SOUTH FLORIDA WATER MANAGEMENT DISTRICT

A Review and Evaluation of the Minimum Flow and Level Criteria for Northeastern Florida Bay

Final Report

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Executive Summary

Minimum flows and levels (MFL) criteria are established to identify the threshold where further withdrawals would cause significant harm to the water resources or ecology of the area. MFL criteria represent a single element of a multi-faceted water resource management approach used by the South Florida Water Management District (SFWMD), in conjunction with restoration actions and other regulatory authorities, to protect and restore priority water bodies within the SFWMD boundaries including the Greater Everglades system. MFL criteria are not established at sustainable or restoration levels, rather they identify the threshold where water resource functions of the water body are temporarily lost due to changes in surface water or groundwater hydrology, to a degree that it would take several years to recover. Protection of the waters needed to fully restore and protect natural systems is achieved through the prevention of significant harm caused by withdrawals in combination with other regulatory tools such as water reservations or restricted allocation area rules, which ensure a sustainable healthy system over a wide range of hydrologic and demand variability.

SFWMD established MFL criteria for Florida Bay by rule in 2006 [subsection 40E-8.221(5), Florida Administrative Code]. The technical information used in the development of the MFL rule is described in a 2006 technical report by Hunt et al. (2006). As part of the evaluations contained in the technical report, it was determined that under the conditions that existed at the time, violations of the proposed MFL criteria were not anticipated to occur. A prevention strategy was adopted simultaneously with the rule to protect against an MFL violation over the twenty-year planning horizon. The specifics of this prevention strategy are described in Section 1 along with the changes outlined in the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a).

Since the rule was adopted, portions of the Modified Water Deliveries to Everglades National Park project (Modwaters) have been constructed (Tamiami Trail One-Mile Bridge), revisions to water management operations within Water Conservation Area 3A have been enacted (Everglades Restoration Transition Plan [ERTP]), and the C-111 Spreader Canal Western Project was completed in 2012. In addition, several years of research have been completed and monitoring data have been compiled in Florida Bay. Accordingly, the purpose of this report is to review the Florida Bay MFL criteria in light of new scientific data and changed conditions associated with implementation of the prevention strategy project components in order to determine if revisions to the MFL criteria and associated prevention strategy are warranted.

Four objectives were identified for evaluation under this MFL review. Objective one was to determine if the MFL criteria have been violated since the rule was established in 2006. For this evaluation, MFL flow and salinity data were reviewed in conjunction with bay ecological indicators to determine if MFL violations had occurred. Objective two was to assess the potential for meeting the MFL criteria in the future with recently completed restoration project components and operations in place (ERTP, Tamiami Trail One-Mile Bridge and C-111 Spreader Canal Western Project) and 2030 consumptive use demand projections represented. A regional model was used to evaluate flows to the bay with the three project components simulated under current and 2030 water use demand scenarios. Water use demand numbers were derived from the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a). Objective three was to determine whether the existing MFL criteria, in light of updated data and research, represent adequate thresholds for identifying significant harm to the bay. Information produced from the prevention strategy monitoring and research programs were used to assess the overall condition and responses to flows and salinity variations in order to determine if the MFL criteria are

representative of significant harm. Objective four was to examine the relationship between the flow and salinity criteria contained in the rule. In the absence of an updated version of the Flux Accounting Tidal Hydrology Ocean Model (FATHOM), exploratory statistical correlations were developed between multiple flow, stage, and salinity data sets as preliminary assessments of relationships.

Results of the evaluations conducted under this MFL review indicate that since the rule was established in 2006, the minimum annual flow criteria of the rule has been consistently achieved while the salinity criterion was exceeded three times. Despite the exceedances, the MFL salinity criterion was not violated during this time period. Assessment of ecological data collected from the bay before, during and after the salinity exceedance events indicates that, while ecological indicators of the bay pointed to impacts associated with the elevated salinity events, there were no indications of significant loss of water resource functions that would take multiple years to recover. Accordingly, the existing MFL criteria are considered to be adequate thresholds of significant harm to northeastern Florida Bay in terms of the degree of impact that could occur if the MFL criteria were violated.

Since establishment of the MFL rule, changes in hydrology are expected as a result of the newly constructed C-111 Spreader Canal Western Project and the Tamiami Trail One-Mile Bridge along with revised operational criteria for Water Conservation Area 3A (ERTP). Hydrologic simulations using SFWMD’s regional model were used to simulate effects of these new projects and operational conditions implemented since 2006. The evaluation of recent changes using a regional model showed increased flows are expected in the Taylor Slough area, especially during the dry season (Section 4.2). Comparison of overland flow at two transects within the northeastern Florida Bay watershed shows an overall increase of 13.6% in the Taylor Slough area and a decrease of 3% in the Everglades National Park eastern panhandle area. This change is due to flow that has been redistributed in the watershed due to constructed projects (C-111 Spreader Canal Western Project and Tamiami Trail One-Mile Bridge) and revisions to the water management operations within Water Conservation Area 3A.

Evaluation of future conditions showed there will be no reduction in flows to northeastern Florida Bay as a result of new water demands over the twenty-year planning horizon (Section 4.3). An analysis was conducted on projected demands for an the area south of the C-4 Canal from 2010 to 2030 for all water use classes using the demand estimates from the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a). The analysis showed a potential increase in allocation of 2.6 million gallons per day (MGD) for all use classes over the twenty-year planning horizon that have not already been permitted. The projected change in non-public water supply demands is within the uncertainty of the changes in land use projections to determine the demand estimates. At such a small scale, these demands are not significant enough to affect the flows within Florida Bay. This small increase in new urban landscape irrigation demands is projected to occur within the urban footprint rather than within the Everglades water bodies. A restricted allocation area rule that was adopted in 2007 for the Lower East Coast Everglades water bodies effectively prevents new withdrawals that could adversely affect any Everglades water bodies, including northeastern Florida Bay.

Finally, the exploratory statistical evaluations conducted under this MFL review indicated that the relationship between annual flows through the five creeks identified in the rule and salinity at the Taylor River salinity monitoring station is weak. It is recognized that several of the correlations attempted herein are not very insightful in addressing the scale and complexity of this system and that further evaluations including the use of an updated version of FATHOM are needed to improve the understanding of flows through the creeks and salinity distributions across northeastern Florida Bay. Salinity is a good indicator of ecologic conditions within the transition zone and the bay but is strongly influenced by non-withdrawal related factors such as rainfall, evapotranspiration, wind, bay currents, drainage and water management features/operations. Accordingly, assessment of significant harm in the bay as it relates to salinity criterion should consider these non-withdrawal based factors.

It is concluded that no changes to the MFL rule criteria or prevention strategy for Florida Bay are necessary at this time. Performance of the Florida Bay MFL should be periodically assessed through the Lower East Coast water supply planning process and when significant changes associated with construction and operation of future restoration project components are completed. Rule-specified monitoring and research should be continued. It is anticipated that further improvements to northeastern Florida Bay freshwater inflows will be achieved with the implementation of future Everglades restoration project components.

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Section 1. Introduction and Overview

1.1 Minimum Flow and Levels Overview

The overall purpose of the Florida Water Resources Act (Chapter 373, Florida Statutes [F.S.]) is to account for cumulative impacts of water management actions on the water resources of the state and to manage those resources to ensure their sustainability and realize their full beneficial use (Section 373.016, F.S.). To carry out this responsibility, the Water Resources Act provides the South Florida Water Management District (SFWMD) with a variety of statutory tools to be applied across a wide range of demands and hydrologic variability. These tools provide for the allocation of water to reasonable beneficial uses, the preservation, restoration and enhancement of natural systems and to promote the health, safety and general welfare of the people of south Florida.

The relationship between consumptive water use, environmental protection/restoration and hydrologic variation within SFWMD boundaries is shown in **Figure 1**. SFWMD has utilized the statutory authorities granted to manage water resources and ensure sustainability around a common level-of-certainty concept (1-in-10 year drought condition). Under this concept, both natural systems and permitted uses operate without withdrawal induced harm or water shortage cutbacks under hydrologic conditions up to and including drought conditions that are of a severity that can be expected to occur on average once every ten years. When hydrologic conditions more severe than a 1-in-10 drought occur and harm to natural systems is imminent or begins to occur, temporary water shortage cutbacks are imposed on consumptive use withdrawals that impact hydrology in the vicinity of the natural systems experiencing harm until the drought conditions subside. **Figure 1** shows that the magnitude of the water shortage cutbacks increases commensurate with the severity of the drought and the associated harm to the natural system.

Harm to the natural system can also be caused by non-withdrawal-based hydrologic impacts such as drainage, land use alterations and water management infrastructure. Often natural systems impacted by these types of alterations experience harm at a higher frequency than a 1-in-10-based drought condition. Imposition of water use cutbacks on withdrawals, which are not causing the harm, would not be effective in preventing harm or restoring the natural system. In these cases, water resource development and restoration projects or operational changes are used to restore sustainable hydrologic conditions and prevent harm. Water needed for natural system restoration associated with such projects can be reserved from allocation under authorities granted to SFWMD through Chapter 373, F.S.

Minimum flows and levels (MFL) criteria are one of the statutory tools that make up this framework as shown in **Figure 1**. The scope and context of the MFL tool revolve around the objective of preventing significant harm from occurring to priority water bodies identified by SFWMD. Specifically, Section 373.042(1), F.S. authorizes the water management districts to establish MFL criteria (minimum flows or levels) for priority surface waters and aquifers within their jurisdiction to the "…limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.…" The statute further directs water management districts to use the best information available in establishing MFL criteria. In addition, when establishing MFLs, Section 373.0421(1), F.S. provides direction to the governing boards to consider changes and structural alterations to the hydrology of an affected watershed, surface water or aquifer. The SFWMD Governing Board may determine that setting an MFL for such a water body based on its historical condition is not appropriate, if it no longer serves its historical hydrologic functions. Recovery of these water bodies to historical hydrologic conditions may not be economically or technically feasible or could cause adverse environmental or hydrologic impacts.

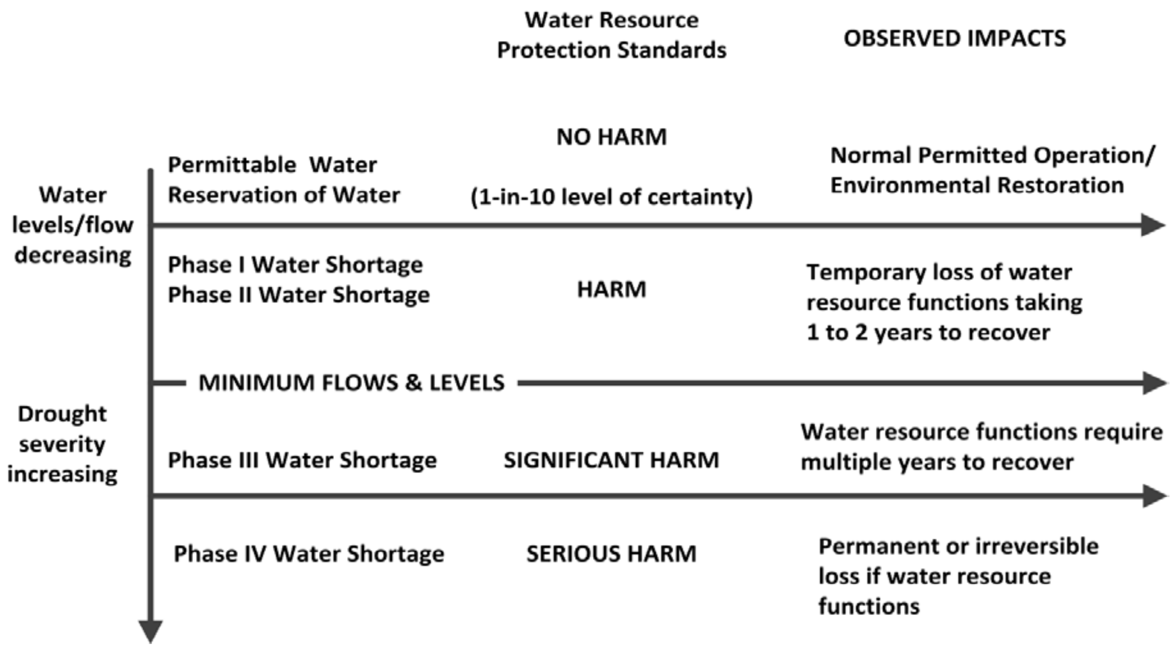

Figure 1. Conceptual relationships among the terms harm, significant harm and serious harm.

The general narrative definition of significant harm contained in subsection 40E-8.021(31), Florida Administrative Code (F.A.C.), for the water resources of an area is as follows:

> Significant Harm means the temporary loss of water resource functions, which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm. The specific water resource functions addressed by a MFL and the duration of the recovery period associated with significant harm are defined for each priority water body based on the MFL technical support document.

Accordingly, the MFL significant harm threshold is not considered a sustainable condition or indicative of a healthy natural system. Rather, MFL criteria are established for water bodies that are experiencing or are reasonably expected to experience significant harm in order to develop and expeditiously implement a recovery or prevention strategy capable of preventing significant harm from occurring. Depending on the specific causes of the significant harm, a recovery or prevention strategy could focus on reducing stress caused by withdrawals or could consist of water resource development projects and modified water management operations to address non-withdrawal-based stresses, or a combination of both.

1.2 Overview of the Florida Bay MFL Rule and Prevention Strategy

The *Lower East Coast Regional Water Supply Plan* (SFWMD 2000) included a recommendation that MFL criteria be established for Florida Bay. In 2005, SFWMD's MFL Priority List was updated to add Florida Bay for MFL establishment in 2006. The technical analyses to support the development of MFL criteria for northeastern Florida Bay was completed in 2006 (Hunt et al. 2006). This included (1) identification of Florida Bay's resources and functions, (2) surveying available information, (3) documenting historical conditions, and (4) synthesizing and analyzing data to determine relationships between freshwater inflow and ecological responses, with the purpose of identifying impacts on the bay's resources to identify threshold conditions (e.g., freshwater flow, water levels, and salinity) that impact Florida Bay's natural resources. The technical analyses to support the development of MFL criteria were completed in 2006 (Hunt et al. 2006). The MFL criteria that followed were focused on northeastern Florida Bay and its adjacent salinity transition zone (extending from the southern Everglades freshwater marshes to the open waters of northeastern Florida Bay), because this area is sensitive to managed freshwater inflow.

As detailed in the technical supporting document (Hunt et al. 2006), a resource-based approach using the submersed aquatic vegetation (SAV) indicator species *Ruppia maritima* (widgeon grass) in the Everglades-Florida Bay transition zone was used for setting the MFL criteria for northeastern Florida Bay. Inflow and salinity conditions in northeastern Florida Bay and the transition zone were considered concurrently in the development of the MFL criteria. A representative gradient traversing the transition zone into northeastern Florida Bay was used that contained monitoring information for salinity, flow, and SAV resources. This gradient comprises the following three regions:

- Ponds in the Taylor River region of the mangrove dominated transition zone containing the indicator species *Ruppia*
- Little Madeira Bay, which is a coastal embayment on the northern boundary of Florida Bay
- Eagle Key Basin, which is a northeastern Florida Bay open water area

The gradient includes SAV resources ranging from freshwater SAV (dominated by *Ruppia*) at the inland ecotone (e.g., transition zone) to mixed seagrass communities that are dominated by *Halodule wrightii* (shoal grass) and *Thalassia testudinum* (turtle grass) in the coastal transition zone of northeastern Florida Bay.

The 2006 technical evaluation and report (Hunt et al. 2006) concluded that SAV and macroalgal habitat within the Taylor River/Little Madeira Bay/Eagle Key gradient is an important feature of the Florida Bay ecosystem and are suitable indicators of the overall health of the entire transition zone and adjacent northeastern Florida Bay ecosystem. Impacts to *Ruppia* and other SAV habitat were found to occur when monthly average salinity exceeded 30 at the Taylor River salinity monitoring station. Further, long-term impacts requiring multiple years for *Ruppia* and SAV habitat to recover were considered likely to occur when average salinity exceeded 30 at the Taylor River salinity monitoring station for at least one month during consecutive years. A combination of modeling tools was used to establish a 33-year historical reconstruction of freshwater inflows and salinity conditions for northeastern Florida Bay and the Everglades-Florida Bay transition zone corresponding to locations where monitoring information for both resources and salinity existed. Based on estimates from these evaluations, an annual inflow of 105,000 acre-feet (ac-ft) to northeastern Florida Bay was determined to be generally sufficient to avoid monthly average salinity to exceed 30 at the Taylor River site, although several exceptions relative to early dry season conditions were noted. The 2006 technical report included recommendations to address some of the limitations in the existing monitoring data and evaluations.

An independent, three member, scientific panel reviewed the 2006 technical report, and provided feedback on 15 questions (Hunt et al. 2006, Appendix K). The panel members concurred that the selection of *Ruppia* as an indicator species appeared to be an appropriate candidate for evaluating the impacts of inflow to the bay. The northeastern portion of the bay was the most logical place to set the MFL criteria since it is the area most influenced by Taylor Slough, the dominant inflow source. The panel also concluded that the existing Taylor River salinity monitoring station provided an ideal measurement location as well as adequate historical data to gauge changes over time. It was indicated that the salinity-resource relationships could be expanded in the future to potentially account for the option to switch to more sensitive species (such as *Uticulara* spp.) if appropriate, but more information regarding the species composition within the transition zone would be needed. The panel agreed that the treatment of the ecology of the Florida Bay seagrass community and associated modeling was “state of the art”. However, it was also acknowledged that the treatment of the potential impact of flows on seagrass associated fauna (e.g., higher trophic levels) that utilize the SAV habitat was much less detailed and relied on correlative information. A general recommendation was suggested for continued corroborative study among active research groups (including SFWMD, Everglades National Park and Audubon) to include additional sampling and evaluation of seagrass and associated higher trophic level organisms. An adaptive management approach was recommended that included monitoring and review of the minimum inflow goal of 105,000 ac-ft per year.

Based on the 2006 technical report findings, scientific peer review findings, and stakeholder input, MFL regulatory criteria were developed and establish by rule in 2006 (40E-8, F.A.C.). The MFL criteria contained in the rule are included in **Figure 2**.

(5) Florida Bay.

(a) The minimum flow is that necessary to maintain salinity as described in paragraph (b), below. A net discharge into northeastern Florida Bay of 105,000 acre-feet of water over a 365-day period (a running total measured at West Highway Creek, at 25º14'33" north and 80º26'50" west; Trout Creek, at 25º12'53" north and 80º32'01" west; Mud Creek, at 25º12'09" north and 80º35'01" west; Taylor River, at 25º11'27" north and 80º38'21" west; and McCormick Creek, at 25º10'03" north and 80º43'55" west), is estimated to be necessary to maintain salinity as described in paragraph (b), below.

(b) An exceedance of the minimum flow criteria will be deemed to occur when the average salinity over 30 or more consecutive days exceeds 30 parts per thousand at the Taylor River salinity monitoring station, located at 25º13'29" north and 80º39'10" west. Multiple events of 30 or more day periods with salinity greater than 30 parts per thousand, occurring within a single calendar year, are considered as a single exceedance.

(c) A minimum flow violation occurs when an exceedance occurs during each of two consecutive years, more often than once in a ten-year period. By this definition, three consecutive years of exceedances constitute a violation.

Figure 2. MFL criteria for Florida Bay (40E-8.221(5), F.A.C.).

The rule identifies the minimum flow criterion in sub-section (a) while MFL exceedance and violations are based on salinity levels at the Taylor River salinity monitoring station (sub-section (b) and (c), respectively). Although salinity in the estuary and wetlands responds to a number of factors (including canal inflows, precipitation, wind direction, tide, and evapotranspiration rates), it is utilized in the current MFL rule to indicate significant harm to the ecology of Florida Bay for several reasons. The target system is an estuary, continuously submerged by fresh or marine water, or a mixture. As such, water depth and flow per se are not the parameters that affect the biological resources. The proper salinity regime is important to the function of the estuarine ecosystem. Freshwater inflow is potentially a controllable parameter that could maintain the salinity regime, both spatially and temporally. However, due to the uncertainty identified between the flow criteria and the salinity, combined with the anticipation of changes in hydrology from Comprehensive Everglades Restoration Plan (CERP) restoration projects, CERP studies and other scientific data, the MFL rule included a provision for initial review of the MFL within five years after adoption. Subsequent reviews were to be completed at five-year intervals with updates to the Lower East Coast Water Supply Plan.

As part of the initial rule development process in 2006 and pursuant to statute (Section 373.0421(2) F.S.), SFWMD conducted an assessment of the potential for the Florida Bay MFL criteria to be violated under existing conditions and over a twenty-year planning horizon. It was determined that based on implementation of specific planned CERP projects and future water use trends consistent with those contained in the *2005–2006 Lower East Coast Water Supply Plan Update* (SFWMD 2007), the MFL would not be violated. Accordingly, a prevention strategy was developed and incorporated in rule (40E-8.421(8) F.A.C.). There were two main components of the prevention strategy: (1) continue field monitoring and research to assess salinity, water level, flow conditions, and biological resource responses, and (2) implement modifications to operations for improved management of freshwater discharges to the headwaters of Taylor Slough and the southeastern Everglades including (a) the Modified Waters Deliveries to Everglades National Park project (Modwaters), C-111 Canal Project, and any associated operational and construction plans pursuant to these projects, (b) the C-111 Canal Spreader Acceler8 and CERP projects and (c) the CERP Florida Bay and Florida Keys Feasibility Study. The adopted prevention strategy also included a provision that the MFL criteria be reviewed and revised if necessary based on new information/scientific data made available as a result of implementing the prevention strategy components. Assessment of the implementation of the prevention strategy to date is discussed below.

In response to the peer review comments discussed above and requirements of the prevention strategy to monitor research and assess the performance of the MFL criteria, the following programs and evaluations were implemented:

- Continued monitoring of flow and salinity at five creeks discharging into Florida Bay as well as at the salinity compliance monitoring point located at the Taylor River salinity monitoring station
- Monitoring of the species composition and distribution of benthic vegetation throughout the transition zone and the open waters of Florida Bay within the MFL footprint
- Continued monitoring of species composition and distribution of key fish species that depend on transition zone plant cover as critical habitat
- Modeling of the response of Florida Bay SAV to environmental conditions, including salinity
- Modeling the relationship between stage at upstream monitoring points and downstream salinity levels
- Determining life history stages, demographics and critical conditions required to maintain a healthy *Ruppia* community
- Assessing the *Ruppia* seed bank, its distribution and viability throughout the MFL footprint

In addition to the monitoring and research, CERP components and revised operations contained in the prevention strategy were implemented. The results of the new studies, monitoring programs and hydrologic impacts of the new projects and operations are discussed in Sections 2 through 4.

The *2013 Lower East Coast Water Supply Plan* provided an update to the prevention strategy (SFWMD 2013a). The modifications to operations for improved management of freshwater discharges to the headwaters of Taylor Slough and the southeastern Everglades were modified to include the C-111 South Dade project. The CERP Florida Bay and Florida Keys Feasibility Study was removed since this study is currently inactive pending state and federal funding for completion and no progress has been made since the MFL was adopted in 2006.

1.3 Boundaries of the Florida Bay MFL Water Body

The MFL rule for Florida Bay applies to the bays, basins, and sounds within Taylor Slough and the C-111 Canal basin watersheds, including Long Sound, Little Blackwater Sound, Blackwater Sound, Buttonwood Sound, Joe Bay, Little Madeira Bay, Madeira Bay, Terrapin Bay, Eagle Key Basin, and other open waters of Florida Bay northeast of a boundary line between Terrapin Bay and Plantation Key (**Figure 3**). The resulting footprint encompasses the area most directly affected by freshwater inflow, or lack of inflow, from upstream regional canals. The boundary encompasses the southern Everglades freshwater marsh, the mangrove transition zone between the marsh and Florida Bay and the northern and central sections of open water Florida Bay that are influenced by Taylor Slough and the C-111 Basin.

1.4 Purpose of This Report

This report fulfills the requirement outlined in the prevention strategy (subsection 40E-8.421(8)(d), F.A.C.) that the Florida Bay MFL criteria be reviewed based on new information or other scientific data made available since adoption of the MFL. Hydrologic and salinity data and evaluations conducted since 2006 are provided, and historical relationships between these parameters are explored. New research results concerning the relationships of biological resources and conditions are summarized. In addition, the impacts of the recently completed regional water resource development project components of the MFL prevention strategy are assessed. The *2013 Lower East Coast Water Supply Plan Update* provides information about how future water use demand projections for 2030 will comply with the Florida Bay MFL (SFWMD 2013a). Recommendations are given based on analyses and review of the currently best available information.

Specifically, four objectives are identified for evaluation under this MFL review. These objectives are summarized below and this report focuses on these points with technical supporting information included in the appendices.

1. Determine whether the Florida Bay MFL criteria have been met since the rule was established in 2006.

2. Assess the potential for meeting the MFL criteria in the future with 2013 existing project components and operations in place and 2030 consumptive use demand projections to determine whether changes to the existing prevention strategy are needed.

3. Evaluate the existing MFL criteria in light of updated data and studies to determine if the thresholds contained in the rule reasonably represent significant harm to the bay.

4. Investigate potential relationships between the flow and salinity criteria contained in the rule.

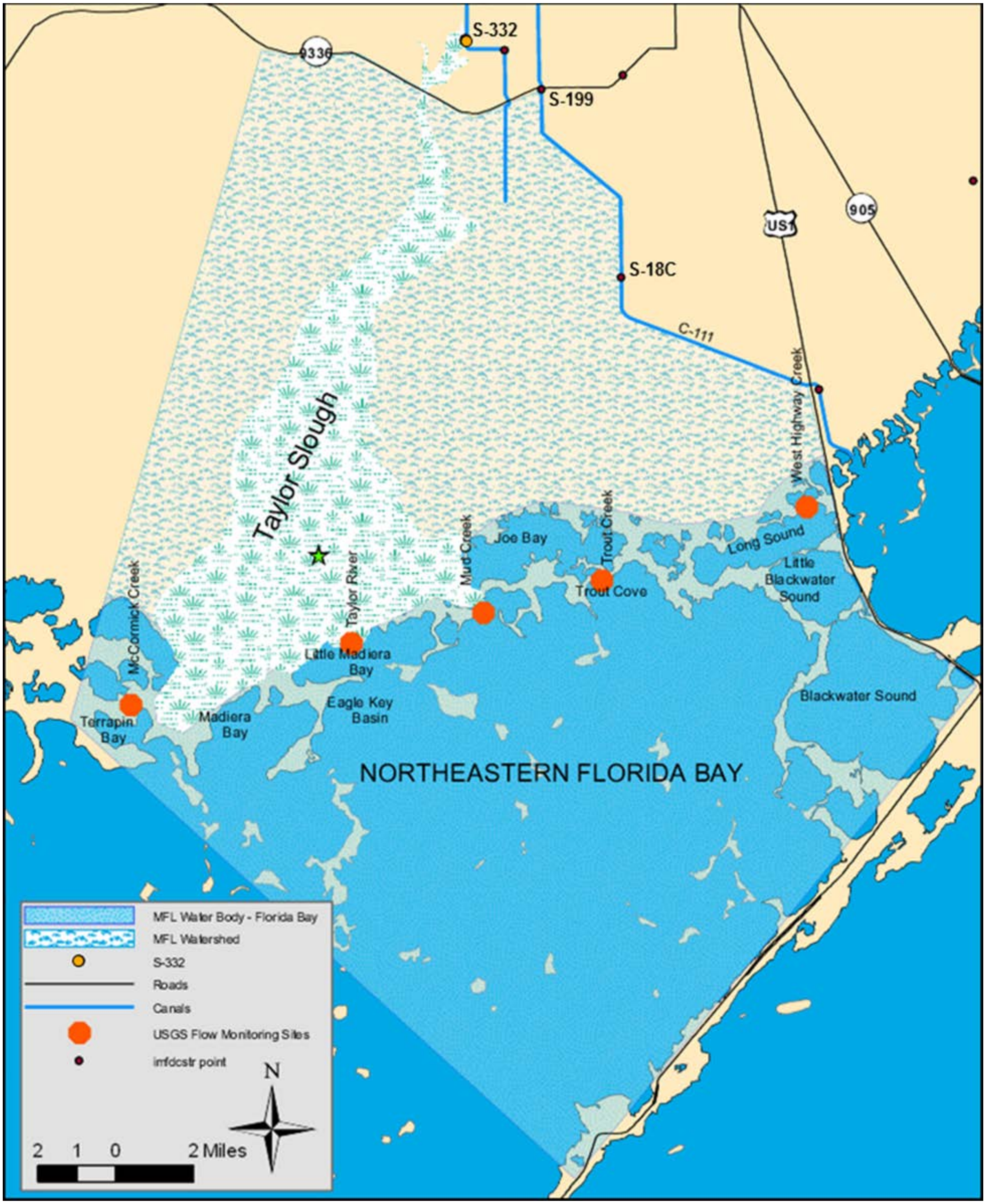

Figure 3. Northeastern Florida Bay with the MFL rule boundaries. Red dots represent United States Geological Survey flow monitoring stations. Green star marks the location of the Taylor River salinity monitoring station.

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Section 2. Review of Available Hydrologic Information

2.1 Purpose of the Hydrological Review

Since rule adoption in 2006, changes to the watershed in the form of CERP project construction and revised operations have been initiated. Empirical relationships between stage and salinity within the transition zone and northeastern Florida Bay were investigated previously for potential use during the technical evaluations prior to rule adoption in 2006. However, direct application was not pursued because available information including monitoring locations and period of record did not provide a suitable technical basis to establish linkages with the biological resources. It was recognized that new monitoring and tools would become available as a result of future activities (e.g. CERP projects, revised operations and other initiatives) and the following recommendation was made (Hunt et al. 2006):

> Relationships should be further investigated between salinity and gauged water levels and flows at various sites in Florida Bay and in the Southern Everglades and C-111 basin. Future analyses should be based on improved hydrologic and hydrodynamic models currently being developed for the FBFKFS [Florida Bay and Florida Keys Feasibility Study] or other projects in the region.

The status of existing hydrologic modeling tools including tools used in the development of the MFL (Section 2.2) and Florida Bay and Florida Keys Feasibility Study model tools were reviewed, and for reasons discussed in Section 2.3, analyses using such tools were not pursued for this MFL review. Updated watershed evaluations summarizing inflows and rainfall are presented in Section 2.4 using the Regional Simulation Model (RSM) (SFWMD 2005). This regional tool was also needed to evaluate changes caused by future projects and operations (see Section 4.2). General relationships among hydrologic variables and salinity are described in Section 2.5 as part of an exploratory investigation of these variables with up-to-date information in the southern Everglades and C-111 basin.

2.2 Hydrologic Approach Used in the Development of the MFL

A combination of modeling tools was used in the development of the MFL criteria to (1) establish a historical reconstruction of freshwater inflows and corresponding effects for northeastern Florida Bay and the Everglades-Florida Bay transition zone; (2) construct a water budget; (3) identify the areas within Florida Bay sensitive to freshwater inflows; and (4) establish the link with the regional South Florida Water Management Model (SFWMM) to allow evaluation of future conditions. The detailed water budget assessments and hydrologic modeling evaluations performed and the period of record encompassing 1970–2002 as described in the technical document supporting the 2006 rule (Hunt et al. 2006) is significant because it includes both periods of low flow resulting from drought conditions as well as low flow periods resulting from historical water management activities. The assessment provided for a range of both historical water management practices as well as climatically-driven patterns and the impacts on salinity conditions within the Everglades-Florida Bay transition zone and within the different basins of Florida Bay. The modeling approach was necessary because existing observations and empirically-derived assessments were not adequate to evaluate the complex hydrology, including diffuse inflow sources connected to the southern Everglades by a combination of climatic factors and upstream management activities.

Several hydrologic analyses were conducted to support development of flow-salinity relationships for northeastern Florida Bay. A salinity model for Florida Bay, known as Flux Accounting Tidal Hydrology Ocean Model (FATHOM), was applied to reconstruct a history of salinity within 47 tidal basins throughout Florida Bay for the period 1970–2002 (Cosby et al. 2005, Hunt et al. 2006), and establish areas within Florida Bay that were sensitive to the influence of freshwater inflows. Basins within Florida Bay in which salinity was significantly correlated to changes in inflow, were found to be clustered in the northeast and eastern interior and analyses were then focused on these areas and the contributing freshwater inflows (Hunt et al. 2006). Multi-linear regression models (MLRs) were also employed to predict salinity at the Taylor River salinity monitoring station in the Everglades-Florida Bay transition zone (Marshall et al. 2004). The results from the combination of tools represented a reasonable approximation of historical conditions in both northeastern Florida Bay and within the Everglades-Florida Bay transition zone and were consistent with locations of existing field monitoring and observation of resources. Additionally this combination of tools allowed coupling with the regional SFWMM to evaluate future conditions and a linkage with inflow from upstream managed water control structures over long periods. Since the SFWMM included 31 years of actual climatic variability (1965–2000), a multi-decadal period was simulated. These were the best available tools at the time, but they all possessed varying degrees of uncertainty. It was envisioned that these modeling tools would be improved over time, and other promising tools might be developed for future application. Of these, only the SFWMM has been improved over time. SFWMD has also developed and adopted a newer hydrologic simulation tool, the RSM. FATHOM is currently being upgraded, but the new version was not available for this MFL review. A hydrodynamic model for Florida Bay based on the Environmental Fluid Dynamics Code (EFDC) is not in use at this time.

2.3 Current Status of Hydrologic Modeling Tools

Observed data at relevant spatial and temporal scales are often inadequate to represent the water resource throughout a variety of climatic conditions and water management changes within the region of interest. Models can be used to estimate historical conditions where empirical information is absent, and are necessary when predicting future conditions. As it is always, the goal is to use the "best available" information and provide a review of new tools or update existing tools.

The modeling tools developed and applied in the freshwater Everglades, the Everglades-Florida Bay transition zone, and downstream estuaries and marine systems have been reviewed and evaluated periodically as part of the Florida Bay Science Program and for Everglades National Park (e.g., Marshall et al. 2006, PMC 2000), and most recently as part of the CERP effort (Marshall and Nuttle 2011). It is important to recognize that most of these tools were developed for different objectives over the course of many years and evaluation of tools for any one purpose is relevant only within the context of the intended application. Existing models used in freshwater marsh and mangrove areas of northeastern Florida Bay include statistical regressions; a wetland basin hydrology and estuarine basin salinity model (PHAST); SFWMM; Natural System Model (NSM); RSM and; the Flow and Transport in a Linked Overland/Aquifer Density Dependent System (FTLOADDS)/Tides and Inflows in the Mangroves of the Everglades (TIME) domain. Existing models for northeastern Florida Bay include MLR salinity models; Four Box Florida Bay Model, FATHOM for Florida Bay; FTLOADDS/TIME domain; and EFDC. Technical evaluations supporting the development of the MFL included extensive review of these models, all of which were either available or under development (Hunt et al. 2006). Since MFL rule adoption in 2006, there have been updates and improvements to some of these models as described by Marshall and Nuttle (2011). However, at the present time, the limitations associated with their application to the MFL have not changed. The Florida Bay and Florida Keys Feasibility Study has been inactive and the hydrologic tools developed as part of that effort were not fully completed.

The hydrologic tool, FATHOM was used in the development of the Florida Bay MFL (Hunt et al. 2006, Cosby et al. 2005) and continues to be widely applied in a variety of ongoing efforts to predict salinity within Florida Bay. It has undergone several updates and modifications since 2006 as described below. It was not used for this MFL review because it is currently undergoing several key updates and was not ready for application.

The FATHOM model, originally developed in 1999, is a dynamic, spatially explicit, mass-balance model designed to simulate the response of salinity in Florida Bay to runoff, climate, and variation in salinity on the Florida Shelf (Cosby et al. 1999, 2005, 2010, Nuttle et al. 2000). For the modeling associated with the development of the MFL, the bathymetry of Florida Bay was updated and freshwater inflows were improved based on best available information (Cosby et al. 2005, Hunt et al. 2006). This effort produced a 31-year (1970–2002) historical reconstruction of salinity in each of 47 FATHOM basins. The primary inflow sources used in the MFL analyses were gauged inflows to Florida Bay from observed upstream structure inflows (Taylor Slough Bridge + S18C – S197). Additional flow was added to the measured structure flow to account for excess rainfall over the wetland and ungauged flows.

In 2010, a new version of FATHOM (Version 6.10) was created in support of a Critical Ecosystems Studies Initiative project for Everglades National Park. Improvements included updated bathymetry, and adding more structural detail, which resulted in a new 54 basin configuration (Cosby et al. 2010). Additionally, regions with similar water quality characteristics were identified by principal component analyses (Briceno and Boyer 2010). The most significant change relative to MFL evaluation was the application of a new approach for specifying freshwater runoff inputs to FATHOM basins along northern Florida Bay. The model was recalibrated using freshwater inflows from the SFWMM at 12 boundary cells nearest to the edge of Florida Bay. A drawback of this approach is that when compared to measured inflows at several gauged creeks within the cells for the period 1996–2000, these discharge values underestimated measured creek flows by about one-half. Several applications of this version in 2010 and 2012 resulted in significant issues with the output salinity generated by FATHOM and this version could not be considered for the MFL review.

A new calibration and verification for FATHOM is underway, and is expected to be completed in December 2013 (Marshall 2013). The major modification to the 2010 Version 6.10 is in the way the inflow input to FATHOM basins of northern Florida Bay is established. In this effort, SFWMM input values have been calibrated to stage instead of flow and MLRs that relate observed creek flows to stage at locations in the calibrated SFWMM are used to generate FATHOM flow inputs. Additional Manning's n adjustments that modify flows between basins are included and expected to provide the best fit to observed salinity within basins to complete this effort. Additional work would be needed once this model is complete to link this newest version to appropriate regional inflows, and then test prior to specific project application.

2.4 Updated Watershed Hydrology Evaluations

The watershed boundary of northeastern Florida Bay can vary depending upon water levels within the Everglades. The flat topography of the watershed has a bearing on the movement of water from the Everglades to northeastern Florida Bay. When water levels are higher, water can flow overland out of Shark River Slough towards the bay. During drier periods, most of the watershed inputs are derived from nearby canals and localized rainfall. Additionally, prevailing winds may impact the movement of water and at times negative net flows may result (e.g., water from the bay may move up into the Everglades-Transition zone). For purposes of estimating a water budget reflecting 2012 operations, and updated projects and operations (presented in Section 4.2), the Regional Simulation Model-Glades Lower East Coast Service Area (RSMGL) was used. Similar to the 2006 technical analyses (Hunt et al. 2006), Florida Bay Water Budget Area shown in **Figure 4** is the main focus in this modeling effort. Model Documentation of the RSMGL used for this Florida Bay MFL review is included in Appendix A.

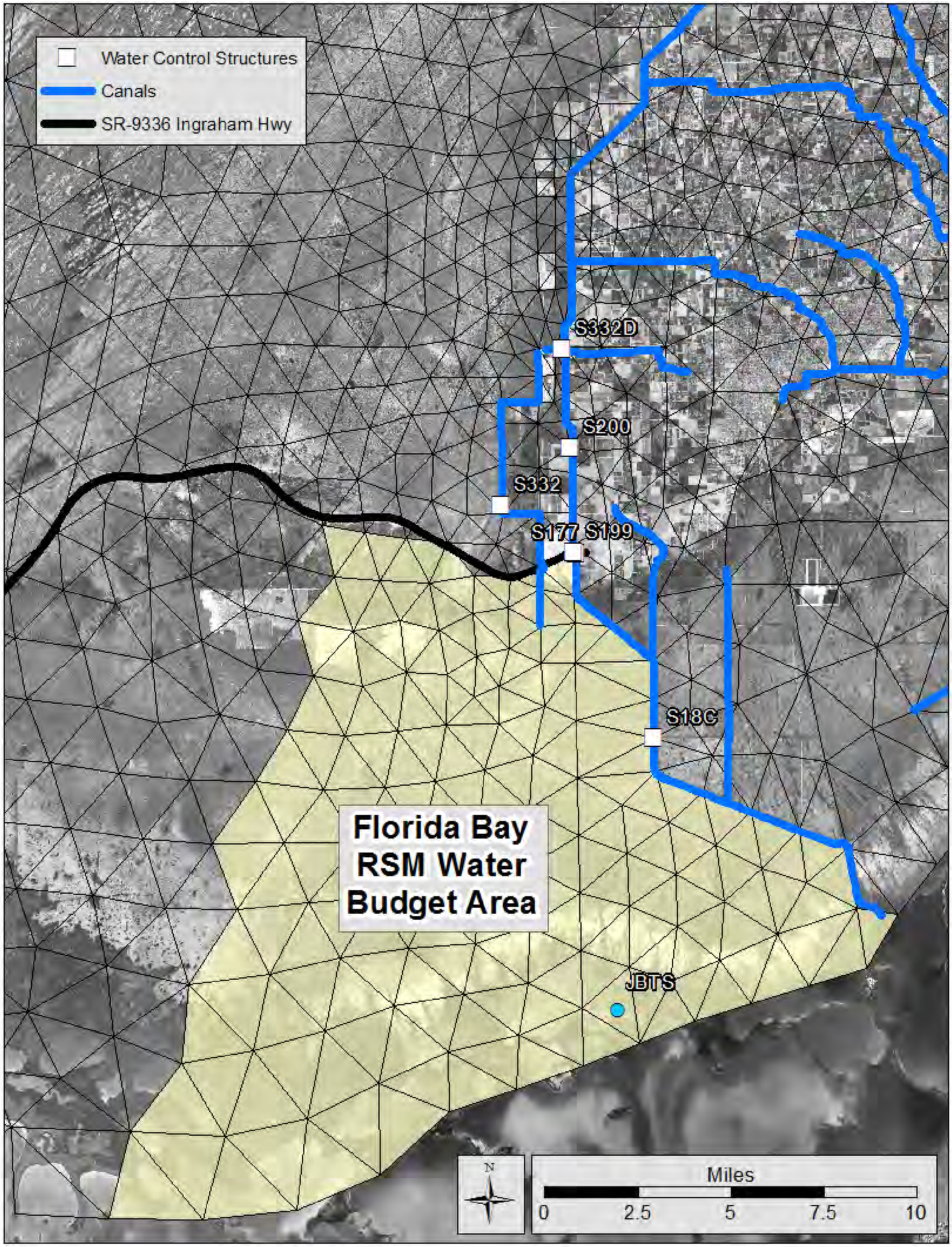

Figure 4. Elements within the RSMGL approximating the watershed for northeastern Florida Bay.

2.4.1 Freshwater Inflows

A freshwater budget for the northeastern Florida Bay watershed assuming climatic conditions of 1965 through 2005 and early 2012 project conditions and operations were simulated with the RSMGL (see **Table 6** later in this document and Figure 6A in Appendix A). Appendix A describes water budget components that should be used with care, especially boundary flows.

The overland inflow term that enters the drainage basin from the north is measured approximately along Ingraham Highway, which acts as an artificial hydrologic divide, accounts for the majority of the flow in Taylor Slough. Most of the flow through this divide occurs at Taylor Slough Bridge, and is composed of both structural flows from S-332D and rainfall runoff from the small watershed upstream of the bridge. Water discharges at S-332D affect water levels and flow at the Taylor Slough Bridge (Kotun and Renshaw 2013), and are correlated with stage (0.803, Spearman's rho). Some portion of the overland flow term results from these canal discharges. Under the conditions of this simulation, structural flows account for the majority of the total watershed inputs on an average annual basis. Other freshwater inflows include flows through S-18C which account for the majority of flows that enter the eastern panhandle of Everglades National Park, south of the lower C-111 canal.

Since evaporation or evapotranspiration results in a deficit of water inputs to the watershed based on rainfall alone, the inputs from canal sources may be important in producing a net surplus of fresh water that discharges into the bay. This is consistent with analyses from 2006, which showed that direct inflow accounts for more than one-third of the net freshwater supply in late summer through the fall (Hunt et al. 2006).

2.4.2 Rainfall

Rainfall is a significant component of the overall water budget of northeastern Florida Bay and estimating historical rainfall within the northeastern Florida Bay watershed includes a fair degree of uncertainty due to the small number of rainfall monitoring sites, varying period of record, and variability in spatial rainfall amounts. In this MFL review, historical rainfall was estimated using the methods used for the RSM (SFWMD 2005). These estimates have been completed for the period 1965–2005. According to these results, rainfall has averaged about 48 inches annually during the period and has ranged from about 33 to 68 inches. An alternative spatial estimate can be calculated based on radar data collected during rainfall events and processed to estimate spatial rates (RAINDAR, Vieux & Associates, Inc. 2012). Historical RAINDAR results have been estimated by basins (**Figure 5**) from 2001 through 2012 for areas much larger than the northeastern Florida Bay watershed. For example, average rainfall has been estimated for the Eastern Miami-Dade and Everglades basins both of which include part of the northeastern Florida Bay watershed. Averaging the estimates from these two basins yields 52.6 inches per year. Rainfall quantities over the bay itself are typically less, on average, than the mainland, and trend lower from north to south (Stabenau and Kotun 2012).

