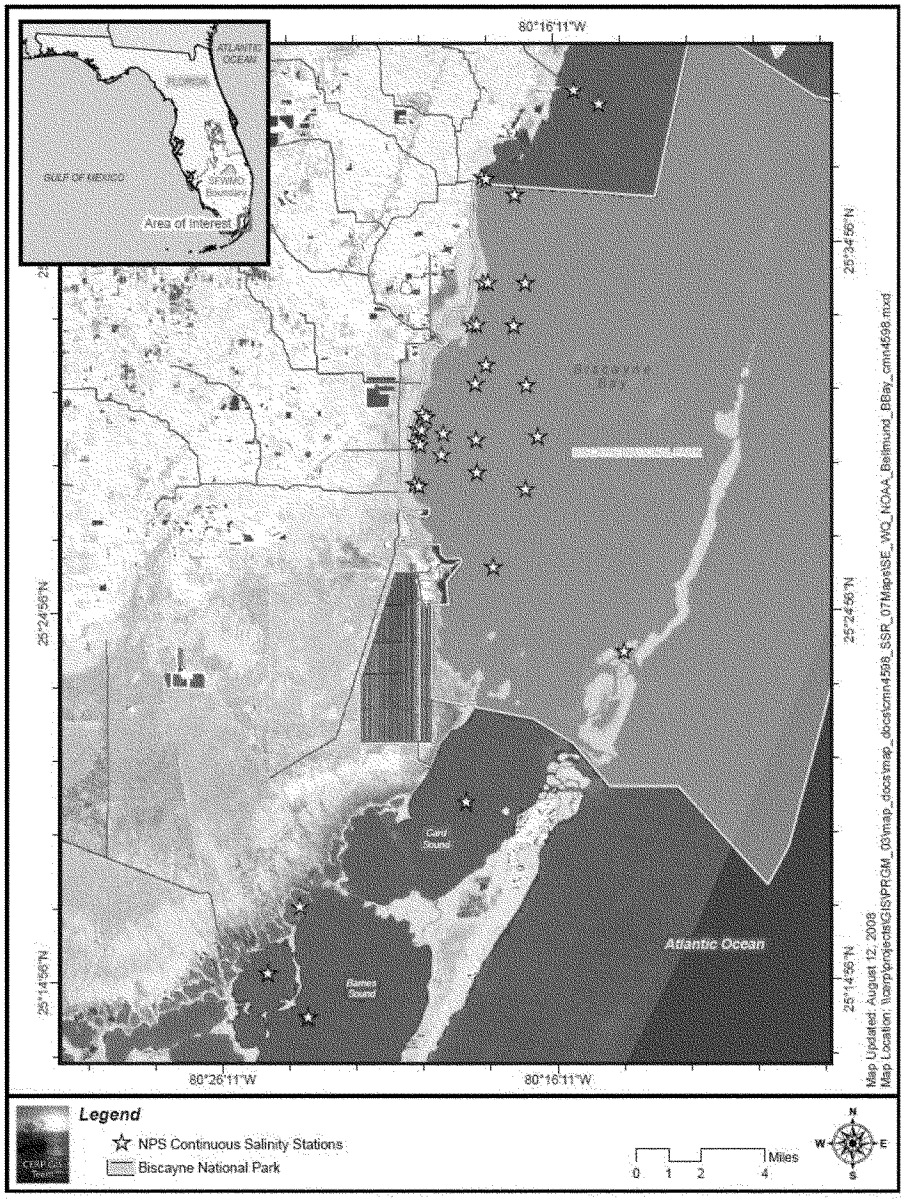

FIGURE F-5: SITES MONITORED AS PART OF THE BISCAYNE BAY SALINITY MONITORING NETWORKS

F.2.6.2 Shoreline Fish Community Visual Assessment (Monitoring and Assessment Plan Activity Number 3.2.3.6)

Because of their position at land-sea interface, it is within mainland mangrove habitats that CERP-related impacts are likely to be the strongest and most easily discerned from other effects. Southern Biscayne Bay's shoreline fish community has been monitored visually by NOAA/NMFS twice a year since 1998. This effort was initiated to compare fish use of mangrove prop root habitats along the mainland with that along the leeward side of the northernmost Florida Keys (Serafy et al., 2003). Seasonal and spatial variation in fish taxonomic composition and diversity, as well as variation in the frequency of occurrence, density and size structure of the dominant taxa has been examined (Serafy et al., 2005). The purpose of this MAP activity is to ensure the continuation of this time-series, and in a manner similar to Lorenz (1999), place emphasis on evaluating relationships between the shoreline fish community and variation in salinity/freshwater flow. Previous studies in Biscayne Bay (Faunce et al., 2002; Serafy et al., 2003; Barimo and Serafy, 2003; Faunce, 2005) suggest that mangrove-dominated shorelines support high densities of juvenile and adult stages of several economically important fishes, including snappers, grunts, great barracuda and snook and even higher densities of their prey (e.g., silversides, killifishes and mojarras). If CERP can realize a return of more natural salinity regimes along the mainland shoreline, bay-wide increases in fish diversity and density should be apparent in mangrove-fish assemblages. Because the exact timing of both CERP-related changes and the ecological responses to them are unknown, a long-term, multi-faceted approach to monitoring is critical.

Mangrove shoreline fish assemblages are characterized and quantified using a visual "belt transect" survey method (Serafy et al., 2003). This entails snorkeling 30 meter-long transects parallel to the shore and recording the identity, number, and the size structure (minimum, mean and maximum total length) of observed fish by species. Measured landward from the prop root edge, the belt transect width is two meters, thus the area surveyed per transect is 60 square meters (m^2). At each station, water temperature, salinity and dissolved oxygen are measured using a multi-probe water quality instrument; water depth will also be measured at various points (i.e., at 0, 15 and 30 meters) along each transect. Visual surveys are conducted during consecutive wet and dry seasons (i.e., July to September and January to March, respectively) and span from the mangrove shorelines south of Matheson Hammock (south Biscayne Bay) southwest along Card Sound and Barnes Sound (Manatee Bay; ***Figure F-6***). Other sampled shorelines include those near the Oleta River (northern Biscayne Bay) and western edge of the northernmost Keys (i.e., Sands and Elliot Keys). The latter serve as reference sites that are beyond the direct influence of CERP activities. The anticipated number of transects (i.e., stations) per shoreline per season will be adjusted to optimize statistical power to detect change

(Integrative Assessment Team, 2004). Thus far, 145 stations per season have been sufficient. Exact transect locations will continue to be chosen based on previous fish density and diversity information as well as measured and modeled salinity variation.