The relatively high water temperatures in the marshes of the watershed and in the bay promote evaporation. One estimate of evaporation in Florida Bay yielded an average of about 65 inches per year (Price et al. 2007). However, water budget analyses from 2006 showed that although direct inflow is not an overall large component of the annual water budget for Florida Bay, it accounts for more than one-third of the net freshwater supply in late summer through the fall (Hunt et al. 2006). Thus seasonal timing of inflow is an important factor in the overall water budget and salinity in Florida Bay.

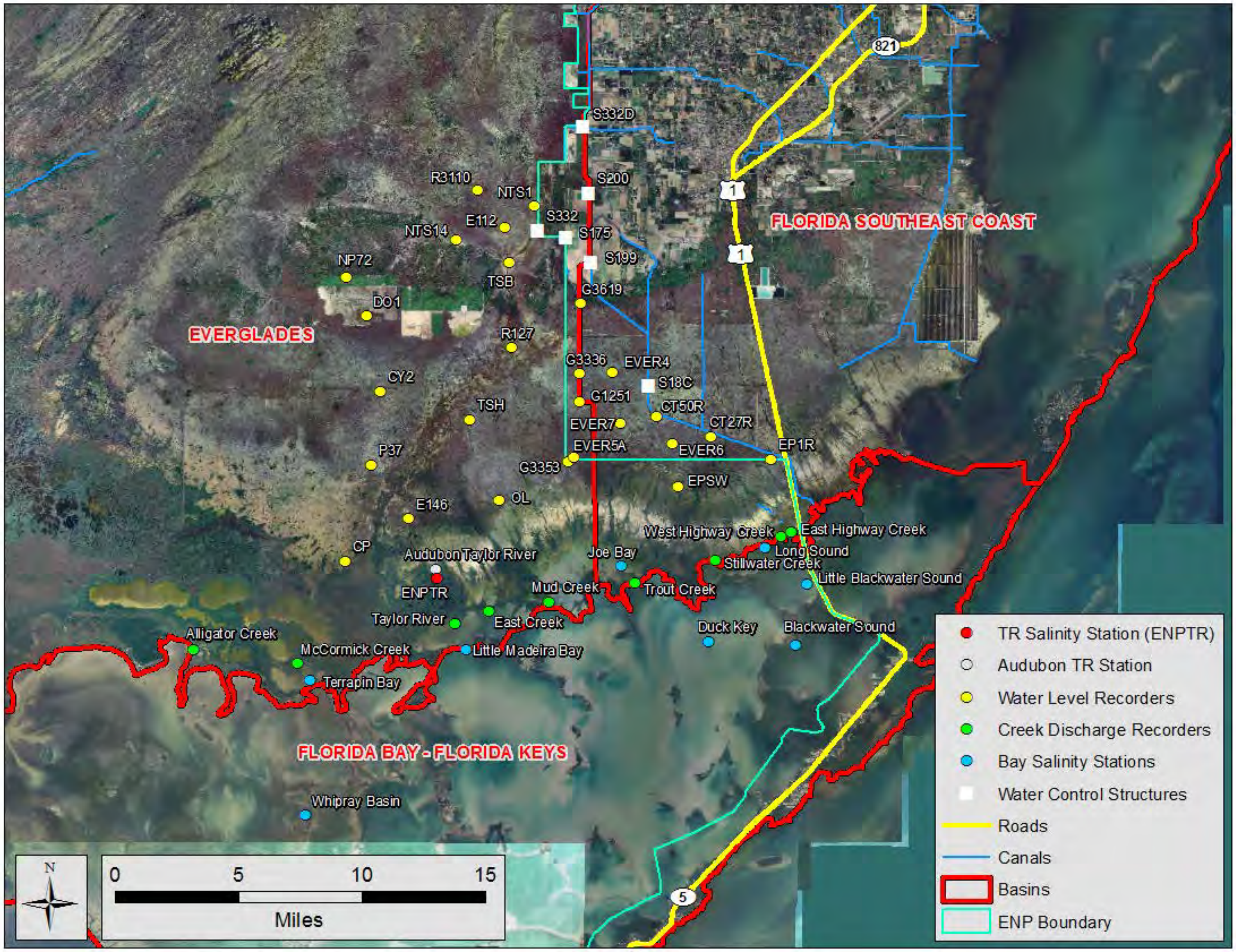

Figure 5. Map of rainfall basins and monitoring stations.

Rainfall exhibits a distinctive seasonal pattern. Average monthly results based on RAINDAR indicate that the greatest rainfall quantities occur during the months of June through September (> 7 inches) and the least during the months November through March (< 2 inches). Average monthly evaporation rates also follow a seasonal pattern, but different than the rainfall pattern with highest rates in March through May (Stabenau and Kotun 2012).

2.4.3 Water Levels

Water level is recorded at several locations throughout the watershed of northeastern Florida Bay, (**Figure 5**). Long-term average stages (National Geodetic Vertical Datum of 1929) south of Ingraham Highway range from 1.1 to 3.0 feet. Average stages decrease from north to south. Historical water levels at these and other gauges in the Everglades have been used to predict salinity in Florida Bay using statistical regressions (Marshall et al. 2011). Water levels are higher, on average, during the wet season than the dry season (**Figure 6**).

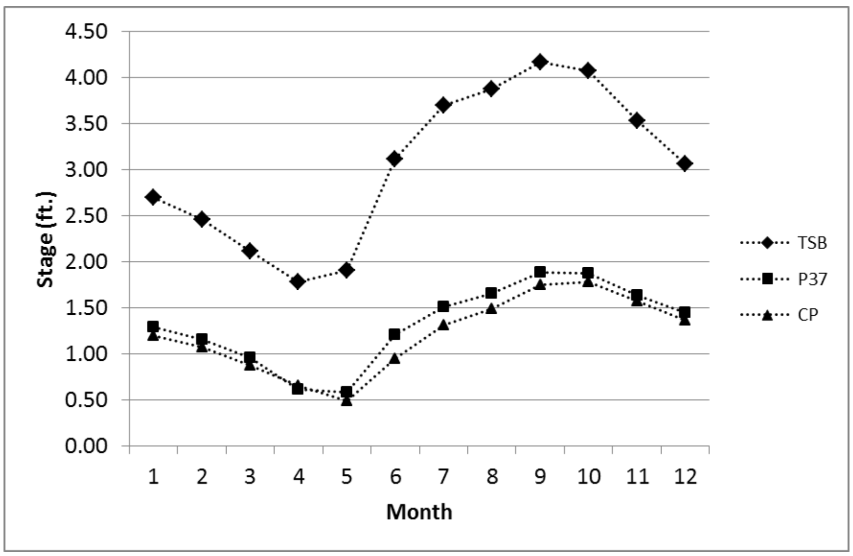

Figure 6. Examples of long-term monthly mean water levels at three gauges within the watershed.

Water level or tide in Florida Bay influences the hydrology and salinity in the marshes near the shoreline. For example, when the stage in Little Madeira Bay is higher than the stage at Station E146 in Taylor Slough, salinity tends to be greater at the Taylor River salinity monitoring station (Stabenau and Kotun 2012).

2.4.4 Structural Inflows

The hydrology of the northeastern Florida Bay watershed is affected by water inputs from canals and associated infrastructure. The current water management configuration has been in place since the middle of 2012, having evolved over time. The current primary structural inflows from the water management system occur at pump station S-332D into Taylor Slough, pump stations S-200 and S-199 into the marsh east of Taylor Slough, and gravity flow through S-18C where the water overflows the bank of the C-111 canal and into the marsh of the panhandle (**Figure 5**). The current configuration is designed to move available water into the watershed of northeastern Florida Bay, and lower salinity in the bay (USACE and SFWMD 2011).

Historical flow rate results from the S-200 and S-199 pump stations were not available through 2012 as the newly constructed features were tested for just a short period during the 2012 wet season. The long-term average flow (1999–2012) at S-332D is 152 cubic feet per second (cfs), and at S-18C, it is 185 cfs. Mean daily flow varies considerably at these inputs, where discharges are typically largest during the wet season, but are very little during much of the dry season (**Figure 7**).

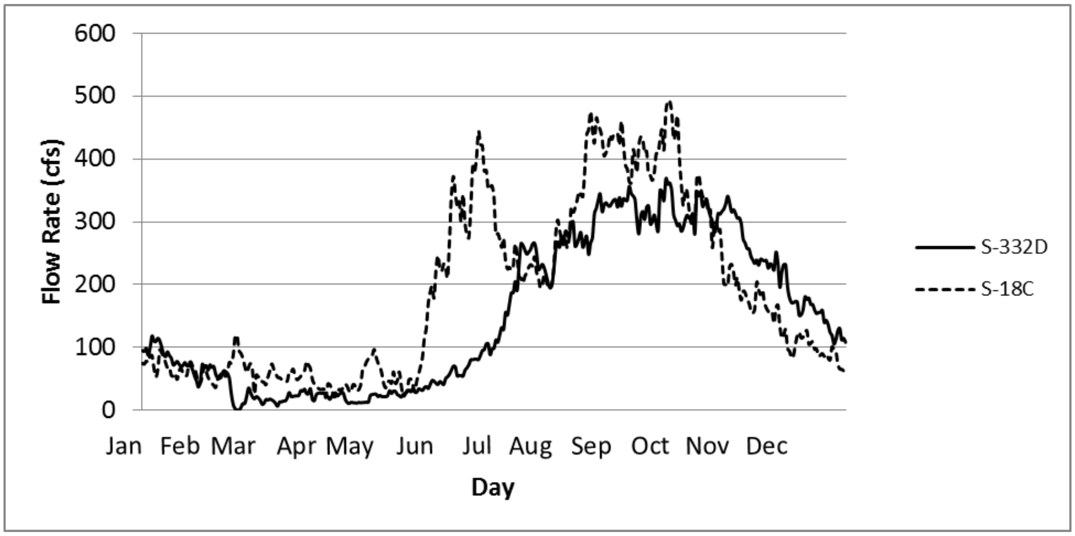

Figure 7. Long-term (1999–2012) mean daily flow rate at two structural inflows locations.

2.4.5 Tidal Creeks

The majority of freshwater input into northeastern Florida Bay itself occurs via several creeks that breech a low berm near the shoreline called the Buttonwood Embankment. Nine of the creeks have been monitored for flow rate and some for salinity (**Figure 5**), although the period of record varies. The largest rates of discharge have occurred at Trout Creek (210-cfs mean flow) and West Highway Creek (45-cfs mean flow). Mean discharge at all of the monitored creeks totals about 410 cfs. Meteorological forcing causes bidirectional flow and discharged water is often saline. For example, average salinity has ranged between about 15 at Taylor River to 22 at McCormick Creek (1995–2012). Because of the variability of the salinity in these inflows and the bay, and potential storage of salt within the wetlands and soils, a precise estimate of the equivalent rate of input of fresh water is difficult to calculate. Stabenau and Kotun (2012) used a constant reference salinity of 35 to estimate the equivalent fresh water. The greatest correction to net flux occurs during June through September, on average, when inflow rates are highest, a difference of roughly 30 cfs, according to their estimates.

Historical annual total discharges from the five coastal creeks given in the MFL rule (i.e., West Highway, Trout, Mud, Taylor, and McCormick) have ranged from 121,349 ac-ft (lowest in 2004) to 407,462 ac-ft (highest in 2005) from 1996 through 2012. The grand mean of the 365-day running sums from February 17, 1997 when records for all five creeks are available through 2012 is 248,009 ac-ft and sums range from 97,765 ac-ft to 470,727 ac-ft. About 1% of the values prior to 2007 were below 105,000 ac-ft, and none were observed from 2007 through 2012.

2.5 General Relationships among Hydrologic Variables and Salinity at the Taylor River Salinity Monitoring Station

Relationships among variables such as water levels, creek discharge, canal discharge and salinity were investigated using updated data sets. One of the potential weaknesses of evaluating the empirical relationships between these variables is that evolving hydrology (summarized in the next section) could change relationships through time. This is especially true where sensitivity to canal discharges have occurred since 1961 (Kotun and Renshaw 2013). The hydrologic conditions and thus any existing relationships will continue to change as infrastructure projects are completed and operational practices adapted in the future (USACE and USDOI 2010). Therefore, caution is advised when interpreting how the system responded in the past, and assuming it will continue to respond the same in the future. Other variables that affect salinity and hydrology over longer periods include oscillating climatic conditions and sea level rise. A particular period of record may not contain enough records to average out multi-decadal trends.

2.5.1 Creek Flows and Salinity

The Florida Bay MFL rule identifies an estimated net discharge into northeastern Florida Bay of 105,000 ac-ft of water over a 365-day period (a running total measured at five creeks specified in the rule). As expected, no relationship exists statistically between the 30-day average salinity at the Taylor River salinity monitoring station and the 365-day running total discharges at the five MFL designated creeks (-0.10, Spearman's rho) (1996–2012). However, the relationship between the daily mean salinity at the Taylor River salinity monitoring station and daily mean total MFL creek discharge is somewhat stronger (-0.38, Spearman's rho). Further, examination of records indicate that when the equivalent flow rate of 145 cfs (i.e., equal to 105,000 ac-ft per year) has been met or exceeded, the 30-day average salinity has exceeded 30 only nine times historically, or less than 1% of the time (**Figure 8**). So, while there is not a general empirical relationship between the total creek discharge rate and salinity at the Taylor River salinity monitoring station, the probability the salinity criterion will be exceeded is small if the continuous flow rate is equal to or greater than 145 cfs. One key drawback of these analyses is that it assumes the flow is continuous. However, historically, this rate has been variable with a daily mean of 350 cfs and a standard error of 2.1, ranging from -3,375 cfs to 4,050 cfs, with substantial instances of negatives flows apparent in the existing period of record as a result wind conditions (**Figure 8**). In addition, it is not uncommon to have a total daily flow rate that is < 145 cfs and still have salinity conditions < 30 at the Taylor River salinity monitoring station. Therefore, the daily metric would not be useful to implement or track.

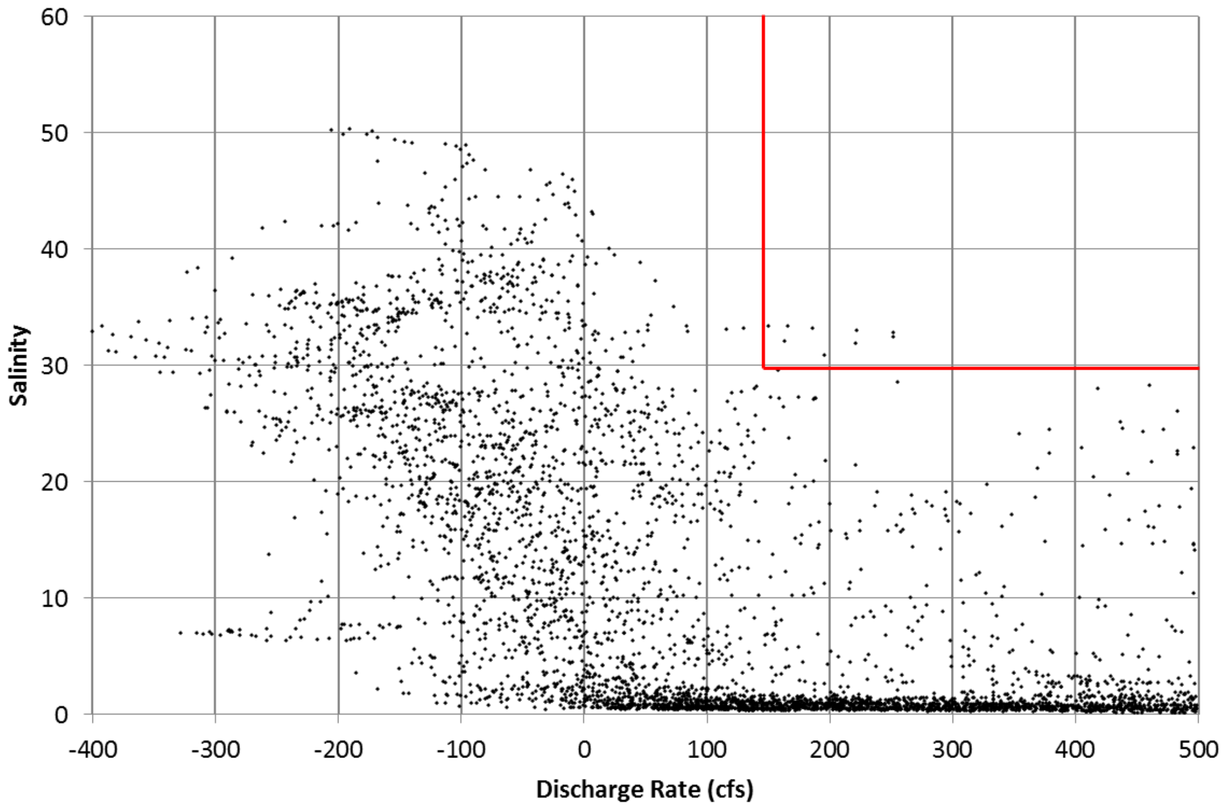

Figure 8. Plot of total daily mean discharge at the five MFL tidal creeks and mean salinity at the Taylor River salinity monitoring station for the period 1996–2012. Values to the right and above the red lines indicate the few times when salinity exceeded 30 and the total daily discharge rate was greater than 145 cfs.

Relationships between individual creek discharge and salinity at various salinity stations in northeastern Florida Bay are mixed, but generally not robust (**Table 1**). Mean daily salinity at the station near the mouth of Trout Creek has the strongest relationship to overall creek discharge (-0.69, Spearman's rho), likely due to the fact that the greatest discharge occurs at Trout Creek. When broken down by month, the creek discharges have had the strongest effect on salinity in northeastern Florida Bay in July and June (**Figure 9**), and the least during April and December.

Table 1. Spearman correlation coefficients (rho) between flow at the creek stations and salinity at the different salinity monitoring stations. Station locations are shown in **Figure 5**.

Salinity Monitoring Stations	Creek Flow Stations								
	Alligator Creek	McCormick Creek	Taylor River	East Creek	Mud Creek	Trout Creek	Stillwater Creek	West Highway Creek	East Highway Creek
Tarpon Bay	-0.55	-0.40	-0.56	-0.51	-0.44	-0.38	-0.03	-0.44	-0.51
Taylor River	-0.48	-0.30	-0.51	-0.47	-0.37	-0.31	-0.06	-0.39	-0.47
Little Madeira Bay	-0.43	-0.23	-0.39	-0.40	-0.29	-0.25	0.00	-0.31	-0.40
Joe Bay	-0.59	-0.40	-0.66	-0.60	-0.52	-0.45	-0.14	-0.53	-0.60
Trout Cove	-0.73	-0.58	-0.76	-0.76	-0.69	-0.65	-0.23	-0.64	-0.76
Duck Key	-0.31	-0.10	-0.21	-0.28	-0.15	-0.14	-0.02	-0.18	-0.28
Long Sound	-0.54	-0.35	-0.60	-0.60	-0.48	-0.42	-0.29	-0.51	-0.60
Little Blackwater Sound	-0.43	-0.27	-0.49	-0.41	-0.39	-0.33	-0.10	-0.42	-0.41
Blackwater Sound	-0.37	-0.19	-0.35	-0.34	-0.25	-0.24	0.02	-0.30	-0.34

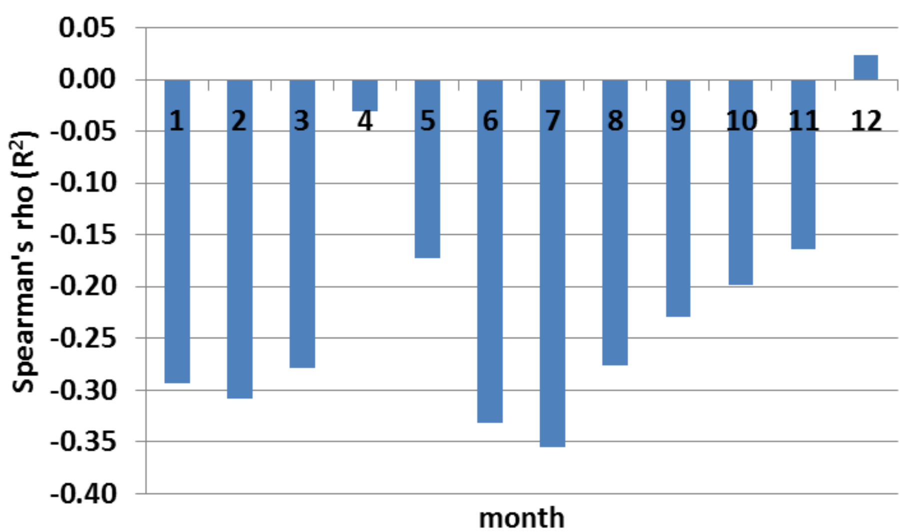

Figure 9. Mean correlation coefficients by month (1-12) between total creek discharges and salinity (stations listed in **Table 2**).

2.5.2 Canal Flows and Salinity

The relationships between inflows at S-332D and S-18C are discussed here, because these are the most relevant in terms of recent management (1999–2012). The period of record is too short to draw conclusions about the flows produced by the new pumps stations S-199 and S-200. The relationships are very weak between canal inflows and salinity at the Taylor River salinity monitoring station, overall (**Table 2**). When broken down by month, the historical relationship has been strongest and most related to lowering salinity at Taylor River salinity monitoring station in the dry season and early wet season (January through July) (**Figure 10**). Poor relationships between these canal inputs from August through December may have occurred because canal inputs have been less important in lowering salinity than the excess runoff during these months from rainfall and overland flow.

Table 2. Spearman correlation coefficients (rho) between flow at the canal inflow structures and salinity at salinity monitoring stations. The values given for S-199 and S-200 are for a short period of record (May or June 2012 through December 2012). Station locations are shown in **Figure 5**.

Salinity Monitoring Stations	Canal Flow Stations					
	S-332D	S-200	S-332	S-175	S-199	S-18C
Terrapin Bay	-0.38	-0.32	-0.20	-0.21	-0.63	-0.29
Taylor River	-0.42	-0.36	-0.34	-0.32	-0.78	-0.34
Little Madeira Bay	-0.30	-0.21	-0.17	-0.24	-0.75	-0.28
Joe Bay	-0.59	-0.25	-0.24	-0.26	-0.64	-0.49
Trout Cove	-0.56	-0.28	-0.19	-0.33	-0.53	-0.54
Duck Key	-0.11	-0.35	-0.27	-0.27	-0.49	-0.19
Long Sound	-0.55	-0.17	-0.29	-0.39	-0.44	-0.56
Little Blackwater Sound	-0.44	-0.25	-0.37	-0.33	-0.62	-0.40
Blackwater Sound	-0.27	-0.35	-0.37	-0.30	-0.71	-0.22

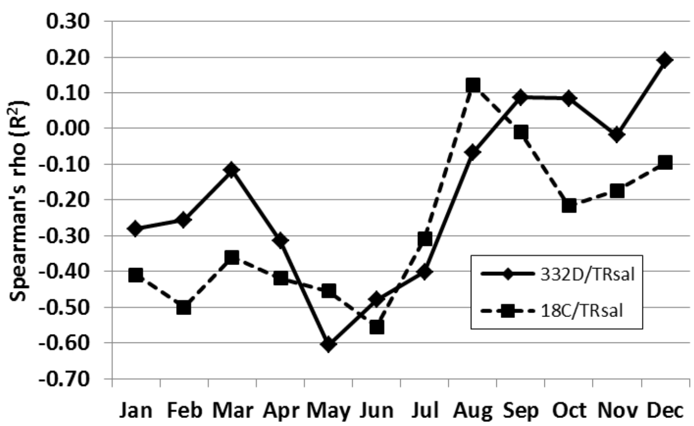

Figure 10. Correlation coefficients by month between canal inflows and salinity at the Taylor River salinity monitoring station.

The relationships of S-332D and S-18C daily flows are most strongly related to salinity at Trout Cove, Long Sound and Joe Bay.

2.5.3 Canal Flows and Creek Flows

Overall, the relationship between combined canal inflows and creek discharges is weak (0.45, Spearman). Individually, S-332D inflows have had the most influence on flows at East Highway Creek, Taylor River and West Highway Creek (**Table 3**). S-18C inflows have had the most influence on flows at East Highway Creek, Taylor River, West Highway Creek and Mud Creek. Canal inflows are most related to creek flows in June and July (**Figure 11**).

Table 3. Spearman correlation coefficients (rho) between mean daily canal inflow and tidal creek discharges. All available data sets come from SFWMD, Everglades National Park and USGS with variable periods of record.

Flow at Tidal Creek Stations	Canal Flow Stations	
	S-332D	S-18C
Alligator Creek	0.41	0.31
McCormick Creek	0.36	0.35
Taylor River	0.57	0.57
East Creek	0.48	0.43
Mud Creek	0.49	0.52
Trout Creek	0.43	0.47
Stillwater Creek	0.25	0.40
West Highway Creek	0.52	0.57
East Highway Creek	0.60	0.57

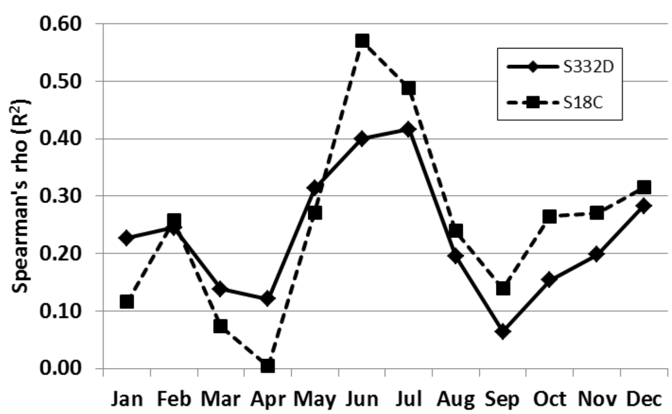

Figure 11. Mean monthly correlation coefficients between individual canal inflows and creeks discharges.

2.5.4 Water Levels and Salinity

Water levels (stages) have been utilized in regression models to predict salinity in Florida Bay including the Taylor River salinity monitoring station when monitoring data is not available (Marshall et al. 2011). An MLR model for the Taylor River salinity monitoring station site produced by Marshall et al. (2011) has an adjusted coefficient of determination (R^2) of -0.78, but a 95% confidence interval of predicted values of about ± 9.2 salinity (i.e., 2*RMSE of 4.6). So, while the model establishes an empirical relationship and may be adequate for assessing general salinity response due to water level differences, it may not be precise enough to determine if a threshold is exceeded as in the case with the MFL criteria. In addition, one must also assume that the relationships between historical and current or future water levels and salinity are the same, which adds more uncertainty especially if used to provide salinity estimates over long time periods or for future conditions.

Stabenau and Kotun (2012) provided a compelling example of how the difference between water level in the bay and water level in the marsh may be a driver of salinity within Taylor River using weekly mean values. It stands to reason that as water levels rise in Florida Bay, more salt water will be forced into the marsh, and at some threshold, could influence salinity at the Taylor River salinity monitoring station. A similar regression between the mean daily stage difference between Little Madeira Bay (LM) and Taylor River (TR), and salinity at Taylor River lagged by two days yields a model with a coefficient of determination that is better than regressions with weekly or 7-day means (**Figure 12**). According to the example regression (R^2=0.70), when the mean daily water level difference is 0.59 feet or less, salinity at the Taylor River salinity monitoring station will be 30 or less two days later on average. Even in this example, however, the 95% confidence level is about ±12.2 about the mean predicted salinity. To be assured that salinity at Taylor River salinity monitoring station was 30 or less, the stage difference would have to be maintained at 0.17 feet or less.

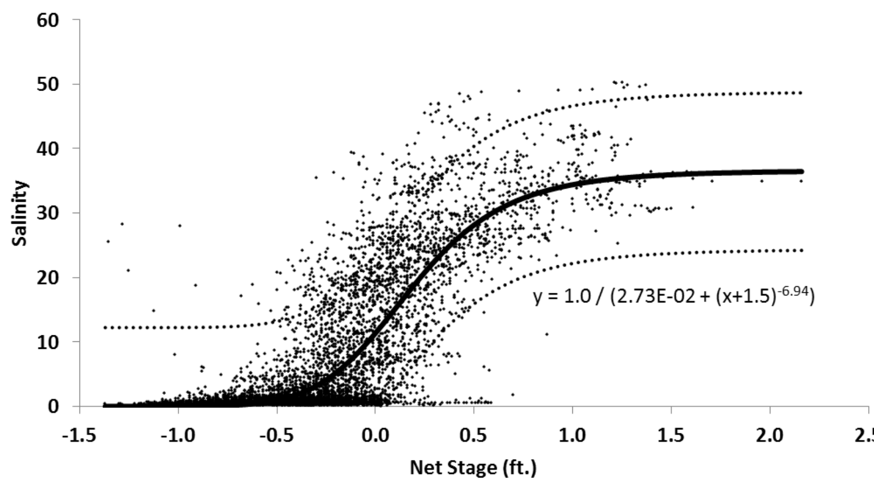

Figure 12. Example of a regression between the difference in water level (net stage in feet) between mean daily stages at Little Madeira and Taylor River, and mean daily salinity at the Taylor River salinity monitoring station lagged by two days. The dashed lines represent the 95% confidence interval of the predicted values.

Salinity at the Taylor River salinity monitoring station is also related to water level at the Craighead Pond monitoring station (CP) (Hunt et al. 2006). Of all the water level variables available, salinity at the Taylor River salinity monitoring station has been most related to the Craighead Pond stage, historically (-0.72, Spearman). Perhaps, due to its location near the shoreline, water levels at Craighead Pond may be influenced by tidal fluctuations and, therefore integrate some of the driving effect discussed in the previous paragraph. Despite the relationship between mean daily salinity at Taylor River salinity monitoring station and Craighead Pond stage, a plot of daily means shows considerable dispersion (**Figure 13**). As an example, a six-term polynomial regression between the 90-day mean Craighead Pond stage and the 30-day average salinity at the Taylor River salinity monitoring station produces a coefficient of determination of -0.84. The confidence interval in this example however is still relatively large at ±8.5. According to this model, on average if the 90-day mean stage was at least 0.43 feet, salinity was 30 or less. The salinity was less than 30 at least 95% of the time when the 90-day mean stage was 0.69 or greater. The 90-day mean stage at the Craighead Pond station has been equal to or greater than 0.69 feet about 88% of the time, historically (**Figure 14**).

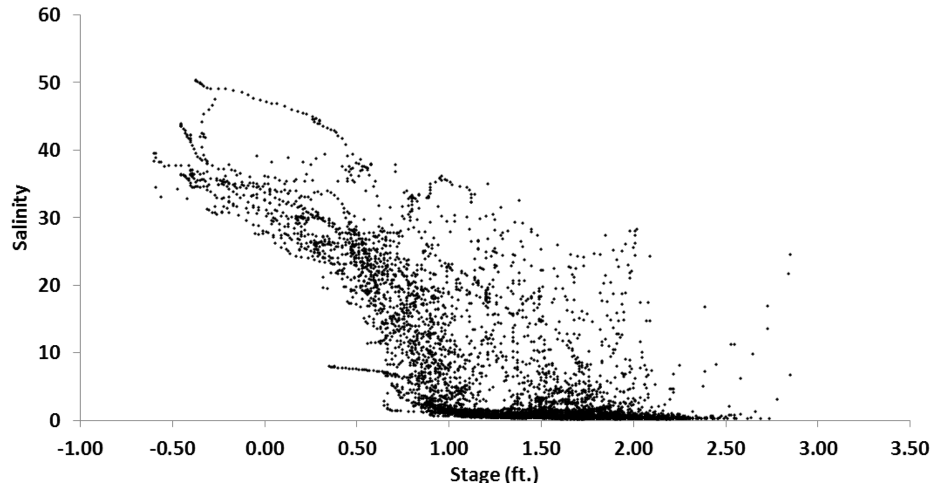

Figure 13. Plot of mean daily stage at the CP station and mean daily salinity at Taylor River salinity monitoring station.

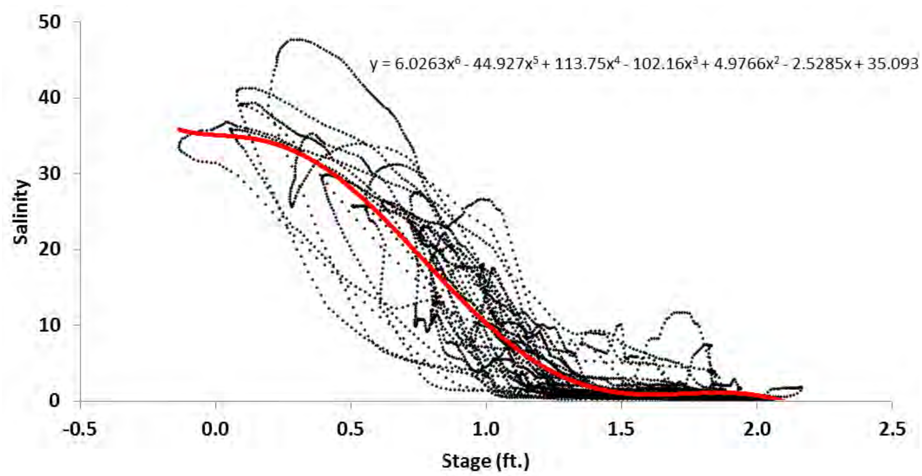

Figure 14. Example of a regression between 90-day mean stage at the CP station and 30-day mean salinity at the Taylor River salinity monitoring station.

2.5.5 Canal Flows and Water Level

Correlations between inflows from S-332D and S-18C indicate relationships to water level stages at several locations within the watershed. For example, Spearman's rho is greater than 0.80 between S-332D and S-18C mean daily flows and mean daily water stages monitoring sites near the canals (**Table 4**). The relationships are weaker, in general, toward the south. For example, Spearman's rho is 0.74 between S-332D flows and stages at E146, and 0.72 at CP. Spearman's rho between flow at S-18C and the same stage monitoring sites is 0.71 and 0.62, respectively.

Table 4. Spearman correlation coefficients (rho) between flow at the canal inflow structures and water levels at gauge stations in the watershed. All available data sets come from SFWMD, Everglades National Park and USGS with variable periods of record.

Water Level Stations	Canal Stations (flow)					
	S-332D	S-200	S-332	S-175	S-199	S-18C
R3110	0.80	0.49	0.03	0.29	0.67	0.73
NTS1	0.86	0.52	0.00	0.21	0.73	0.70
E112	0.82	0.52	0.25	0.37	0.73	0.79
NTS14	0.76	0.46	0.14	0.30	0.61	0.82
TSB	0.80	0.51	0.26	0.38	0.71	0.72
NP72	0.71	0.37	0.13	0.36	0.43	0.68
G3619	-0.46	-	0.02	-0.04	-	-0.27
DO1	0.71	0.42	0.12	0.34	0.43	0.76
R127	0.78	0.47	0.18	0.41	0.80	0.75
G3336	0.81	0.46	-0.03	-0.00	0.81	0.76
EVER4	0.76	0.47	0.13	0.39	0.76	0.76
CY2	0.70	0.47	0.09	0.20	0.67	0.76
G1251	0.76	0.43	0.17	0.43	0.78	0.70
CT50R	0.82	0.44	0.01	0.26	0.51	0.83
TSH	0.75	0.42	0.24	0.33	0.77	0.75
EVER7	0.76	0.42	0.09	0.27	0.65	0.77
CT27R	0.79	0.41	-0.10	0.22	0.49	0.82
EVER6	0.80	0.44	0.02	0.24	0.52	0.81
EP1R	0.79	0.43	0.10	0.33	0.58	0.82
G3353	0.71	-	0.23	0.41	-	0.73
EVER5A	0.74	0.43	0.16	0.36	0.53	0.73
P37	0.74	0.45	0.14	0.36	0.55	0.66
EPSW	0.76	0.48	-0.07	0.25	0.55	0.73
OL	0.74	0.40	0.08	0.20	0.37	0.77
E146	0.74	0.38	0.12	0.27	0.36	0.71
CP	0.72	0.34	0.11	0.33	0.37	0.62

An example shown in **Figure 15** shows that statistical modeling is not robust between canal inflow and water level, but the results suggest that flows up to about 300 cfs at S-332D likely has had some role in increasing water levels at the CP gauge. When stage at CP has been at 0.69 feet or greater, the median flow from S-332D has been about 125 cfs, but flows have ranged from 0 to 572 cfs.

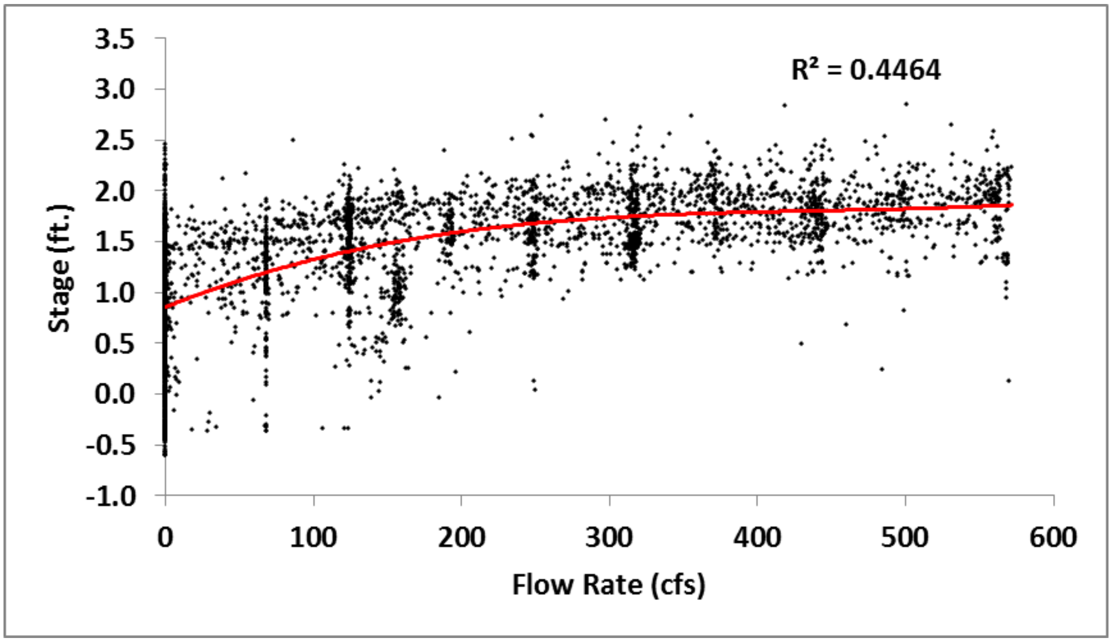

Figure 15. Cubic regression between the mean daily discharge rate from S-332D and water level at the CP station.

2.5.6 Changing Hydrology

Besides climatic variations and sea level trends, hydrologic variables related particularly to canal inflows into the northeastern Florida Bay watershed have changed over time and will continue to change. As the canal water management system has developed, it has caused documented changes to the flows and levels in Taylor Slough (Kotun and Renshaw 2013) and the panhandle region (Hunt et al. 2006). Changes are continuing into the future as CERP projects such as the Tamiami Trail One-Mile Bridge and the C-111 Spreader Canal Western Project begin operation. The location of canal inputs and rates of input have changed in the past and will continue to change in the future. Everglades restoration projects now in the planning stages are expected to result in more water conveyed into Florida Bay (USACE and SFWMD 2013). Consequently, the empirical relationships among some of these variables may change, so predicting future outcomes based in these relationships should be done with caution. Similar to the approach described in Hunt et al. (2006), a combination of mathematical hydrologic models can be employed to generally compare current and expected future conditions and should be evaluated for use in future reviews.

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Section 3. Review of Ecological Information Supporting the MFL Criteria Assessment

Wetland and estuarine habitats of Florida Bay support several important biotic groups. The biota may be permanently resident, forage within the system, or use habitats within the bay during critical parts of their life cycle (Lorenz 1999, Ley and McIvor 2002). Prominent fauna include protected mammals such as the West Indian manatee and bottlenose dolphin, the endangered American crocodile (Mazotti and Brandt 1994), the American alligator, four species of sea turtles, and numerous birds, fish and invertebrates. The proximity of the marsh, mangrove and seagrass communities in and around Florida Bay creates a unique habitat complex and many aquatic and avian species migrate between them on a daily basis for feeding and shelter (Odum et al. 1982, Zieman 1982). Florida Bay is a thriving nursery for numerous fisheries, including the spiny lobster (Davis and Dodrill 1989) and commercial shrimp fisheries in the Gulf of Mexico (Ehrhardt and Legault 1999). Pink shrimp favor seagrass habitats (Sheriden 1992) and both the pink shrimp and the spiny lobster use Florida Bay as a primary nursery ground (Butler et al. 1995). More than 250 species of fish live in south Florida's coastal waters (Loftus 2000, NPS 2005). Gray snapper, sheepshead, red drum, and spotted seatrout are recruited into Florida Bay seagrass habitat as larvae and juveniles and then move into the mangrove habitat for several years to feed and grow to maturity (Odum and Heald 1975, Thayer et al. 1999).

In the transition zone bordering Florida Bay, submersed benthic plants (including seagrasses and macroalgae) collectively known as submersed aquatic vegetation (SAV), provide critical habitat for fauna. Historically, northeastern Florida Bay had a high abundance of *Ruppia*, *Chara hornemanii*, a fresh water macroalga, *Utricularia* sp., a brackish water plant, and other desirable low salinity species in creeks and ponds. These vegetation beds provide food, shelter and structure, nursery areas and high quality food sources for mammals, fish, avian and invertebrate species.

This section of the report includes a review of new information relevant to the Florida Bay MFL that has been obtained since the establishment of the rule in 2006, and a reevaluation of the following important issues:

1) Salinity Criterion: An average salinity of 30 as an appropriate threshold for determining significant harm to the system.

2) Response Species: *Ruppia* as an appropriate indicator species.

3) Monitoring Station: The Taylor River salinity monitoring station as an effective MFL compliance point.

4) Condition of SAV: The SAV condition in the post-MFL period is reviewed in relation to observed salinity patterns.

3.1 Salinity Patterns and Distribution in Northeastern Florida Bay

Water column salinity has been measured at numerous sites throughout the transition zone and in the embayments of Florida Bay. Salinity stations maintained by various organizations, including Audubon of Florida, Everglades National Park, SFWMD, and United States Geological Survey (USGS), provide long-term data sets with a period of record going back as far as 1988 for the longest deployed stations in Everglades National Park (**Figure 16**).

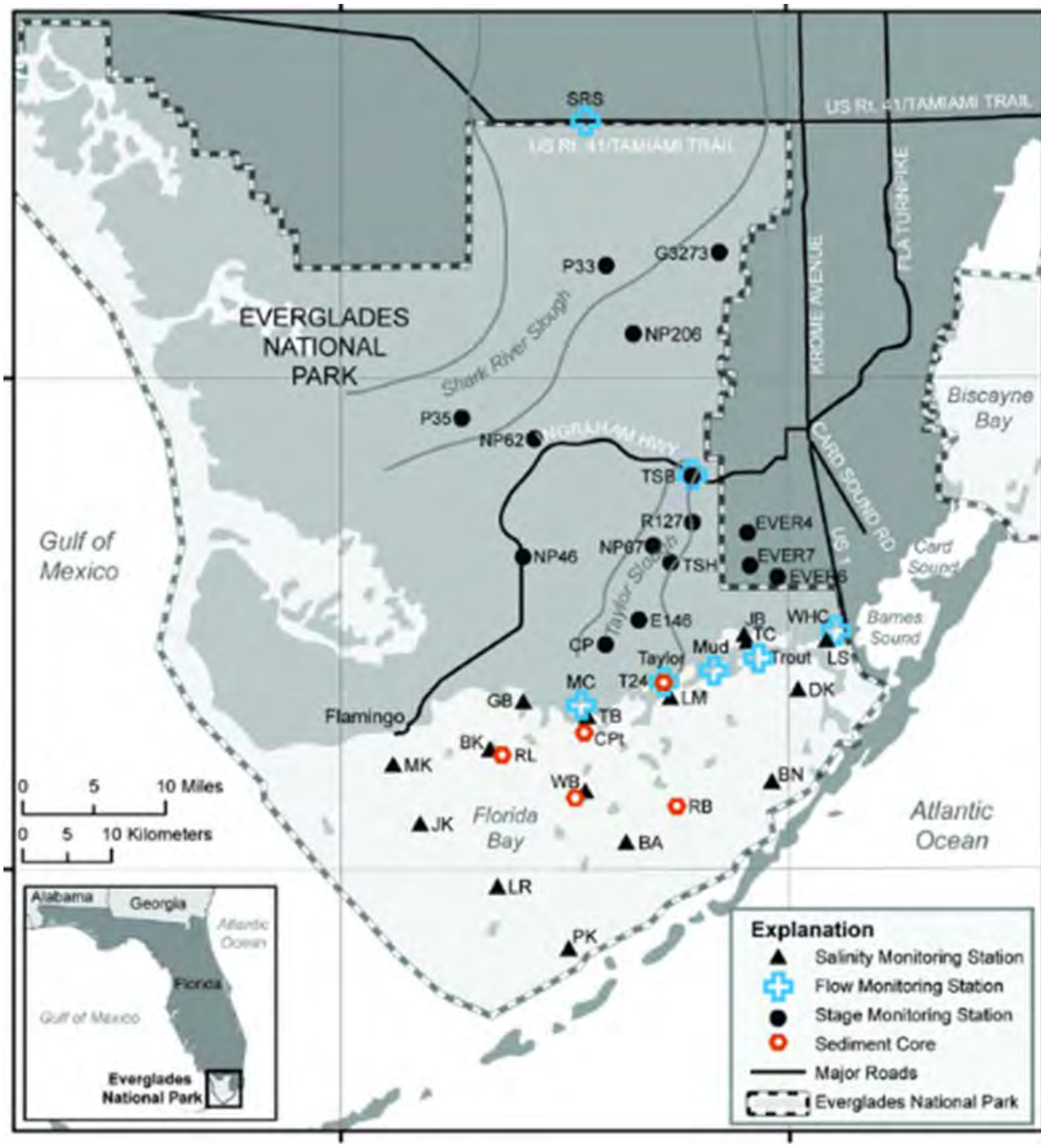

Figure 16. Salinity monitoring stations within Florida Bay and the Everglades -Florida Bay transition zone.

3.1.1 General Salinity Patterns

In general, average salinity increases from north to south within the MFL boundaries. Average salinity at the nearshore stations (LM, JB, LS; **Figure 16**) from 1991 through 2012 was 18.5. The distribution of the daily mean values from these stations was relatively normal with some skewing toward the upper end of the salinity range (**Figure 17**). Annual salinity during this period has varied, but appears to be higher beginning in 2004 (**Figure 18**). Both observed canal flows and rainfall appear to be relatively lower than the decade prior (e.g., 1990s), which was generally considered a wet period (Hunt et al. 2006).

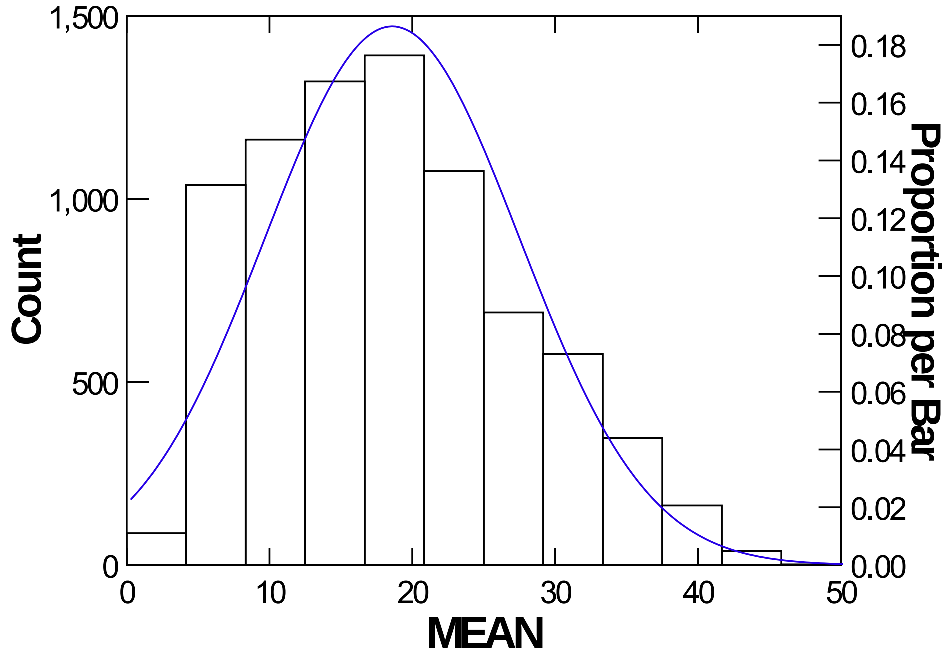

Figure 17. Distribution of mean daily nearshore salinity (stations LM, JB and LS).

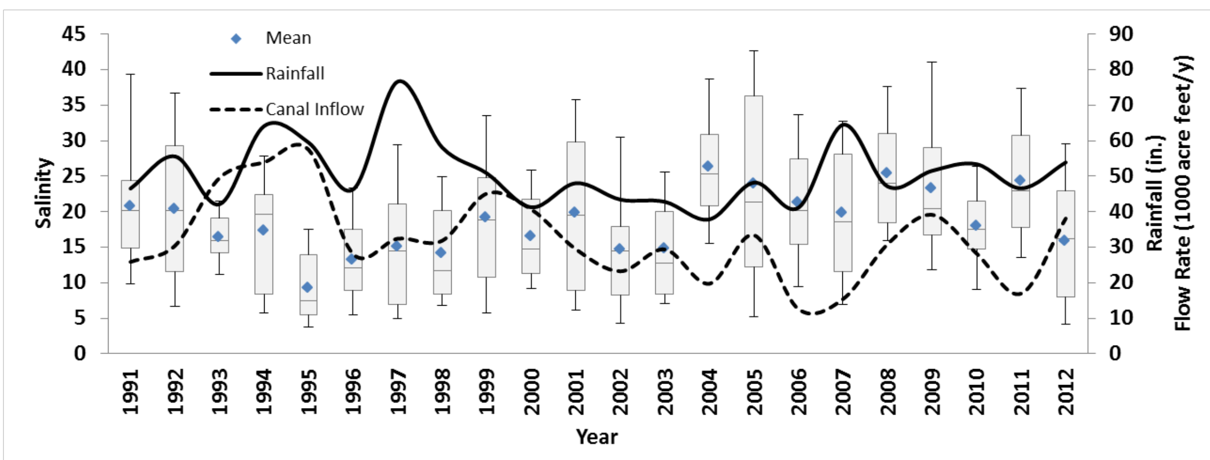

Figure 18. Period of record annual values for mean nearshore salinity (boxes), total mean rainfall (solid line) and total canal inflows (dashed line). The annual salinity box plots are based on the daily means averaged among stations LM, JB and LS. Rainfall is the total annual sum based on daily means averaged among water control structures S-177 and S-18C and station JB. Canal inflow is based on the annual sum of available daily discharge means at water control structures S-8C, S-175, S-332, S-332D, S-199 and S-200.

Seasonal fluctuations in salinity are apparent at stations in Florida Bay, northeastern Florida Bay and the transition zone (**Figure 19**). The similarity among these widely separated sites suggests that some of the same factors affecting salinity at station TR in the transition zone are likely affecting salinity at downstream locations, including open water areas of Florida Bay (WB and DK). Hypersaline conditions, defined here as salinity of 40 or greater, can occur in the eastern and central regions of Florida Bay when there are combined effects of inadequate freshwater inputs from rainfall and upstream sources, high evaporation rates, and limited circulation and flushing with seawater from more distal areas of the bay. During the pre-MFL period in the early 1990s, salinity in Duck Key Basin and Whipray Basin exceeded 40 continuously for two years, and exceeded 30 for over three years. Those extreme multi-year events have not been repeated, but shorter instances of hypersalinity have occurred several times in the years since then.

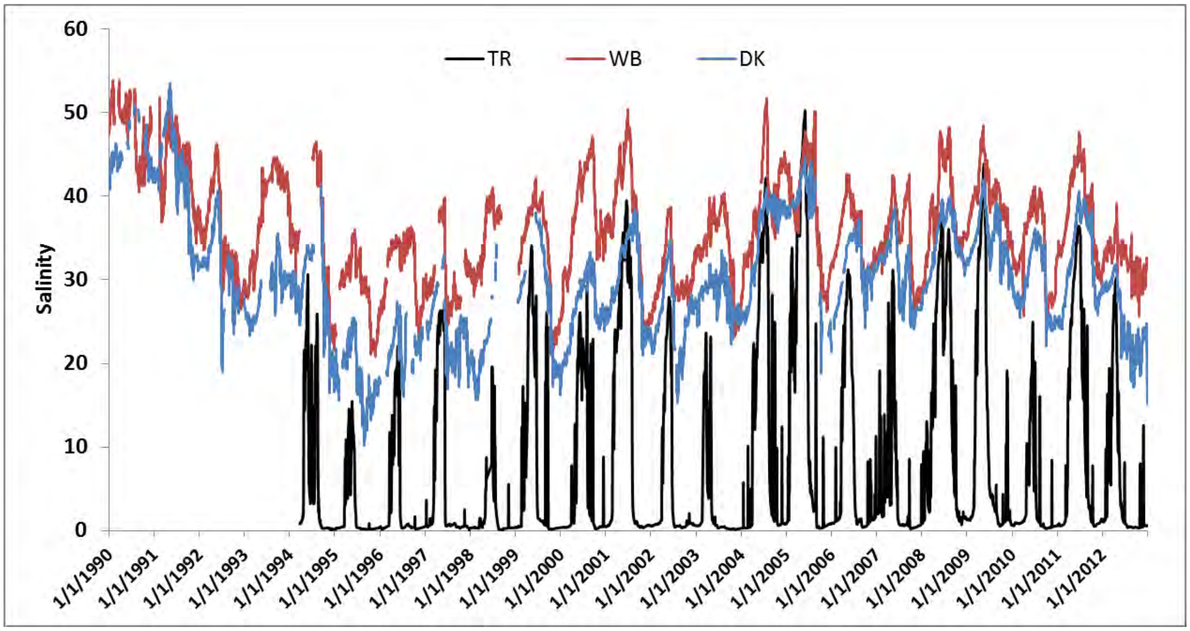

Figure 19. Salinity time series plot at Taylor River (TR), Whipray Basin (WB) and Duck Key (DK).

The lakes in the transition zone upstream of the central bay region have notably different characteristics than the upstream areas of the Taylor River and Joe Bay transition zone. These western lakes are apparently less well flushed by bay water than the coastal embayments to the east because they are more saline (Frankovich et al. 2011). They receive water of lower salinity during the wet season but never become fresh (**Figure 20**). The western lakes do not support a large population of *Ruppia*, although the freshwater macroalga *Chara* is a major component of the biota in part of the lakes complex (Frankovich et al. 2011). Therefore, it seems that the hydrology of these lakes is connected with the Taylor Slough catchment. The existing MFL salinity criterion (i.e., 30-day mean = 30) appears to also be protective of a freshwater (*Chara*) community in the upper lakes. Conditions within the lower lakes support a community that is different (more saline) than the eastern ecotone areas within the current MFL boundary (discussed below). Additional work is needed to determine detailed hydrology of the region, and it is possible that a different salinity criterion would apply to the transition zone in the western lakes than applies in central Taylor Slough. This area is undergoing a change in hydrology as the C-111 Spreader Canal Western Project is being implemented, and salinity may be reduced as a result.

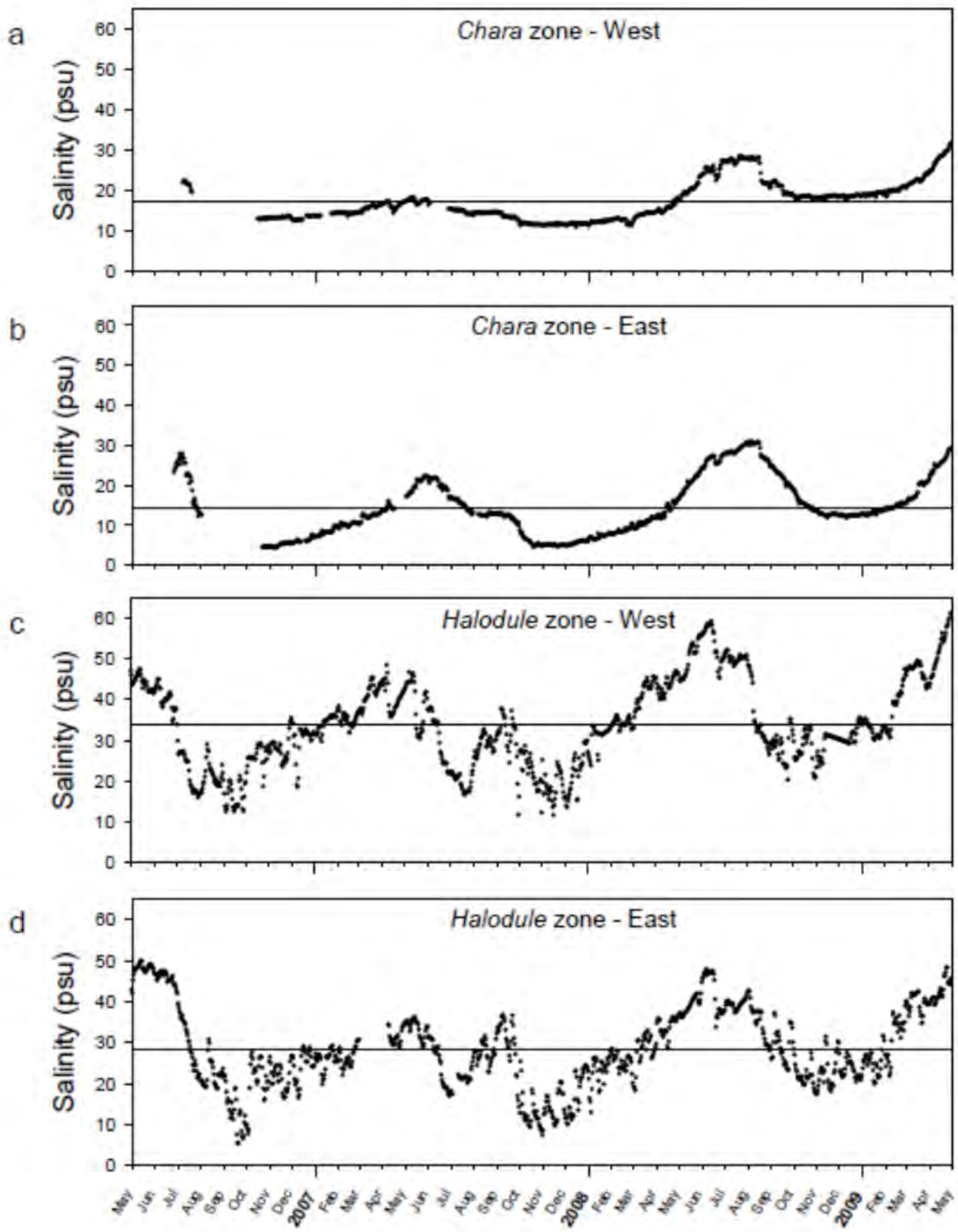

Figure 20. Time series salinity plots in the western lakes segregated by eastern and western lakes and by lower (*Chara*) and higher (*Halodule*) salinity zones (from Frankovich et al. 2012). Horizontal lines represent the mean.

3.1.2 Relationship of Salinity in Taylor River to Other Areas

Monthly average salinity time series show a concordance in salinity fluctuations between station TR and station JB (**Figure 21**). The profiles track each other closely and individual averages month-to-month are nearly identical, with JB being slightly higher at times and both sites going completely fresh during the wet season. The mean daily values at these sites correlate strongly (0.86, Spearman's rho). Salinity results at Duck Key (DK), downstream of Joe Bay, and Whipray Basin (WB) downstream and west of Taylor River are higher, on average, with the seasonal oscillations more damped.

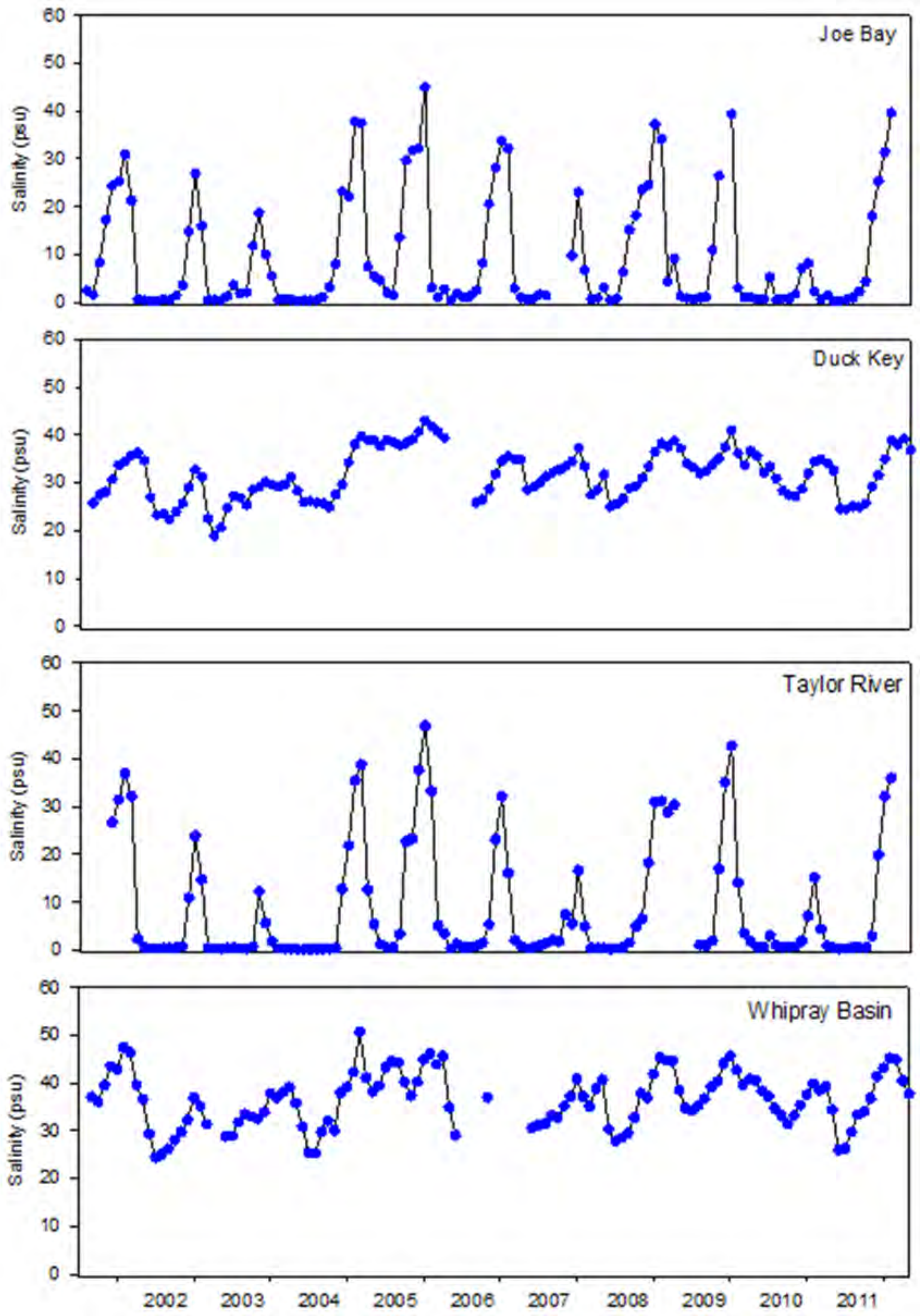

Figure 21. Ten-year monthly mean salinity in Whipray Basin, (Everglades National Park, WB Platform), Duck Key, (Everglades National Park, DK Platform), Taylor River (Audubon, TR Platform), and Joe Bay (Audubon, JB Platform).

3.2 Relationships between Salinity and Bottom Communities in the Ecotone

SAV responds to several environmental variables including salinity, temperature, light, nutrients and herbivory (Frankovich et al. 2011). Discriminant function analysis has yielded some success in predictively modeling the presence and areal coverage of a particular SAV group based on a statistical analysis of primary variables (Fourqurean et al. 2003). Understanding of the mechanism of species distribution is complicated by the interactions of these variables with factors such as antecedent conditions, genetics and recruitment. Nevertheless, salinity is such a strong driver of submersed aquatic plant physiology (Koch et al. 2007a) that empirical and statistical results show that it is a primary determinant of the distribution of SAV in the Florida Bay transition zone (Fourqurean et al. 2003, Herbert et al. 2011). For this reason salinity was chosen as a reliable metric for tracking ecosystem response to inflows with respect to the MFL rule (Hunt et al. 2006). Since a resource-based approach using a gradient of ecotones from the Everglades-Florida Bay transition zone to northeastern Florida Bay was used to establish the MFL, it is also important to review and evaluate the condition of the associated SAV resources in the period since establishment of the MFL.

3.2.1 Temporal Patterns of SAV and Salinity

The Audubon monitoring program has measured salinity and vegetation in the transition zone on a water year calendar (i.e., May 1 to April 30 of the following year) from Water Year (WY) 2006 through WY 2012. The data are directly applicable in evaluating post-MFL salinity distributions and the condition of biological resources. In this section of the report, empirical data from three of four major transects monitored by Audubon of Florida (**Figure 22**) are assessed to determine how salinity patterns affect SAV in situ. These transects are located in Taylor River (TR), Joe Bay (JB) and Highway Creek (HC), each containing a number of sites (e.g. TR1, TR2, TR3, TR4A, TR5, TR6, etc.). The TR sites mentioned in this section are associated with an Audubon transect and is different from the Taylor River salinity monitoring station where MFL compliance is verified (see **Figures 3** and **22**). The Audubon transect in Barnes Sound was not included in this analysis since it is located outside the MFL boundary. In much of the analysis of SAV pattern below, the station within each transect where SAV is most prevalent is presented because the important temporal patterns are most obvious there.

It is important to understand the relationship of salinity to biological response in order to determine whether a salinity-based metric is feasible as a means of gauging MFL effectiveness in preventing significant harm across a diverse landscape. Lorenz et al. (2010) conducted a rainfall assessment using data from National Climate Division 6 for Florida, which extends along the Lower East Coast from Miami-Date to Martin County. They found that the six years of post-MFL monitoring included two relatively wet years (WY 2007 and WY 2010), one year of nearly average conditions (WY 2011), and three years that were either dry (WY 2008) or extremely dry (WY 2009 and WY 2012).These rainfall-based classifications are expressed non-quantitatively herein because they encompass a limited climatic time span (since 1982) and characterize an irregular portion of the area contributing inflow to northeastern Florida Bay. The area encompassing the Florida Bay MFL contains three different overlapping Florida Climate Divisions, each with different ranging rainfall patterns and quantities in most years. Thus different characterizations will likely occur based on the rainfall data and evaluations used. A series of figures (**Figures 23** through **25**) presents the sites in each transect that had the most abundant *Ruppia* populations.

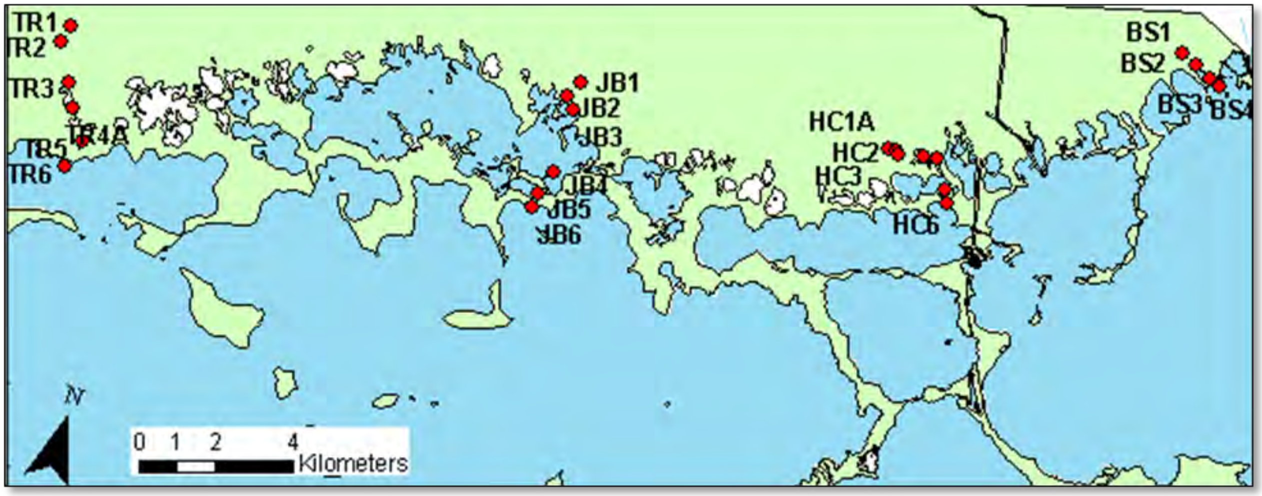

Figure 22. Map of the mangrove transition zone showing four Audubon transects located in Taylor River (TR), Joe Bay (JB), Highway Creek (HC) and Barnes Sound (BS).

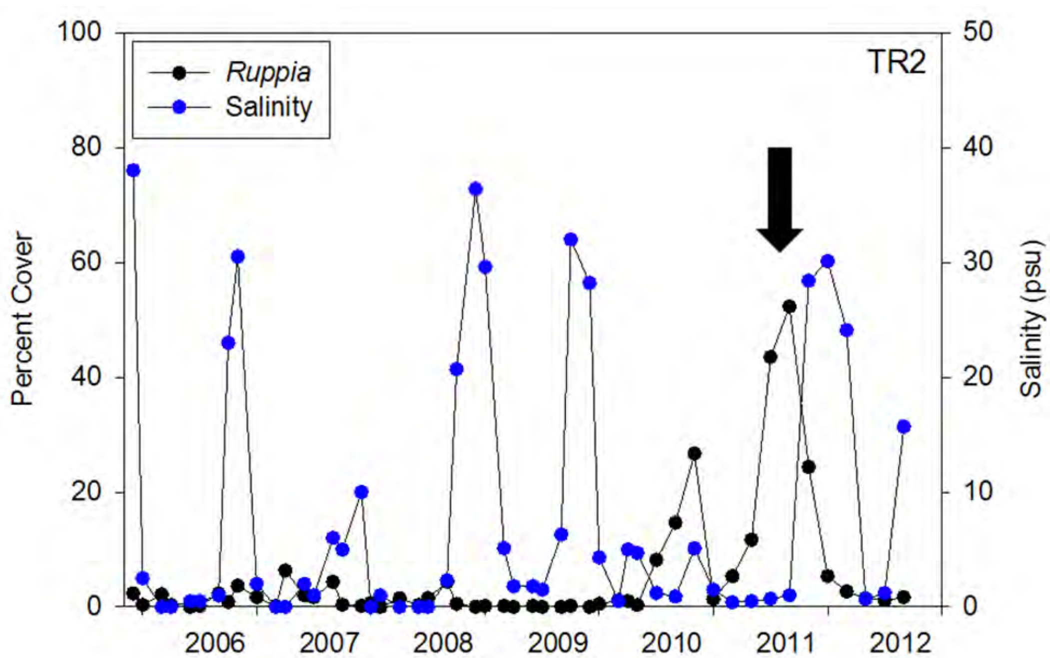

Figure 23. Time series plot of monthly percent coverage of *Ruppia* and salinity at Taylor River Site 2. During 2012, *Ruppia* percent coverage decreased dramatically from a record peak, following extended dry season conditions in 2011 (black arrow).

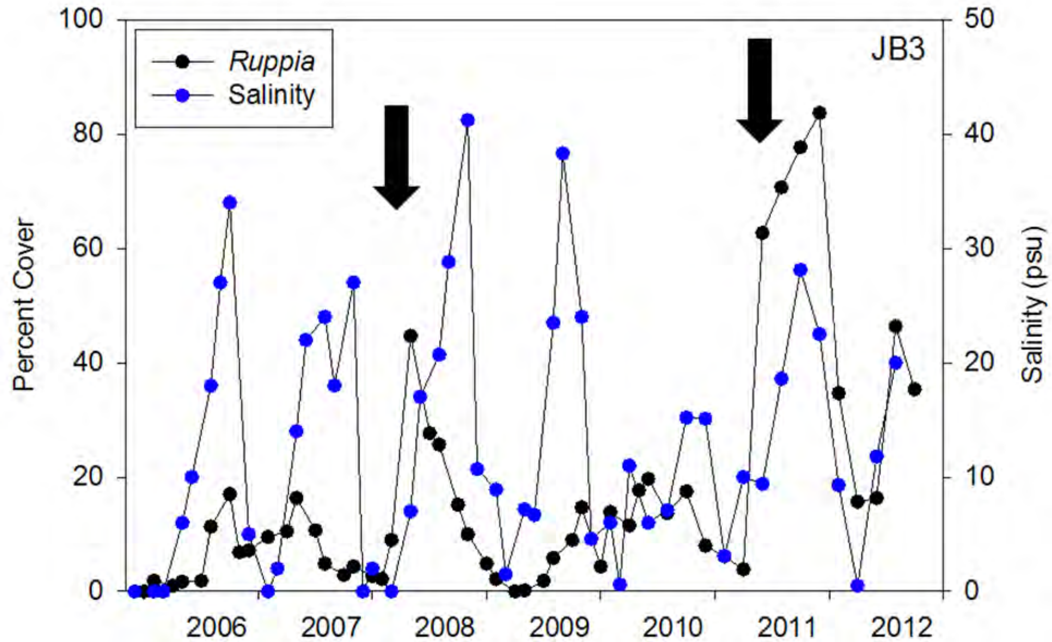

Figure 24. Time series plot monthly percent coverage of *Ruppia* and monthly salinity at Joe Bay Site 3. *Ruppia* percent coverage decreased during 2008 in conjunction with high salinity (first black arrow). Percent coverage of *Ruppia* increased dramatically in 2011 following an extended period of low salinity in 2010 (second black arrow).

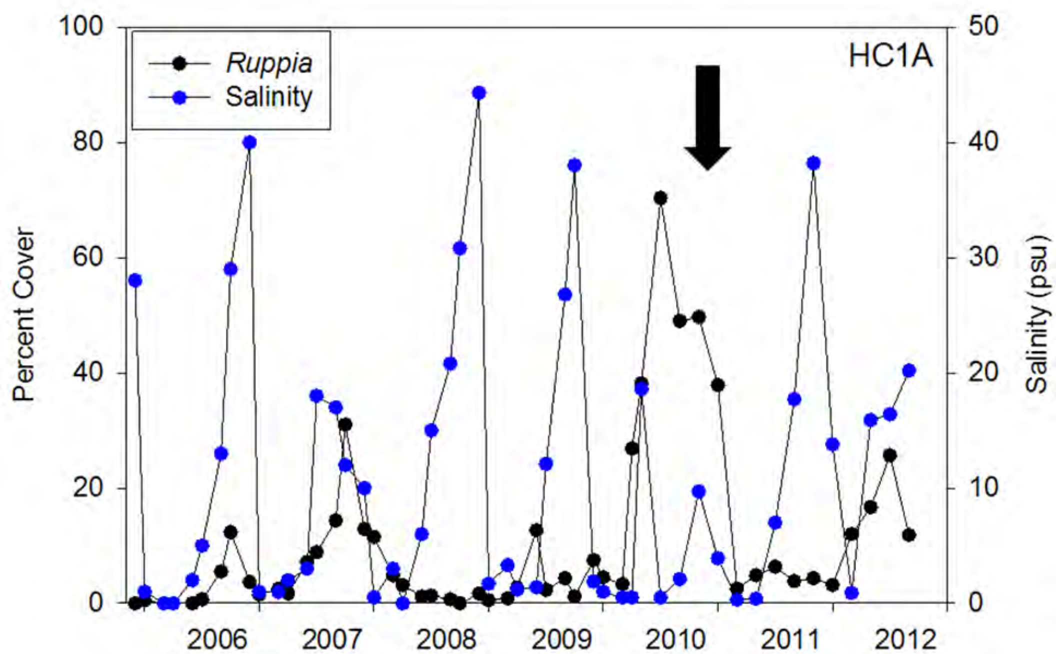

Figure 25. Time series plot of monthly percent coverage of *Ruppia* and salinity at Highway Creek Site 1A. Record high *Ruppia* and *Chara* coverage was observed in 2010 due to low salinity in the C-111 watershed (black arrow).

The Florida Bay MFL rule was enacted in December 2006 after a year of particularly high salinity. The higher than usual salinity may have negatively affected SAV coverage in Taylor River in the following year. In Taylor River at site TR2, WY 2007 was characterized by low salinity, although *Ruppia maritima* had only a small increase in areal cover during that time (**Figure 23**), because it may have been in a recovery mode. Although salinity was again lower than average during the WY 2008 wet season in Taylor Slough and fresh conditions persisted until later than normal, salinity was above average during the dry season, which may have contributed to a near complete loss of *Ruppia* cover for two years through WY 2009. Conditions were much wetter during WY 2010 and through a prolonged wet season in WY 2011. Salinity in Taylor Slough dropped well below dry season, wet season, and annual means during this period, and record high coverage of *Ruppia* was measured in the Taylor Slough basin in WY 2010 and WY 2011, peaking at 50% coverage in WY 2011. In late WY 2011, salinity was slightly above average during the dry season and percentage cover of *Ruppia* decreased. Above average salinity conditions at the end of WY 2011 into the beginning of WY 2012 lead to a very small increase in *Ruppia* cover.

Site JB3 had a much greater presence of *Ruppia*, persisting throughout the post-MFL rule period of record, although salinity there was slightly higher and persisted longer than in Taylor River (**Figure 24**). A clear annual cycle of growth and decline can be seen in the results with expanding *Ruppia* coverage during the wet season and a decline in coverage initiating in the dry season after salinity began to rise. Peak salinity ranged from 30 to 40 during most years, except in relatively wet WY 2010, when salinity peaked at around 15 for the year. As in Taylor River, percent cover in Joe Bay peaked at about 40 in WY 2011 immediately following the wet conditions in WY 2010. Of note is that in several years, *Ruppia* maintained a presence even throughout the period of high salinity in the dry season. This is consistent with experimental results showing that, once established, adult plants have a greater salinity tolerance. The critical period with respect to salinity is at the germination stage, which is extremely sensitive to high salinity (Strazisar et al. 2013a). Experimental data indicate that seeds failed to germinate at salinity above 25, and the optimal range for germination was 0 to 10. Therefore, the annual cycle of wet periods of low salinity is critical to *Ruppia* community viability, with the majority of seed germination occurring during the warm rainy season when salinity should be at its lowest point for the year.

Salinity at many of the SAV monitoring sites has not been measured continuously, but typically just at the time when the site was being sampled. Due to lags in the plant community response and variability in the salinity signal, determination of the relationship of *Ruppia* to these instantaneous salinity observations can be problematic. Instantaneous measurements may not be representative of true salinity exposure or salinity may vary too rapidly to induce an observable response in plant cover. As an alternative, the relationship between *Ruppia* and salinity was investigated by statistically estimating the 30-day average. This has the advantage of also aligning with the calculation of the salinity criterion for the MFL rule (a 30-day average). Average 30-day salinity at the sites was extrapolated from regressions of instantaneous measurements taken during monitoring visits against daily average salinity measured at nearby continuous monitoring platforms. Percent cover data for *Ruppia* were grouped into discrete salinity categories (i.e., 0–10, 10–20, 20–30, and > 30) based on these computed salinity data sets. Statistical differences among discrete categories were investigated using analysis of variance (ANOVA) and pair-wise t-tests (**Figure 26**). ANOVA analysis showed that cover means were statistically different ($F3, 1105 = 7.67$, $p < 0.0001$) and a pair-wise t-test identified that the percent cover within the > 30 salinity category was significantly lower than the 0–10 and 10–20 categories ($p < 0.05$). These results are consistent with the findings in the 2006 technical report (Hunt et al. 2006).

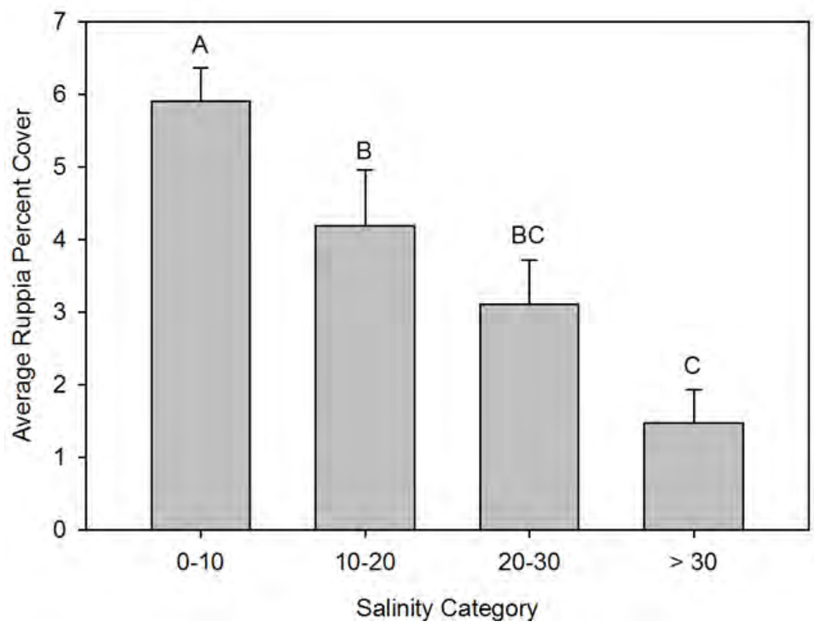

Figure 26. *Ruppia* percent cover along the Joe Bay and Taylor River transects with respect to salinity category. Error bars represent standard deviation. Category C is statistically lower than categories B and A, and salinity in the range of 0–10 (Category A) is significantly more favorable for *Ruppia* than higher salinity categories.

Although *Ruppia* cover was generally dependent on the mean of salinity, the variability of salinity was also investigated as a possible factor contributing to differences among monitoring sites. Koch and Strazisar (2013) showed that salinity variability increases downstream, with maximum variance nearest the bay (**Figure 27**). The upper site (TR1) can be characterized as relatively constant, with few high salinity events, and the lower site (TR6) as highly variable where tide and wind action cause pulses of alternating fresh and salt water through the area. The central site was of intermediate variability.

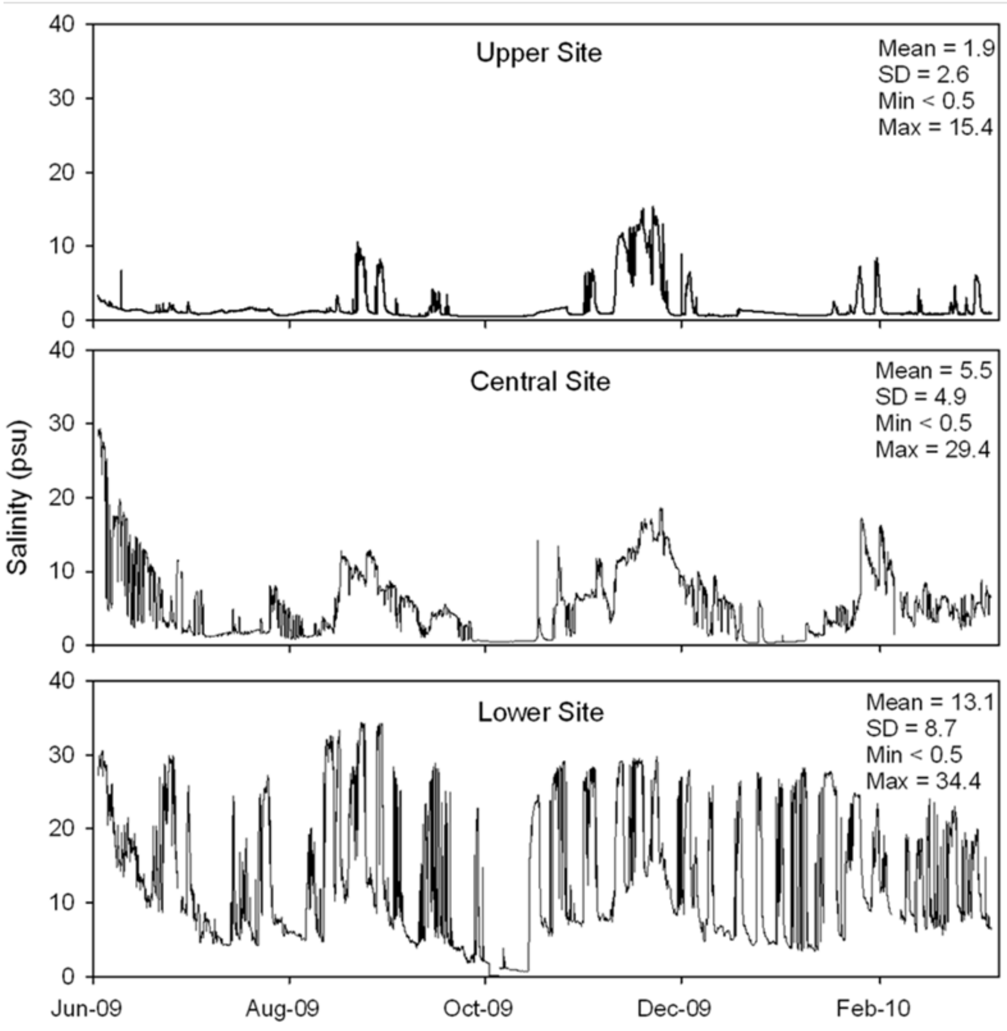

Figure 27. Salinity profiles through the wet and dry seasons at sites in the Taylor River transect from north to south in the transition zone.

3.2.2 SAV and Salinity Variability

For this analysis, average *Ruppia* cover was compared with the standard deviation of salinity at each monitoring site. Results indicate that *Ruppia* cover was negatively correlated (R2 = -0.815, $p < 0.05$, Pearson) with salinity variability (**Figure 28**). This is consistent with previous studies showing similar relationships between macrophyte biomass and salinity as well as between *Ruppia* seedling survival and salinity in northeastern Florida Bay (Montague and Ley 1993, Strazisar et al. 2013b). The salinity variability analysis was limited to sites with greater than five percent cover in order to remove bias caused by sites with little to no *Ruppia*. Data from site JB3 were excluded from the analysis because they were considered outliers. Site JB3 had an exceptionally robust population of *Ruppia* with a high average coverage (17.2%) yet it had an intermediate salinity standard deviation (11.1) relative to the other sites. In addition, the *Ruppia* population at JB3 recovered rapidly following high salinity events, while most sites were negatively impacted for a prolonged period following these events. *Ruppia* cover at JB3 was consistently high regardless of exposure to elevated salinity. The reason for the high degree of resilience at this site is unknown but may be related to interspecific competition with other SAV species or a particularly robust seed bank (Strazisar 2013a).

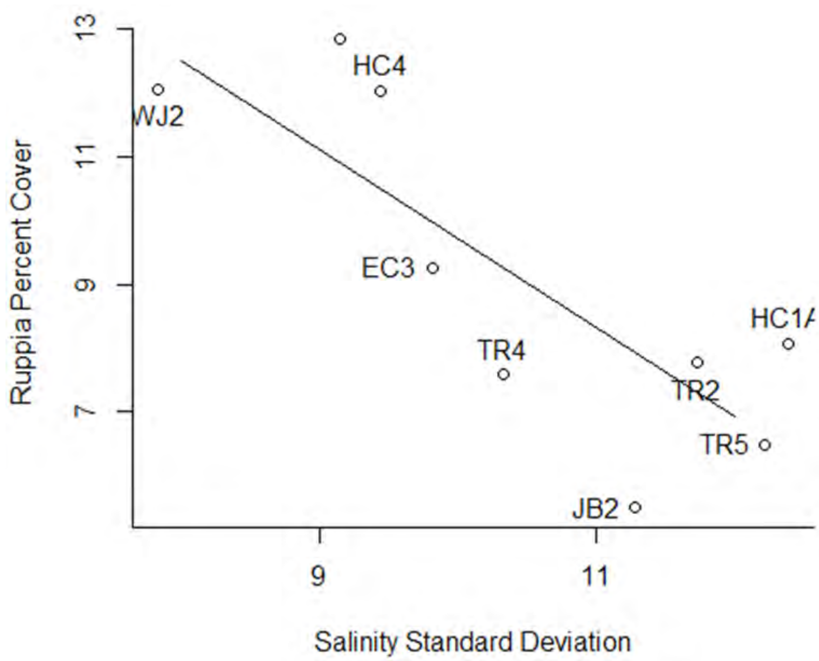

Figure 28. Relationship between salinity variability (standard deviation) and *Ruppia* cover (R = -0.82, $p < 0.05$). Analysis was limited to sites with > 5% average *Ruppia* cover. Site JB3, which had an exceptionally robust population, was excluded from this analysis.