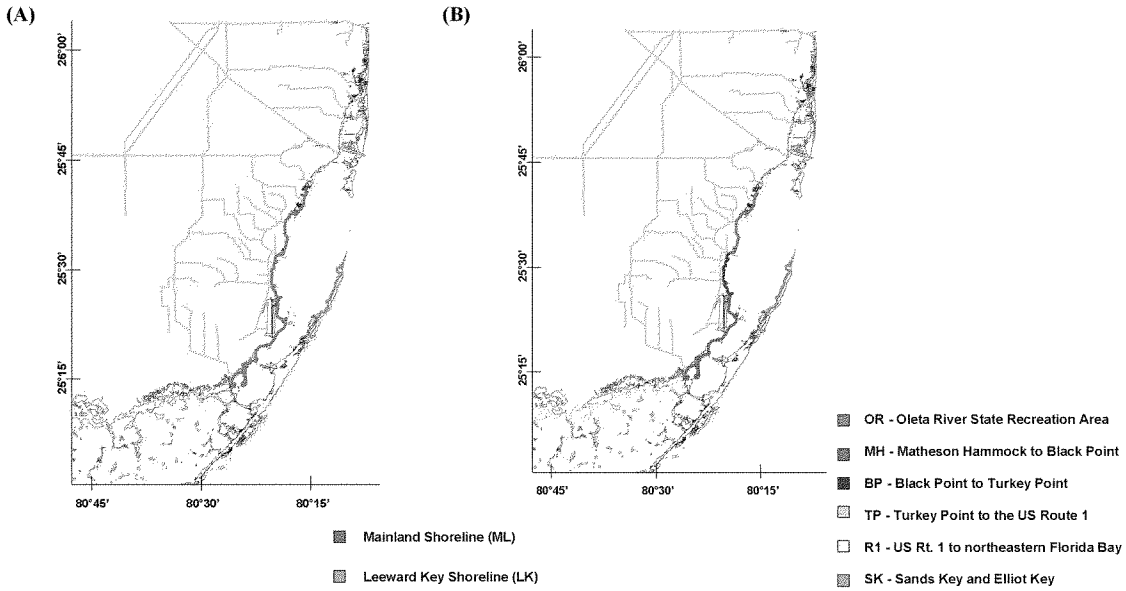

FIGURE F-6: MONITORING AND ASSESSMENT PLANS INDICATING THE SPATIAL DOMAIN OF THE SHORELINE FISH COMMUNITY VISUAL ASSESSMENT MONITORING COMPONENT. DEPENDING ON THE FISH COMMUNITY METRIC, ANALYSES WERE CONDUCTED AT THE LEVEL OF SHORELINE (A) OR SHORELINE SEGMENT (B)

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F.2.6.3 Literature Cited

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F.2.6.4 Biscayne Bay Coastal Wetland Fish Communities (Monitoring and Assessment Plan Activity Number 3.2.3.3)

Since 2002, dwarf mangrove wetlands that line the mainland of southern Biscayne Bay have been monitored by the NOAA/NMFS to evaluate the demersal prey base fish community in reference to salinity and water levels that fluctuate on inter-annual and seasonal cycles. These habitats have been largely neglected by existing and historical monitoring programs because of difficulties associated with access to the shallow water and tightly spaced trees within the mangrove swamp. Similar studies have been performed in the mangrove habitats in northeastern Florida Bay and have demonstrated that this fish community responds to changes in salinity and water depth (Lorenz, 1999); water management practices have been implicated to explain some of these changes (Lorenz, 1999; Lorenz and Serafy in press). These fishes are excellent subjects for studies relating faunal changes to changes in physical conditions such as those proposed by CERP. By assessing this fish community, the relative value of the wetlands to these higher trophic levels can be inferred. Because of their relatively quick response time to changes in hydrologic conditions and

because of their trophic importance, this fish community is an ideal attribute for assessing the impacts of CERP related projects. The goal of this MAP activity is to provide: (1) a comprehensive, spatially-explicit baseline database on the seasonal species composition, distribution, diversity, and abundance of demersal fishes that constitute the prey base in mangrove habitats; and (2) relate fish abundance and community structure with changes in salinity and water level that may be altered by future CERP activities. Water level and salinity are continuously monitored at the four fish sampling sites by existing hydrostations. Because the exact timing of both CERP-related changes and associated ecological responses are unknown, a long-term approach to monitoring is critical for these habitats.

The methods used by Lorenz et al., (1997) and Lorenz (1999) in less impacted, more frequently wetted wetlands adjacent to northern Florida Bay will be employed in the southern Biscayne Bay mainland coastal wetlands at four locations in Manatee Bay, Barnes Sound, Card Sound and Turkey Point. A nine-square meter drop net method developed for sampling fish in the coastal creek/open wetland flats type of habitat samples small demersal fish effectively and without bias (Lorenz et al., 1997) will be used. Nets will be set up, left in place overnight, and deployed the following day within two hours after sunrise. Each net will surround an individual dwarf mangrove tree, thereby sampling both prop-root habitat and the open area between trees. Trees for sampling will be selected so that each site has a similar array of tree sizes with roughly equivalent prop-root density sampled between sites. Six nets will be used during each sampling trip, with three deployed in each sub-habitat (flats and creek). Previous studies (Lorenz et al., 1997; Lorenz 1999) indicate that the abundance of demersal fishes differs between creeks and flats or deep and shallow areas in the case of freshwater wetland sites, even though salinity was uniform across the two sub-habitats, thereby indicating a need to stratify sampling effort. Fish will be cleared from the net using rotenone, a fish toxicant.

F.2.6.5 Literature Cited

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F.2.6.6 South Florida Seagrass Fish and Invertebrate Assessment Network (Monitoring and Assessment Plan Activity Number 3.2.3.5 and 3.2.4.5)

Studies quantifying seagrass-associated fish and invertebrate community composition and abundance using the one-square meter throw-trap as used in Fish and Invertebrate Assessment Network (FIAN) have been ongoing in south Florida since 1983 (Robblee et al., 1991). In southern Biscayne Bay a three-year pre-MAP dataset exists (funded by the SFWMD, Biscayne Bay Initiative). This MAP project enhances the data available from previous studies by providing a regional context; FIAN samples 19 monitoring locations in Florida Bay, Biscayne Bay and the southwest mangrove coast including Whitewater Bay. To the extent possible FIAN monitoring locations coincide with locations sampled previously; sites where long-term data are available, Johnson Key Basin in western Florida Bay and north and south of Black Point in southern Biscayne Bay, are included explicitly as monitoring locations in FIAN.

The goal of this project is to assess the success of upstream water management activities related to restoration through observation and analysis of the response of the nearshore epibenthic fish and invertebrate (shrimp and crab) communities in south Florida Bay estuaries. Specific objectives include: 1) quantifying fish and invertebrate (caridean and penaeid shrimp, crabs) species abundance and community composition at 19 locations in Florida Bay, along the southwest mangrove coast including Whitewater Bay, and in Biscayne Bay (including Card and Barnes Sounds and Manatee Bay) and 2) linking species abundance and community composition with measures of habitat (i.e., seagrass/algae characteristics, water depth) and environment (i.e., salinity, temperature, turbidity). This project will quantify change and trends in the nearshore epibenthic fish, shrimp (including the pink shrimp) and crab communities in response to upstream restoration activities as a means of assessing the success of CERP. An understanding of habitat relations will be developed by direct measurement and through coordination with the MAP seagrass monitoring project; results to date demonstrate that an understanding of species and community habitat relations is essential as a covariate in analyses relating species and community responses to salinity a primary variable affected by restoration.