At each transect site, species co-occurring with *Ruppia* showed dynamics reflective of their optimal salinity ranges. For example, at site JB3, in the periods when salinity was elevated, inhibiting *Ruppia* growth, *Halodule* increased in percent cover (**Figure 29**). *Ruppia* percent cover decreased during 2008 in conjunction with high salinity (first black arrow in **Figure 29**). This decrease was followed by increases in *Halodule* percent cover, peaking in 2009. Decreases in *Halodule* then occurred following the onset of low salinity during 2010 (red arrow in **Figure 29**). *Ruppia* percent cover increased dramatically the following year (second black arrow in **Figure 29**). These dynamics serve to maintain a viable SAV presence even in periods unfavorable for the oligohaline plant consortium.

At the site HC1A, salinity conditions that favored *Ruppia* also favored the fresh to brackish water macroalga *Chara*, which varied in concert with *Ruppia*, although lagging slightly (**Figure 30**). *Ruppia* and *Chara* percent cover decreased during 2008 in conjunction with high salinity (first black arrow in **Figure 30**). Record high *Ruppia* and *Chara* cover was observed in 2010 due to extremely low salinity (second black arrow in **Figure 30**). At site JB2, upstream of and fresher than site JB3, *Chara* dominated, oscillating inversely with salinity (**Figure 31**).

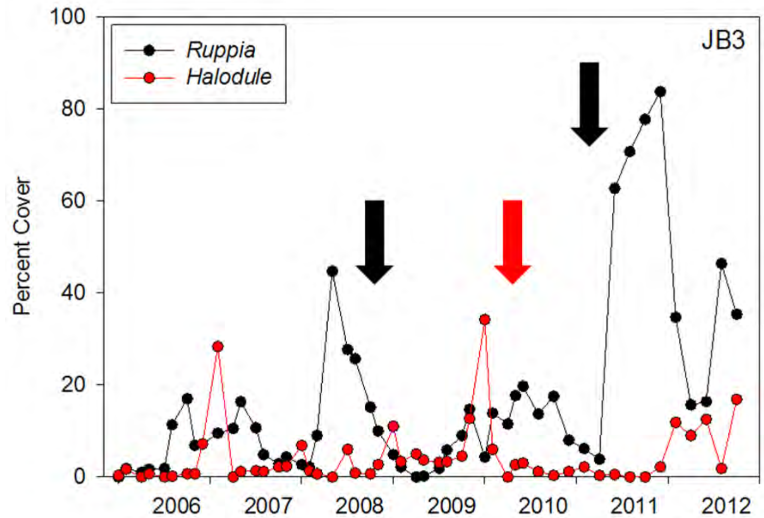

Figure 29. Time series plot of monthly percent cover of *Ruppia* and *Halodule* at Joe Bay Site 3.

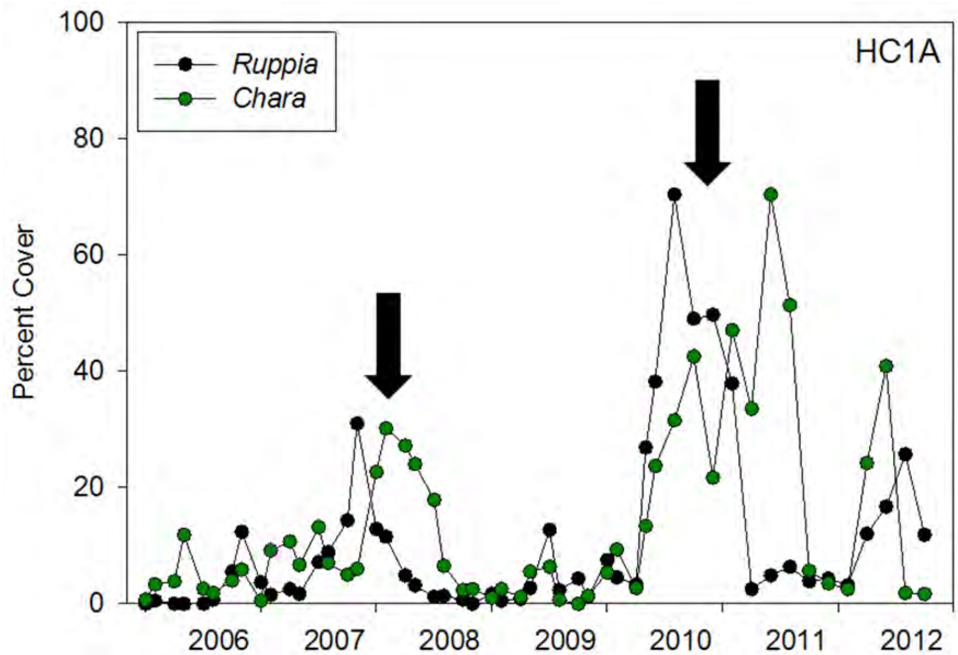

Figure 30. Time series plot monthly percent cover of *Ruppia* and *Chara* at Highway Creek Site 1A. *Ruppia* and *Chara* percent cover decreased during 2008 in conjunction with high salinity (first black arrow). Record high *Ruppia* and *Chara* cover was observed in 2010 due to extremely low salinity in (second black arrow).

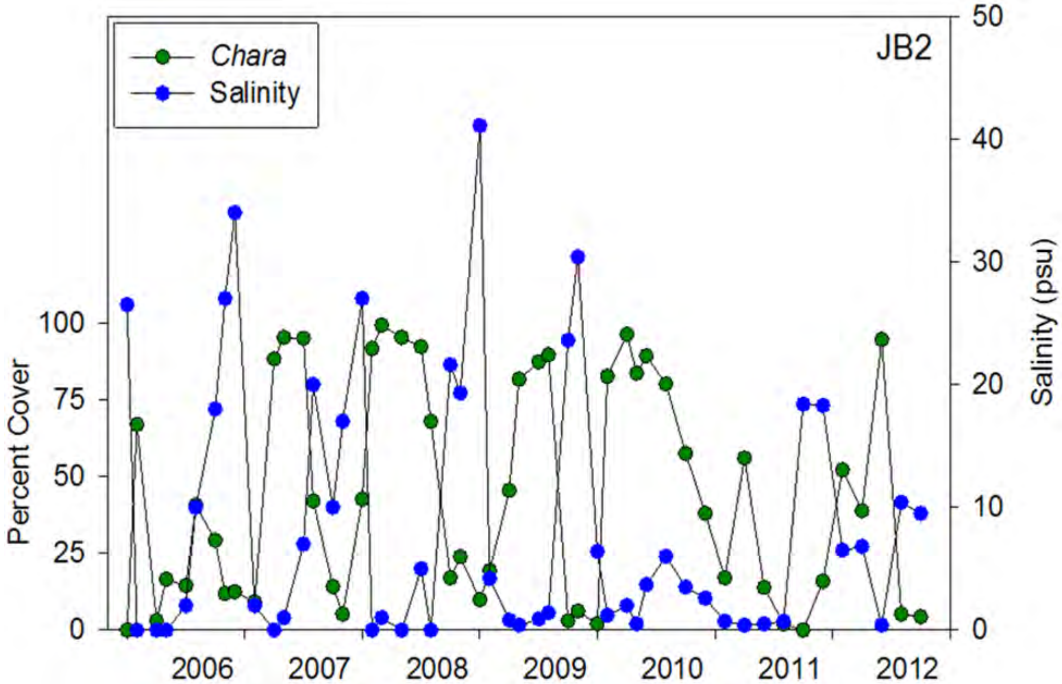

Figure 31. Time series plot of monthly percent coverage of *Chara* and salinity at Joe Bay Site 2.

3.3 SAV within the Lakes Region of the Transition Zone

The western lakes are centers of high phytoplankton productivity, relatively high nutrients and a diverse SAV/macroalgal community (Frankovich et al. 2011). The response of biological communities in the lakes to changing water and salinity is of interest in the context of MFL assessment and restoration impacts related to the C-111 Spreader Canal Western Project. Recent research examined the spatial and temporal distribution of SAV and macroalgae in these lakes and their relationships with salinity and other variables from May 2006 through April 2009 (Frankovich et al. 2011). The westernmost complex of lakes feature a different species assemblage than that found in Taylor River, Joe Bay or the Highway Creek to the east, and they do not support large populations of *Ruppia*, with this species only occurring sporadically on mud banks. The water column is turbid in the western lakes due to high phytoplankton concentrations and low light availability, which are implicated in limiting *Ruppia* (Frankovich et al. 2012). *Chara* is a major component of the lakes, including those within the Florida Bay MFL boundary (Seven Palm, Monroe and Middle Lakes) (Frankovich et al. 2011), while the seagrass *Halodule* dominates in the coastal embayments farther downstream. Populations of *Chara* and *Halodule* were found to segregate by salinity regime within the region (**Figure 32**).

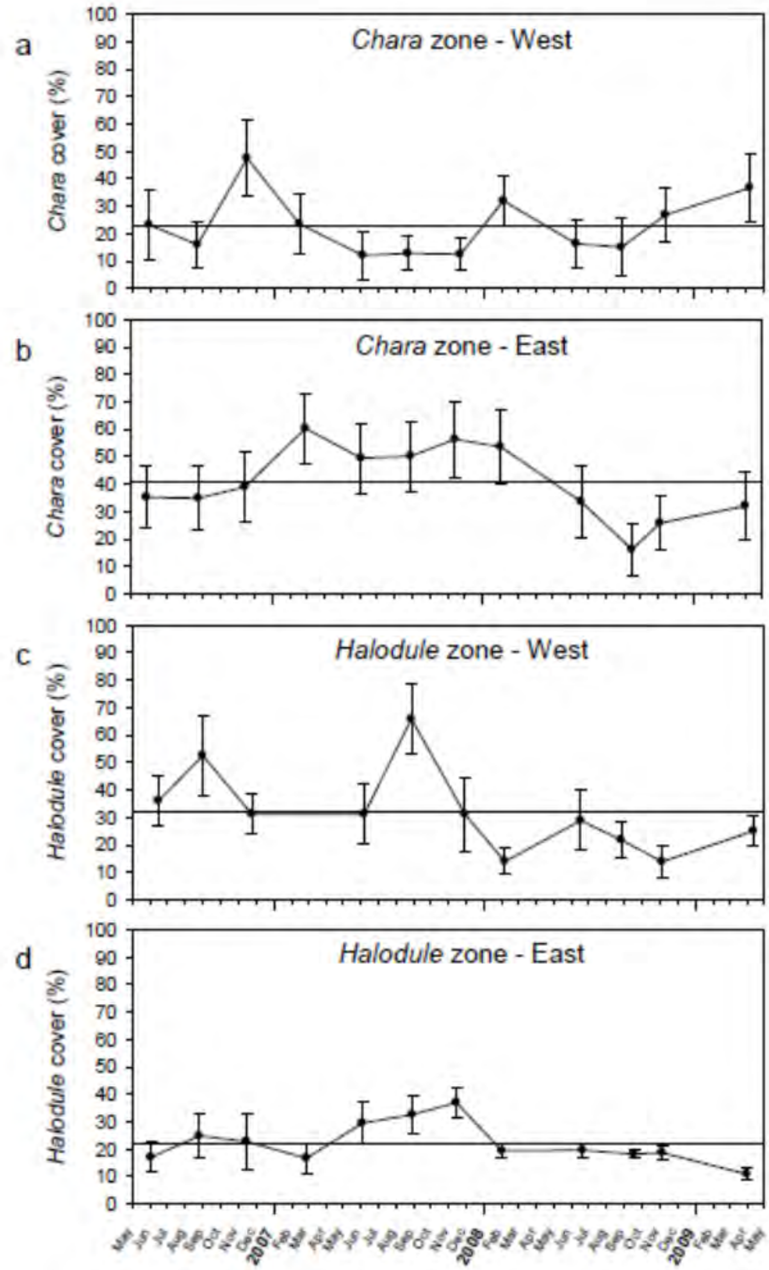

Figure 32. SAV percent cover time series from the western lakes and coastal embayments of central Florida Bay. Plots are segregated by eastern and western drainages and lower (*Chara*) and higher (*Halodule*) salinity zones. Horizontal lines are grand means (from Frankovich et al. 2011).

3.4 Downstream Distribution and Trends of SAV in Florida Bay

In the process of developing the MFL criteria, *Ruppia* was chosen as the indicator species that represented the most salt tolerant species within the SAV community of the Everglades-Florida Bay transition zone (Hunt et al. 2006). Downstream in the open waters of Florida Bay, the salinity regime is generally marine in character and the benthic vegetation community is dominated by marine seagrasses, primarily *Thalassia* and *Halodule*. Hydrologic modeling analysis indicated that maintaining salinities at or below 30 in the transition zone through adequate freshwater inflow (supporting *Ruppia* production), would prevent northeastern Florida Bay from becoming hypersaline (salinity > 40), providing adequate conditions for a desirable mixed seagrass community of *Thalassia* and *Halodule*. Mixed seagrass communities tend to be more stable and resilient than monocultures (Zieman et al. 1999). They also provide better habitat for forage fish (Sogard et al. 1989).

Experimental mesocosm studies (Koch et al. 2007a) and modeling studies (Madden et al. 2009) indicate that both marine SAV species can tolerate relatively high salinity. Of the two dominant marine species in the northeast bay, *Halodule* is the more sensitive to hypersalinity and begins to decline above a salinity of 40 at which point *Thalassia* has a competitive advantage and can dominate (Koch et al. 2007a). This was the situation during the high levels of hypersalinity in the late 1980s, possibly setting up a *Thalassia* die-off that occurred when the carrying capacity was exceeded and the community temporarily collapsed (Robblee et al. 1991). The MFL salinity criterion is designed to protect northeastern Florida Bay by minimizing occurrences of hypersalinity. Salinity results (e.g. **Figures 19** and **21**) suggest this has generally been true in the eastern bay. Salinity has remained mostly below 40 in northeastern Florida Bay, usually well below, and the seagrass community has been generally healthy and resilient.

Three separate regional monitoring programs monitor benthic vegetation percent cover in different areas of Florida Bay using a randomized design and 0.25-square meter quadrats (Cline et al. 2013). Data and maps from two of these monitoring programs, for the period 2005–2011, were used in this MFL review to evaluate annual trends in SAV distribution and density in northeastern Florida Bay, and to assess salinity regime effects on seagrass distribution in the bay. They utilize a modified Braun-Blanquet Cover-Abundance index (Fourqurean et al. 2002). Miami-Dade County Environmental Resources Management conducts benthic habitat surveys quarterly in nearshore embayments of the transition zone (Miami-Dade County 2009) (**Figure 33**). The South Florida Fisheries Habitat Assessment Program (FHAP) monitors SAV in 17 basins throughout the bay annually at the end of the dry season (Hall and Durako 2012) (**Figure 34**).

The FHAP surveys show that average *Thalassia* cover significantly decreased from May 2008 to May 2009 in the Duck Key Basin, but the frequency of *Thalassia* presence did not change significantly (**Figure 35**). *Halodule* frequency of occurrence increased from May 2005 to May 2006, and then returned to the 2005 level by May 2008. In Eagle Key Basin offshore of Taylor River, *Thalassia* increased from May 2005 to May 2006 and a decrease in *Halodule* was observed through May 2007. While *Halodule* remained stable after 2007, *Thalassia* significantly decreased in density from May 2008 to May 2009. The pattern of alternating *Thalassia* and *Halodule* peaks indicates that the mixed species community stabilizes the SAV community advantageously as one species can remain or increase in extent/density as the other declines.

Figure 33. FHAP annual SAV monitoring basins since 2009 where sampling occurred annually.

Figure 34. Miami-Dade County's Division of Environmental Resources Management SAV monitoring basins where sampling occurred quarterly.

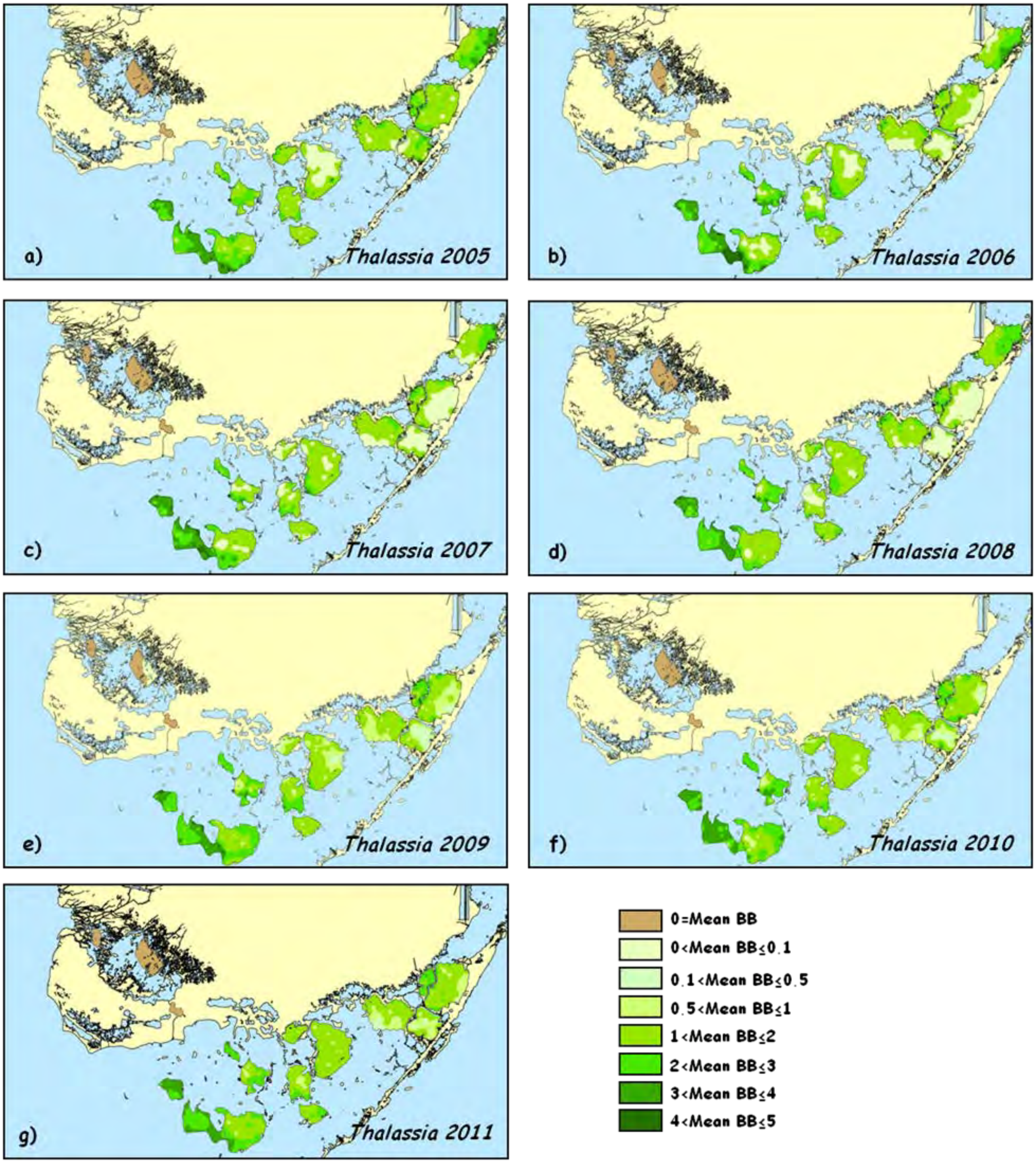

Figure 35. Contour plots illustrating Braun-Blanquet cover of *Thalassia* in a) 2005, b) 2006, c) 2007, d) 2008, e) 2009, f) 2010, and g) 2011. Note that stations in the far northeast portion of the map were eliminated in 2009 and absence of SAV there represents no data.

In the northeastern bay, SAV declined from 2005 through 2007 in Little Blackwater Sound, Blackwater Sound, and Barnes Sound with the greatest decline in Blackwater Sound, corresponding with the timing and location of a multi-year phytoplankton bloom in the eastern bay (Glibert et al. 2010). Reduced light at the bottom of the water column was identified as the primary driver of the loss of SAV, as supported in simulation modeling calculations using the SEACOM seagrass community model (Madden 2013) (**Figure 36**).

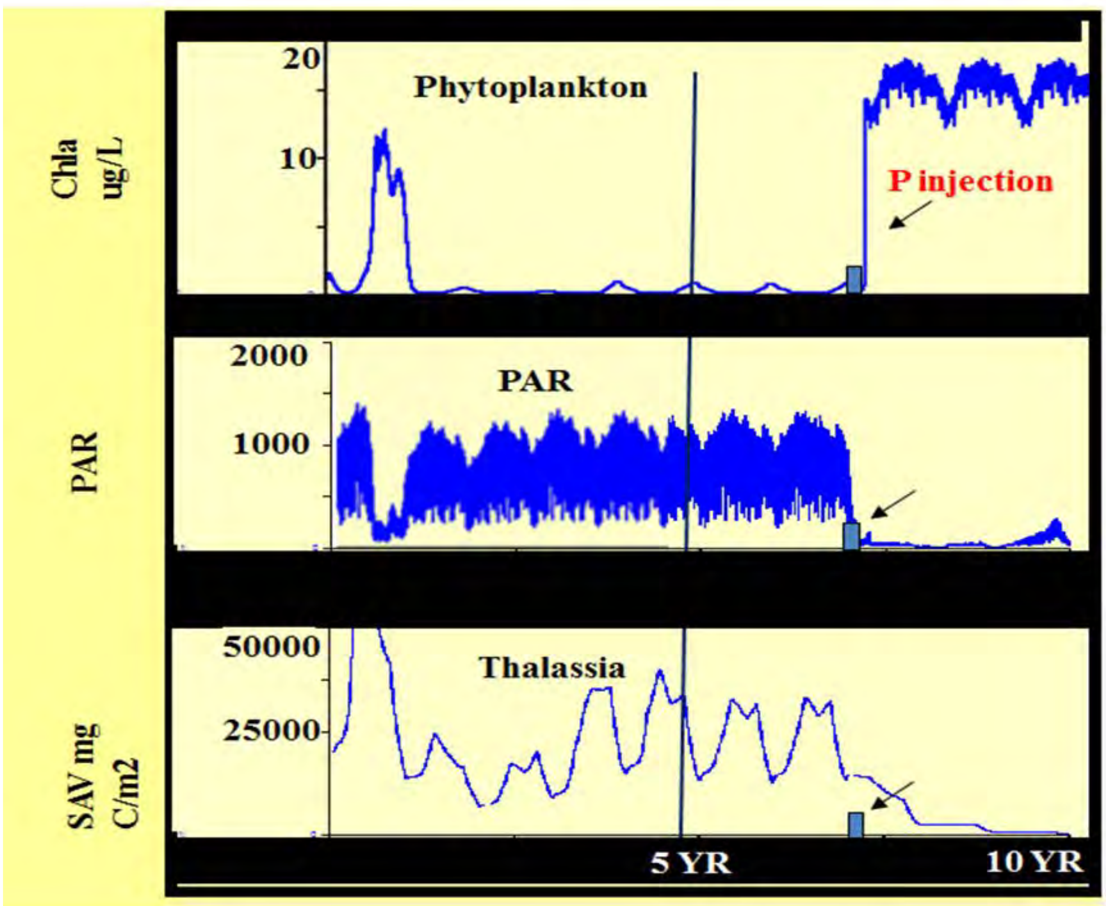

Figure 36. SEACOM model output showing how a moderate phytoplankton bloom can attenuate light sufficiently at the canopy to reduce and eliminate *Thalassia* in a 1.5-meter water column consistent with events in Barnes Sound during 2005–2008. The vertical black line indicates stabilization of the model after initialization. The arrow represents the addition of total phosphorus to the water column. (Note: µg/L – micrograms per liter, Chla – chlorophyll a, mg C/m2 – milligrams carbon per square meter, P – phosphorus, PAR – photosynthetically active radiation, and YR – year.)

Thalassia cover decreased (**Figure 35**) in areas affected by the bloom from 2006–2007 as *Halodule* cover increased (**Figure 37**), consistent with higher light requirement of *Thalassia* and greater quantum efficiency of *Halodule* at low light levels (Koch et al. 2007b). Following the termination of the algal bloom in 2008 and subsequent clearing of the water column, the frequency of *Thalassia* occurrence began to increase to pre-bloom levels in this area (**Figure 35**), although high intra-annual variability persists. Throughout this period, *Thalassia* and *Halodule* showed increased cover in central Florida Bay.

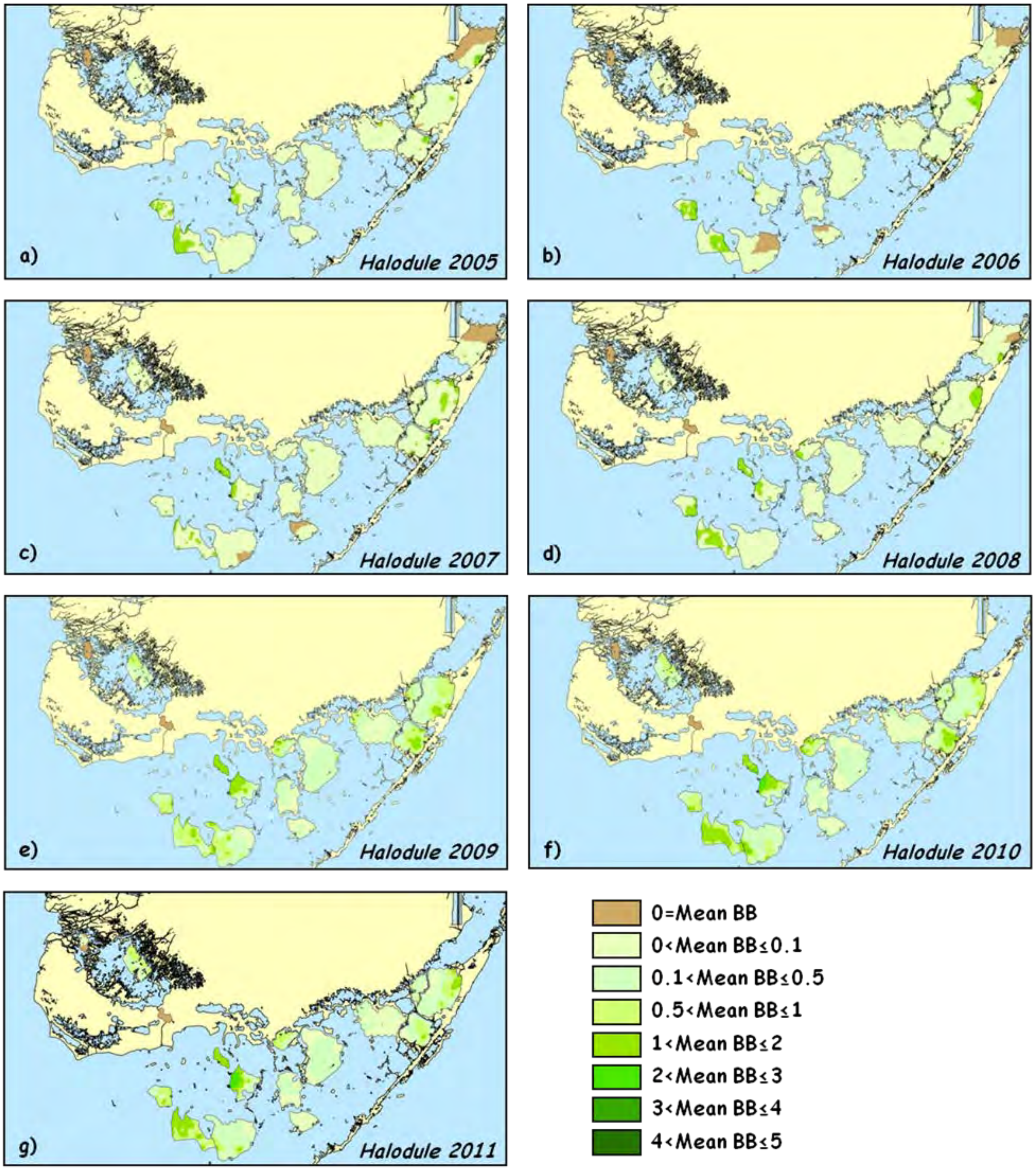

Figure 37. Contour plots illustrating Braun-Blanquet cover of *Halodule* in a) 2005, b) 2006, c) 2007, d) 2008, e) 2009, f) 2010, and g) 2011. Note that stations in the far northeast portion of the map were eliminated in 2009 and absence of SAV there represents no data.

3.5 Summary of SAV Monitoring in Post-MFL Adoption Period (2006–2012)

Wide area mapping of SAV in Florida Bay indicates that SAV has been moderately abundant in the bay since 2005. Both *Thalassia* and *Halodule* have often occurred in a mixed community, which is a desirable state of species richness contributing to ecosystem stability and biodiversity. Mapping results from May 2011 show that plant condition is more indicative of salinity conditions in the prior year than current conditions. Salinity conditions in 2011 were about average throughout the bay, and as a result, in all monitored basins within Florida Bay, the frequency of occurrence for both *Halodule* and *Thalassia* changed by less than 10% while 60% of sites changed by less than 5%. The occurrence of a phytoplankton bloom in the eastern bay from 2005 to 2009 caused a decline in *Thalassia* that was unrelated to salinity and has since recovered. SAV within and near the tidal creeks has been variable depending on the antecedent salinity conditions.

In general, monitoring conducted during the post-MFL period (2006–2012) indicates expected fluctuations in adult *Ruppia* populations according to salinity. Variations in the composition of the SAV community (e.g., species and percent cover), did not indicate significant harm as defined by SFWMD rule subsection 40E-8.021(31), F.A.C. ("the temporary loss of water resource functions which are a result of a change in surface or ground water hydrology that take more than two years to recover").

3.6 *Ruppia* as an Ecosystem Indicator

The relationships between the abundance of key indicator species (i.e., *Ruppia*, *Chara* and *Halodule*) and salinity in the mangrove transition zone continues to be assessed. As part of this MFL review, data from the Audubon monitoring sites (1996–2012; transects TR, JB and HC) were used to examine the distribution and abundance of SAV and the role of *Ruppia* as an indicator species. A site was considered occupied, and a species was considered present if the percent cover of a given species was greater than or equal to five percent. *Ruppia* occupied the greatest number of sites throughout the transition zone (i.e., present at 32 of 42 sites) (**Table 5**). *Chara* was nearly as prevalent (i.e., present in 32 of 42 sites), and had a higher average coverage than *Ruppia* when present. *Thalassia* had the highest average cover but was present in the fewest sites, as it was confined to the most saline end of the transects. *Ruppia* beds were rarely observed when salinity exceeded 30 (**Figure 38**). Freshwater macroalgae such as *Chara* were found at fewer sites than *Ruppia*, and were more heavily impacted under mesohaline conditions. *Halodule* showed no consistent response to salinity and sometimes increased in frequency at intermediate and higher salinity (**Figure 38**).

Table 5. Summary statistics for the six most abundant benthic plants in the transition zone.

Species	Type	Number of Sites Present/Total	Average Coverage	Number of Observations
Ruppia maritima	Vascular	33/42	18.1%	537
Batophora oerstedii	Algal	32/42	20.2%	447
Chara hornemanii	Algal	26/42	30.9%	656
Halodule wrightii	Vascular	23/42	32.5%	1055
Utricularia sp.	Vascular	13/42	22.0%	160
Thalassia testudinum	Vascular	12/42	39.8%	467

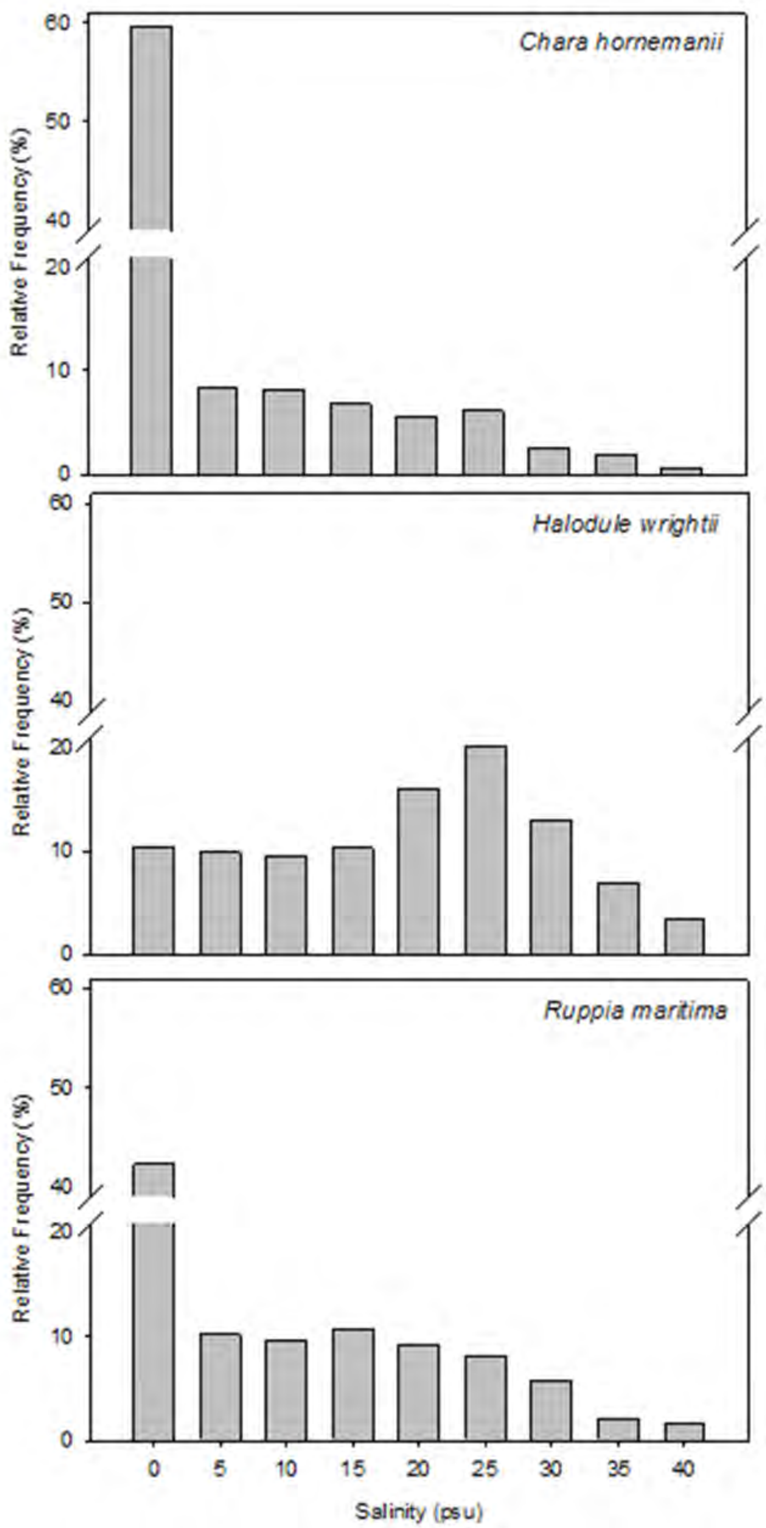

Figure 38. Relative frequency of *Chara*, *Ruppia* and *Halodule* (> 5% coverage) at all transition sites in relation to salinity categories.

A change point analysis was performed to estimate probable salinity thresholds beyond which *Ruppia* cover declined. This analysis was performed using the bcp R package (Erdman and Emerson 2007) that implements the Bayesian method of Barry and Hartigan (1993). The procedure starts by calculating the probability of all possible partitions of the data and evaluating them based on those that minimize the within-group sum of squares while maximizing the between-group sum of squares. This involves successively splitting the data set into two groups according to average salinity. At each split, the statistical properties of the two groups are evaluated to determine the likelihood that each group is statistically similar unto itself and at the same time statistically distinct from the opposing group. These change point probabilities are collected into a probability distribution by averaging over the partitions (salinity groups). The most probable change point was considered to represent a salinity threshold. The "uncertainty" of the identified salinity threshold was quantified by constructing a high density credible interval (analogous to a confidence interval) around this threshold. Probabilities within this interval can take a variety of shapes. They may peak at one value with which we can regard confidently as a change point or they may be broadly distributed. In the latter case, there is much less confidence that the highest probability change point represents a functional threshold.

Two separate analyses were performed using the MFL criterion of a 30-day moving average as well as a shorter 7-day moving average. The first analysis (30-day moving average) identified a salinity threshold of 34 with an "uncertainty envelope" from 28 to 34. The second analysis (7-day moving average) identified a salinity threshold of 28 with an "uncertainty envelope" from 23 to 32 (**Figure 39**). It is important to note that probabilities within the uncertainty envelope of the 7-daily moving average analysis peaked sharply (28 was selected at a 0.81 probability) while they broadly sloped in the 30-day moving average analysis (34 was selected at 0.31 probability). As a result, there is much greater confidence that the true change point within the 7-day moving average uncertainty envelope is 28 relative to the 30-day moving average analysis where the 34 salinity threshold was selected at the highest probability but did not stand out from the other values. Uncertainties in the salinity threshold likely arise because of buffering by the seed bank, differences in the salinity tolerance of plants at different life history stages, antecedent conditions, and spatial variability.

The information in **Figures 38** and **39** support the conclusion that substantial decreases in *Ruppia* cover and shifts in the SAV community occur beyond a salinity threshold of 30. Below this threshold, *Ruppia* and *Chara* are present at relatively high frequency. Above this threshold the frequency and cover of these species is substantially reduced resulting in diminished habitat for higher trophic level organisms. One aspect of salinity tolerance not fully addressed in this section is the extent to which the duration or severity of elevated salinity results in loss of ecological integrity.

The effect of wet season onset on *Ruppia* populations in the transition zone was evaluated by examining maximum *Ruppia* cover in transects of the transition zone versus the day of the year when 7-day mean salinity at station TR first dropped below 10 (**Figure 40**). This occurrence was assumed to be synonymous with the onset of the effect of the wet season. Each point on the x-axis of **Figure 40** represents a different year and the numbers represent the day of that year when salinity at station TR first dropped below 10 (154 = June 3, etc.). While this analysis revealed no clear trend in the effect of wet season timing on *Ruppia* populations, it did reveal increasing cover and more variability in cover among transects through mid-June (day 170). The marked decline among all transects after that point may indicate an effect of prolonged dry season conditions

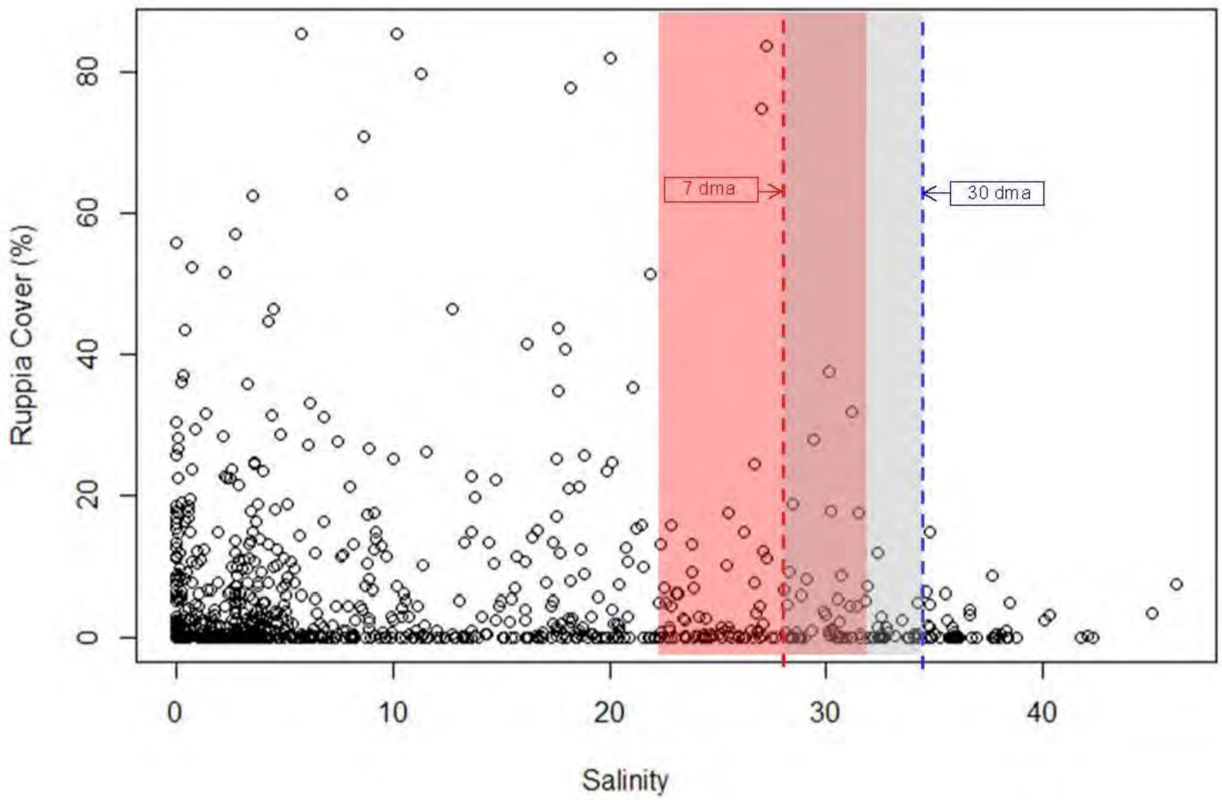

Figure 39. Relationship between salinity and *Ruppia* cover. The dashed lines indicate most probable change points, identified in the 30-day moving average (dma) analysis (34 salinity) and the 7-dma analysis (28 salinity). The shaded boxes represent the credible intervals associated with each change point estimate.

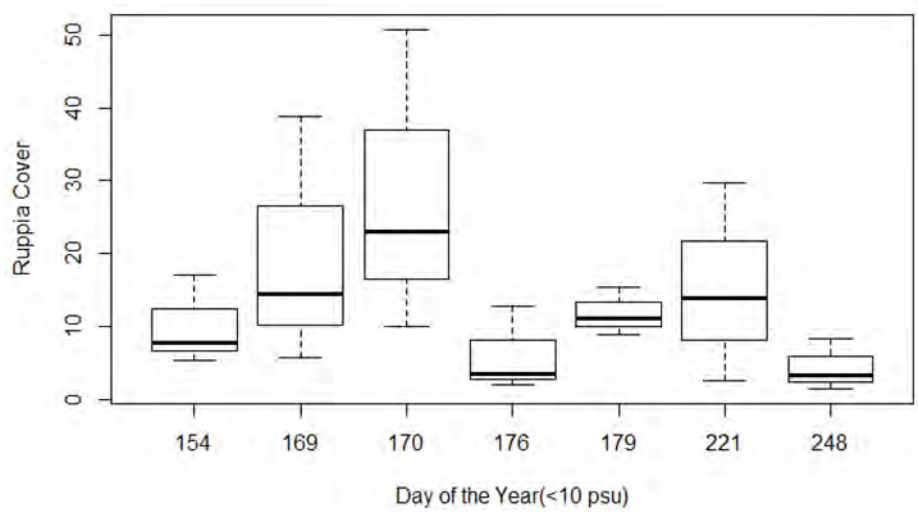

Figure 40. Maximum annual *Ruppia* cover along the TR, HC and JB transects versus the day of the year when TR salinity (7-day mean) dropped below 10. (Note: psu – practical salinity units.)

3.7 Community Dynamics of *Ruppia* in the Transition Zone

Research has shown that optimal conditions for *Ruppia* habitat occur when salinity has been low in the wet season with low salinity variability in the dry season (Strasizar et al. 2013a). A more detailed study was conducted to determine the timing of seed germination, the conditions required to successfully germinate, and conditions required to promote seedling survival to recruit new adult plants. These life history factors contributed to the resiliency of the *Ruppia* community following a loss of plant cover. In a series of experiments (Strasizar et al. 2013b), seed germination was measured across a range of salinity (i.e., 0–45) known to occur within the ecotone, and with and without low temperature (i.e., 6–10 degrees Celsius [^{o}C]) pretreatments. Seed densities were quantified, and seed viability was measured in transects across the ecotone at sites where rapid expansion of *Ruppia* reproductive shoots was observed.

Survey results showed that intact germinated seeds were found throughout the transition zone, from Barnes Sound to West Lake. The locus of major seedling production was in the western sites (**Figure 41**), and most germination occurred in the middle to upper (i.e., fresher) sites in each transect. Across the salinity range, *Ruppia* seed germination rates were low and primarily restricted where salinity was less than 25 (**Figure 42**). However, when seeds were exposed to higher salinity, then experimentally transferred to fresh water, higher germination rates occurred than in those seeds not exposed to salinity "pre-conditioning" resulting in viable seedlings (**Figure 42**). Germination success was strongly related to the concentration of pre-treatment salinity (R^2 = 0.98). These results suggest that osmotic shifts from high to low salinity may promote germination by pre-conditioning the seed coats. Seeds successfully germinated at the relatively high temperature (i.e., > 30 ^{o}C) characteristic of the subtropical temperatures in the Everglades ecotone during the wet season (i.e., June–October). It is important to note that although seed germination may be enhanced by a variable salinity regime as is typical within the ecotone, freshwater conditions are required to promote germination and low salinity is essential to promoting rapid development of seedlings to adult plants. Further, it is clear that without regular freshening of the *Ruppia* habitat to a very low salinity, the development and recruitment of new plants into the community will be curtailed.

In the seed bank, total seed density ranged from 150 per square meter (/m^2) to 1,783/m^2 along transects, the number of viable seeds in the seed bank was very low (18 seeds/m^2). Based on these data, the *Ruppia* ecotone population may currently be recruitment-limited. Seed distribution varied spatially along a gradient with the highest total seed densities at a western ecotone site (7,782/m^2) to a low and non-existent seed bank (0–184/m^2) at eastern sites. The investigation showed that although the Everglades-Florida Bay ecotone in general has a depauperate viable seed bank, there are high density seed "hot spots" that can rapidly generate a large biomass of *Ruppia* reproductive shoots, particularly in the more nutrient enriched western ecotone region. *Ruppia* seeds have a dormant life span of about three years, after which they become non-viable (Koch and Strazisar 2013), so if conditions are not conducive for germination within this timeframe where existing plants have been lost, the community will likely not recover for a few years.

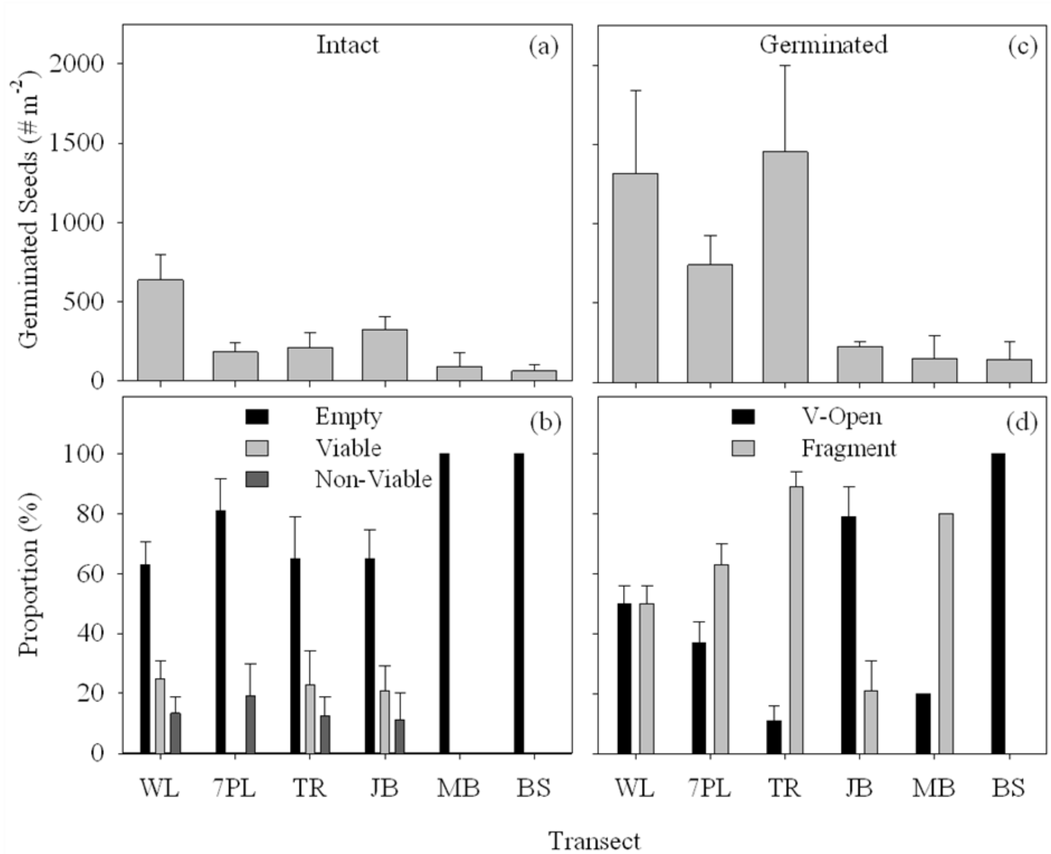

Figure 41. Average *Ruppia* a) intact seeds (number per square meter [m^{-2}] ± standard error) in the seed bank across the ecotone transects (WL = West Lake, 7PL = Seven Palm Lake, TR = Taylor River, JB = Joe Bay, MB = Manatee Bay and BS = Barnes Sound) are outside the MFL boundary area), b) the proportions (%) of those seeds that were empty or with a viable or non-viable embryo, c) average germinated seeds in the seed bank across the ecotone transects, and d) the proportions (%) of those seeds that were viable (V)-open or fragments with intact pedicels (n = 40–60 cores per transect).

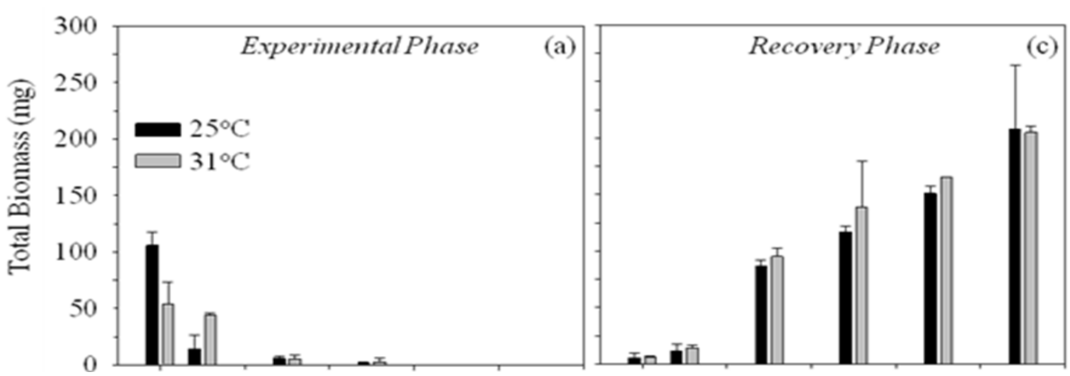

Figure 42. *Ruppia* seedling biomass in milligrams (mg) after germination at two temperatures when seeds were (a) held at salinity treatments for 150 days, and (c) after treatment salinity was lowered to fresh water for 24 days.

3.8 Prey Base of the Florida Bay Salinity Transition Zone

The prey base fish community in the transition zone is considered to be an excellent ecological indicator (Trexler et al. 2005). It changes rapidly in response to changing hydrologic and habitat conditions and is important in the regional food web, especially in sustaining populations of roseate spoonbill population, which is listed as a Florida Species of Special Concern (FWC 2011). Audubon of Florida monitors the prey base fish community at several sites in the transition zone. This monitoring is supported by SFWMD in order to provide a means to assess performance of Florida Bay MFL criteria. Prey base monitoring is conducted and evaluated in conjunction with SAV habitat monitoring in order to investigate important linkages between SAV and prey base dynamics. The importance of SAV habitat to the prey base assemblage was evident in the analyses described in the 2006 MFL technical support document (Hunt et al. 2006). Declines in fish density were predicted in conjunction with salinity increases and *Halodule* decreases in northeastern Florida Bay. Monitoring and analysis in the transition zone since 2006 further demonstrated the linkages between SAV habitat and higher trophic level organisms, and ultimately validated the use of SAV habitat as an ecosystem indicator (Lorenz et al. 2002).

Implementation of the C-111 Spreader Canal Western Project (completed in 2012) is expected to lower salinity and improve habitat quality. This may increase prey base fish production and lead to increases in the roseate spoonbill populations that feed upon them. Understanding the relationships among hydrologic patterns, aquatic prey populations, and wading bird reproductive success is important in operational management of the regional water conveyance system. The role of antecedent hydrologic conditions in structuring the aquatic food web and regulating key predatory wading bird populations has been the focus of recent study. In particular, Cook and Kobza (2011) provide evidence that extreme drought conditions can have an important influence on the structure of the aquatic food web by decreasing predatory fish populations. These dynamics may be related to impairment of the SAV habitat.

Audubon of Florida maintains an extensive network of stations at which they collect continuous hydrologic data (salinity and water level), perform bimonthly SAV surveys, and sample prey base fish populations eight times per year in wading bird foraging areas across the transition zone and southern Everglades National Park (**Figure 43**, Lorenz 1999). At each site, prey fish are sampled from both shallow flats and deeper creek sub-habitats using 9-square meter drop traps (n=3 for each sub-habitat at a site; see Lorenz, et al. 1997 for details on traps). Fish are euthanized and collected, and taken back to the lab where they are identified and measured. Weight is calculated from length-weight regressions for each fish species. Depth-adjusted density and biomass are then calculated as weighted-stratified means (Snedecor and Cochran 1968) whereby each collection is weighted by the percentage of potential flooded sub-habitat (creek or flats) that is actually inundated at the time of sample collection, thus correcting for the concentration effect of fluctuating water levels. Data are reported in terms of stratified mean-density (number of fish/m^2) and biomass (grams [wet weight]/m^2), as an average of the six nets sampled for a given site. Additional details can be found in Lorenz (1999) and Lorenz and Serafy (2006).

Comparisons were made between prey fish density summarized across all species for six sites within the transition zone, salinity measured on the day of fish sampling, and total SAV frequency of occurrence expressed as the percentage of quadrats containing at least 5% cover for the period of record, which is June 2005 through May 2011. SAV surveys at three stations did not begin until October 2009. SAV frequency data were interpolated between actual surveys to provide an estimate for each fish sampling event. Only SAV data at the first site nearest fish sample sites (e.g., TR1, HC1, JB1, etc.) were used for these comparisons. SAV frequency of occurrence was used in the analysis rather than percent cover because it is regarded as a better surrogate for habitat.

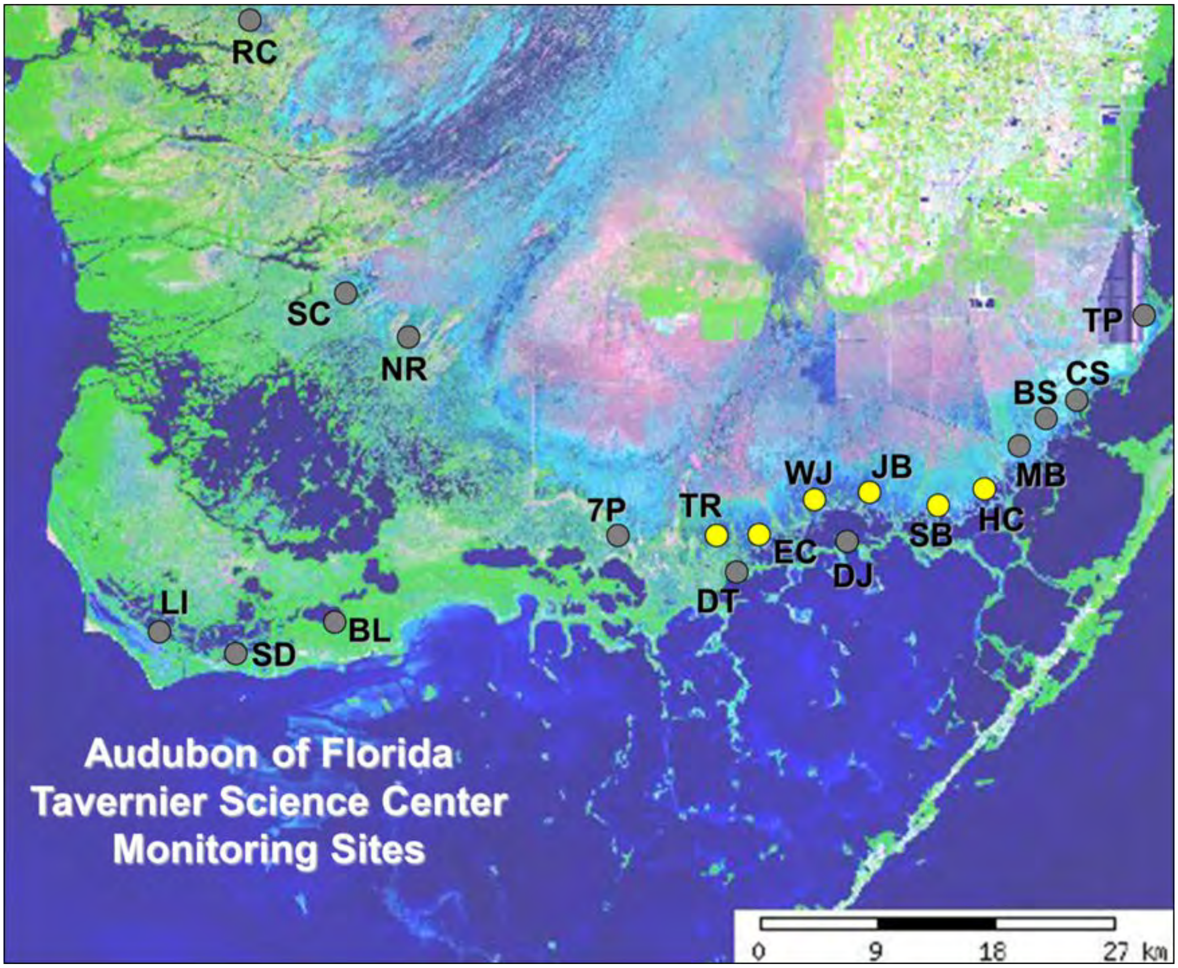

Figure 43. Locations of Audubon monitoring stations.

Results showed that above normal rainfall in 2010 that caused very high water levels and below average salinity were still evident through the early part of 2011, providing the southern Everglades with a hydrologic buffer for what was otherwise a dry year (Frezza et al. 2012). These beneficial hydrologic conditions contributed to very high mean fish densities at most stations (**Figure 44**), especially in the Taylor River watershed where sites had record numbers of fish in the dry season samples and the highest mean fish densities for the respective periods of record (Frezza et al. 2012). Prey fish density as a function of SAV and salinity was largest along the low salinity isolines and increased with SAV frequency of occurrence (**Figure 44**). Many of the higher density results occurred as a result of very wet conditions in 2010 and a combination of low water depths and uninterrupted recession in 2011.

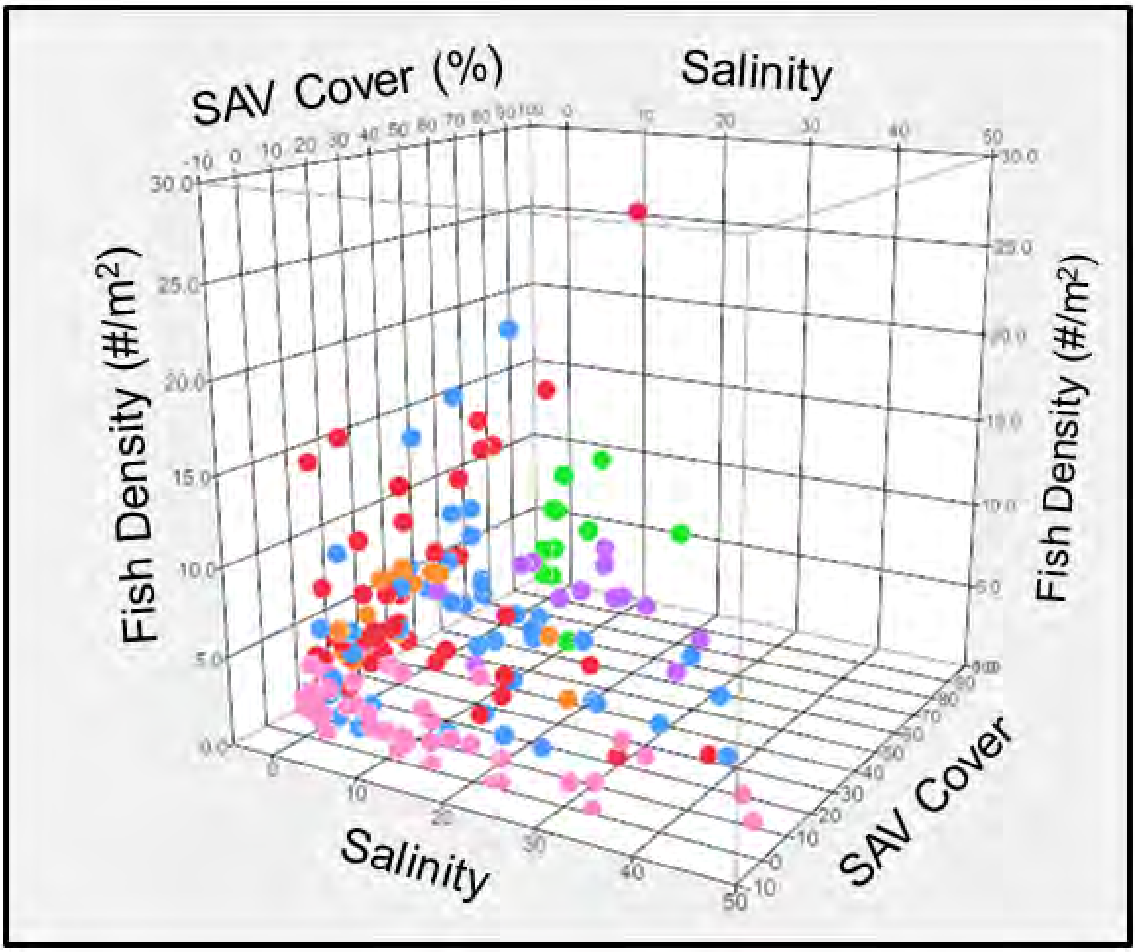

Figure 44. Depth-adjusted (stratified mean) prey fish density (number/m^2) versus salinity and total SAV frequency of occurrence (%, proportion of quadrats with minimum 5% total SAV cover, mixed species). Each bar represents a given fish sampling event, color-coded by site.

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Section 4. Assessment of MFL Performance

4.1 MFL Compliance

Monitoring of the salinity and creek discharge locations identified in the MFL rule is conducted by the U.S. Department of Interior. Results can be obtained from the National Water Information Service (creek sites) or Everglades National Park (Taylor River salinity monitoring station). Running 365-day flow totals from the five inflow sites combined (West Highway Creek, Trout Creek, Mud Creek, Taylor River, and McCormick Creek) and average salinity over 30 consecutive days (30-day average running total) from the TR salinity monitoring station from when the rule became effective (December 2006) through 2012 are shown in **Figure 45**.

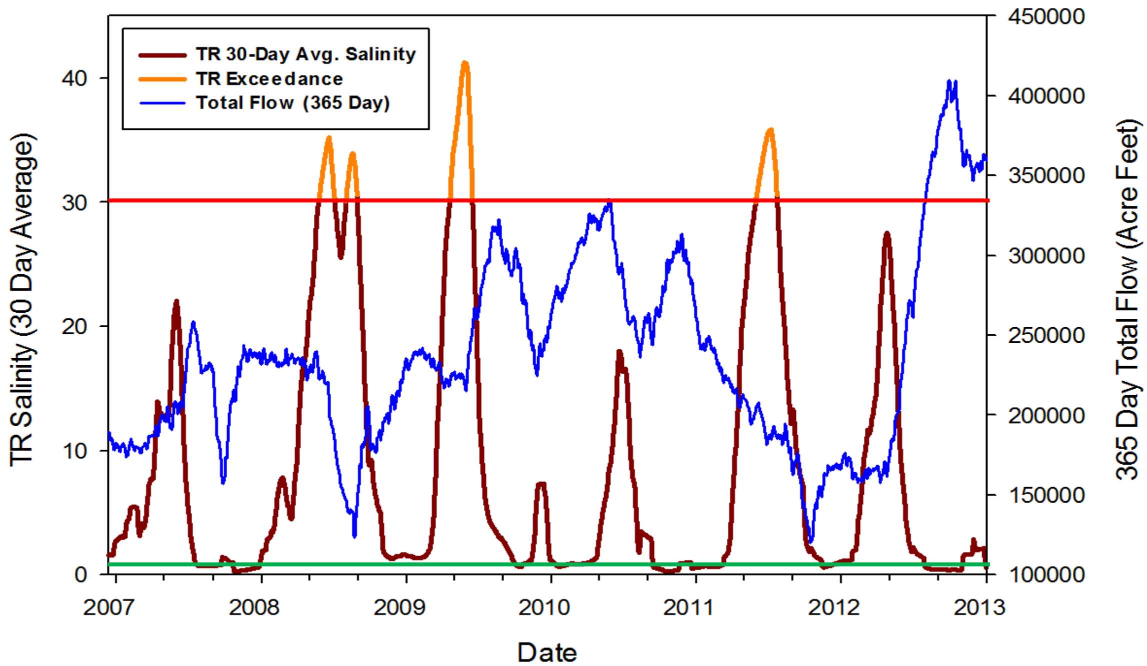

Figure 45. Time series plot of MFL salinity and flow data.

The minimum flow for Florida Bay is a 365-day running total of 105,000 ac-ft, which is represented graphically as a green straight line on **Figure 45**. An exceedance of the MFL criteria occurs when the average salinity over 30 or more consecutive days exceeds 30 at the Taylor River salinity monitoring station (also shown on **Figure 45**). Multiple events of 30 or more day periods with salinity greater than 30, occurring within a single calendar year, are considered as a single exceedance. A violation occurs when an exceedance occurs during each of two consecutive years, more often than once in a ten-year period.

Running total 365-day combined flow data indicates that since the rule was established, flows have consistently been higher than the 105,000 ac-ft minimum flow criterion. The two lowest 365-day total inflow events (approximately 125,000 ac-ft) occurred in 2008 and 2011, closely following salinity exceedances. Since 2006, the threshold of the average salinity over 30 or more consecutive days exceeds 30 has been exceeded three times: in 2008, 2009 and 2011. In calendar year 2008, the 30-day average salinity exceeded 30 for a total of 41 consecutive days. During 2009, the salinity criterion was exceeded for 58 consecutive days. In 2011, the salinity criterion was exceeded for a total of 54 consecutive days. In summary, a violation of the MFL salinity and flow criteria of the MFL Rule has not occurred since the rule was adopted in 2006.

It is apparent from the evaluation described in Section 2 that the flow component and the salinity components of the rules are not closely correlated. The 30-day salinity change point evaluation indicates substantial decreases in *Ruppia* cover and shifts in the SAV community occur at salinities between 28 and 34, near the average salinity of the three exceedance events. The monitoring data (described in Section 3) indicate that *Ruppia* and the SAV community responds as predicted to the three salinity exceedances. Assessment of ecological data collected from the bay before, during and after the salinity exceedance events indicate that, while the bay ecological indicators of the bay pointed to impacts associated with the elevated salinity events, there were no indications of significant loss of water resource functions that would take multiple years to recover. The return frequency that defines the MFL violation appears to be adequate to protect the SAV community from significant harm. While there were no discharge events below the flow criterion, it is reasonable to expect that salinity measurements at the Taylor River salinity monitoring station would be much greater than 30 should the 365-day total combined creek discharges drop below 105,000 ac-ft. Therefore, when determining whether significant harm has occurred to the bay, consideration should be given to both flow and salinity criteria along with an assessment of the actual conditions within the SAV communities.

4.2 Evaluation of Changes Caused by Projects and Operations

In the long-term, it is expected that when CERP is fully implemented, it will result in changes to the hydrology within northeastern Florida Bay (USACE and SFWMD 2013). Most of the projects that will provide benefits are many years away. Nevertheless, some shorter-term changes that have been implemented since the MFL rule adoption. These changes include the newly constructed C-111 Spreader Canal Western Project and the Tamiami Trail One-Mile Bridge along with revised operational criteria for Water Conservation Area 3A known as the Everglades Restoration Transition Plan (ERTP).

RSMGL was used to simulate effects of these new projects and operational conditions implemented since 2006 (Appendix A). On a regional-scale, RSMGL has been used recently to test changes that might result from the Central Everglades Planning Project. For the Florida Bay MFL review, results were compiled and compared for the watershed of northeastern Florida Bay approximating the area analyzed as part of the MFL evaluations (Hunt et al 2006) (**Figure 46**). Two baseline conditions were simulated using RSMGL: (1) an existing conditions without projects and (2) existing conditions with projects. For both simulations, the climatic period was 1965–2005 (41 years) and water use included 2010 permitted demands. The Existing Conditions Baseline without Projects (referred to as ECB1) represents the 2006 condition when the MFL was adopted and does not include the following projects: ERTP, C-111 Spreader Canal Western Project, or Tamiami Trail One-Mile Bridge. Future projects such as Broward County Water Preserve Areas, 8.5-square Mile Area, etc. were also excluded from ECB1. The second simulation, Existing Conditions Baseline with Projects (referred to as ECB2) is identical to ECB1 with the addition of ERTP operations, C-111 Spreader Canal Western Project, and Tamiami Trail One-Mile Bridge.

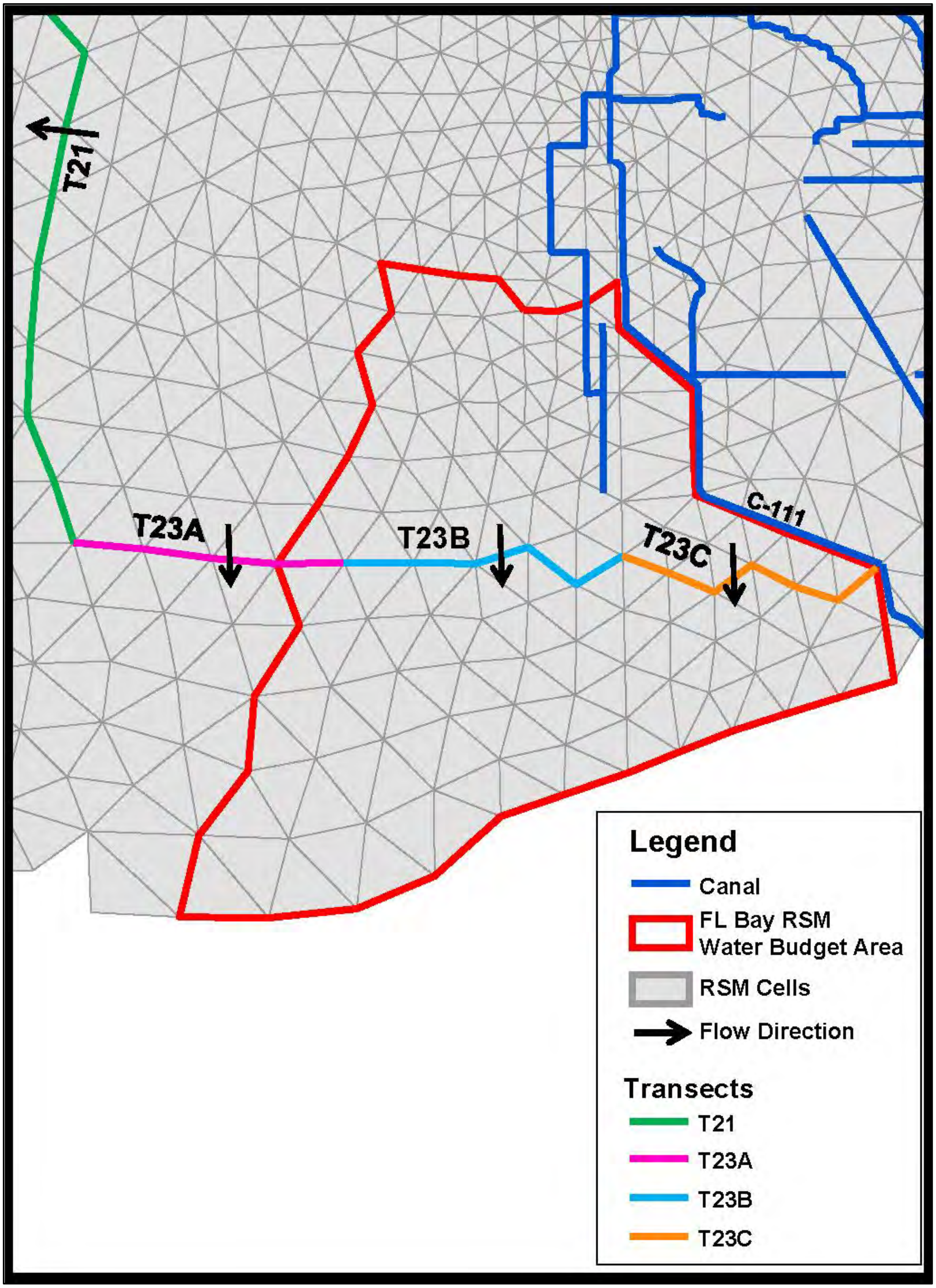

Figure 46. Overland flow transects within the northeastern Florida Bay watershed simulated by RSM (cells delineated with USGS High Accuracy Elevation Data [USGS 2013]).

Comparison of overland flow at two transects within the northeastern Florida Bay watershed (**Table 6**) shows an overall increase of 13.6% across transect T23B (located in the Taylor Slough area) and a decrease of 3% across transect T23C (located in the Everglades National Park eastern panhandle area). The combined transects T23B+T23C show a net increase of 1.7%.

Table 6. Overland flow volumes across transects in the watershed of northeastern Florida Bay.

Transects	Average Annual Overland Flow (1,000 ac-ft)						Percent Difference Projects Relative To Baseline
	Simulation of Baseline (ECB1)			Simulation of Projects (ECB2)			
	Wet Season	Dry Season	Water Year	Wet Season	Dry Season	Water Year	Water Year
T23B	50	16	66	54	21	75	13.6%
T23C	128	41	169	124	40	164	-3.0%
T23B+T23C	178	57	235	178	61	239	1.7%

The change in the overland flow distribution is primarily due to the implementation of ERTP and the C-111 Spreader Canal Western Project. Under ERTP, the operation of S-332D was modified to increase the maximum pumping during the sparrow breeding season. Between February 1 and July 14, the maximum pumping was raised from 165 cfs to 250 cfs to increase flows to Taylor Slough. This results in an increase in overland flows at the headwaters of Taylor Slough. When comparing seasonal changes between the without (ECB1) and with projects (ECB2) simulations, additional flows are expected to Taylor Slough during the dry season. When the transect 23B+23C flows are compared by month between the base without and with project conditions, the greatest differences occur during the dry season where flows increases between 4% to 12% from December to May (**Figure 47**).

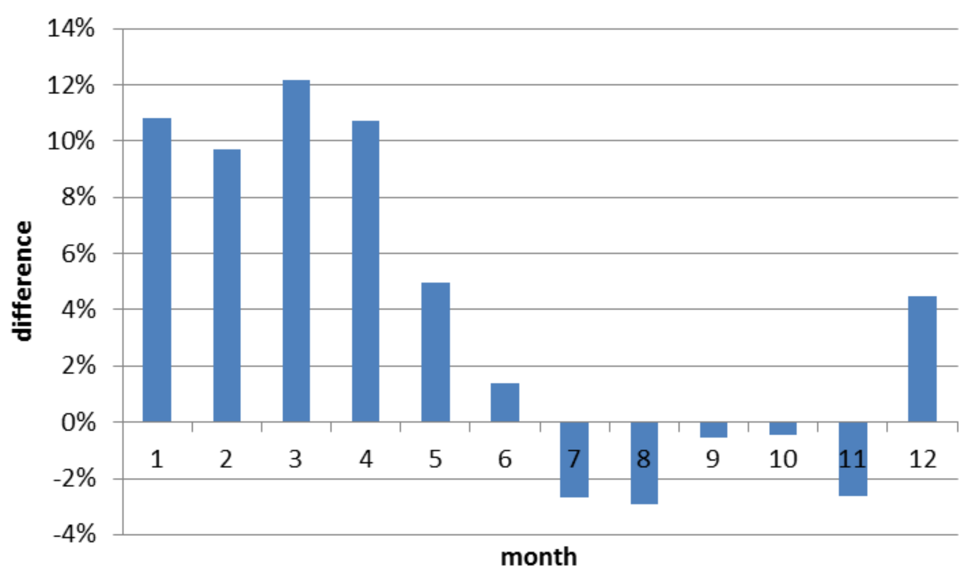

Figure 47. Percentage difference by month between flows across transects 23B+23C simulated between the base condition and the base condition with projects.

The C-111 Spreader Canal Western Project was intended to create a hydraulic ridge adjacent to Everglades National Park so that more of the natural rainfall and flows remains in Taylor Slough. To this end, the pump stations of this project discharge water from the C-111 Canal to the Frog Pond Detention Areas and the Aerojet Canal along the eastern boundary of the park. These areas are surrounded by berms and can hold water at a higher elevation than the adjacent marsh, producing the ridge. The water pumped west from the C-111 Canal by design, redirects a portion of the pre-project flows that used to move south along the C-111 Canal and enter Everglades National Park eastern panhandle for the benefit of Taylor Slough.

In summary, the increase in flows from the L-31N Canal to the headwaters of Taylor Slough, the hydraulic ridge along the eastern edge of Everglades National Park, and the reduction of flows along the C-111 Canal produce increased overland flows in the Taylor Slough transect and reduced overland flows in the Everglades National Park eastern panhandle.

4.3 Changes Caused by Projected Future Water Demands

Water demands within the region span various use classes such as public water supply, domestic uses, agriculture, recreational, landscape, industrial, commercial, etc. The RSMGL model documentation shows that a portion of the water inputs to the watershed of northeastern Florida Bay are derived from canal flow that originates from outside of the watershed (see Figure 6B in Appendix A). Therefore, demands that could affect these canal flows were evaluated because they have the potential for affecting the hydrologic conditions within Taylor Slough. Future water demands along with projected land use changes are assessed through regional water supply plans developed consistent with statutory provisions (i.e., Part VII, Chapter 373 F.S.). The MFL review also looked at the same twenty-year planning horizon to evaluate what effect this may have on the hydrology (minimum flows) associated with northeastern Florida Bay. All regulated water uses are authorized by the District's Consumptive Use Permitting program. The program also implements water resource protection criteria, such as wetland protection, MFLs, water reservations, and restricted allocation area (RAA) criteria to ensure the protection of the natural systems.

In 2007, SFWMD established an RAA rule for the Lower East Coast Everglades Water Bodies and the North Palm Beach County/Loxahatchee Watershed. This rule is incorporated into Section 3.2.1 of the *Basis of Review for Water Use Permit Applications within the South Florida Water Management District* (SFWMD 2013c) and limits consumptive use withdrawals to the "base condition water use." Increases in allocation above the "base condition" can only be granted under limited circumstances, such as terminated uses or offsets created by using alternative water supply sources (SFWMD 2013c). This RAA rule provides protection to the Everglades and northeastern Florida Bay by restricting increases in allocations above the base condition for all use classes in the future. **Figure 48** shows the areas included in RAA rules and the location of the Everglades water bodies, including Florida Bay. In addition to the RAA rule, applicants must meet other consumptive use permitting criteria that are pertinent to the protection of groundwater and surface water. These criteria include the MFL, wetland, saltwater intrusion and other surface water criteria. The MFL criteria protect water bodies from significant harm that would require two or more years for water resource functions to recover. The wetland and other surface water criteria protect wetlands and other water bodies from harm caused by a change in surface water or groundwater hydrology. Saltwater intrusion criteria limit groundwater withdrawals in coastal areas to prevent inland movement of the coastal freshwater-saltwater interface.

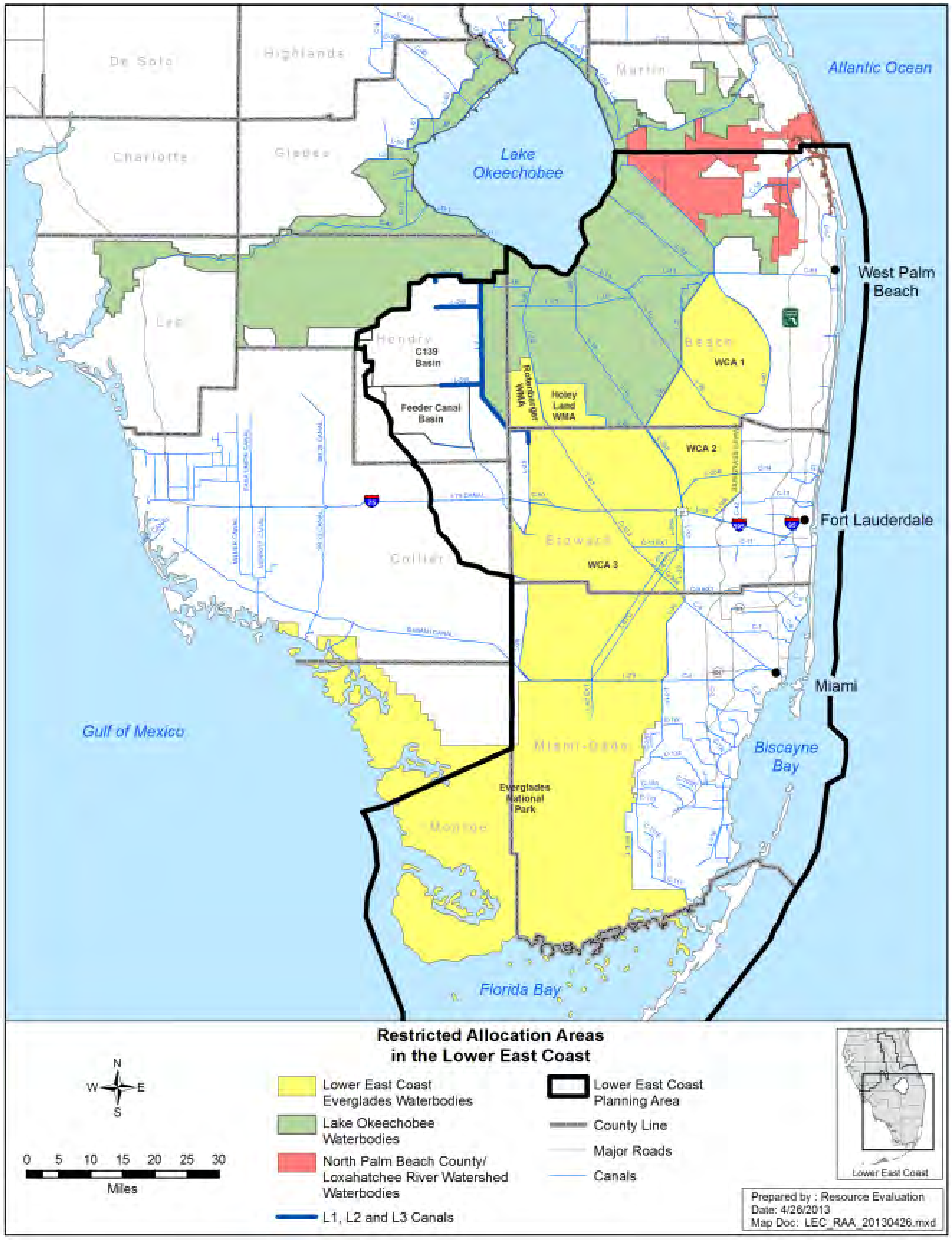

Figure 48. RAAs in the Lower East Coast Planning Area. The Everglades water bodies, including those within Florida Bay, are shown in yellow. (Note: WMA – Wildlife Management Area; WCA – Water Conservation Area).

In June 2012, SFWMD established a water reservation for the Biscayne Bay Coastal Wetlands (BBCW) Project (Phase 1). During the rule development process, a technical document was developed to support the BBCW water reservation rule (SFWMD 2013b). The technical document contains an analysis that focused on projected water use demands in the urban areas south of the C-4 canal (**Figure 49**). This analysis is relevant because the areas south of the C-4 canal have a potential of affecting the resources within Biscayne Bay and northeastern Florida Bay. The analysis evaluated projected demands with projected land use changes from 2010 to 2030 for all water use classes using the demand estimates from the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a). The analysis showed a potential increase in allocation of 2.6 million gallons per day (MGD) over the twenty-year planning horizon for urban landscape irrigation (SFWMD 2013b).

The *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a) identified public water supply (PWS) as the single largest use class, which accounted for approximately 73% (457.3 MGD) of the total gross demands within Miami-Dade County. There are several different utilities and municipalities within Miami-Dade County that provide PWS, however, Miami-Dade Water and Sewer Department (MDWASD) is unambiguously the largest public water supply user. In 2010, MDWASD's allocation to meet future demands was 408.51 MGD. In 2012, MDWASD's allocation to meet future demands was reduced to 349.5 MGD with an increase to 386.5 MGD following implementation of pending aquifer recharge projects as reuse offsets with a targeted completion date of 2027. Any future increases in allocation for MDWASD can only be granted in compliance with consumptive use permitting criteria including all RAA rules.

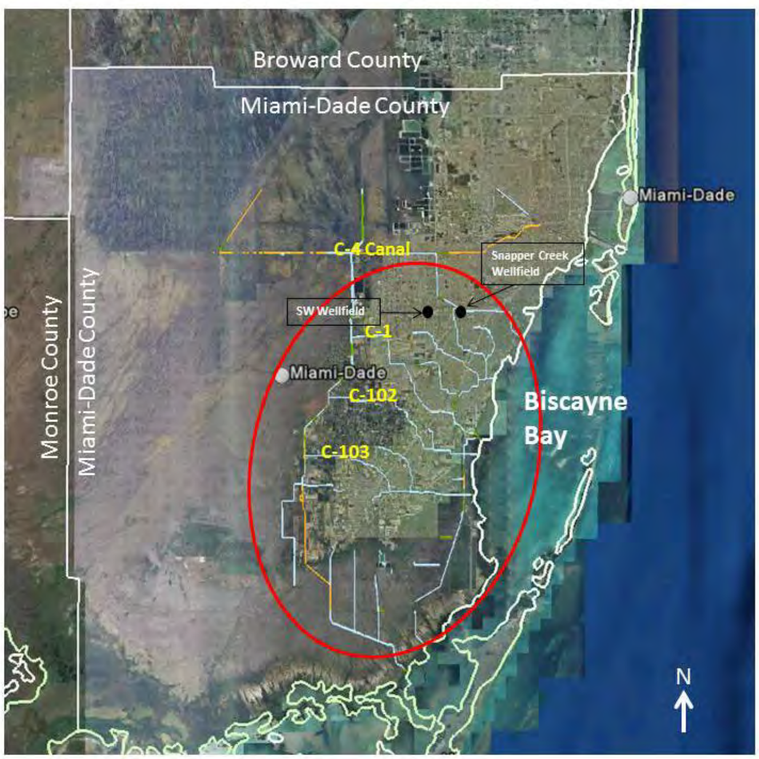

Figure 49. Area circled in red is generally the watershed south of the C-4 canal. Larger wellfields are indicated as black dots.

Table 7 shows a 14.9 percent increase in PWS for the area south of the C-4 canal from 2010 to 2030. The 2030 PWS demands of 201.7 MGD are the volumes allocated in existing permits and are a volume that has already been pumped historically, consistent with the base condition. The 2010 demand of 183.4 MGD for PWS demand is a reduced withdrawal volume due to the economic downturn and a stricter landscape irrigation ordinance. The 2030 demands for the non-PWS water use categories show increases for Industrial/Residential Self-supply and Urban Landscape Irrigation while Agricultural Irrigation has decreased slightly. **Table 7** shows the net new allocation of unpermitted demands of 2.6 MGD, which is largely a result of projected increases from urban landscape irrigated water. These new projected unpermitted demands would also occur within the urban footprint and would not use water from the Everglades. The RAA rule prevents new withdrawals that would adversely affect the Everglades water bodies. The projected change in non-PWS demands (2.6 MGD) is within the uncertainty of the changes in land use projections to determine the demand estimates. At such a small scale, these demands are not significant enough to affect the flows within Florida Bay.

Table 7. Change in water demand between the years 2010 and 2030 in Miami-Dade County for the areas south of the C-4 canal in MGD (from April 2013 model runs).

Water Use Category	2010 Demands	2030 Demands	Change in Volume 2030 minus 2010	Percentage Change (%)
PWS	183.4*	210.7*	27.3*	14.9
Golf Courses	2.1	2.1	0.0	0.0
Industrial & Residential Self Supplied	3.6	3.9	0.3	8.0
Urban Landscape Irrigation	81.5	84	2.5	3.1
Agricultural Irrigation	50	49.8	-0.2	-0.4
Total Allocations	**320.6**	**350.5**	**29.9**	**9.3**
Less PWS - Permitted			- 27.3*	
Total Net New Allocations - Unpermitted			2.6	0.8

*Change in volume already allocated by existing PWS consumptive use permits.