In FIAN, seagrass-associated fish and invertebrates are sampled with the one square meterthrow-trap at 19 locations within three south Florida regions: Biscayne Bay, Florida Bay, and the southwest mangrove coast including Whitewater Bay (***Figure F-7***). Collections are made biannually at the end of the dry season (April-May) and at the end of the wet season (September-October). At each monitoring location, sampling occurs within a randomly-sited grid of 30, equal sized, tessellated hexagonal cells established in coordination with the MAP seagrass monitoring component (South Florida Fish Habitat Assessment Program FHAP-SF); 18 of the 19 FIAN monitoring locations and grids coincide

with those used in FHAP-SF; Ponce de Leon is the only FIAN monitoring location that is not also a FHAP-SF location. Grid-size, while equal at monitoring locations, differs across FIAN (***Table F-10***). A distinct advantage of this sampling design is that it ensures that sampling encompasses gradients of environment and habitat present at each monitoring location. For each collection, one throw-trap sample is randomly located within each of the 30 grid-cells at each of the 19 monitoring locations, resulting in 570 samples collected each season. Animals trapped in the throw-traps are removed with five passes of a sweep-net. Material collected in each sweep is maintained separately in the field and processed separately in the laboratory. This procedure has been demonstrated to remove 95 percent or more of penaeid and caridean shrimps and small fishes from the throw-trap. Scuba is used to sample in water deeper than about 75 centimeters; cover nets seal the open top of the throw-trap in water deeper than 45 centimeters. Surface and bottom temperature and salinity, water depth and sediment depth are measured with each sample. Benthic vegetation (seagrass and/or algae) in the vicinity of each animal sample is characterized using Braun-Blanquet[2] cover/abundance estimation; the Braun-Blanquet technique is the standard method (Fourqurean et al., 2002) used in FHAP-SF and generally for monitoring seagrasses in south Florida.

[2] Potential revision to current methodology may be advised. Quantitative data would be more valuable; percent cover is just as fast as and much more accurate than BB.

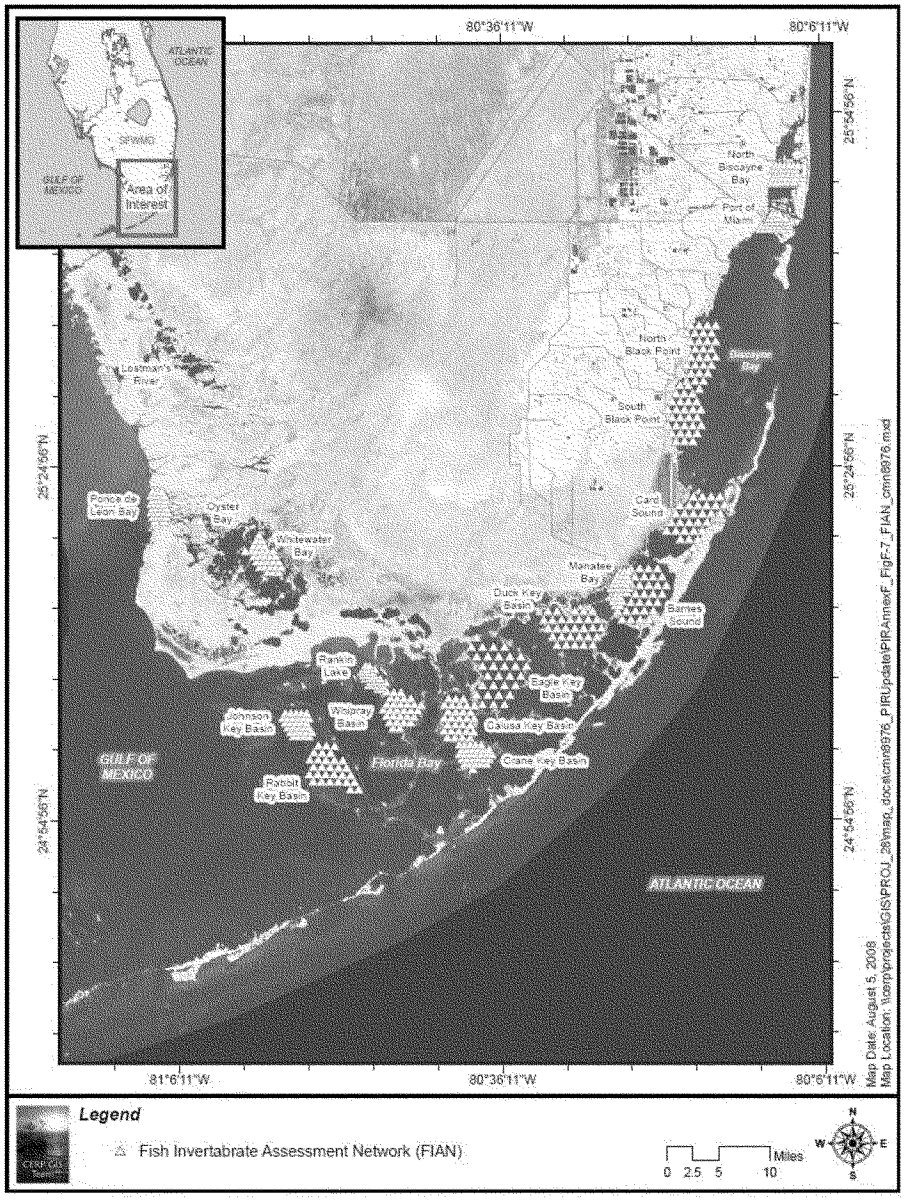

FIGURE F-7: MONITORING LOCATIONS INCLUDED IN FIAN

TABLE F-10: GRID-CELL SIZE AND GRID CENTER LOCATION FOR SOUTH FLORIDA FISH AND INVERTEBRATE ASSESSMENT NETWORK MONITORING LOCATIONS

Monitoring Location	Cell Area (hectares)	Cntr. Longitude	Cntr. Latitude
North Biscayne Bay	46.14	-80.15813	25.82800
Port of Miami	35.35	-80.17312	25.75858
North Black Point	162.51	-80.29142	25.57599
South Black Point	162.80	-80.31755	25.48800
Card Sound	185.30	-80.30153	25.34344
Barnes Sound	185.55	-80.38268	25.23558
Manatee Bay	46.36	-80.41760	25.24600
Duck Key Basin	185.48	-80.49211	25.18840
Eagle Key Basin	259.81	-80.61069	25.12563
Calusa Key Basin	118.28	-80.67040	25.06035
Crane Key Basin	64.95	-80.64598	25.00943
Rankin Lake	30.01	-80.80405	25.11816
Whipray Basin	101.41	-80.76139	25.07375
Johnson Key Basin	59.86	-80.92022	25.05295
Rabbit Key Basin	146.02	-80.86949	24.99069
Lostmans River	18.06	-81.21365	25.54068
Ponce de Leon Bay	46.36	-81.13663	25.36140
Oyster Bay	18.09	-81.07477	25.32688
Whitewater Bay	72.41	-80.97170	25.28950

F.2.6.7 Literature Cited

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Robblee, M. B., S. D. Jewell, and T. W. Schmidt. 1991. Temporal and spatial variation in the pink shrimp, Penaeus duorarum, in Florida Bay and adjacent waters of Everglades National Park. SFRC, Everglades National Park, Homestead Florida. Annual Report. 28 pp.