Based on the modeling completed for the BBCW project as part of the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a), there will be minimal changes in the future water demands projected over the next 20 years. There is also sufficient regulatory criterion in place to protect flows to the Everglades water bodies, including Florida Bay. In conclusion, there will be no reduction in flows to northeastern Florida Bay as a result of new water demands over the twenty-year planning horizon.

Accordingly, MFL violations for northeastern Florida Bay are not anticipated to occur in the future assuming future rainfall patterns persist, existing projects and operations continue, and water demands follow projections. Therefore, the current prevention strategy is adequate to ensure protection of the MFL water body in the future over the next twenty-year planning horizon and until the next MFL review-evaluation occurs.

4.4 MFL Performance Summary

Based on evaluation of changes since establishment of the MFL rule from recently completed restoration projects and operational changes along with an evaluation of future conditions for the twenty-year planning horizon, MFL violations are not anticipated to occur in the future.

The evaluation of recent changes using RSM showed increased flows is expected in the Taylor Slough area, especially during the dry season (Section 4.2). This is anticipated due to flow that has been redistributed in the watershed due to constructed projects (C-111 Spreader Canal Western Protect and Tamiami Trail One-Mile Bridge) and revisions to water management operations (ERTP). Comparisons of with and without project components indicate an average increase of 1.7% increase in flows toward northeastern Florida Bay.

Evaluation of future conditions showed there will be no reduction in flows to northeastern Florida Bay as a result of new water demands over the twenty-year planning horizon. Based on information from the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a), the small increase (2.6 MGD) in projected new unpermitted non-PWS demands will occur within the urban footprint. The RAA rule effectively prevents new withdrawals that could adversely affect any Everglades water bodies, including northeastern Florida Bay. The projected change in non-PWS demands is within the uncertainty of the changes in land use projections to determine the demand estimates. At such a small scale these demands are not significant enough to affect the flows within Florida Bay.

The evaluations conducted using the best available information indicates that no MFL violations occurred since rule adoption for northeastern Florida Bay and no violations are anticipated to occur in the future. Therefore, the current prevention strategy described in the *2013 Lower East Coast Water Supply Plan Update* (SFWMD 2013a) is adequate to ensure protection of the MFL water body in the future over the next twenty-year planning horizon and until the next MFL review-evaluation occurs. It is recognized, that future restoration projects and operational changes may occur within the twenty-year horizon that may modify the inflow to northeastern Florida Bay and these changes will be evaluated in future MFL reviews.

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Section 5. Key Findings

Below is a summary of key findings resulting from the review-evaluation analyses.

There has been no violation of the MFL salinity criterion as defined in the rule since it was adopted in December 2006, but three exceedances have occurred (i.e., in 2008, 2009, and 2011). In addition, the flow criterion contained in the rule (i.e., 105,000 ac-ft per 365 days) as discharge from the five tidal creeks named in the rule was also met throughout the same period.

Substantial *Ruppia* beds (i.e., > 5% coverage) have been observed most frequently within the Everglades-Florida Bay transition zone including the western lakes, but rarely in areas of Florida Bay where salinity frequently exceeds 30. *Ruppia* monitoring results show that its abundance is variable through time, but varies with salinity conditions. Optimal conditions for *Ruppia* are low salinity during the wet season and low variability of salinity during the dry season. A breakpoint analysis between salinity and *Ruppia* abundance revealed that abundance decreases dramatically when salinity was greater than 30. The successful germination of *Ruppia* seeds that may be necessary to repopulate areas after plant mortality is also related to salinity. Germination success is best when salinity is low.

The salinity habitat most associated with *Ruppia* is also favorable for other beneficial species essential to the ecosystem. Important submersed plants such as *Chara* and *Utricularia* are frequently observed within the same habitat. Prey fish density and biomass is also associated with this habitat and greatest when salinity has been low with benthic plants present. A suitable habitat for *Ruppia* within the transition zone produces a healthy condition for marine seagrass populations within the bay. Seagrass coverage within northeastern Florida Bay has been stable since 2006, except in eastern areas near a phytoplankton bloom unrelated to freshwater inflows from Taylor Slough.

The exploratory statistical evaluations indicate that the relationship between annual flow through the five creeks identified in the rule and salinity at the Taylor River salinity monitoring site is weak. It is recognized that several of the correlations attempted herein are not very insightful in addressing the scale and complexity of this system. Statistical analyses can however provide insight about how the hydrology works within the watershed for northeastern Florida Bay. For example, the relationship of salinity at the Taylor River monitoring station to salinity at other salinity monitoring sites within the nearshore area were moderate to strong, indicating that the nearshore sites may respond similarly to freshwater inflow. In separate evaluations, canal inflows were weakly related to salinity in Taylor River overall, but when broken down by months, the relationship was strongest in the dry season, and especially in May. This type of assessment yields insight into the importance of seasonality and timing of upstream canal inflows. Changing water management infrastructure and operations in the past may have changed some of the relationships among the hydrologic variables and salinity. Recent modifications as well as future water management changes contemplated in the long term could change existing empirically-derived relationships.

Hydrologic simulations using SFWMD's regional model RSMGL provided results investigating recently implemented hydrologic changes within the watershed. The evaluation of recent changes using the regional model showed increased flows is expected in the Taylor Slough area, especially during the dry season (Section 4.2). This is anticipated due to flow that has been redistributed in the watershed due to constructed projects (C-111 Spreader Canal Western Project and Tamiami Trail One-Mile Bridge) and revisions to the regulation schedule for ERTP. Comparisons of with and without project components indicate an average increase of 1.7% increase in flows toward northeastern Florida Bay.

Evaluation of future conditions showed there will be no reduction in flows to northeastern Florida Bay as a result of new water demands over the twenty-year planning horizon. Based on information from the *2013 Lower East Coast Water Supply Plan Update*, the new demands that are projected to occur within the area south of the C-4 Canal will occur within the urban footprint (SFWMD 2013a). The RAA rule effectively prevents new withdrawals that could adversely affect any Everglades water bodies, including northeastern Florida Bay.

Section 6. Conclusions

The results of the information and findings from this MFL review of the northeastern Florida Bay MFL criteria leads to several conclusions. In regard to the criteria as described in the rule, it appears reasonable to expect that if the flow and salinity criteria are violated, significant areas within the bay would experience losses of a magnitude that could take several years to fully recover. Accordingly, based on the existing rule criteria, if a violation occurs, it will provide reasonable expressions of significant harm to Florida Bay. It is possible, given further research and analysis, this threshold could be refined slightly, but it is clearly very close to the appropriate value as applied within the boundary given in the rule. The return frequency of exceedances described in the rule is also confirmed based on the results of the lifespan of a dormant *Ruppia* seed being about two to three years, after which it becomes non-viable. By maintaining a two-year cap on repeated exceedances, the rule is protective of the *Ruppia* seed bank, a key to reestablishment of plants after salinity-related impacts. Further, the return frequency criterion necessary to constitute an MFL violation (when exceedances occur during each of two consecutive years, more often than once in a ten-year period or three consecutive years) is adequate to protect essential habitats in northeastern Florida Bay based on observations of the system response.

Ruppia was selected as an indicator species, originally, based on its assumed association and correlation with important habitats within northeastern Florida Bay. Monitoring results have verified these assumptions. The presence or absence of the plant is closely linked to salinity conditions in a range that also affects the health of downstream SAV and the presence of prey fish on which higher trophic levels are based.

In regard to the estimate of tidal creek discharge given in the rule, the rate of 105,000 ac-ft per 365 days is technically adequate to prevent a violation of the salinity criterion based on the fact that the flow rate has not fallen below the threshold through 2012, while no violations of the salinity criterion have occurred. Further evaluations and refinement of the timing and associated preferential flow rates (e.g., examine potential relationships between early dry season inflows and late dry season salinity patterns in the transition zone) could be helpful in providing advanced indications of potential salinity increases and provide water managers lead time to implement operational flexibility to moderate Florida Bay salinities later in the dry season.

Compliance with the salinity criterion is monitored at just one location within the boundary. The 30-day mean (average) salinity is tracked at the Taylor River salinity monitoring station. This monitoring location is appropriate as a sentinel site. The relationship between the salinity at this station and other salinity monitoring stations within northeastern Florida Bay is robust, especially the critical nearshore area. Salinity results at Taylor River monitoring station is representative of how other areas within the transition zone and nearshore areas of northeastern Florida Bay respond to freshwater influx.

Based on model simulation results, it is not likely that the MFL criteria will be violated in the future (not withstanding prolonged severe drought conditions). The overall changes in the hydrology of the watershed due to water management are expected to increase water inputs from the canal system. Comparison of overland flow at two transects within the northeastern Florida Bay watershed (**Table 6**) shows an overall increase of 13.6% across transect T23B (located in the Taylor Slough area) and a decrease of 3% across transect T23C (located in the eastern panhandle area of Everglades National Park). The combined transects T23B+T23C show a net increase of 1.7%. As future CERP projects are completed and implemented this should result in increased flows to northeastern Florida Bay.

Evaluation of future conditions showed there will be no reduction in flows to northeastern Florida Bay as a result of new water demands over the twenty-year planning horizon. Future demands from the

2013 Lower East Coast Water Supply Plan Update shows minimal increases in new withdrawals that have not been permitted previously (SFWMD 2013a). Additionally, the RAA rule effectively prevents new withdrawals that could adversely affect any Everglades water bodies, including northeastern Florida Bay.

No MFL violations occurred since rule adoption for northeastern Florida Bay and no violations are anticipated to occur in the future. Therefore, the current prevention strategy described in the *2013 LEC Water Supply Plan Update* is adequate to ensure protection of the MFL water body in the future (SFWMD 2013a).

Salinity and flow rates should continue to be monitored. Salinity integrates the hydrologic conditions and is closely tied to habitat requirements. Relationships between hydrologic variables such as canal inflows and creek discharges need further evaluation in order to produce improved understanding of flow salinity relationships that would be helpful in improving management of flows to northeastern Florida Bay. Water level results at gauges close to Taylor River are related to salinity, but dispersion of the data still imparts enough uncertainty that the use of water level thresholds to infer habitat quality would be problematic.

Section 7. Recommendations

Based on the findings and conclusions in this report, some key recommendations are as follows:

- Retain the existing MFL criteria and prevention strategy in the rule, and continue to track compliance as the 30-day running arithmetic mean (average) of salinity.
- Since the 30-day mean statistic can be potentially affected by missing values, determine an acceptable standard approach on how to handle missing values.
- Continue tracking the 365-day running sum for the tidal creek discharges. Consideration should also be given for further analyses of empirical flow-salinity relationships using shorter integrated flow intervals (e.g., 30–90 day) and possibly lag times. Continue monitoring the indicator species, *Ruppia*, with the current monitoring protocol to build robust data sets that can be used for adaptive management and future reviews.
- For the same purpose, continue monitoring of SAV and macroalgae within the Everglades-Florida Bay transition zone and Florida Bay.
- To expand knowledge and certainty about the relationships of freshwater inflow, salinity, and ecosystem health, consider expanding the spatial coverage of monitoring within the transition zone, and investigate the importance of mixed SAV/macroalgal communities to habitat quality and fisheries.
- Further investigation and development of relationships for hydrology and salinity should combine up-to-date existing expanded empirical data sets with updated simulation models such as FATHOM.
- The spatial distribution and seasonal timing of inflow (e.g., early dry season inflow and relationship to later season salinity conditions) to northeastern Florida bay should be further investigated using combination of existing conditions and modeling tools such as FATHOM in order to identify if operational opportunities exist to manage deliveries earlier in the dry season in a manner to reduce elevated salinity levels later in the dry season.
- Given the importance of rainfall in the overall water budget (and salinity conditions in the transition zone and the bay), a standard characterization and evaluation of rainfall quantity and pattern for the area including both components of the watershed contributing inflow, and the bay should be developed using a water year basis and applied in future characterizations and reviews.
- Evaluation of changes to freshwater inflows to the bay resulting from construction and operation of future Everglades restoration project components should be incorporated into the Lower East Coast water supply plan updates. In addition, the plan updates should also address Florida Bay MFL compliance for both the current and twenty-year planning horizon.

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Appendix A: Model Documentation Report for Regional Simulation Model – Glades Lower East Coast Service Area Florida Bay MFL Update

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Model Documentation Report

Regional Simulation Model – Glades LECSA Florida Bay MFL Update

June 7, 2014

1.0 Overview

Identification

This report documents the assumptions and the implementation of the Regional Simulation Model for Glades-LECSA (RSMGL) in support of the Florida Bay minimum flows and levels (MFL) Update during 2013. The Regional Simulation Model (RSM) is a finite volume, object oriented based hydrologic model that simulates groundwater flow, overland flow in wetlands, canal flow, groundwater/surface water interactions and other critical components of the hydrologic cycle (SFWMD, 2005b).This report also discusses and compares the modeling results. This work was completed by the Hydrologic and Environmental Systems Modeling section at the South Florida Water Management District (SFWMD or District).

Scope and Objectives

The intent of the RSMGL modeling was to simulate two hydrological conditions upstream of northeastern Florida Bay for evaluating current and future changes that may affect salinity. Of particular interest are changes related to the MFL criterion that was adopted by rule in 2006. The Florida Bay MFL Update 2013 evaluates the effects of three distinct infrastructure and operational changes (projects) upstream of northeastern Florida Bay that have been implemented and were not in place since 2006 when the MFL rule was initially adopted.

Potential hydrologic changes are due to operational and infrastructure modifications that reflect the three projects. The selection of the RSMGL model is based on its capability to simulate the hydrologic conditions upstream of Florida Bay at a resolution that makes comparing results adequate to address the questions related to the implementation of recent or imminent projects that could affect hydrology in the area of interest.

Two baseline conditions were simulated using RSMGL. Water use demands represented in both baselines included 2010 permitted demands. The climatic period for both simulations was 1965–2005 (41 years).

1. Existing Conditions Baseline Without Projects: This baseline is referred to as Existing Conditions Baseline (ECB)1 in the model and in this document. This model run represents the 2006 conditions when the MFL was adopted and does not include the following projects: Everglades Restoration Transition Plan (ERTP), C-111 Spreader Canal Western Project, or Tamiami Trail One-Mile Bridge. Future projects such as

Broward County Water Preserve Areas, 8.5 Square Miles Area, etc. were also excluded from ECB1.

2. Existing Conditions Baseline With Projects: This baseline is referred to as ECB2 in the model and in this document. This model run is identical to ECB1 with the addition of ERTP operations, C-111 Spreader Canal Western Project, and Tamiami Trail One-Mile Bridge.

The primary area of interest is the drainage basin for northeastern Florida Bay as depicted in Figure A-1. The delineation of this basin is roughly equivalent to the one used in the original analysis that established the MFL criteria (Hunt et al. 2006). In the figure, the dark grey and yellow areas represent the RSM cells that align with the Florida Bay Drainage Basin delineated from the United States Geological Survey (USGS) High Accuracy Elevation Data (HAED) (http://sofia.usgs.gov/exchange/desmond/desmondelev.html). The dark grey cells are located upstream of the Taylor Slough Bridge. Since, there is good monitoring of overland flow data for the Taylor Slough Bridge, the yellow area downstream of the bridge is chosen for the water budget analysis.

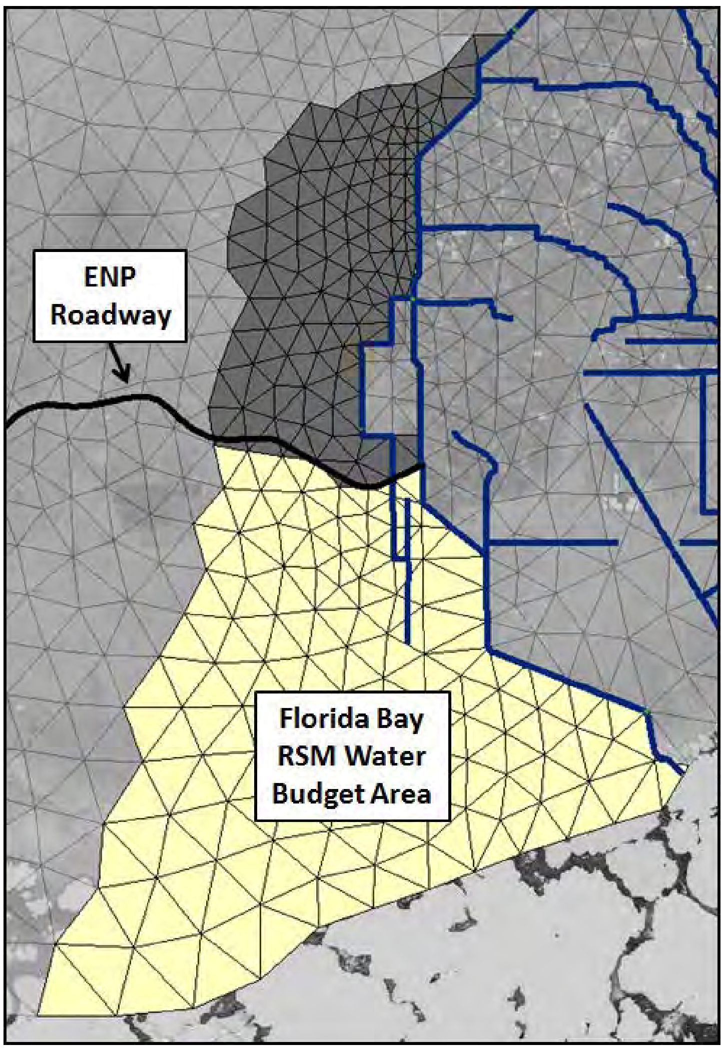


Figure A-1: Drainage Basin for Northeastern Florida Bay Used for Water Budget Analysis

Selected Model

The RSMGL, originally implemented for the Water Conservation Area (WCA) 3A Decompartmentalization and Sheetflow Enhancement Project (DECOMP) and subsequently implemented for Central Everglades Planning Project (CEPP) is the starting point for the Florida Bay MFL Update modeling application (Hunt et al., 2006). Throughout the development of the RSMGL simulations, the modeling and project teams determined the appropriate modeling techniques and assumptions to be used while also leveraging the knowledge and information gained during the previous implementation of RSMGL for CEPP. The CEPP modeling effort, led by SFWMD, started in 2011 and continues as of this writing. Figure A-2 illustrates the RSMGL model domain.

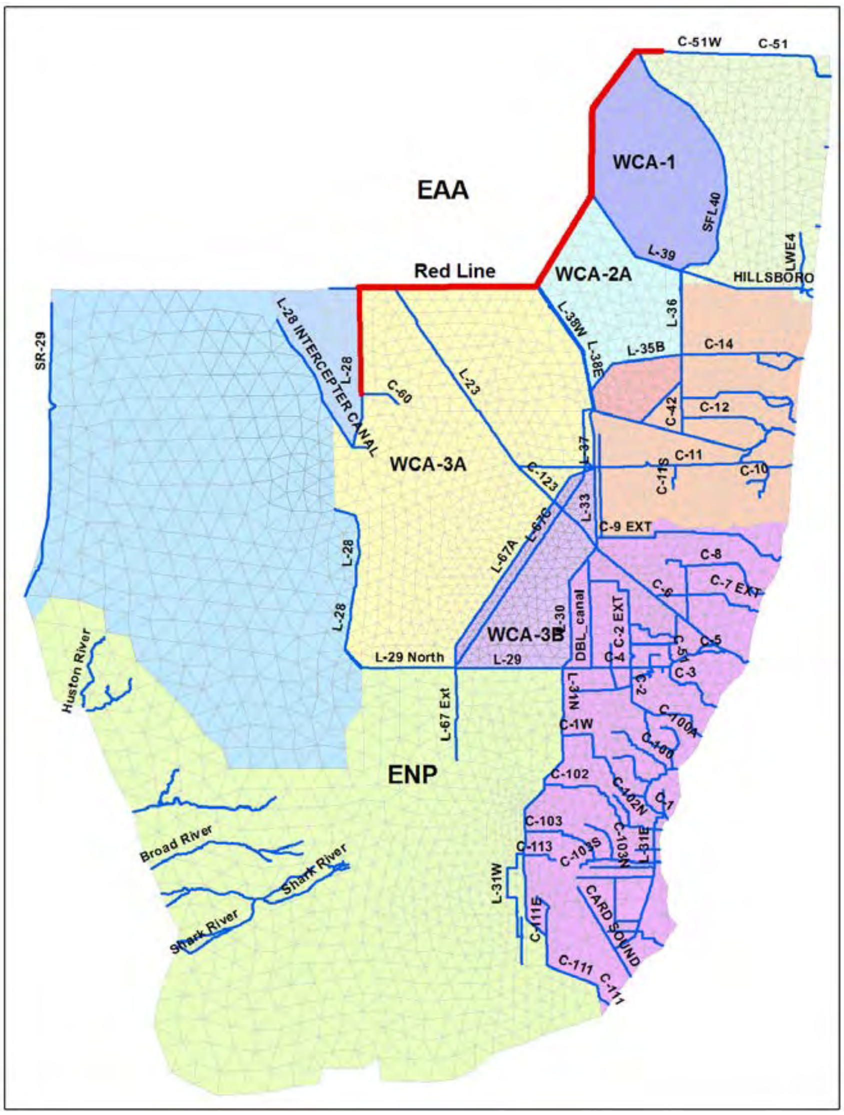


Figure A-2: Map of RSMGL Model Domain

Intended Use of Results

The simulations of the ECB1 and the ECB2 are required to enable estimates of long-term hydrologic trends in the northeastern Florida Bay watershed as a result of the three projects. The purpose of comparing these two model runs is to evaluate changes in freshwater flow toward Florida Bay as a result of changes from the three projects identified above. Flows toward Florida Bay and water levels in Everglades National Park (ENP) can be used in estimating the resulting salinity in Florida Bay.

2.0 Basis

Boundary Conditions

The data from the South Florida Water Management Model (SFWMM) and the Regional Simulation Model - Basins (RSMBN) are used as boundary conditions for the RSMGL.

The SFWMM is a regional-scale computer model that simulates the hydrology and management of water resources system from Lake Okeechobee to Florida Bay, covering an area of 7,600 square miles (SFWMD, 2005a). A SFWMM simulation of existing conditions that is consistent with ECB1 was used for this purpose and can be downloaded from the subversion repository: http://dcluster2/viewvc/svnroot/trunk/CentEver/sfwmm/ECB1.3_CEPP-daily_2010-11_WMM6.6.0r_042312_out/

The RSMBN (VanZee, 2013) is a link-node based model designed to simulate the transfer of water from a pre-defined set of watersheds, lakes, reservoirs or any "'waterbody" that either receives or transmits water to another adjacent waterbody. The model assumes that water in each waterbody is held in level pools. The RSMBN uses the same source code as the mesh-based RSM, which includes the RSMGL regional model. An equivalent RSMBN model that is consistent with ECB1 and was used for boundary conditions can be found in the following directory in the Data, Access, Storage and Retrieval (DASR) application:
P:\IMC_Modelers_Space\Secure_Modelers_Space\PROJ 51 - Central Everglades Planning\Analysis_Phase\2PlanFormulation\1Baselines\Final_Output_121312\rsmbn_model_output\ECB

Structural flows along the northern boundary (red line, see Figure A-2) are imposed from the RSMBN model into the RSMGL model. Structural flows outside the red line along the boundary are imposed from the SFWMM model in the RSMGL model. The groundwater and surface water flows for the northern areas of the modeling domain are imposed from the SFWMM.

Water Demands

The assumptions for water demands in RSMGL Florida Bay Models are consistent with the assumptions for RSMGL CEPP Existing Conditions Baseline Model. The water demand assumptions used for the CEPP model are outlined below:

- Lower East Coast (LEC) public water supply (PWS) values were based on 2010 consumptive use permit information as documented in the *C-51 Reservoir Preliminary Design and Cost Estimate Final Report* (LWDD et al., 2013).

- Industrial pumpage and residential self-supplied values were based on 2030 projected demands calculated by the SFWMD Water Supply Bureau in 2012 for the water supply plan in progress (*2013 Lower East Coast Water Supply Plan Update*; SFWMD, 2013). The LEC demands in the ECB reflect current permits for consumptive use that are consistent with the LEC Regional Availability Rule, and are the same as the values used in the simulation conducted for water supply planning (Future Without Project 2030 or FWO 2030). The ECB demands also reflect the land use projected for 2030, with the corresponding agricultural and recreational irrigation demands. Correspondingly, the ECB demands reflect 2030 projections for residential self-supplied use and industrial pumpage.

- LEC land uses are based on 2008–2009 coverage, and consumptive use permits as of 2011 were used to update the land use in areas where it did not reflect the permit information.
- There is no change between ECB1 and ECB2 in terms of demands.

Projects

The RSMGL is used to investigate the potential effects of the three recent or imminent projects on flows toward Florida Bay:

1) Tamiami Trail One-Mile Bridge (USACE and SFWMD, 2013). This project is implemented.

2) ERTP (USACE, 2011). This project is implemented.

3) C-111 Spreader Canal Western Project (SFWMD, 2011). This project is implemented.

Assumptions in ECB1 and ECB2 are described in the Attachments A and B of this appendix. All assumptions are consistent between ECB1 and ECB2 except for these three projects. A comparison of the assumptions for ECB1 and ECB2 are presented in Attachment C.

The basis and implementation of the above mentioned projects are discussed below:

1. Tamiami Trail One-Mile Bridge

The construction of the Tamiami Trail One-Mile Bridge (Figure A-3) was completed in March 2013 and is open for traffic. This bridge will help restore water flow into Shark River Slough within ENP (USACE, 2008).

The flow under the bridge was modeled in RSMGL as weirs. Four weirs (based on four L-29 canal segments) are used in the model to span the 1-mile length of the Tamiami Trail Bridge. The sum of crest lengths of these four weirs equals 5,280 feet.

Although raising maximum water level in L-29 canal to 8.5 feet National Geodetic Vertical Datum of 1929 (NGVD) is part of the plan in Tamiami Trail One-Mile Bridge Project, maximum water level in L-29 canal is not raised (water level kept at 7.5 feet NGVD) in ECB2 simulation to be consistent with the ongoing CEPP effort.

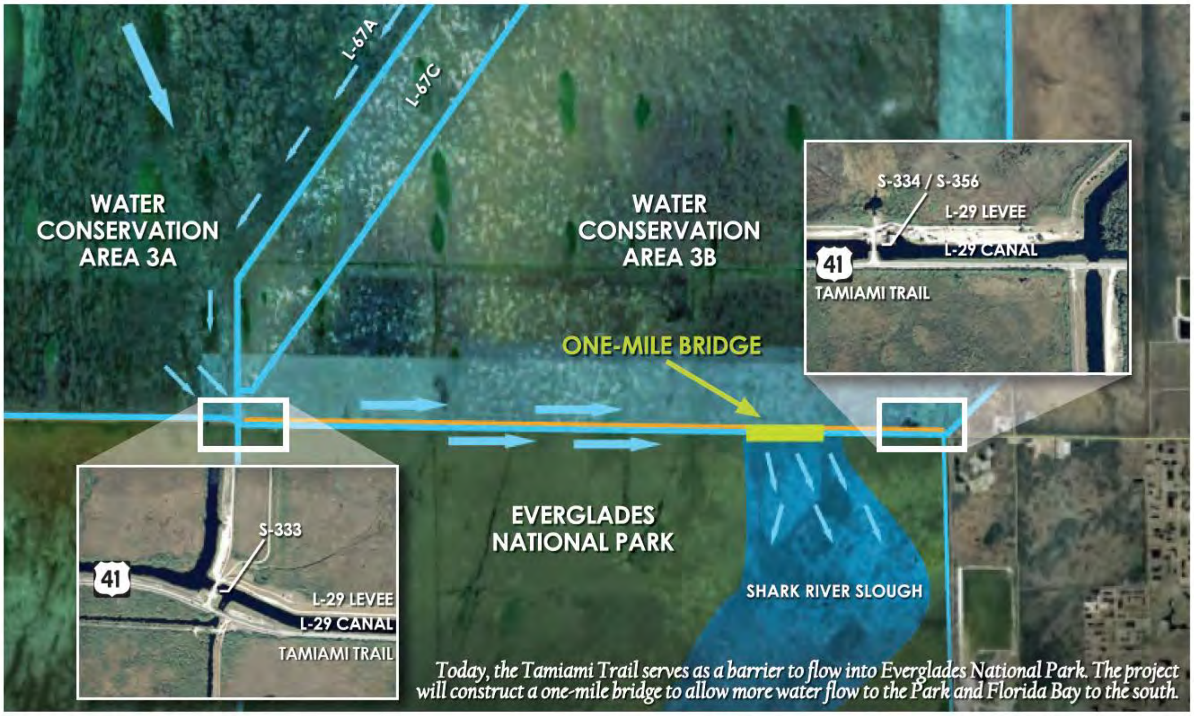


Figure A-3: Tamiami Trail One-Mile Bridge (USACE and SFWMD, 2013)

2. Everglades Restoration Transition Plan (ERTP)

Figure A-4A and Figure A-4B show WCA 3A Interim Operations Protocol (IOP) schedule (implemented in ECB1) and WCA 3A ERTP schedule (implemented in ECB2), respectively. In 2012, the ERTP schedule superseded the 2006 IOP schedule for the protection of the Cape Sable Seaside Sparrow (CSSS).

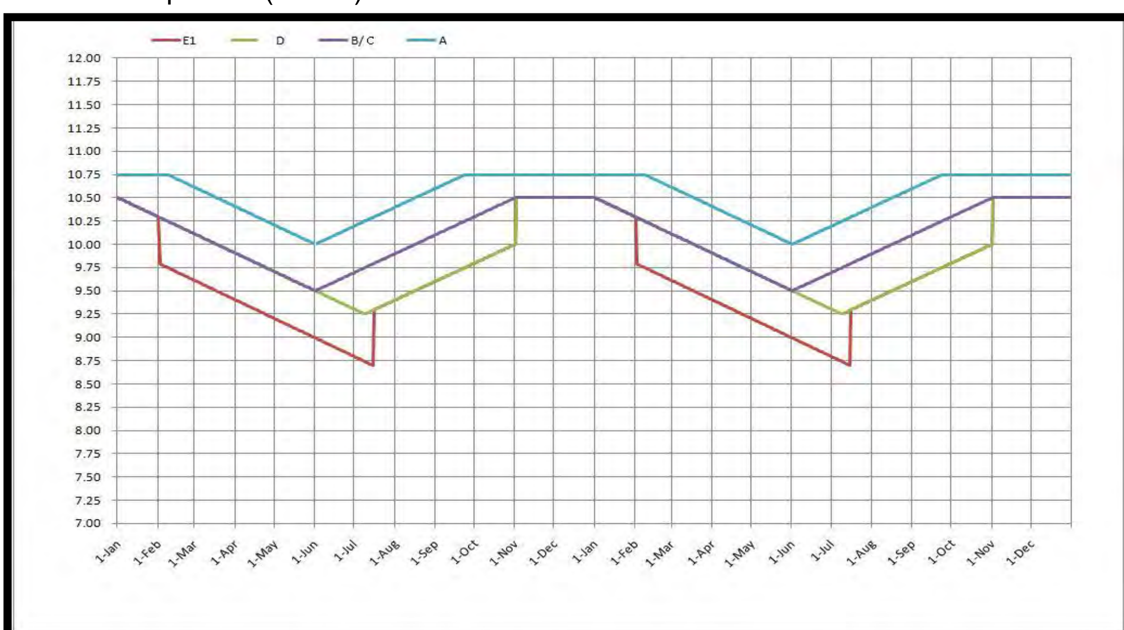


Figure A-4A: WCA 3A IOP Schedule implemented in RSMGL ECB1

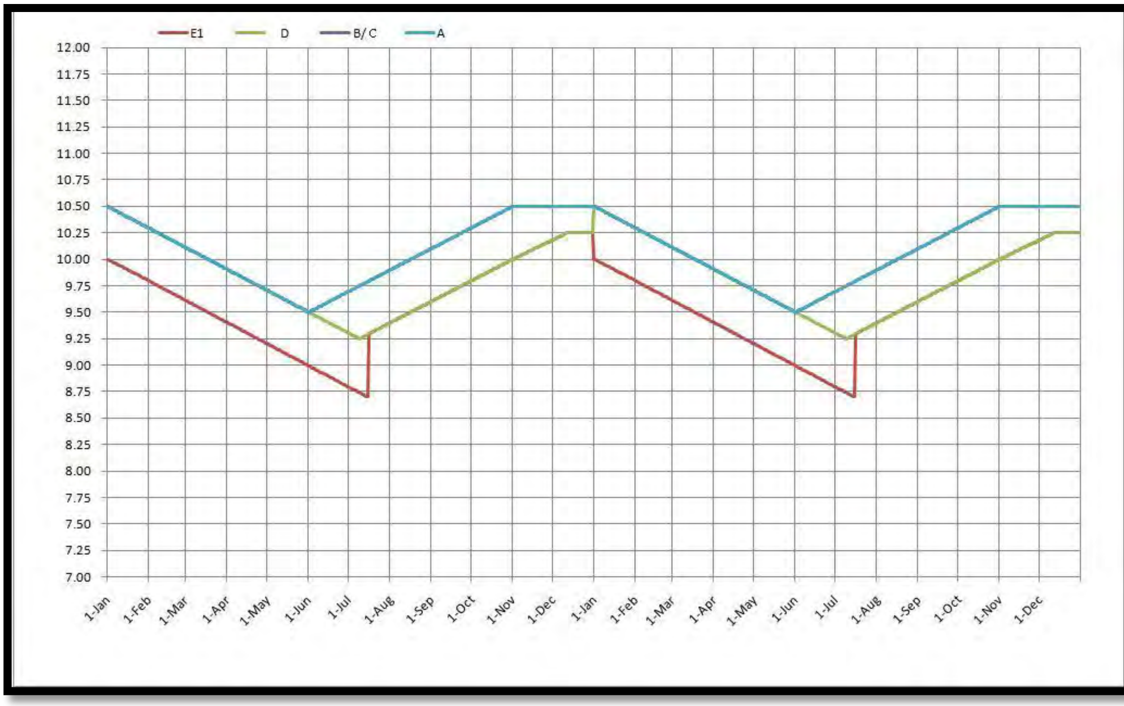


Figure A-4B: WCA 3A ERTP Schedule implemented in RSMGL ECB2

In addition to change in WCA 3A schedule, operations of water control structures S-12C and S-12D have been changed. The only change in operations between IOP and ERTP is the fraction of flow target to be met by S-12 structures. Table A-1 and Table A-2 show the fraction of flow target to be met by S-12 Structures in IOP and in ERTP, respectively.

Table A-1: Fraction of flow target to be met by S-12 Structures in IOP

Date	S-12A	S-12B	S-12C	S-12D
1-Jan	0	0	0.4	0.6
31-Jan	0	0	0.4	0.6
1-Feb	0	0	0	1
15-Jul	0	0	0	1
16-Jul	0.1	0.2	0.3	0.4
31-Oct	0.1	0.2	0.3	0.4
1-Nov	0	0.2	0.4	0.4
31-Dec	0	0.2	0.4	0.4

Table A-2: Fraction of flow target to be met by S-12 Structures in ERTP

Date	S-12A	S-12B	S-12C	S-12D
1-Jan	0	0	0.4	0.6
31-Jan	0	0	0.4	0.6
1-Feb	0	0	0.4	0.6
15-Jul	0	0	0.4	0.6
16-Jul	0.1	0.2	0.3	0.4
31-Oct	0.1	0.2	0.3	0.4
1-Nov	0	0.2	0.4	0.4
31-Dec	0	0.2	0.4	0.4

3. C-111 Spreader Canal Project Western Features

The C-111 Spreader Canal Western Project is part of the original C-111 Spreader Canal Project (Figure A-5) to assist operators in maximizing flows to Central Florida Bay via Taylor Slough, and improving hydroperiods within the Model Land basin (USACE, 2008), while maintaining or improving the existing Central and Southern Florida (C&SF) Project purposes (e.g., flood damage reduction). Due to regional resolution of the model, only main features of the C-111 Spreader Canal Western Project are implemented in RSMGL which include Frog Pond Detention Areas, Aerojet Canal and S-199 and S-200 pumps.

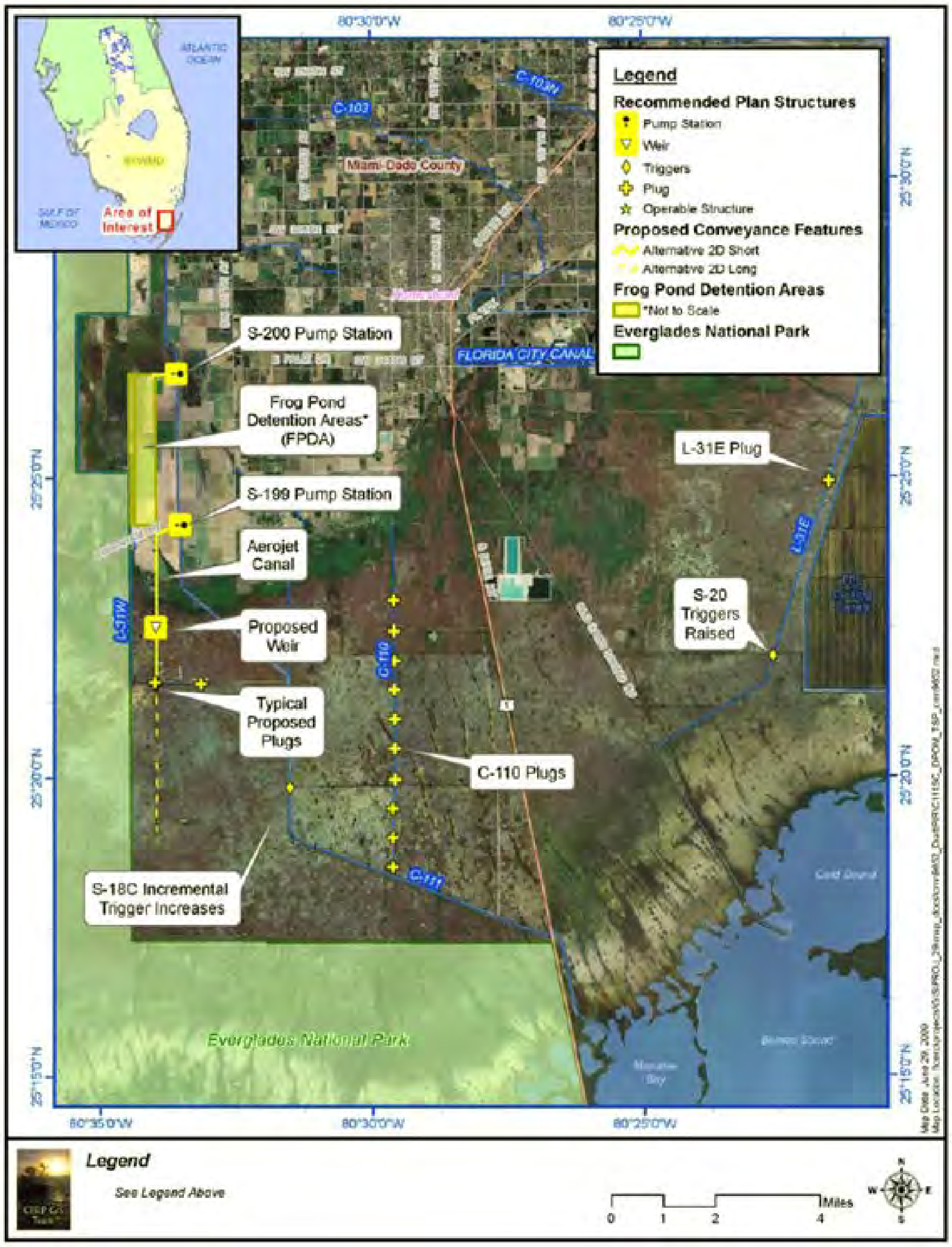


Figure A-5A: C-111 Spreader Canal Western Project Features

A. Implementation C-111 Spreader Canal Western Project

C-111 Spreader Canal Western Project features as implemented in RSMGL ECB2 are shown in Figure A-5B. The detail implementations of these features are discussed below.

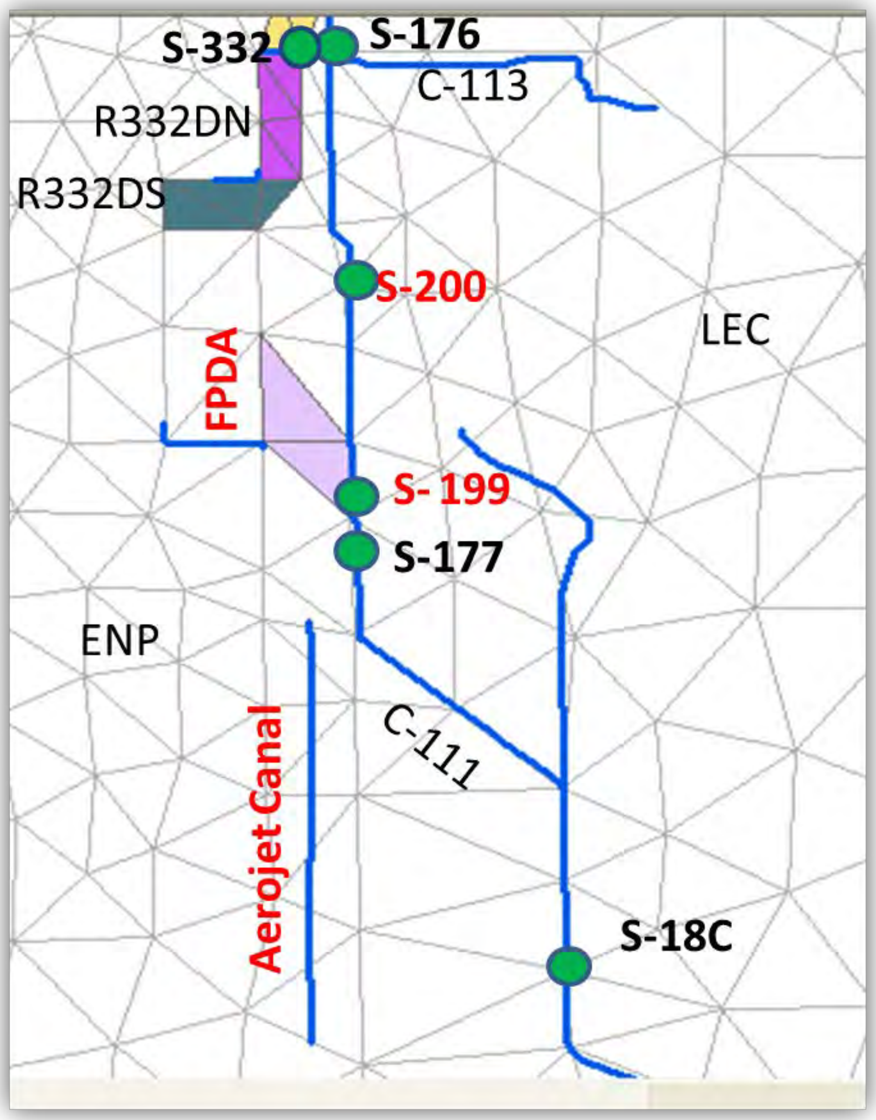


Figure A-5B: C-111 Spreader Canal Western Project Features (as Implemented in RSMGL ECB2)

- Frog Pond Detention Areas

Due to the resolution of the RSMGL model, the header canal and series of three separate overflow detention cells with three overflow weirs were not modeled. Instead of three detention cells with weirs, the detention area was modeled as an impoundment with two cells consisting of 590 acres (including the header canal). This resulted in a shorter length along the north-south direction, but kept the simulated area of the impoundment as close as possible to the actual area. The bottom elevation of the impoundment was five feet (as modeled). Water levels were maintained at a maximum depth of two and a half feet above existing ground (elevation 8.5 feet NGVD).

- Aerojet Canal

Aerojet Canal was modeled at the proposed location, which consisted of two segments with total length of 5.58 miles. The cross-section was trapezoidal with a bottom width of 25 feet at the bottom elevation of -12 feet and with side slope of 1.5 feet.

- S-200 Pump Station

Three pumps (S200A, S200B, and S200C), each with an individual capacity of 75 cubic feet per second (cfs), feed the detention area. The pumps have a tailwater OFF trigger of 8.5 feet NGVD in the impoundment, and a CSSS Population Site C remote OFF trigger of 0.33 feet above ground elevation for the period of March 15 to June 30. The remote OFF trigger was measured at cell 3586 where ground elevation is 4.63 feet. The operations of the S-200 pumps are also shown in Table A-3.

Table A-3: Structural Operations for the S-200 Pumps as Implemented in RSMGL ECB2

Pump Name	Design Capacity	Purpose	Open (feet)	Close (feet)	Tailwater Head Limit (feet)	Remote Off Trigger (March 15 to June 30, feet)	CSSS Site at Cell 3586 (elevation = 4.63 feet)
S-200A	75 cfs	Flood control	3.8	3.6	8.5	2.41	C
S-200B	75 cfs	Flood control	3.9	3.6	8.5	2.41	C
S-200C	75 cfs	Flood control	4.0	3.6	8.5	2.41	C

- S-199 Pump Station

Three pumps (S199A, S199B, and S199C) each with an individual capacity of 75 cfs, feed the Aerojet Canal. The pumps have a tailwater OFF trigger of 0.33 feet above ground elevation for the CSSS Population Site D at cell 4776 (elevation = 2.08 feet) for the period of March 15 to June 30. The operations of pumps are also shown in Table A-4.

Table A-4: Structural Operations in S-200s as implemented in RSMGL ECB2

Pump Name	Design Capacity	Purpose	Open (feet)	Close (feet)	Tailwater Head Limit (feet)	Remote Off Trigger (March 15 to June 30, feet)	CSSS Site at Cell 4776 (elevation = 2.08 feet)
S-199A	75 cfs	Flood control	3.8	3.6	8.0	4.96	D
S-199B	75 cfs	Flood control	3.9	3.6	8.0	4.96	D
S-199C	75 cfs	Flood control	4.0	3.6	8.0	4.96	D

Model Limitations

The RSM is a robust and complex regional-scale hydrologic model. Due to the large scale of the model, it is frequently necessary to implement abstractions of system infrastructure and operations that will, in general, mimic the intent and result of the desired project features while not matching the exact mechanism by which these results would be obtained in the real world. Additionally, it is sometimes necessary to work within established paradigms and foundations within the model code (e.g., use available input-driven options to represent more complex project operations).

RSMGL is the best available tool to simulate the response of the drainage basin of Florida Bay for the implementation of projects that directly or indirectly affect the flows toward Florida Bay and the salinity in the bay. However, like all simulation models, some level of forecast uncertainty may result when applying the model, reflecting the limitations of the calibration data sets (data range, measurement error, short duration, etc.). For example, RSMGL assumes that the operational criteria and infrastructure are constant over the 41-year period. Another specific limitation of RSMGL is that the resolution of the model in some areas may not be sufficient to model specific details of some of the projects. The model is run on daily time step, so it is not possible to mimic certain conditions that occur within a day such as tide along the boundary. Also, In RSMGL, no consideration has been given to sea level rise in the 41-year period of record. The tidal data used as boundary conditions for the 41-year simulation reflects the observed sea level rise of about 4 inches that occurred between 1965 and 2005. The two modeling scenarios produced for the Florida Bay MFL Update assume existing conditions near the end of the 41-year period for tidal data. The simulations do not reflect future conditions and do not attempt to project additional sea level rise beyond what was observed up to 2005

3.0 Simulation

Model Implemented

RSMGL Florida Bay (RSMGL_FL_Bay), revision 9313, last modified on April 25, 2013.

Modeling Input Files

All modeling files pertaining to RSMGL_FL_Bay are located in subversion repository (svn) and can be found in the following link:
http://dcluster2/viewvc/svnroot/trunk/rsm_imp/RSMGL_FL_Bay/?view=log
The file/folder structures are shown below (as modeled and checked into svn):

Level 1:

/ [svnroot] / trunk / rsm_imp / RSMGL_FL_Bay

Index of /trunk/rsm_imp/RSMGL_FL_Bay

Files shown: **0**
Directory revision: 9313 (of 9362)
Sticky Revision: Set

File	Rev.	Age	Author	Last log entry
Parent Directory				
ECB1/	9313	5 weeks	fkhatun	FL BAy ECB1: cleanup
ECB2/	9312	5 weeks	fkhatun	FL BAy ECB1: add cellmonitors for E146
geodatabase/	9299	7 weeks	fkhatun	FL Bay: Water budget Area of concern
scripts/	9308	6 weeks	fkhatun	transect sripts

Level 2:

/ [svnroot] / trunk / rsm_imp / RSMGL_FL_Bay / ECB2

Index of /trunk/rsm_imp/RSMGL_FL_Bay/ECB2

Files shown: **1**
Directory revision: 9312 (of 9362)
Sticky Revision: Set

File	Rev.	Age	Author	Last log entry
Parent Directory				
input/	9312	5 weeks	fkhatun	FL BAy ECB1: add cellmonitors for E146
output/	9307	6 weeks	fkhatun	FL Bay ECB2: update control files
run_FLB_ECB2.xml	9311	5 weeks	fkhatun	FL Bay ECB2: rename cellmonitor file

Level 3:

Index of /trunk/rsm_imp/RSMGL_FL_Bay/ECB2/input

Files shown: **0**
Directory revision: 9312 (of 9362)
Sticky Revision: Set

File	Rev.	Age	Author	Last log entry
Parent Directory				
BCs/	9244	2 months	fkhatun	FL_Bay: changed naming convention- ECB_2013 as ECB2
canal/	9260	7 weeks	fkhatun	FL Bay ECB2: added aerojet canal
dss_files/	9244	2 months	fkhatun	FL_Bay: changed naming convention- ECB_2013 as ECB2
impoundment/	9265	7 weeks	fkhatun	FL Bay ECB2: added Frog pond detention area
lakes/	9244	2 months	fkhatun	FL_Bay: changed naming convention- ECB_2013 as ECB2
mesh/	9244	2 months	fkhatun	FL_Bay: changed naming convention- ECB_2013 as ECB2
mse/	9266	7 weeks	fkhatun	FL Bay ECB2: added C-111 SC (western) project
output/	9312	5 weeks	fkhatun	FL BAy ECB1: add cellmonitors for E146
trigger/	9244	2 months	fkhatun	FL_Bay: changed naming convention- ECB_2013 as ECB2
watermovers/	9266	7 weeks	fkhatun	FL Bay ECB2: added C-111 SC (western) project
wcd/	9244	2 months	fkhatun	FL_Bay: changed naming convention- ECB_2013 as ECB2

<u>Modeling Input Additions/Modifications</u>

<u>Changes Made in RSMGL_FL_Bay_ECB1:</u>

The starting point for modeling of Florida Bay ECB1 is the CEPP Existing Conditions Baseline (RSMGL ECB_2010-11), which reflects 2010–2011 conditions. The following corrections have been made in Florida Bay ECB1:

- S-9 operations were changed to be consistent with SFWMM operations:
  In CEPP RSMGL ECB_2010-11 baseline, S-9 pump is operated only to pass additional flows when S-9A reaches its capacity. But in the real world, S-9 is operated more frequently. The open and close levels of S-9 were lowered (information is borrowed from the SFWMM model) to mimic the real world situation. The changes in S-9 operations are consistent with those of ECB2.

- L-40 levee seepage coefficient was corrected:
  In CEPP RSMGL ECB_2010-11 baseline, L-40 levee seepage coefficients are too high causing the downstream of the levee (LEC side) to be too wet compared to the real world. To avoid this situation, L-40 levee seepage coefficients were lowered. The change in the L-40 levee seepage coefficient was consistent with that of ECB2.

<u>Changes Made in RSMGL_FL_Bay_ECB2:</u>

The starting point for modeling of Florida Bay ECB2 is the CEPP 2012 Existing Conditions Baseline (RSMGL 2012EC), which includes S-9 operational updates and L-40 levee seepage corrections as described above. The following projects were added in the Florida Bay ECB2 simulation:

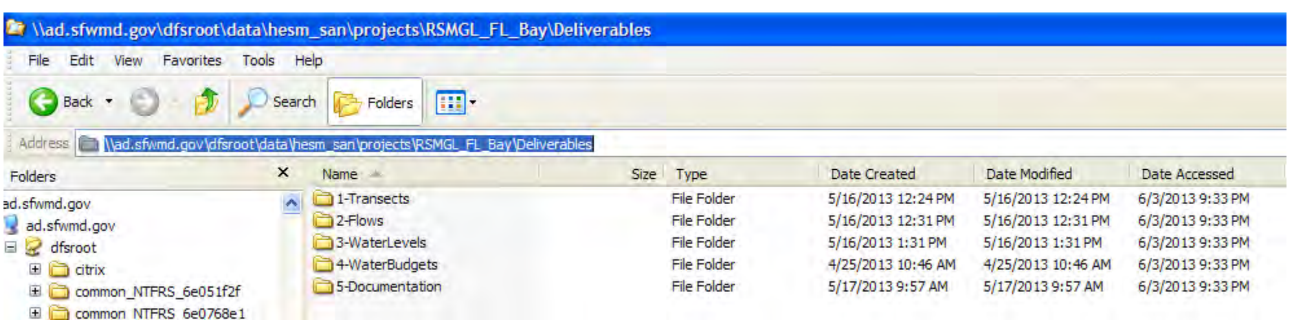
- Tamiami Trail One-Mile Bridge
- ERTP instead of IOP
- C-111 Spreader Canal Western Project

4.0 Results

<u>Identification of Simulation</u>

The deliverables produced for Florida Bay MFL Update are located in the following directory:

<u>\\ad.sfwmd.gov\dfsroot\data\hesm_san\projects\RSMGL_FL_Bay\Deliverables</u>



A brief description of the structure and contents of the deliverables are presented below:

- Deliverables
  - 1-Transects
    This directory contains a map showing location of transects, all transect flows in dss files, comparison of ECB1 and ECB2 average annual overland flow across transects 23A, 23B, 23C
  - 2-Flows
    This directory contains two dss files (ECB1 and ECB2) with daily flows for S-332B, S-332C, S-332D, S-18C, and S-197. ECB2 file also contains flows through structures S-199 and S-200.
  - 3-WaterLevels
    This directory contains two dss files (ECB1 and ECB2) with daily water levels at the gage locations of TSB, E146, EVER4 and EVER6. It also contains the gage identity map for the entire model domain. Comparisons of ECB1 and ECB2 ponding depth hydrographs and duration curves for each gage locations are also included in this directory.
  - 4-WaterBudgets
    - ECB1
      This directory contains, annual water budgets reports, average annual water budget reports and an average annual water budget map for ECB1
    - ECB2
      This directory contains, annual water budgets reports, average annual water budget reports and an average annual water budget map for ECB2
  - 5-Documents
    This directory contains the assumptions for ECB1, ECB2 and a comparison of assumptions between ECB1 and ECB2 simulations. It also contains this model documentation report.

Project Specific Results

Water Budget Analysis in the Northeastern Florida Bay Drainage Basin

A summary of the water budgets for ECB1 and ECB2 of the drainage basin of northeastern Florida Bay is presented in Tables A-5 and A-6. Water budget maps for Florida Bay ECB1 and ECB2 are shown in Figure A-6A and Figure A-6B. From the comparison of the water budget maps between ECB1 and ECB2, it is evident that canal flows from the north side of the drainage basin to the L31W canal are significantly higher in ECB2. Because, the C-111 Spreader Canal Western Project feature (S-199 and S-200) creates enough pull to have more direct flows into the canal. On the other hand, canal seepage toward the L31W canal is significantly lower in ECB2 compared to ECB1. The reason is as the canal inflow increases in ECB2, the stage rises in the canal and the head between the marsh and the canal decreases, which reduces the seepage from the marsh to the canal. The combined flow (canal flows + canal seepage) remains about the same. Another difference is the existence of S-199 structure in ECB2 that diverts 27,700 acre feet (27.7 kac-ft) of water from the LEC to the Florida Bay drainage basin. As a consequence, the flows in S-18C are reduced by 11.2 kac-ft and levee seepage from ENP to LEC is increased by 11.2 kac-ft. A slight increase in tidal outflow to Florida Bay (2.1 kac-ft) is observed in ECB2 due to increase in Taylor Slough flows, a direct effect of the C-111 Spreader Canal Western Project.

Care must be taken when using two of the water budget components: 1) total overland inflow into the drainage basin and 2) total tidal outflow from the drainage basin to the Florida Bay. A significant portion of the total overland inflow is comprised of flows from west to east along the southern boundary (near the coastline) of the model. Historical tidal stage data from Flamingo tidal monitoring stations were imposed along the coastline of Florida Bay and tidal outflows are simulated. Like other hydrology and hydraulics model, the magnitude and direction of the overland flows are less reliable near the boundary due to the boundary effect. So, the magnitude of the total overland inflows to the drainage basin near the southern boundary is most likely overestimated. This in turn inflates the tidal boundary outflows from the drainage basin to Florida Bay. Therefore, percentages of water budget components relative to the total water budget are not useful or reliable for analysis of modeling results. Likewise, the absolute values of the total overland inflow or the total tidal outflows are not useful or reliable for analysis of modeling results.

Useful information can be extracted from the water budget, Differences in the water budget components between the baseline simulation and the simulation of the with-project condition produces useful information about the effects of the projects. For example, the water budget correctly shows that S-18C flows are reduced in the with-project condition relative to the baseline, showing the effect of the C-111 Spreader Canal Western Project that shifts flows westward.

Table A-5: Summary of Water Budget for Drainage Basin of Northeastern Florida Bay in ECB1

##

Annual Average Basin Water Budget Summary

##

Model Name = RSMGL

Run Title = Florida Bay ECB1

FLORIDA BAY RSM Water Budget Area

SUBBASIN AREA (square miles) = 204 Square Miles
(All values in thousand acre-feet)
(Positive values indicate inflows, negative values indicate outflows)

Water Budget Component	Mean
Rainfall	520.5
Evapotranspiration	-564.6
Net overland flow for the entire drainage basin	354.7
Net groundwater flow for the entire drainage basin	38.5
Levee seepage across LEC protection levee east of the drainage basin	-29.4
L-31W canal flow from canal reach north to the drainage basin	12.9
*L-31W canal seepage entering to the drainage basin from north	13.2
BOUNDARY FLOW	-512.6
TIDAL Outflows to from the drainage basin to Florida Bay	-512.6
Total Structural Inflows to the drainage basin	183.7
Overbank flows into L-31W canal from north of the drainage basin	0.1
S-18C	183.6
Structural outflows from the drainage basin	-16.5
S-197	-16.5
Total inflows to the entire drainage basin	1123.5
Total outflows from the entire drainage basin	-1123.1
Change in storage within drainage basin	0.5
RESIDUAL = Change in Storage – (Total Inflows –Total Outflows)	0.1

* Clarification of "L-31W canal seepage" term: A portion of the L-31W canal segment near the northern boundary of Florida Bay drainage basin is not fully contained within the basin. The L-31W canal seepage term quantifies the amount of seepage from the adjacent marsh (north to the drainage basin) toward that particular L31W canal segment.

Table A-6: Summary of Water Budget for Drainage Basin of Northeastern Florida Bay in ECB2

##
Annual Average Basin Water Budget Summary
##

Model Name = RSMGL
Run Title = Florida Bay ECB2

FLORIDA BAY RSM Water Budget Area
SUBBASIN AREA (square miles) = 204 Square Miles
(All values in thousand acre-feet)
(Positive values indicate inflows, negative values indicate outflows)

Water Budget Component	**Mean**
Rainfall	520.5
Evapotranspiration	-566.9
Net overland glow for the entire drainage basin	352.8
Net groundwater flow for the entire drainage basin	38.8
Levee seepage across LEC protection levee east of the drainage basin	-40.6
L-31W canal flow from canal reach north to the drainage basin	26.2
L-31W canal seepage entering to the drainage basin from north	0.3
BOUNDARY FLOW	-514.7
TIDAL Outflows to from the drainage basin to Florida Bay	-514.7
Total structural inflows to the drainage basin	200
Overbank flows into L-31W canal from north of the drainage basin	0.1
S-18C	172.4
S-199A	16.7
S-199B	8.5
S-199C	2.5
Structural outflows from the drainage basin	-15.9
S-197	-15.9
Total inflows to the entire drainage basin	1138.7
Total outflows from the entire drainage basin	-1138.1
Change in storage within drainage basin	0.6
RESIDUAL = Change in Storage – (Total Inflows –Total Outflows)	0

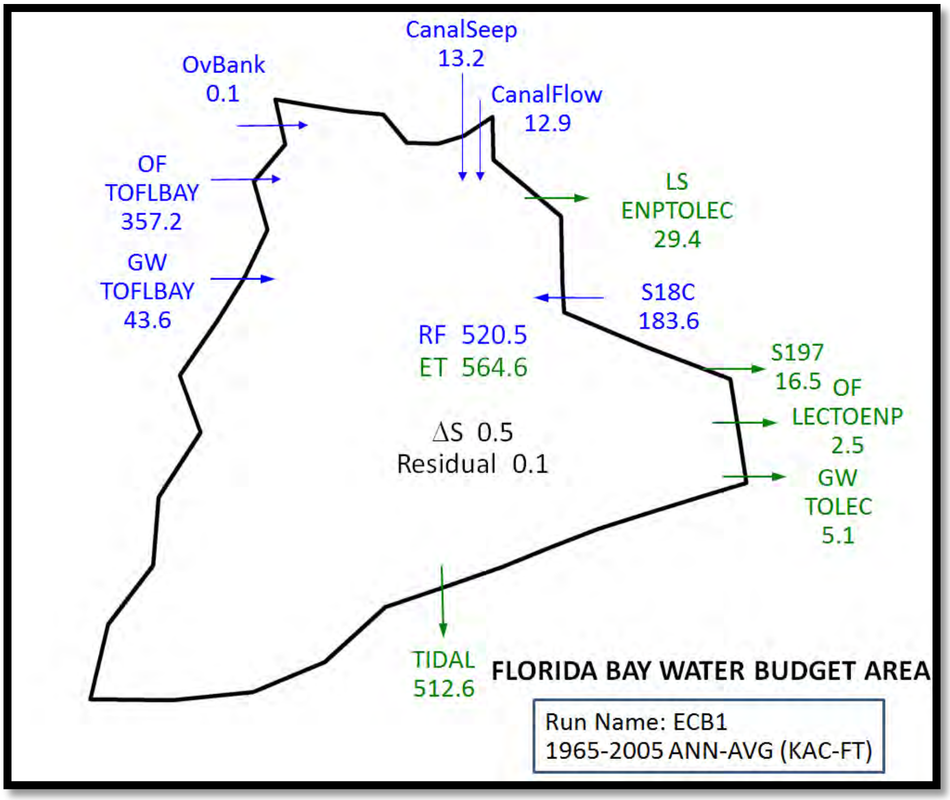


Figure A-6A: Water Budget Map for Florida Bay Water Budget Area in ECB1

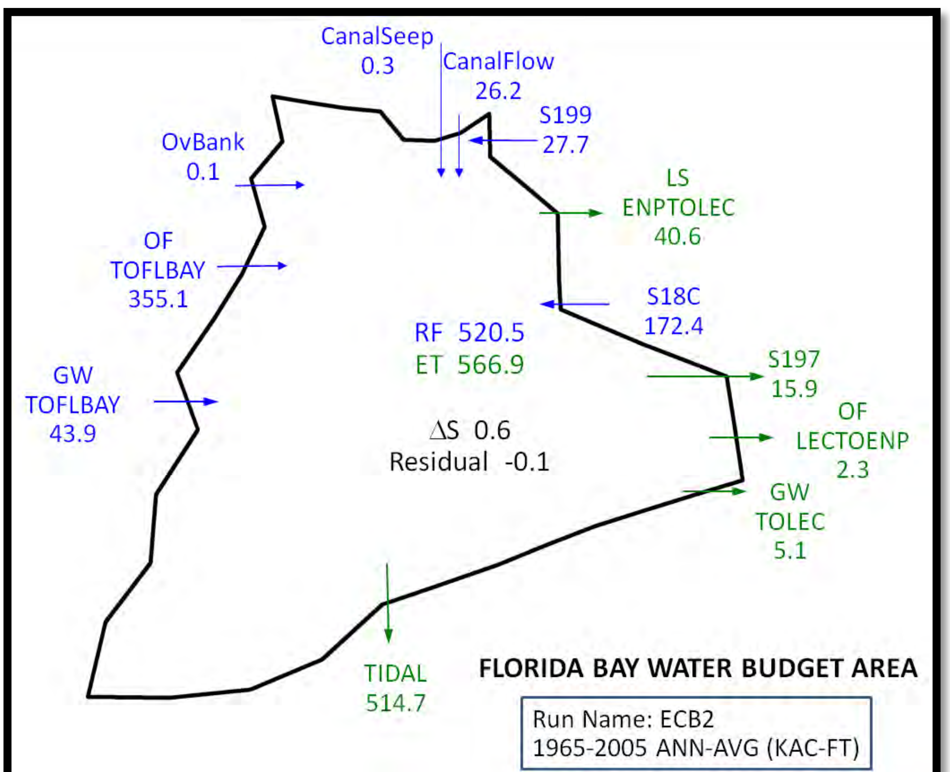


Figure A-6B: Water Budget Map for Florida Bay Water Budget Area in ECB2

Analysis of Transect Flows

Figure A-7A shows a map with location of overland flow transects in the entire RSMGL model domain. Figure A-7B shows the location of the transects within the Florida Bay drainage area only (T23A, T23B and T23C).

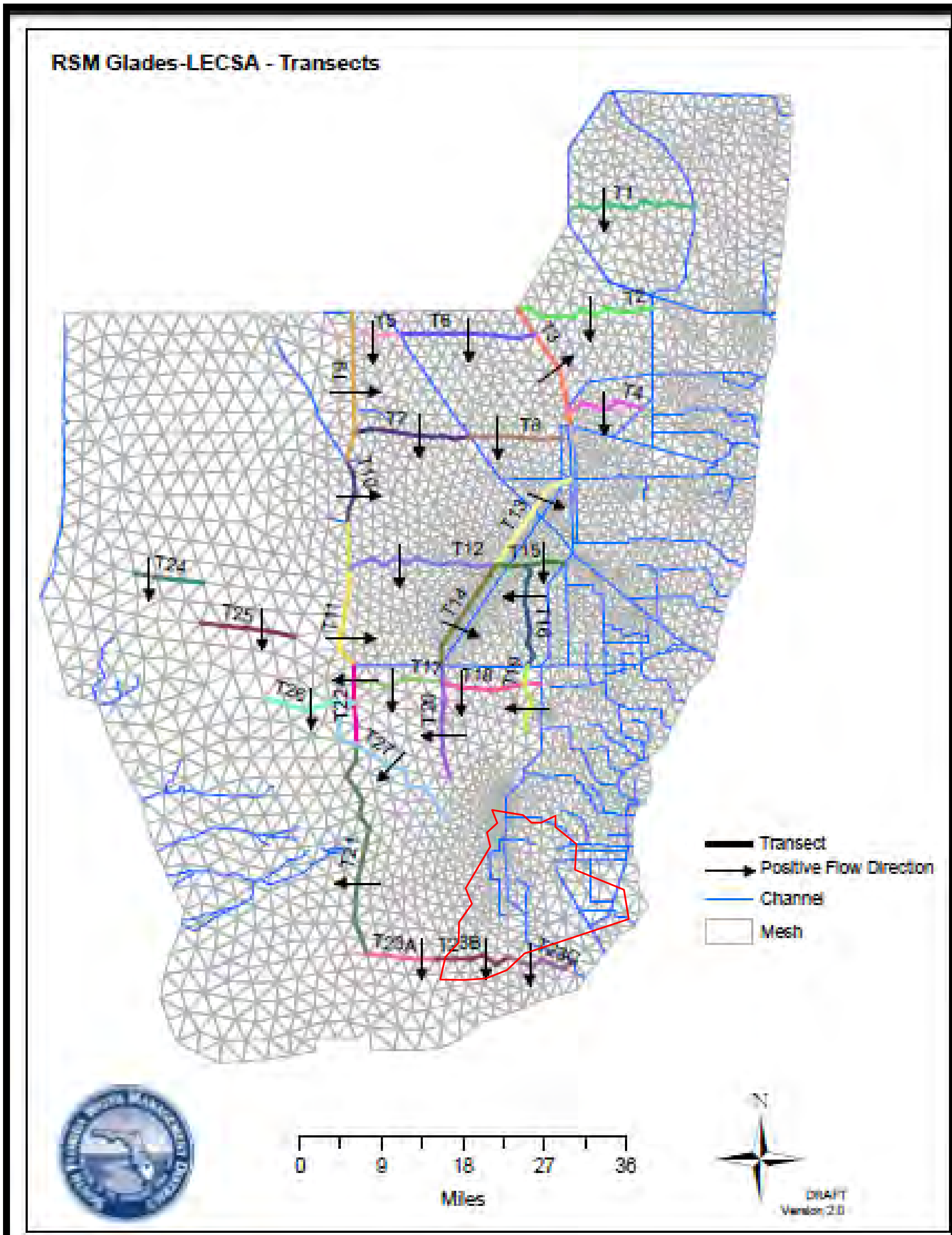


Figure A-7A: Map with Location of All Overland Flow Transects in RSMGL

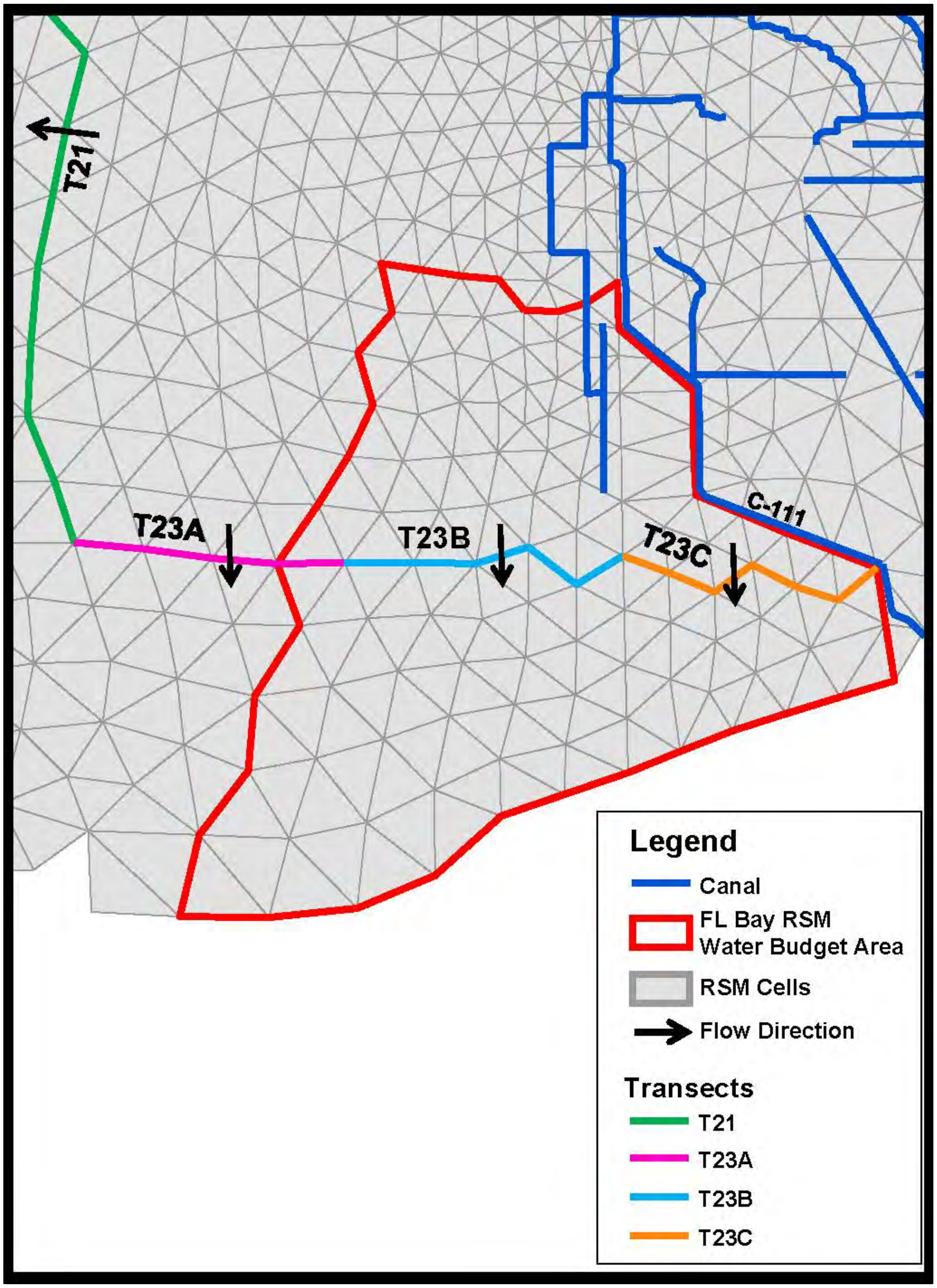


Figure A-7B: Map with Location of Overland Flow Transects in Florida Bay Area

Average annual overland flow across transects 23A, 23B and 23C are shown in Figure A-8A, Figure A-8B and Figure A-8C. T23A represents overland flows to northeastern Florida Bay west of Taylor Slough, T23B represents overland flows in Taylor Slough, and T23C represents overland flows east of Taylor Slough in the eastern panhandle of ENP.

Comparison of overland flow at two transects within the northeastern Florida Bay watershed (Table A-7) shows an overall increase of 13.6% across transect T23B and a decrease of 3% across transect T23C. The combined transects T23B + T23C show a net increase of 1.7%.

The change in the overland flow distribution is primarily due to the implementation of ERTP and the C-111 Spreader Canal Western Project. Under ERTP, the operation of S-332D was modified to increase the maximum pumping during the CSSS breeding season. Between February 1 and July 14, the maximum pumping was raised from 165 cfs to 250 cfs to increase overland flows at the headwaters of Taylor Slough. On the other hand, the C-111 Spreader Canal Western Project was intended to create a hydraulic ridge adjacent to ENP so that more of the natural rainfall and flows remains in Taylor Slough. To this end, the pump stations (S-199 and S-200) of this project discharge water from the C-111 canal to the Frog Pond Detention Areas and the Aerojet Canal along the eastern boundary of ENP. These areas are surrounded by berms and can hold water at a higher elevation than the adjacent marsh, producing the ridge. The water pumped west from the C-111 canal reduces the volume of water moving south along the C-111 canal and entering the ENP eastern panhandle.

In summary, the increase in flows from the L-31N canal to the headwaters of Taylor Slough through S-332D, the hydraulic ridge along the eastern edge of ENP, and the reduction of flows along the C-111 canal produce increased overland flows in the Taylor Slough transect and reduced overland flows in the ENP eastern panhandle. No difference in overland flows across T23A is encountered between ECB1 and ECB2 since this transect is located further west of the area influenced by the C-111 Spreader Canal Western project and ERTP.

Table A-7: Overland Flow Volumes Across the Transects in the Watershed of Northeastern Florida Bay

Transects	Average Annual Overland Flow (kac-ft)						Percent Difference Projects Relative To Baseline
	Simulation of Baseline (ECB1)			Simulation of Projects (ECB2)			
	Wet Season	Dry Season	Water Year	Wet Season	Dry Season	Water Year	Water Year
T23B	50	16	66	54	21	75	13.6%
T23C	128	41	169	124	40	164	-3.0%
T23B+T23C	178	57	235	178	61	239	1.7%

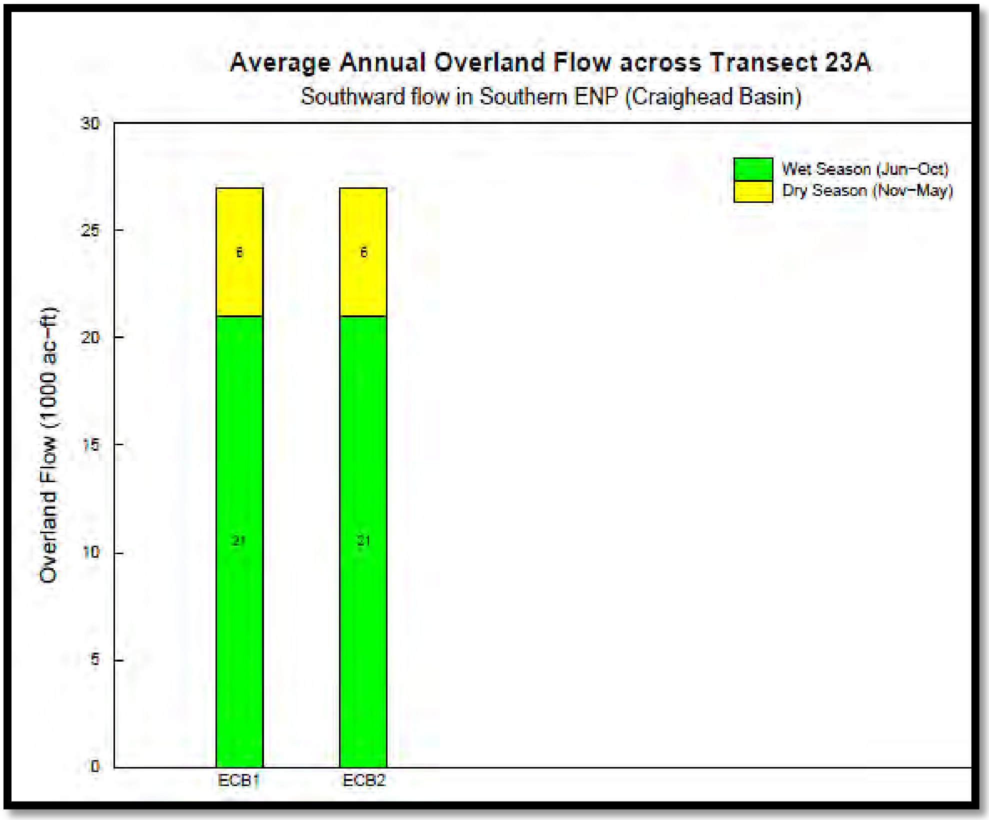


Figure A-8A: Average Annual Overland Flow across Transect 23A

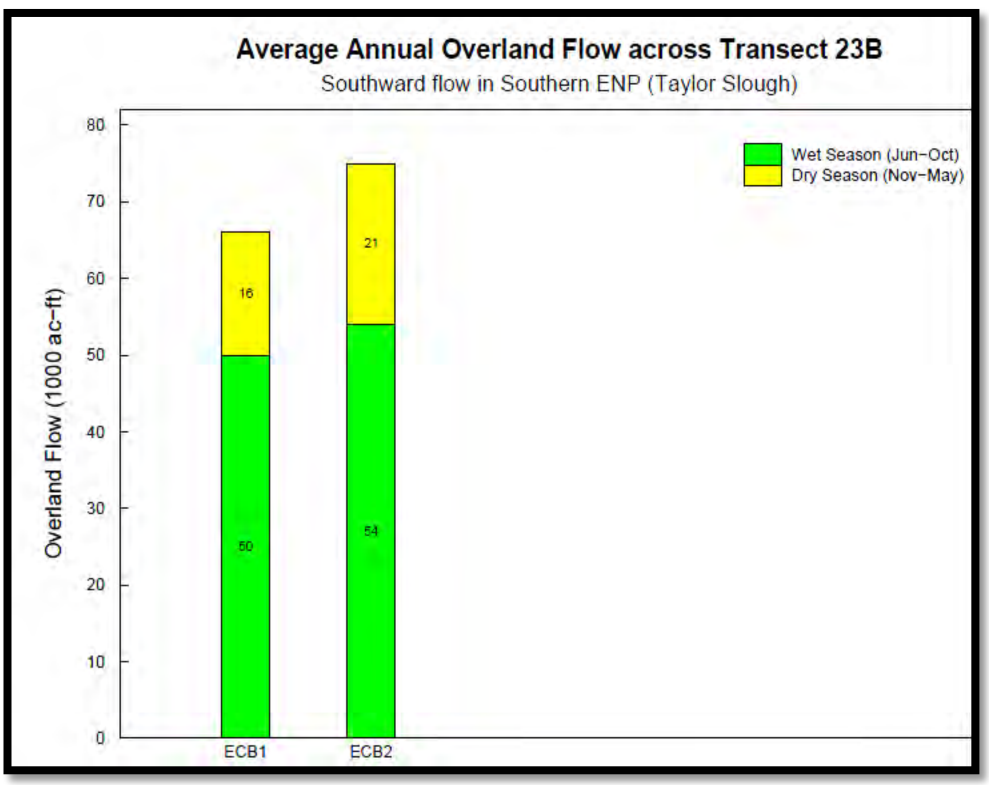


Figure A-8B: Average Annual Overland Flow across Transect 23B

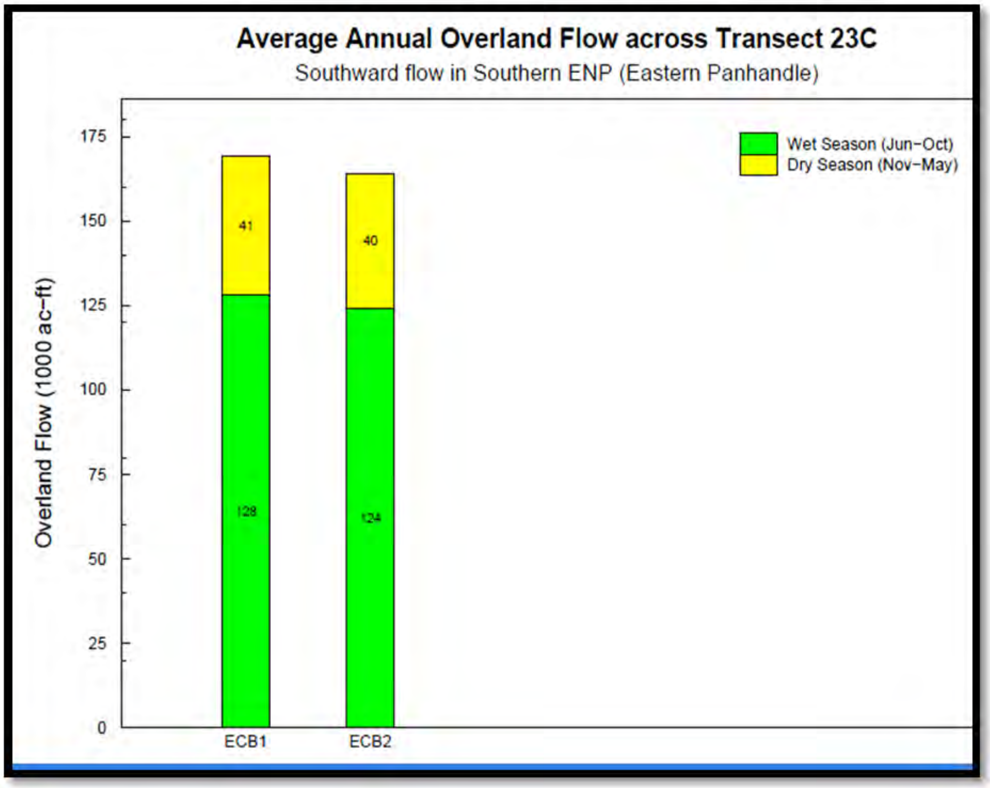


Figure A-8C: Average Annual Overland Flow across Transect 23C

Analysis of Duration Curves

Figure A-9 shows the location of key gages in the Florida Bay drainage area. The key gages are NP-TSB, E146, EVER4 and EVER6 (NP-EV6).

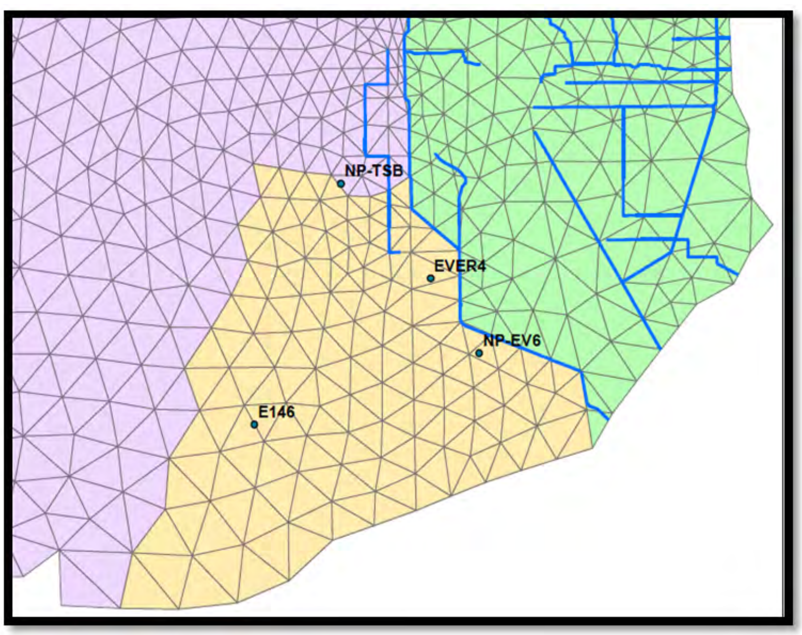


Figure A-9: Location of Key Gages in Florida Bay Drainage Basin

Figures A-10A through A-10D represent duration curves for ponding depths at gage locations NP-TSB, E146, EVER4 and EVER6 respectively. No major differences are encountered in the key gages between ECB1 and ECB2. Duration curves at NP-TSB (located north of the drainage basin) show that ponding depths in ECB2 is slightly higher between the 42nd and 70th percentile compared to ECB1, but slightly lower between 90th and 98th percentile. At E146 (located southwest of the C111 Spreader Canal Western Project), ECB2 is slightly higher between 82nd and 90th percentile. EVER4 is located close to the C-111 Spreader Canal Western Project, so duration curves show a slight increase in ponding depth most of the time. EVER6 is located southeast of the C-111 Spreader Canal Western Project area, and shows a slight decrease in ponding when water levels are above ground and a slight increase when the water level is below ground.