F.2.6.8 Epibenthic Fauna Adjacent to the South Biscayne Bay Shoreline in Relation to Seagrass, Shoreline Fishes, and Freshwater Change in the Comprehensive Everglades Restoration Plan/Southern Estuaries Module Domain (Monitoring and Assessment Plan Activity Number 3.2.4.7)[3]

This MAP project examines the relationship of nearshore seagrass/algal habitat quality (food, shelter, environmental conditions) to game and reef fish populations sheltering in the adjacent mangrove fringe. This project builds upon a two-year database acquired by the NOAA/NMFS and USGS scientists as part of a more spatially extensive project to develop baseline information on the nearshore epifauna of western South Biscayne Bay. The epifauna covered by this project include fishes (mainly small forage fish and toadfish) and decapod crustaceans (crabs and penaeid and caridean shrimps) associated with the bay bottom or the seagrass canopy. The previous project provides three-years of throw-trap data on the larger study area. The database that will be continued with this MAP project is focused on the very shallow open-water area immediately adjacent to the shoreline. Since inception, this project has been integrated in space and time with MAP SE 3.2.3.6, which surveys fish along the mangrove shoreline. This project also is integrated with the fiscal year (FY) 2007 NOAA project on mapping the benthic habitat in the very shallow area adjacent to the shoreline. Information from this project will provide input to an integrated GIS database on habitat and fauna that is being developed as part of the benthic habitat survey. In focusing on the very shallow open-water area along the shoreline, this project differs from, and complements, MAP SE 3.2.3.5 and MAP SE 3.2.4.5, which, in combination, constitute the South Florida FIAN. The network is based on a number of sampling grids strategically located in estuarine areas from the southwest Florida coast to northern Biscayne Bay. Three grids are located in western South Biscayne Bay and a few of the sampling cells of these grids overlap with the very nearshore coverage of this project, which will enhance the ability to integrate the two projects and expand the information obtained.

The objectives of this project are to (1) develop a baseline[4] characterization of the epifauna of the very shallow open-water area immediately adjacent to the South Biscayne Bay shoreline, including species density and size distribution and community composition; (2) relate species density and community metrics to salinity regime; (3) relate species occurrence, concentration, density, and size structure, as well as community metrics (e.g., evenness, diversity) to habitat characteristics (i.e., taxa, canopy height, and relative density of bottom vegetation) measured in association with faunal sampling; and (4) examine

[3] Potential revision to current methodology may be advised. Combining this activity with MAP 3.2.4.5 might represent cost-savings and improve interpretability.

[4] Three years of data currently exist. Baseline condition may already be documented.

potential functional relationships between open-water epifauna and shoreline fishes such as gray snapper, schoolmaster snapper, and great barracuda and the possible influence of salinity regime on these relationships. CERP will alter salinity patterns first and most profoundly in the very shallow water in close proximity to shore; therefore, the focus of this project on the very nearshore zone should enable early detection of changes brought about by CERP. The intensive epifaunal sampling strategy of this project will provide relatively dense coverage of a habitat that is similar in terms of water depth and distance from shoreline, but exposed to a wide range of salinities, from near zero to greater than 40 psu (Johnson et al., 2006). The open-water area immediately adjacent to the shoreline experiences greater spatial and temporal variation in salinity than is experienced even a short distance farther offshore and provides a range of vegetative coverage from dense seagrass to bare-bottom. Braun Blanquet[5] cover estimates made in conjunction with faunal sampling during the 2005 dry and wet seasons indicated that the bottom vegetation is *Halodule wrightii*, *Thalassia testudinum*, or a mixture of the two species--or macroalgae of various species, alone, or in combination with one of the other seagrasses. Our 2005 sampling indicates that a portion of the area sampled contains little or no vegetative cover. A sediment depth map by Lirman et al., (2006) indicates a range of sediment depths from zero to 50 centimeters along this shoreline. The ability to detect ecological changes, when they occur, will be enhanced by the development of an extensive database on epifaunal distributions in conjunction with bottom habitat and salinity along the shoreline.

The monitoring area is located within BNP along the western nearshore of Biscayne Bay between Matheson Hammock to the north and Federal Highway U.S. 1 to the south. Initially, 47 sites, corresponding in latitude to many of the shoreline sampling sites of the visual survey (MAP SE 3.2.3.6), were sampled for epifauna. This MAP project expands the epifaunal sampling area southward to correspond to other visual survey sites on western shoreline of Manatee Bay and Barnes Sounds, adding up to 25 sites. The epibenthic community sampling sites are located in the shallow open-water zone in close proximity to shoreline fishes visual survey transects and at roughly the same latitude. The general study area (i.e., length of shoreline) will be adjacent to a subsection of the visual-fish survey project and was selected based on our previous work in a larger study area (as part of the Biscayne Bay Epifaunal Performance Measures Study co-funded by NOAA and the SFWMD). The sites will be sampled bi-annually during the months January-February (Dry Season) and August-September (Wet Season). This schedule corresponds to the sampling schedule of the visual surveys. The selected gear for this monitoring activity is the 1 m^2 throw-trap of Robblee et al. (1991) and is consistent with other epifaunal monitoring in the southern estuaries (MAP SE 3.2.3.5 and MAP SE 3.2.4.5). The throw-trap

[5] Quantitative measurements are advised.

samples a one square meter area of bottom and can be used in depths ranging from a few centimeters to more than three meters. The throw-trap is most successful at collecting organisms that shelter in benthic habitats with vegetative cover of seagrass and/or algae. Organisms primarily sampled include penaeid and caridean shrimps, crabs, and small fish. In conjunction with the throw-trap, a visual estimate of benthic habitat (i.e., seagrasses, macroalgae) is also made at each of the sampling sites. Trained observers follow the Braun-Blanquet visual survey method as outlined by Fourqurean et al. (2002) to estimate abundance, distribution and percent coverage of benthic organisms. The sediment or bottom type is also recorded. The data from on-site Braun-Blanquet sampling will be compared with the benthic habitat map developed by the associated NOAA FY 2007 Southern Estuaries project (Lirman et al., in press). Conductivity, temperature, salinity, dissolved oxygen, and pH will be measured with a YSI Model 556 recording instrument, which also notes time of day. Water samples will be collected for salinity confirmation in the lab using an Argent salinometer[6]. Water depth[7] will be measured with a ruled (one-centimeter increments) poly-vinyl chloride (PVC) pipe. Sediment depth will be measured with a ruled pipe or rod.

F.2.6.9 Literature Cited

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Johnson, D. R., J. A. Browder, J. Serafy, M. B. Robblee, and D. S. Hazra. 2006. EpibenthicFauna Adjacent to the South Biscayne Bay Shoreline in Relation to Seagrass, Shoreline Fishes, and Salinity. Report to the South Florida Water Management District under Agreement C-13401 by the Southeast Fisheries Science Center, NOAA/National Marine Fisheries Service, Miami, Florida, and the Center for Water and Restoration Studies, U.S. Geological Survey. 59 pp.

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[6] Potential revision to current methodology may be advised. Use of an argent salinometer in a laboratory setting likely not required as properly calibrated YSI probes possess precision satisfactory for intended use.
[7] Potential revision to current methodology may be advised. Water level measurements should reflect tidal stage.

Robblee, M. B., S. D. Jewell, and T. W. Schmidt. 1991. Temporal and spatial variation in the pink shrimp, Penaeus duourarum, in Florida Bay and adjacent waters of Everglades National Park. Annual report of South Florida Research Center, Everglades National Park. Homestead, FL.

F.2.6.10 Documenting Everglades Restoration Impacts on Biscayne Bay's Shallowest Benthic Habitats (Monitoring and Assessment Plan Activity Number 3.2.3.3)

Since 2004, nearshore benthic habitats (less than 500 meters from shore) of southern Biscayne Bay have been monitored by scientists from the University of Miami and the NOAA's National Geodetic Survey (NGS) and the NMFS to evaluate spatial patterns of abundance of SAV in relationship to distance to shore and water management canals that discharge freshwater from upland sources (Lirman et al., 2006). These habitats have been largely neglected by existing and historical monitoring programs presumably because of difficulties associated with access to extreme shallow zones (less than one-meter in depth). The initial findings of this effort have already indicated distinct seasonal and species-specific patterns of abundance and spatial distribution of seagrasses and macroalgae that are directly influenced by the inflow of freshwater into nearshore Biscayne Bay. These areas are critical nursery habitats for pink shrimp (Diaz, 2001) and economically-valuable fishes such as gray snapper, hogfish, spotted seatrout and pinfish (Serafy et al., 1997; 2003; Faunce et al., 2002). The goal of this MAP activity is to provide: (1) a comprehensive, spatially-explicit baseline database on the seasonal species composition, distribution, diversity, and abundance of benthic organisms that constitute the nearshore seagrass, macroalgal, and hardbottom communities of Biscayne Bay; and (2) detailed, high resolution environmental data (i.e., temperature and salinity) that are essential to relate the current status and future changes of benthic communities to these physical parameters at a scale commensurate with the proposed benthic surveys. Because the exact timing of both CERP-related changes and associated ecological responses are unknown, a long-term approach to monitoring is critical for these habitats. This project expands the coverage of seagrass monitoring activities conducted by Durako and Hall (Florida Fish Habitat Assessment Program [FHAP]) and DERM that currently have a limited number of sampling stations in western Biscayne Bay's shallowest habitats. Miniature (four centimeters in length) salinity and temperature sensors will be deployed at locations chosen to expand the spatial coverage of sensors used by BNP and USACE into in the extreme shallows of Biscayne Bay. These habitats have often been neglected because of restricted boat access and because most water quality instruments are too large to be deployed there. This research will expand the coverage of ongoing modeling and monitoring activities into the shallowest portions of Biscayne Bay, and provide data needed to parameterize hydrodynamics, water quality, fisheries, and ecological models being developed for the region.

The research objectives for this projects are to: (1) continue seasonal video surveys of the SAV components of the nearshore (less than 500 meters from shore) environment of southern Biscayne Bay using an innovative benthic survey technology, the Shallow Water Positioning System (SWaPS) developed by scientists from NOAA's NGS (Lirman et al., 2006); (2) document salinity and temperature patterns of nearshore habitats by deploying arrays of miniature sensor/loggers that collect high resolution data from these habitats that are positioned to allow CERP-related effects to be detected; (3) link patterns of salinity and freshwater inflow from canals and groundwater sources with the abundance, diversity, and distribution of SAV and other benthic organisms like corals and sponges; (4) link the results of the proposed benthic surveys with the results of the surveys of fish and macroinvertebrate community dynamics being conducted in the same areas to investigate potential correlations in relation to higher trophic levels; (5) analyze the existing data collected from more than 400 sites to develop an efficient and statistically robust survey design that will increase the efficiency of the surveys and maximize the statistical power to detect changes in the diversity, abundance, and distribution of benthic organisms as CERP projects are implemented; (6) integrate the data collected into a web-based GIS framework that can be easily accessible to scientists and managers; and (7) develop a centralized GIS framework to explore the relationship between benthic and mobile fauna in western Biscayne Bay that will incorporate the information collected by the present MAP project with that collected by Dr. Serafy (shoreline fishes) and Drs. Browder and Robblee (macroinvertebrates), and will provide much-needed geospatial analytical capabilities to these complementary MAP activities.

This study documents the temporal and spatial patterns of abundance and distribution of benthic organisms in Biscayne Bay using the SWaPS. This system, installed in a shallow-draft skiff, uses a geographic positioning system (GPS) receiver centered over a gimbaled digital camcorder that is suspended in a glass enclosure and provides a clear view of the bottom. As part of the expanded FHAP program, Drs. Hall and Durako survey benthic communities between Matheson Hammock and Turkey Point[8]. However, only 16 of their survey polygons are positioned along the shoreline and sites less than 85 centimeters in depth are avoided for logistical reasons (M. Durako, personal communication). This survey protocol is designed specifically to monitor habitats less than one meter of depth. Moreover, the information collected from more than 400 sites located within the nearshore habitats of southern Biscayne Bay provide a spatial resolution in SAV abundance and distribution presently not available for these important and susceptible environments. Seasonal surveys (wet season, dry season) are conducted between Matheson Hammock and Turkey Point using a

[8] Potential revision to current methodology may be advised. Duplicative efforts seem apparent; it may be advisable to eliminate FHAB expansion into Biscayne Bay, replacing it with this sampling methodology.

stratified random sampling design based on the Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program sampling protocol (Jackson et al., 2000). Nearshore habitats are divided into five 100 meter buffers (strata) at increasing distance from shore. These strata are further divided into equal-size cells and one survey point is generated within each subdivision at random. The GPS coordinates for each point are exported into a GPS for navigation in the field. The video collected during SWaPS surveys is post-processed by "grabbing" non-overlapping frames and storing these as digital images that are analyzed to determine: 1) spatial distribution of seagrasses, macroalgae, and hardbottom organisms (identified to species level when possible); 2) species richness; and 3) abundance and percent cover. For each survey location (i.e., a transect less than 25 meters along the survey track), ten non-overlapping geo-referenced images are chosen at random from the image library and percent cover is estimated[9] for each benthic category using the Braun-Blanquet method used by the Florida Bay and Florida Keys National Marine Sanctuary (FKNMS) seagrass monitoring programs (Fourqurean et al., 2002). In addition to these large-scale surveys, detailed surveys in the immediate vicinity of the seven main canals that discharge freshwater into our study area (Mowry, Military, Princeton, Black Creek, Cutler, Snapper Creek, and Coral Gables Canals) are conducted. These sub-areas are sampled yearly during the wet season in a grid pattern centered near each canal with sites at 50 meter intervals. The benthic communities are characterized as described to evaluate baseline patterns in these areas where the most extreme salinity fluctuations have been recorded due to the seasonal discharge of freshwater from water management structures (Lirman et al., 2006). The data collected for each survey site are incorporated into a GIS platform to produce contour maps[10] of community and species abundance and distribution.

F.2.6.11 Literature Cited

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Faunce, C.H., J.J. Lorenz, J.E. Ley and J.E. Serafy. 2002. Size structure of gray snapper (*Lutjanus griseus*) within a mangrove "no-take" sanctuary. Bulletin of Marine Science 70:211-216.

[9] Potential revision to current methodology may be advised. Direct measurement can easily replace estimation, improving data quality.
[10] This design does not appear to be appropriate for interpolating within GIS, which may require revision of analysis methodology.

Fourqurean, J. W., Durako, M. J.; Hall, M. O., and Hefty, L. N. 2002. Seagrass distribution in South Florida: a multi-agency coordinated monitoring program. *In*: Porter, J.W. and Porter, K.G. (eds.). *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. An Ecosystem Sourcebook*. CRC Press, Boca Raton, Florida. pp. 497-522.

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Lirman, D., G. DeAngelo, J. Serafy, A. Hazra, D. S. Hazra, A. Brown. 2006. Geospatial video monitoring of nearshore benthic habitats of western Biscayne Bay (Florida, USA) using the shallow-water positioning system (SwaPS). Journal of Coastal Research.

Serafy, J.E., C.H. Faunce and J.J. Lorenz. 2003. Mangrove shoreline fishes of Biscayne Bay, Florida. Bulletin of Marine Science 72: 161-180.

Serafy, J.E., K.C. Lindeman, T.E. Hopkins and J.S. Ault. 1997. Effects of freshwater canal discharge on fish assemblages in a subtropical bay: field and laboratory observations. Marine Ecology Progress Series 160: 161-172.

F.2.7 Biscayne Bay Fish Monitoring

Under the auspices of a $750,000 contract, the Florida Fish and Wildlife Conservation Commission (FWC) is executing work intended to satisfy four broad objectives:

1. Establish pre-CERP reference state including variability for each of the performance measures.
2. Determine the status and trends in the performance measures.
3. Detect unexpected responses of the ecosystem to changes in stressors resulting from CERP activities.
4. Support scientific investigations designed to increase ecosystem understanding, cause-and-effect, and interpret unanticipated results.

This work is intended to support the southern estuaries module of the MAP and is directly linked to the monitoring or research component identified in that module as number 3.2.3.3, FHAP-SF. The CERP requires system-wide monitoring of ecological performance measures. The purpose of the monitoring plan is to follow the status and trends of a suite of performance measures in response to CERP-project implementation. The Florida Bay Fisheries Habitat Assessment Program (FHAP-FB) has provided spatially explicit data on the distribution, abundance, and population dynamics of Florida Bay seagrasses and

macroalgae since 1995. Using Braun-Blanquet analysis to estimate macrophyte cover/abundance, and coring to measure seagrass shoot densities and biomass, FHAP-FB has quantified[11] spatial and temporal changes in macrophyte communities through the production of distribution and abundance maps, change maps, and summary graphic and tabular products.

The seagrass monitoring program described herein (FHAP-SF) will expand in geographic scope from ten sampling locations in Florida Bay (FHAP-FB study sites) to a total of twenty-eight locations extending from Lostman's River to Biscayne Bay. These additional sampling locations were selected because they are likely to exhibit changes in response to CERP activities. In addition, FHAP protocols will expand to provide process-oriented data for *Thalassia testudinum* such as photosynthetic quantum yields, reproductive status, and epiphyte loads that may vary in response to CERP activities. By following the status and trends of the major macrophyte species in terms of distribution, abundance, reproductive and physiological status (eco-indicators), FHAP-SF will provide information that will directly support the objectives of the CERP MAP.

In addition to directly addressing MAP 3.2.3.3, FHAP-SF will coordinate seagrass monitoring efforts with faunal sampling conducted by in the Seagrass FIAN (MAP 3.2.3.5). Throw-trap fish and invertebrate monitoring coupled with FHAP-SF seagrass abundance measurements will provide valuable data for development and verification of higher-trophic-level ecological modeling and for interpreting faunal responses to changes in salinity (Browder et al., 1999; Browder et al., 2002). By quantifying the abundance and dynamics of south Florida seagrass communities, and by coordinating with the Seagrass FIAN project, FHAP-SF will address the CERP premise that restoring favorable flow and salinity regimes in south Florida near-shore waters will improve seagrass habitat and enhance the function of Florida Bay and the southwest Florida shelf as a nursery ground for fisheries species.

The goal of FHAP-SF is to provide information for spatial assessment and resolution of inter-annual variability in seagrass and macroalgal communities, and to establish a baseline to monitor responses of s these communities to water-management alterations associated with CERP activities. FHAP-SF will document the status and trends of seagrass distribution, abundance, and reproduction, as well as provide process-oriented data such as photosynthetic quantum yields[12] and epiphyte loads. Resource managers will be able to use these data to address ecosystem-response issues on a real-time basis, and to weigh alternative restoration options.

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[11] Quantification with qualitative data may be problematical, and may require revision of methodology.
[12] Degree of resolution, experimental and controversial methodology proposed to measure photosynthetic rates; may constitute redundancy with other monitoring elements (e.g. Lirman's and DERM's).

Specific objectives of FHAP-SF are:

- to develop a basic understanding of the relationships among salinity, water quality and seagrass species distribution and abundance in south Florida,
- to provide data to separate anthropogenically induced changes from natural system variation, and
- to verify model predictions on species- and ecosystem-level responses to system perturbations.

FHAP-SF will continue to monitor seagrasses in the ten Florida Bay basins that have been sampled since 1995 in FHAP-FB. An additional 18 locations will be selected to extend the geographic scope of existing seagrass monitoring programs, and to support the efforts of the Seagrass FIAN. Stations will be determined using the systematic random-sampling design employed in FHAP-FB (Durako et al., 2002). Sampling for FHAP-SF will be conducted once per year, at the end of the dry season (May-June). Salinity stress on seagrasses may be highest at this time, and this is the period when the dominant seagrass of the region, *Thalassia testudinum* approaches maximum leaf biomass, increasing our ability to detect changes in cover. Reproductive effort (flowering and fruit development) can also be assessed at this time.

In order to characterize macrophyte community structure on the spatial scale[13] required for CERP, sampling protocols must be relatively rapid, but must be precise enough to detect change. Seagrass cover will be visually quantified at each station using a modified Braun-Blanquet frequency/abundance scale (Mueller-Dombois and Ellenberg, 1974; Fourqurean et al., 2002). This method is very quick, requiring only minutes at each sampling site; yet it is robust and highly repeatable, thereby minimizing among-observer differences. Changes in water quality associated with increased freshwater inflow may lead to higher levels of water column nutrients and increased seagrass epiphyte loads. At sites where seagrasses are present, short-shoots will be collected to determine leaf epiphyte biomass. Changes in photosynthetic characteristics of seagrasses in response to environmental changes may occur before changes in standing crop, density, and cover become apparent. Quantum yields and photosynthetic efficiencies will be measured for *Thalassia testudinum* at each station where it is observed by measuring chlorophyll fluorescence *in situ*.

[13] Scale is important consideration.

F.2.7.1 Literature Cited

Browder, J. A., V. R. Restrepo, J. K. Rice, M. B. Robblee, and Z. Zein-Eldin. 1999. Environmental influences on potential recruitment of pink shrimp, Farfantepenaeus duorarum, from Florida Bay nursery grounds. Estuaries 22:484–499.

Browder, J.A., Z. Zien-Eldin, M.M. Criales, M.B. Robblee, S. Wong, T.L. Jackson, and D. Johnson. 2002. Dynamics of pink shrimp (Farfantepenaeus duorarum) recruitment potential in relation to salinity and temperature in Florida Bay. Estuaries 25(6B): 1355-1371.

Durako MJ, Kunzelman JI. 2002. Photosynthetic characteristics of Thalassia testudinum measured in situ by pulseamplitude modulated (PAM) fluorometry: methodological and scale-based considerations. Aquat Bot 73:173–185

Fourqurean, J. W., Durako, M. J.; Hall, M. O., and Hefty, L. N. 2002. Seagrass distribution in South Florida: a multi-agency coordinated monitoring program. *In*: Porter, J.W. and Porter, K.G. (eds.). *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. An Ecosystem Sourcebook*. CRC Press, Boca Raton, Florida. pp. 497-522.

Mueller-Dombois, D., and H. Ellenburg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York.

F.2.8 Biscayne Bay Submerged Aquatic Vegetation Monitoring

The DERM employs FHAP-FB protocols in Biscayne Bay and northeastern Florida Bay, and the Florida Keys National Marine Sanctuary use FHAP-FB protocols in their seagrass monitoring programs. The establishment of compatible sampling protocols among these three large-scale programs has provided a mechanism for the establishment of a regional management-oriented database of unprecedented geographic scope (Fourqurean et al., 2002). FHAP-FB data are currently being utilized to support modeling efforts[14] by the seagrass unit- and landscape-model teams and by the higher trophic-level model team. As part of the RECOVER program these data products can provide resource management agencies with significant quantitative benchmarks from which to assess the efficacy of, and system responses to, the various restoration actions being undertaken in the south Florida region as part of the CERP process.

[14] Modeling requirements may not be adequately supported with qualitative data.

These assessment data will provide scientifically defensible metrics for the RECOVER program to determine if CERP is meeting its restoration goals. Seagrasses are the dominant benthic communities in south Florida coastal waters likely to be affected by CERP, and they provide the majority of the fisheries habitat in this region. One of the main goals of CERP is to improve fisheries habitat by increasing the species diversity and areal extent of seagrass communities. An effective way to determine if this goal is being met is to establish a comprehensive seagrass monitoring program in the south Florida region.

F.2.8.1 Literature Cited

Fourqurean, J. W., Durako, M. J.; Hall, M. O., and Hefty, L. N. 2002. Seagrass distribution in South Florida: a multi-agency coordinated monitoring program. *In*: Porter, J.W. and Porter, K.G. (eds.). *The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. An Ecosystem Sourcebook*. CRC Press, Boca Raton, Florida. pp. 497-522.

F.2.9 Biscayne Bay Coastal Wetlands Area Marsh Vegetative Mapping

The objective of this work order is to produce a spatially and thematically accurate vegetation map of the Corbett and Pal Mar Natural Areas, ENP, southeastern coastal wetlands, and Big Cypress National Preserve. Biscayne Bay Coastal Wetlands are in Priority 1 zone for this effort (***Figure F-8***). Vegetation communities will be mapped with a quarter hectare minimum mapping grid unit (MMU) from 1:24,000 scale color infrared aerial photography. Each distinct vegetation community will be designated according to the *Vegetation Classification System for South Florida National Parks*.

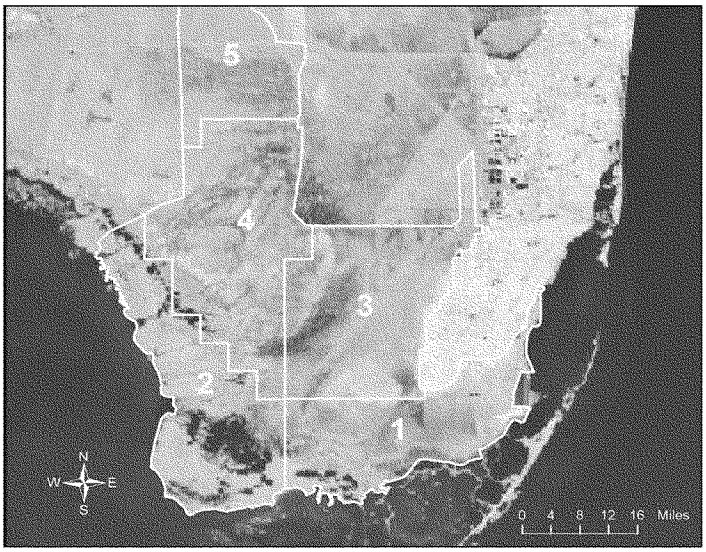

FIGURE F-8: PRIORITY FOR VEGETATIVE MAPPING. BISCAYNE BAY COASTAL WETLANDS FOOTPRINT IS LOCATED WITHIN PRIORITY 1 ZONE

F.2.10 Biscayne Bay Surface Water Quality and Biological Monitoring Program

This Cooperative Agreement with DERM and the SFWMD continues the long-term SAV and water quality monitoring network in south Florida estuaries for three years (October 01, 2006 to September 30, 2009). This cooperative program, ongoing since 1979, has established a substantial period of record that serves as a valuable baseline to evaluate estuarine restoration efforts as well as to identify potential impacts from water management activities.

An objective of the program is to maintain the long-term dataset for characterization of water quality through various climatic cycles, events and watershed changes. DERM County data are used to address Miami-Dade County water quality permitting issues and supports various non-degradation and TMDL planning activities for the Biscayne Bay Watershed. The focus of sampling is within canals and the receiving waters of Biscayne Bay. Several stations are identified in the MAP as important stations for assessment of environmental response to the CERP. Results from this program are expected to support assessment of the effect of specific CERP projects including C-111 Spreader Canal, Biscayne Bay Coastal Wetlands and the Wastewater Re-use Study.

Miami-Dade County conducts monthly surface water quality monitoring at 106 stations throughout Biscayne Bay and its watershed. Water samples are analyzed for a variety of physical, chemical and biological parameters. The primary objective of the Epibenthic Habitat Monitoring program is to identify and document spatial and temporal trends in vegetation across the area, and is executed on an annual basis at 11 fixed sites in Biscayne Bay.

A rapid[15] visual technique to survey bay bottom communities is performed at 100 randomly[16] chosen locations (***Table F-11, Figure F-9*** and ***Figure F-10***). The biological techniques are similar to that used by other researchers conducting work in Florida Bay and the Florida Keys National Marine Sanctuary using the modified Braun-Blanquet[17] cover-abundance scale. Each established benthic site will be sampled annually during the month of June. Parameters will include seagrass shoot and blade density, standing crop biomass by species, and seagrass composition along a 150 foot transect. Shoot and blade density will be determined at each station by sampling a 0.2 square meter section at each of three fixed one meter square grids. Standing crop biomass will be harvested[18] from three 0.04 square meter areas at each station. Biomass samples will be segregated by species, rinsed in a mild hydrochloric acid (HCl) solution, and then dried in an oven at 60 Celsius (C) and to a constant weight and then weighed. Navigation to sample sites is accomplished using GPS and physical line-ups.

[15] Quantifying percent cover may be equally "fast".
[16] Inference space is good but resolution and scale of measurement may be inadequate to detect restoration effects.
[17] Data collected are nominal (i.e., categorical) and the order of the ranks may have little or no significance. Calculating mean or median is not informative. Interpolation across the sampling area may be procedurally flawed.
[18] Estimation of biomass from shoot density and canopy height may be advisable as in many estuaries are strongly correlated.

TABLE F-11: EPIBENTHIC MONITORING SITES

BH06	255401.233	800756.279
BH10	255209.484	800843.021
BH14	254907.526	800941.261
BH22	254536.334	801038.634
BH29	254252.251	801239.588
BH31	253715.137	801216.803
BH34	253908.117	801535.01
BH35	253812.784	801023.033
BH36	253559.843	801410.579
BH37	253408.711	801139.897
BH39	253156.388	801818.192

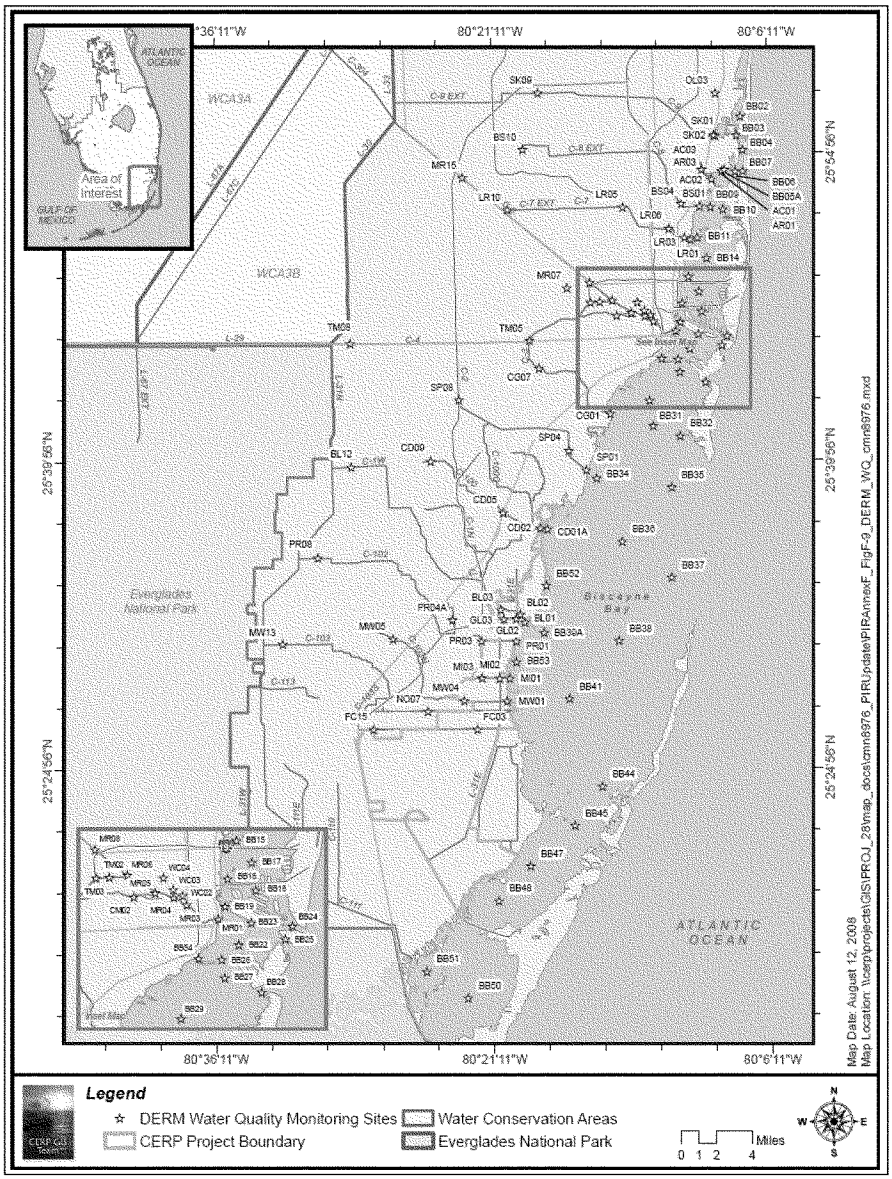

FIGURE F-9: WATER QUALITY MONITORING NETWORK– MIAMI-DADE COUNTY, DEPARTMENT OF ENVIRONMENTAL RESOURCES MANAGEMENT, SOUTH FLORIDA WATER MANAGEMENT DISTRICT

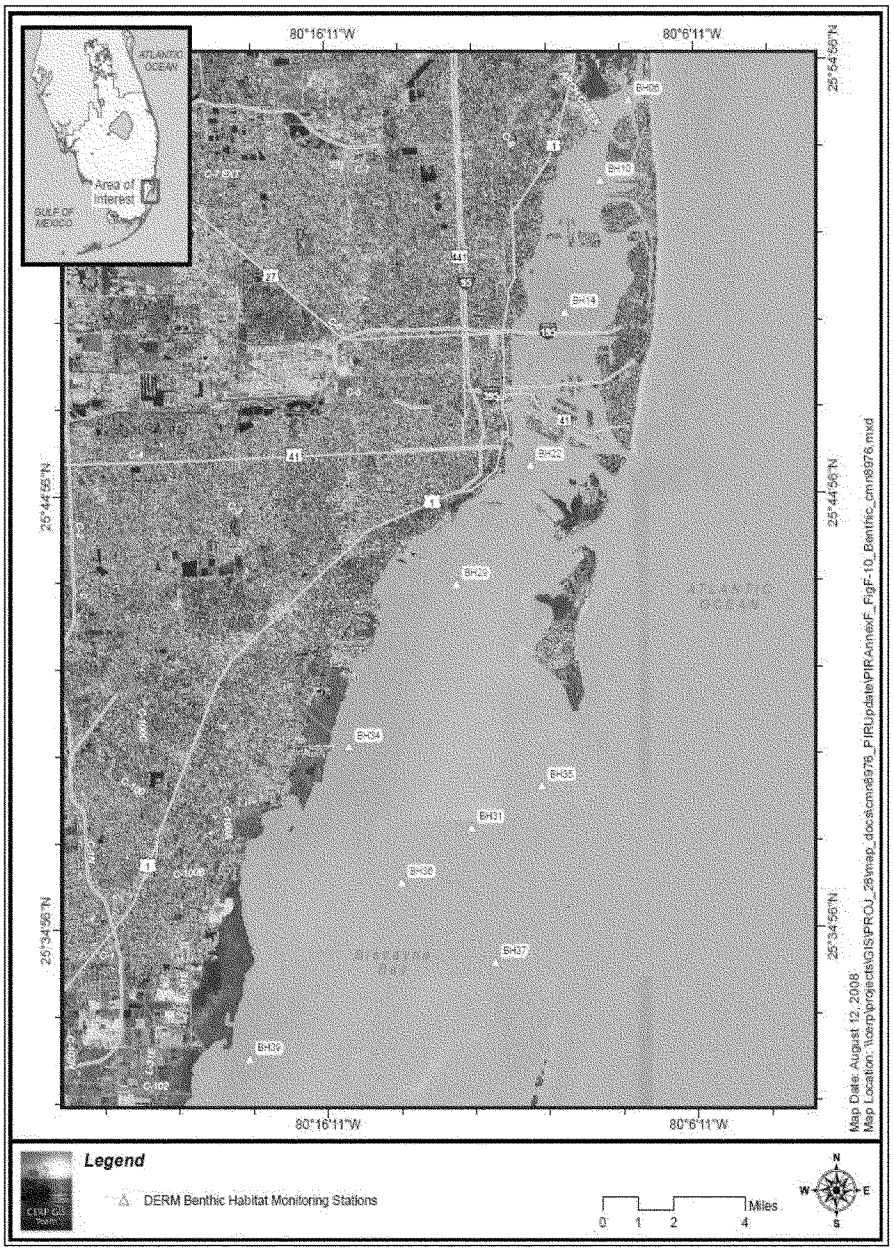

FIGURE F-10: BENTHIC MONITORING STATIONS

US Army Corps
of Engineers ®
Jacksonville District

South Florida Water
Management District

FOR CONTINUATION OF HOUSE DOCUMENT 112-145

BISCAYNE BAY COASTAL WETLANDS FINAL INTEGRATED PROJECT IMPLEMENTATION REPORT AND ENVIRONMENTAL IMPACT STATEMENT

SEE VOLUME 4