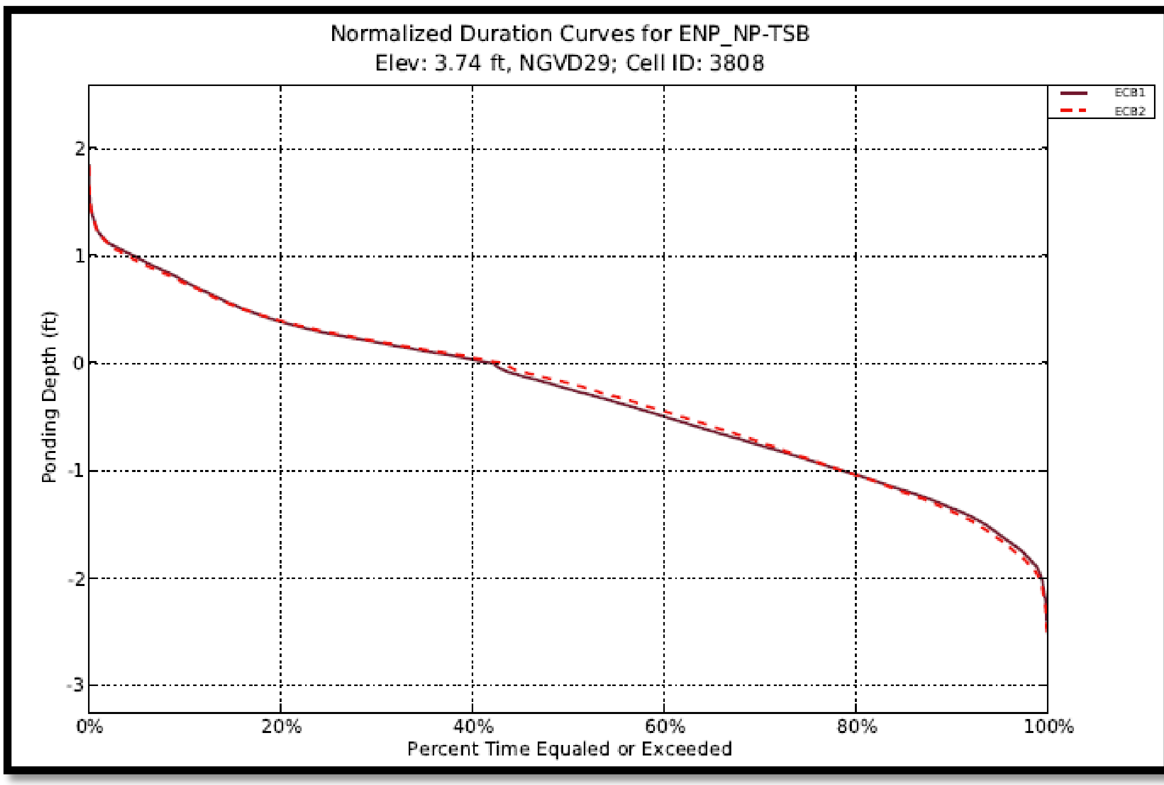


Figure A-10A: Normalized Ponding Depth Duration Curves at Gage NP-TSB

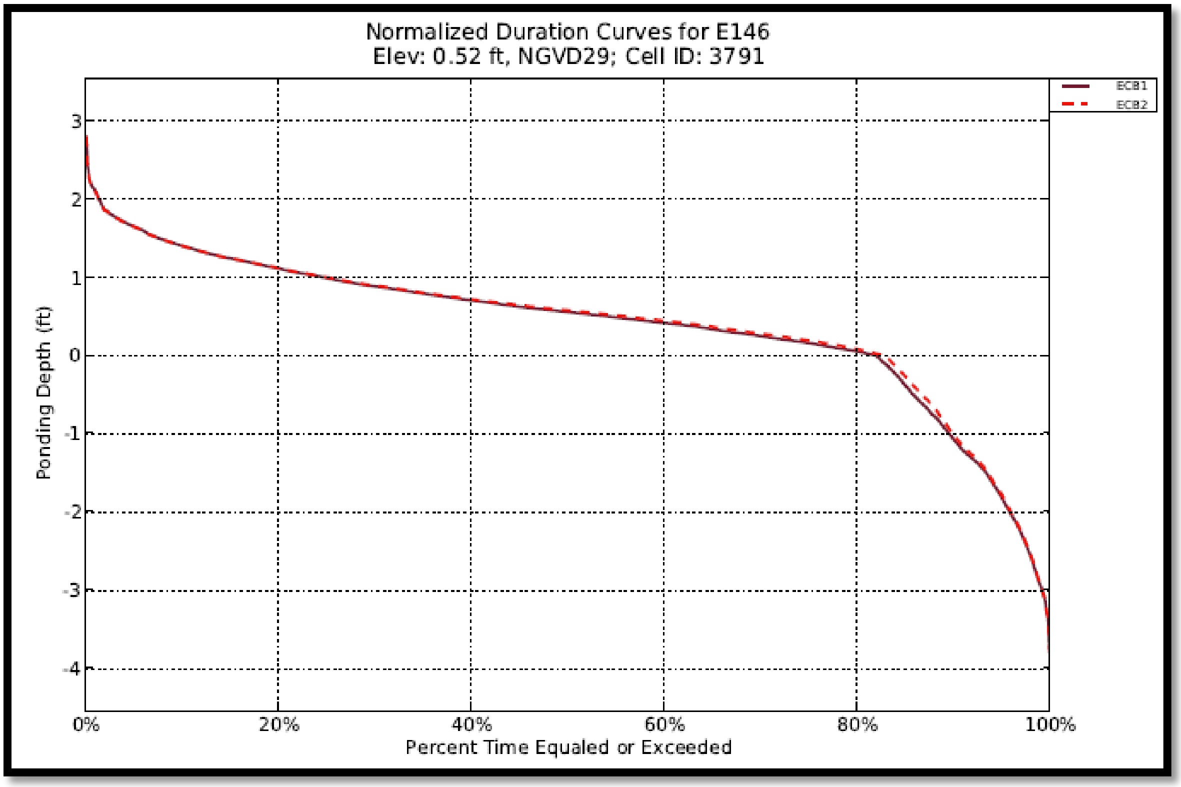


Figure A-10B: Normalized Ponding Depth Duration Curves at Gage E146

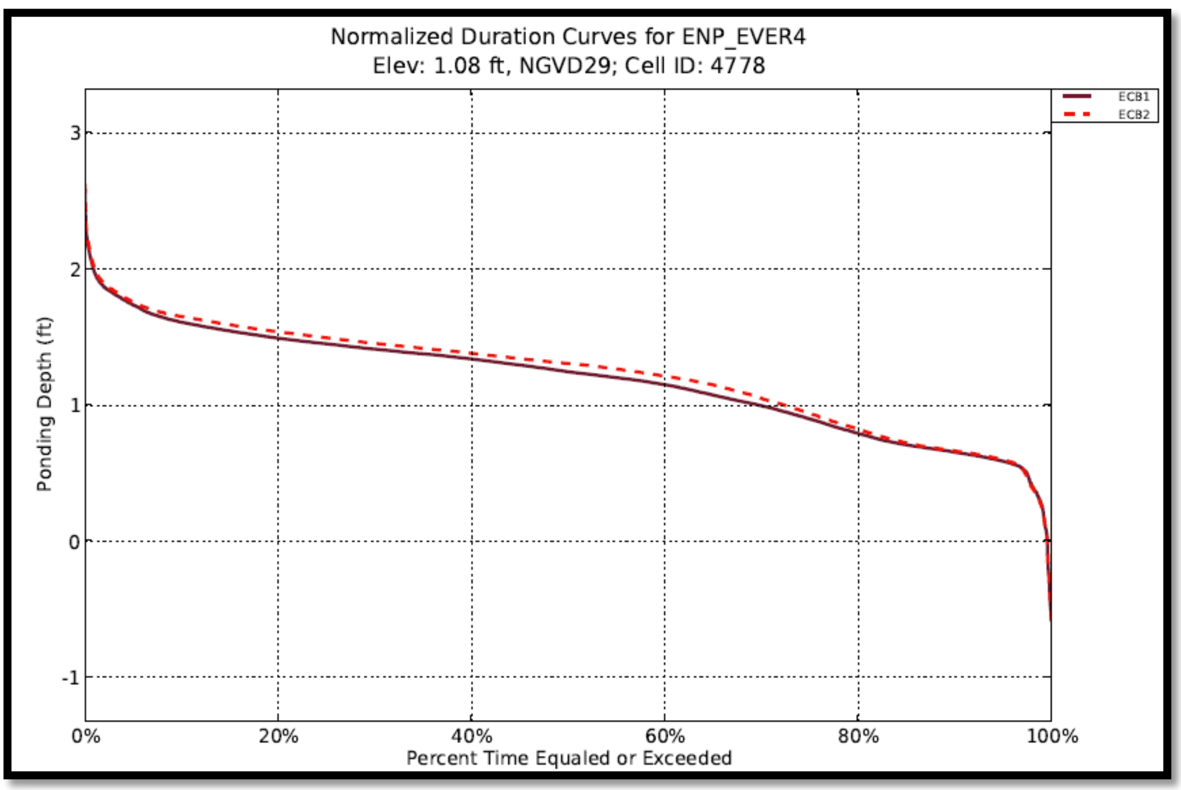


Figure A-10C: Normalized Ponding Depth Duration Curves at Gage EVER4

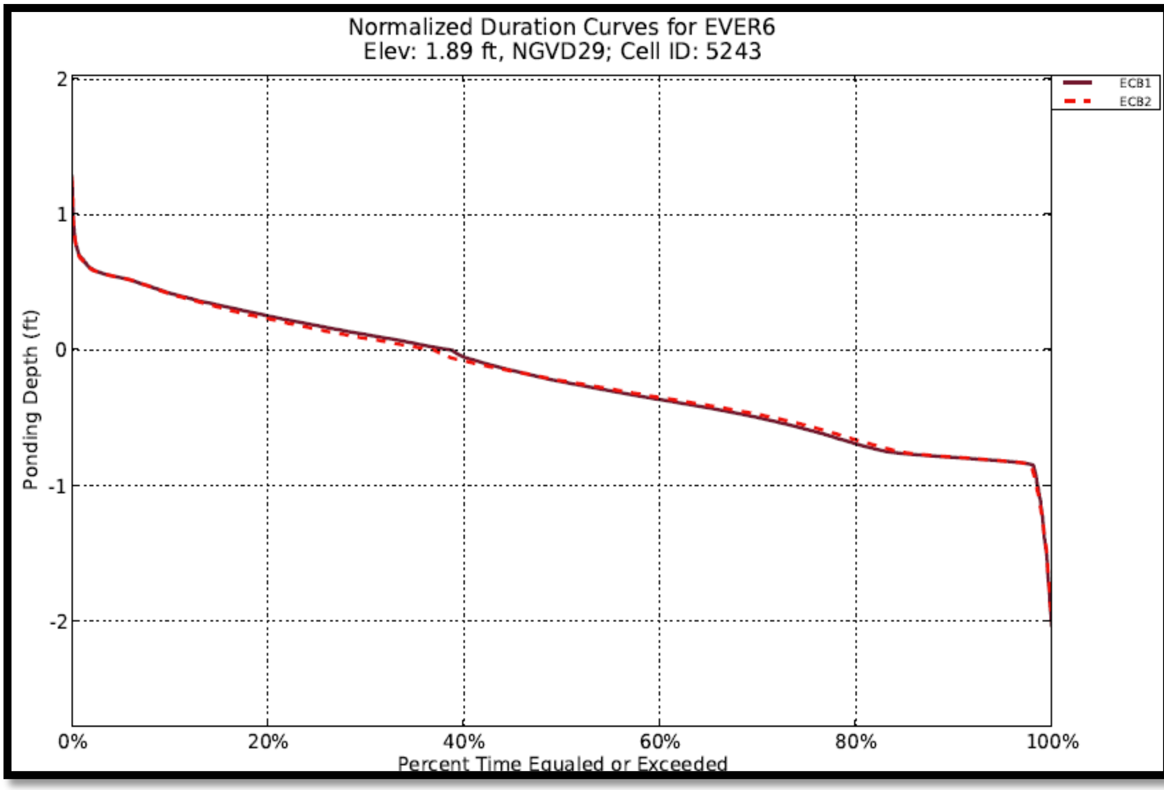


Figure A-10D: Normalized Ponding Depth Duration Curves at Gage EVER6

Analysis of Daily Water Control Structure Flows

Comparisons of average flows for S-18C, S-197 and S-332D are shown in Table A-8 (The location of these structures is shown in Figure A-5B.)

Table A-8: Comparison of Average Flows through Structures

Structure	ECB1 Mean Flow (kac-ft)	ECB2 Mean Flow (kac-ft)	% difference
S-18C	183.6	172.4	-6.1
S-197	16.5	15.9	-3.6
S-332D	98.1	109.5	11.6

Figures A-11A through A-11C show discharge frequency curves for S-18C, S-197 and S-332D, respectively.

Average flows in ECB2 are slightly lower at S-18C compared to ECB1 since water is diverted upstream of S-18C through S-199. Similar observation can be made from discharge frequency curve (Figure A-11A). A 50-cfs decrease in flow at S-18C is noticed between 15% to 35% of times in ECB2 compared to ECB1.

A very little decrease in average flows of S-197 is noticed in ECB2 compared to ECB1 since S-197 is further downstream of S-18C. (Similar observation can be made from the discharge frequency curve shown in Figure A-11B).

Average flows at S-332D increased by 11.6% in ECB2 compared to ECB1 due to implementation of ERTP and Tamiami Trail One-Mile Bridge (higher levels in northeastern Shark River Slough). Similar observation can be made from discharge frequency curve (Figure A-11D). An 80-cfs increase in flow in S-332D is noticed between 27% to 37% of times in ECB2 compared to ECB1.

Regional-Level Results

The effect of the implementation of ERTP and One-Mile Tamiami Trail Bridge can be better explained at the regional level. Regional-level results can be evaluated in terms of ponding depths, hydroperiods, overland and groundwater flow vectors as a 41-year annual average, dry year (1989) and wet year (1995). Transect flows south of Tamiami Trail were also investigated. Flows at the S-12 structures were compared to understand the effect of ERTP.

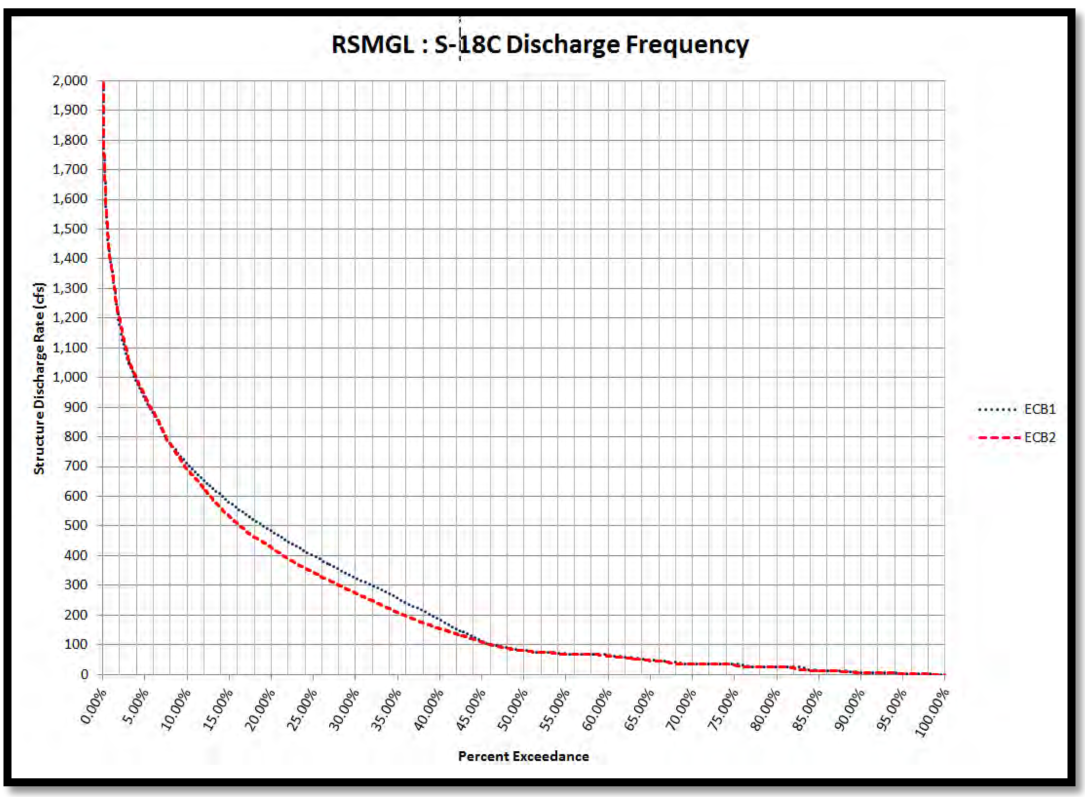


Figure A-11A: Daily Simulated Flows at S18C

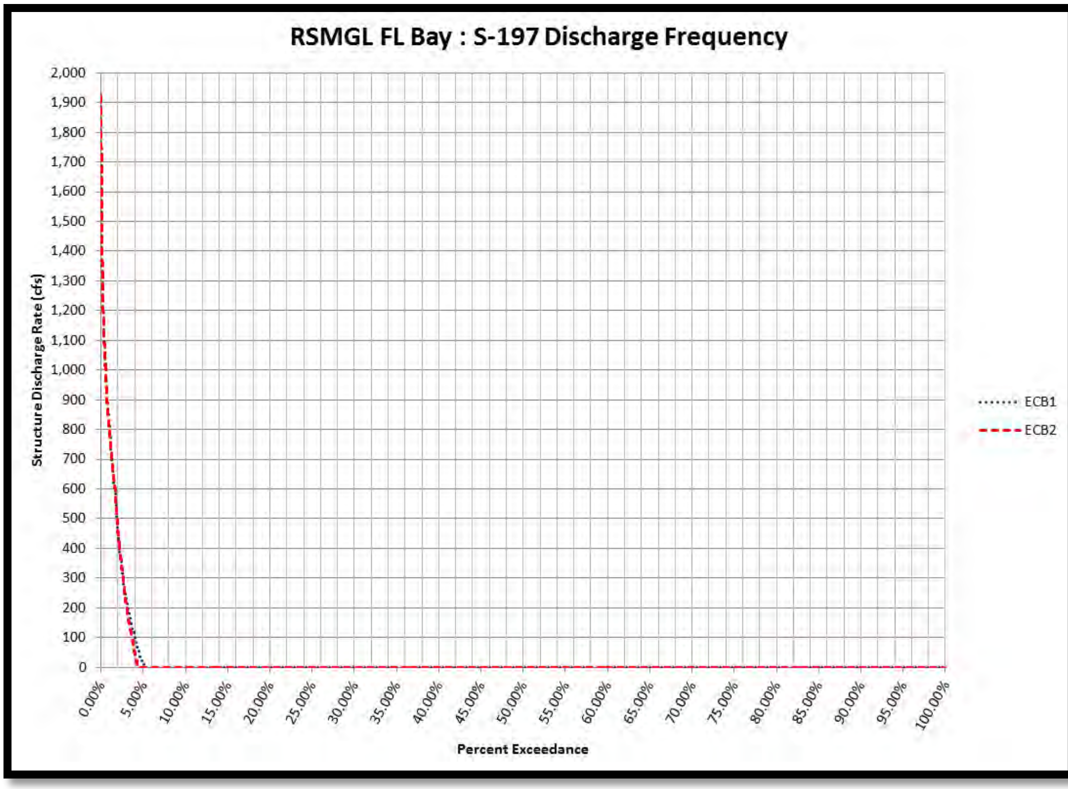


Figure A-11B: Daily Simulated Flows at S197

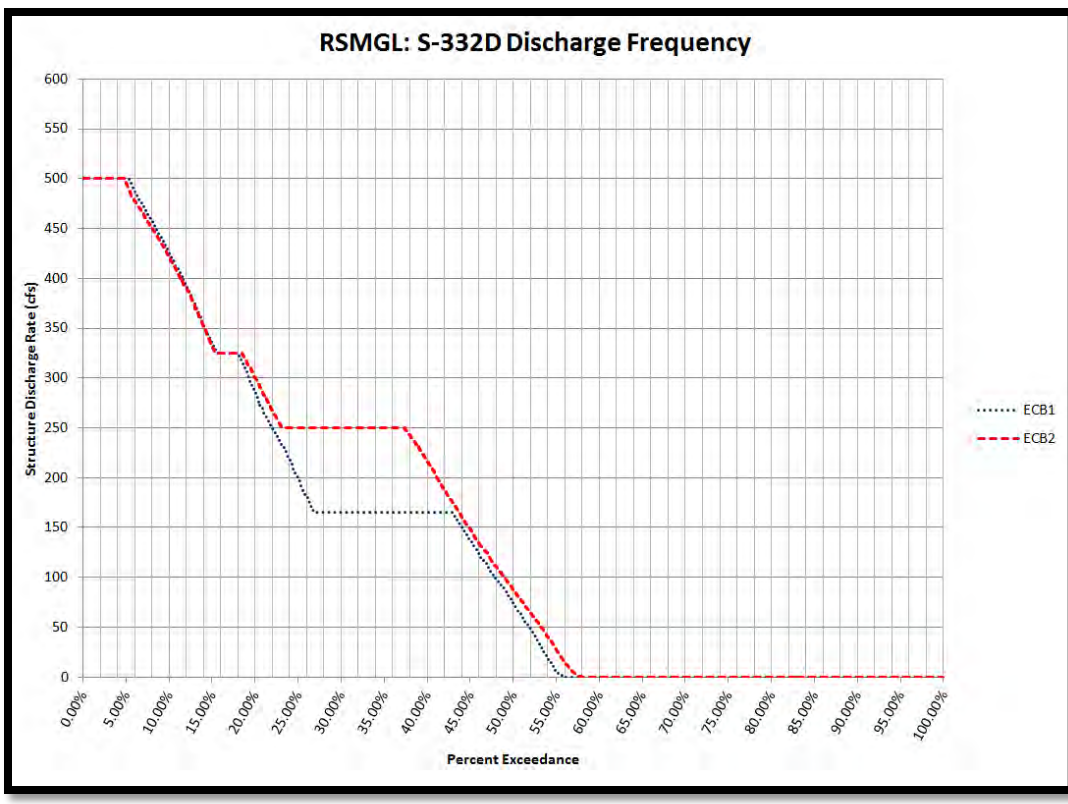


Figure A-11C: Daily Simulated Flows at S332D

Hydroperiods

41-Year Average Annual Hydroperiod Distribution (see Figures A-12A-1 and A-12A-2): No major changes were observed in ECB2 compared to ECB1 except immediately south of western Tamiami Trail at Shark River Slough where shorter hydroperiods were noticed. This is the effect of implementation of ERTP that replaced IOP, in combination with the presence of Tamiami Trail One-Mile Bridge in ECB2.

Dry Year (1989) Hydroperiod Distribution (see Figures A-12B-1 and A-12B-2): A slightly longer hydroperiod was observed south of Tamiami Trail Bridge in ECB2 compared to ECB1, but some drier areas were observed southwest of Tamiami Trail.

Wet Year (1995) Hydroperiod Distribution (see Figures A-12C-1 and A-12C-2): No major difference was observed between ECB1 and ECB2.

Ponding Depths

41-Year Average Annual Ponding Depth (see Figures A-13A-1 and A-13A-2): Ponding depths are higher in some cells in Taylor Slough due to the presence of the C-111 Spreader Canal Western Project in ECB2. No major changes were observed except changes in ponding depth pattern of northeastern Shark River Slough because of the effect of ERTP.

Dry Year (1989) Ponding Depth (see Figures A-13B-1 and A-13B-2) and Wet Year (1995) Ponding Depth (see Figures A-13C-1 and A-13C-2): No major difference in ponding depths was observed between ECB1 and ECB2.

Overland Vectors

41-Year Average Annual Overland Vectors (see Figures A-14A-1 and A-14A-2): As noticed in ponding depth maps, overland vectors show more flows toward Taylor Slough due to the presence of the C-111 Spreader Canal Western Project in ECB2. Overland flow patterns are slightly different immediately south and southeast of the Tamiami Trail because of ERTP and existence of the Tamiami Trail One-Mile Bridge.

Dry Year (1989) Overland Vectors (see Figures A-14B-1 and A-14B-2): No major difference in overland vectors was observed between ECB1 and ECB2.

Wet Year (1995) Overland Vectors (see Figures A-14C-1 and A-14C-2): As noticed in 41-year overland vector maps, overland vectors show more flow towards Taylor Slough due to the existence of C-111 Spreader Canal Western Project in ECB2.

Groundwater Vectors

41-Year Average Annual Groundwater Vectors (see Figures A-15A-1 and A-15A-2), Dry Year (1989) Groundwater Vectors (see Figures A-15B-1 and A-15B-2) and Wet Year

(1995) Groundwater Vectors (see Figures 15C-1 and 15C-2): No major difference was encountered at the regional scale.

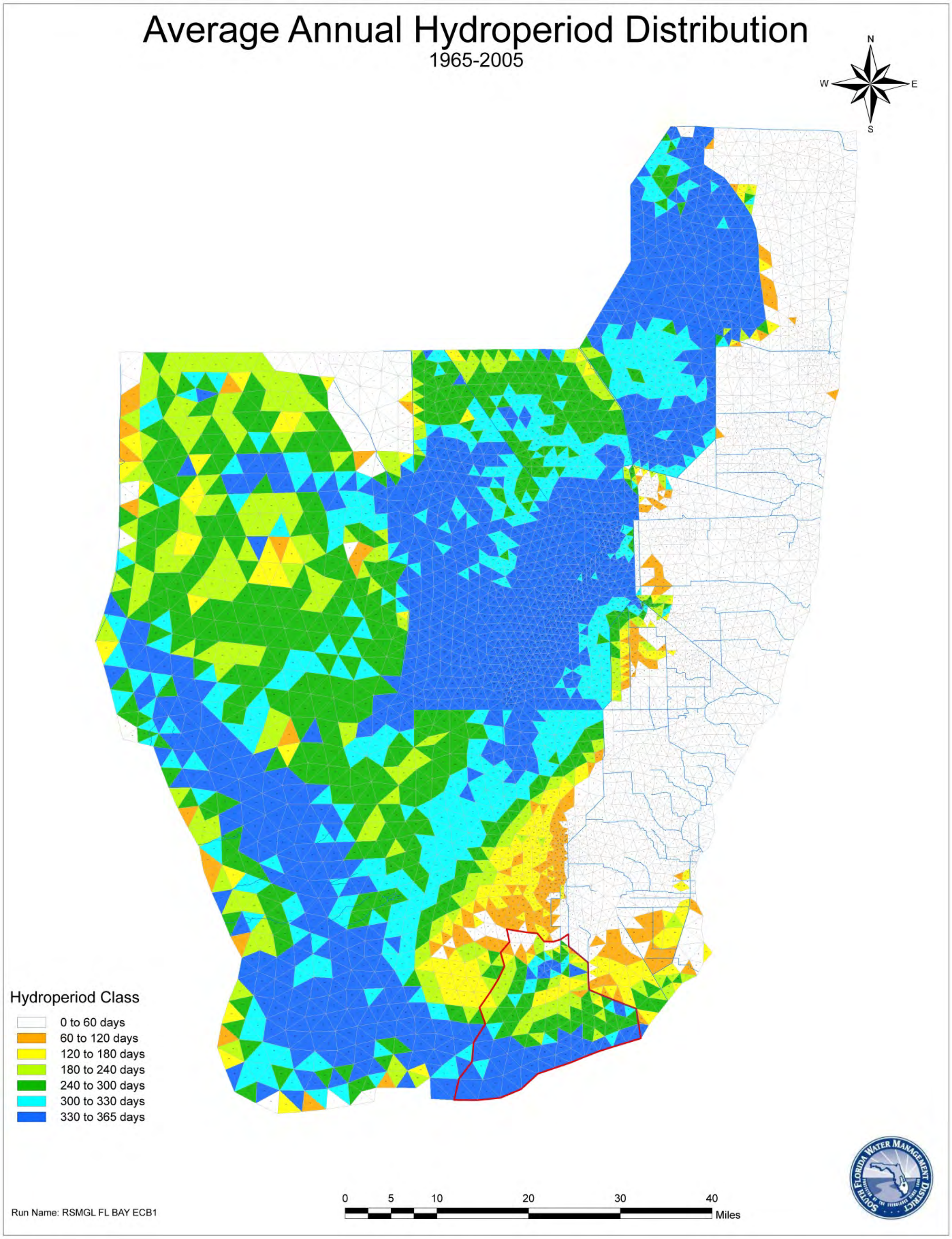


Figure A-12A-1: 41-Year Average Annual Hydroperiod Distribution for ECB1

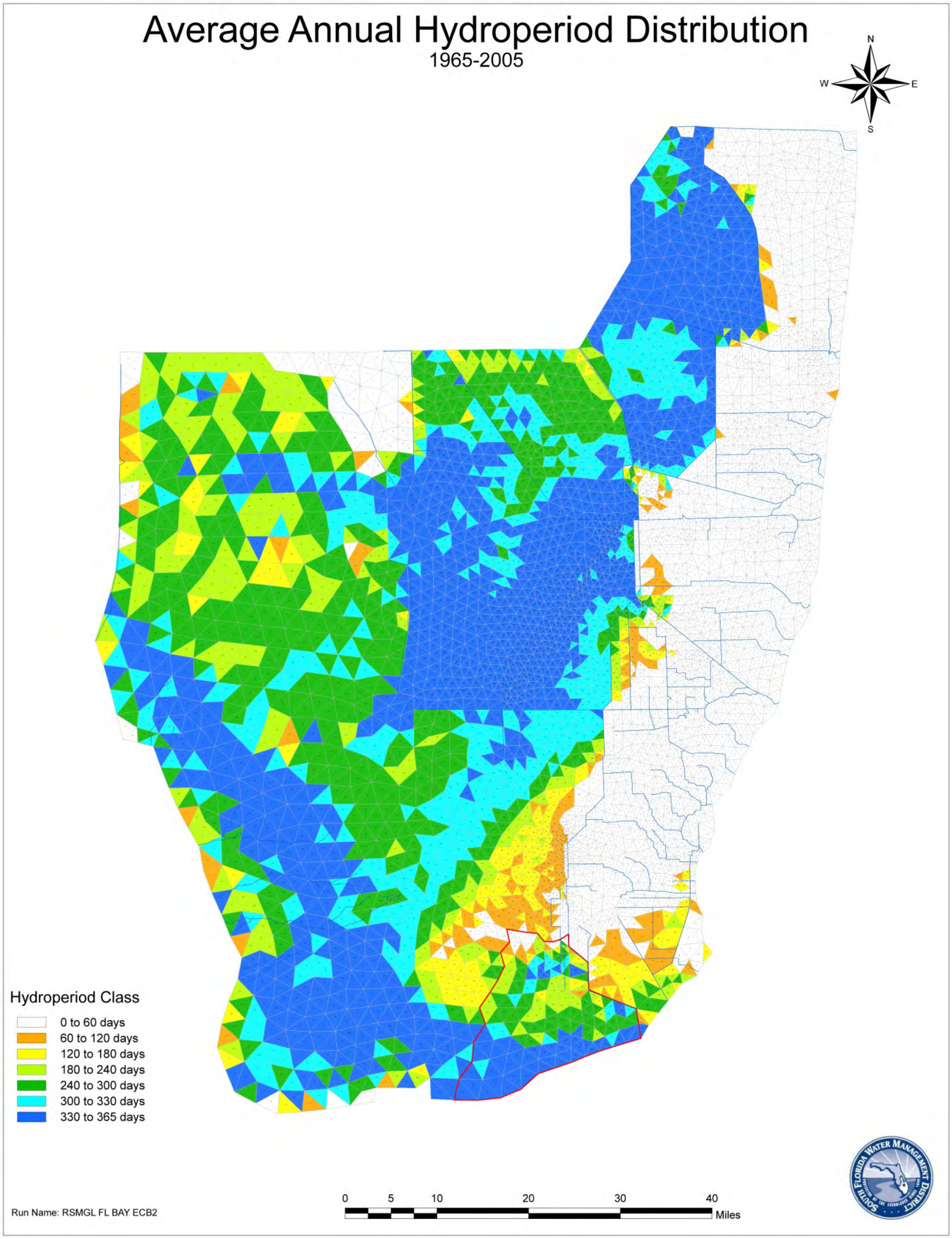


Figure A-12A-2: 41-Year Average Annual Hydroperiod Distribution for ECB2

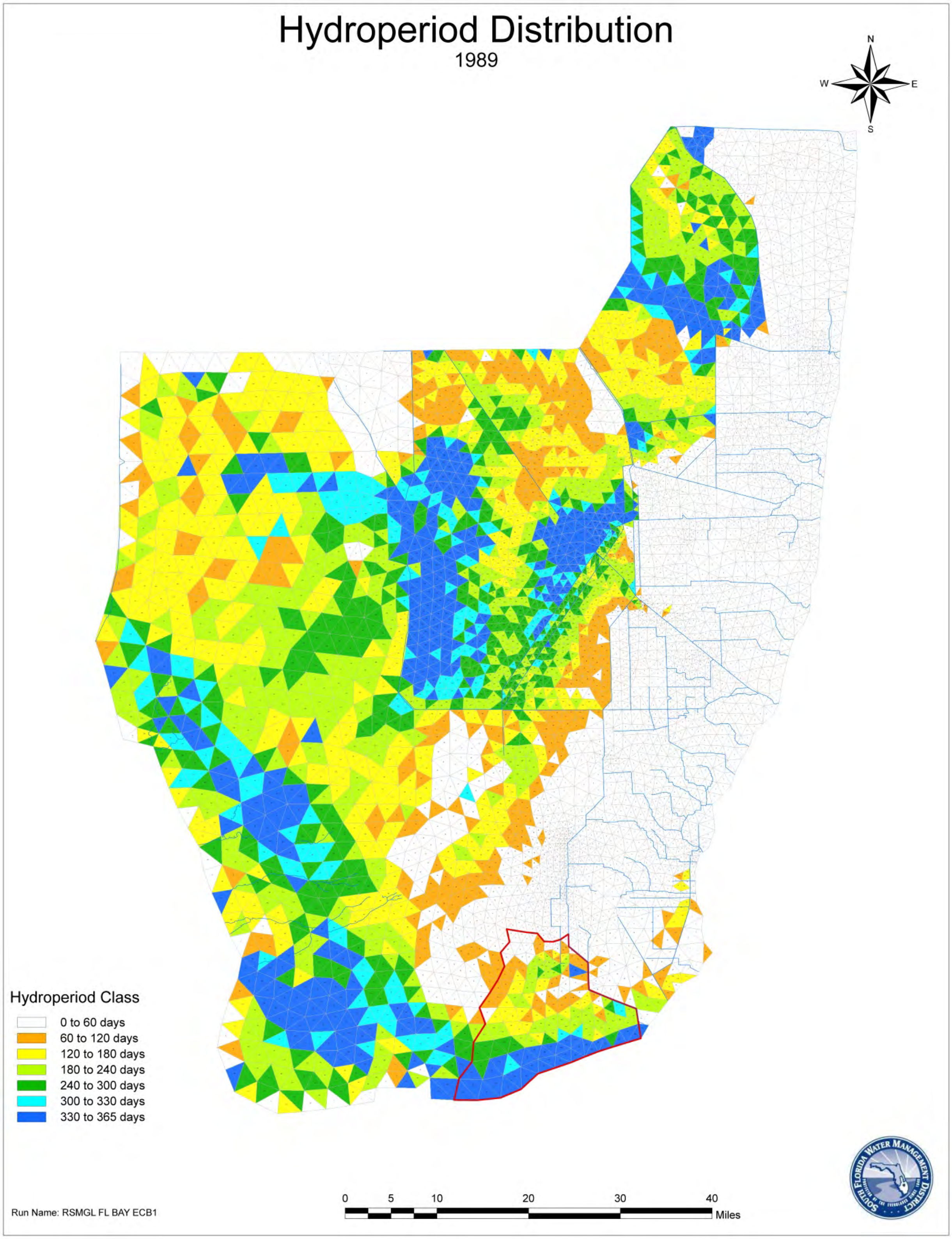


Figure A-12B-1: Dry Year (1989) Hydroperiod Distribution for ECB1

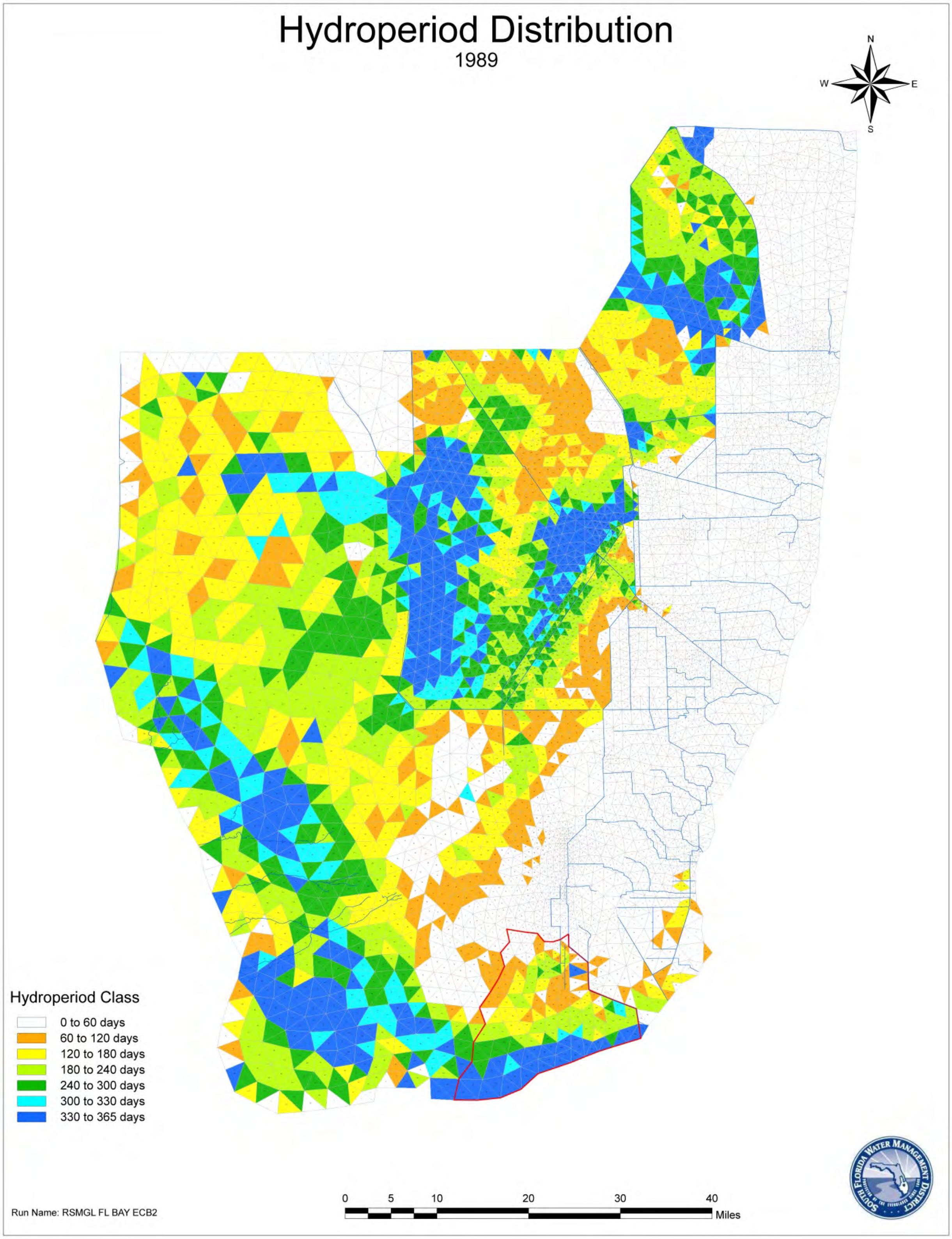


Figure A-12B-2: Dry Year (1989) Hydroperiod Distribution for ECB2

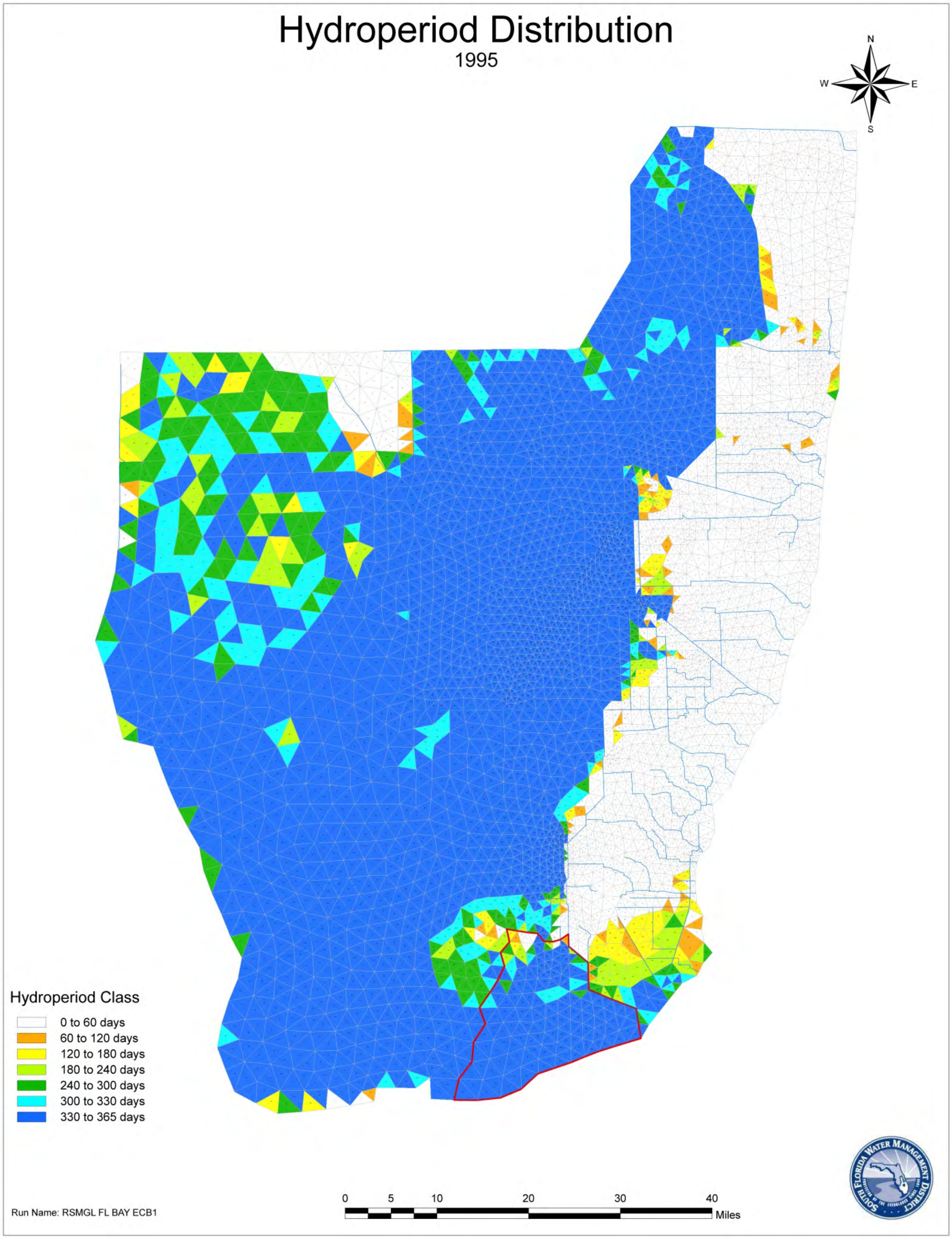


Figure A-12C-1: Wet Year (1995) Hydroperiod Distribution for ECB1

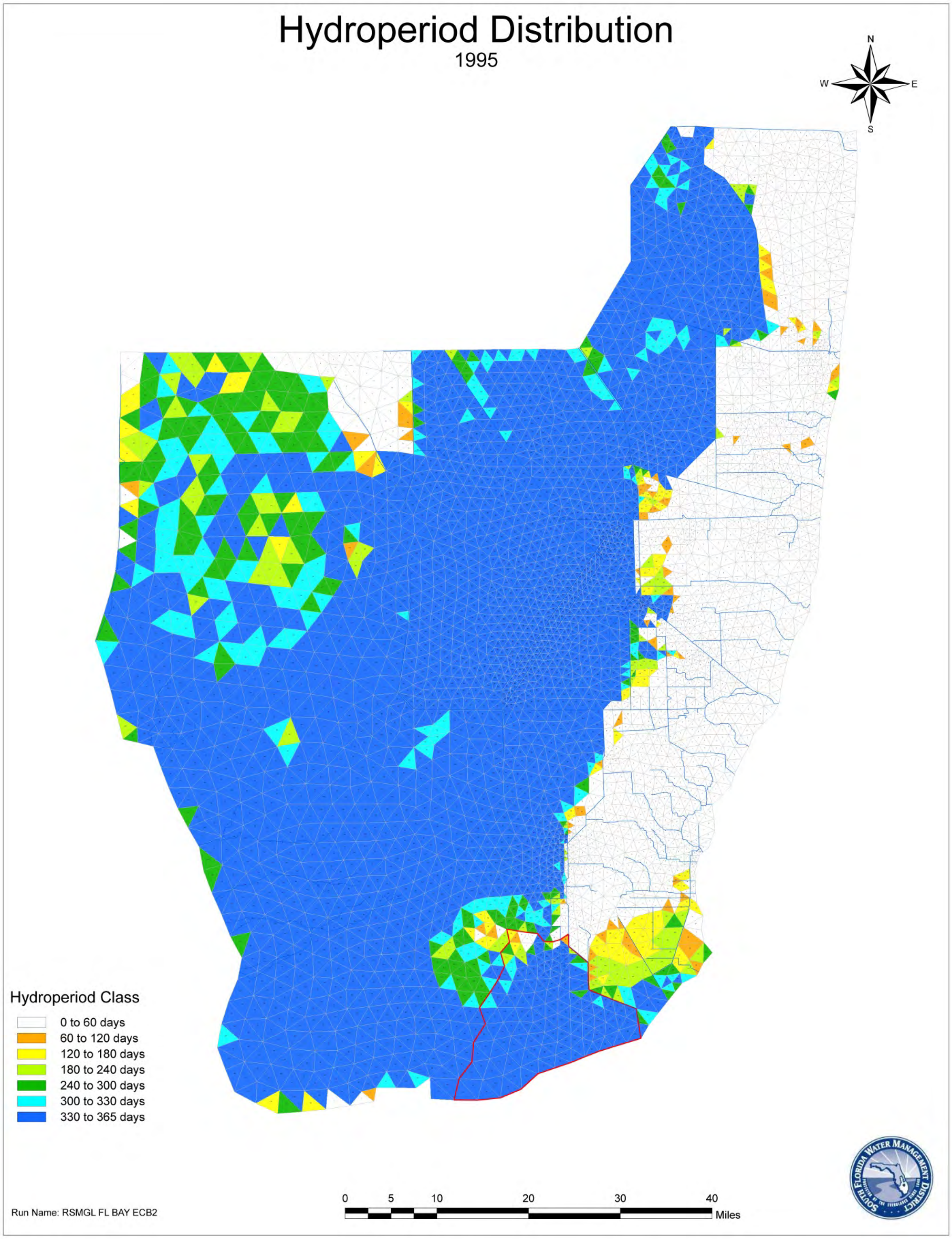


Figure A-12C-2: Wet Year (1995) Hydroperiod Distribution for ECB2

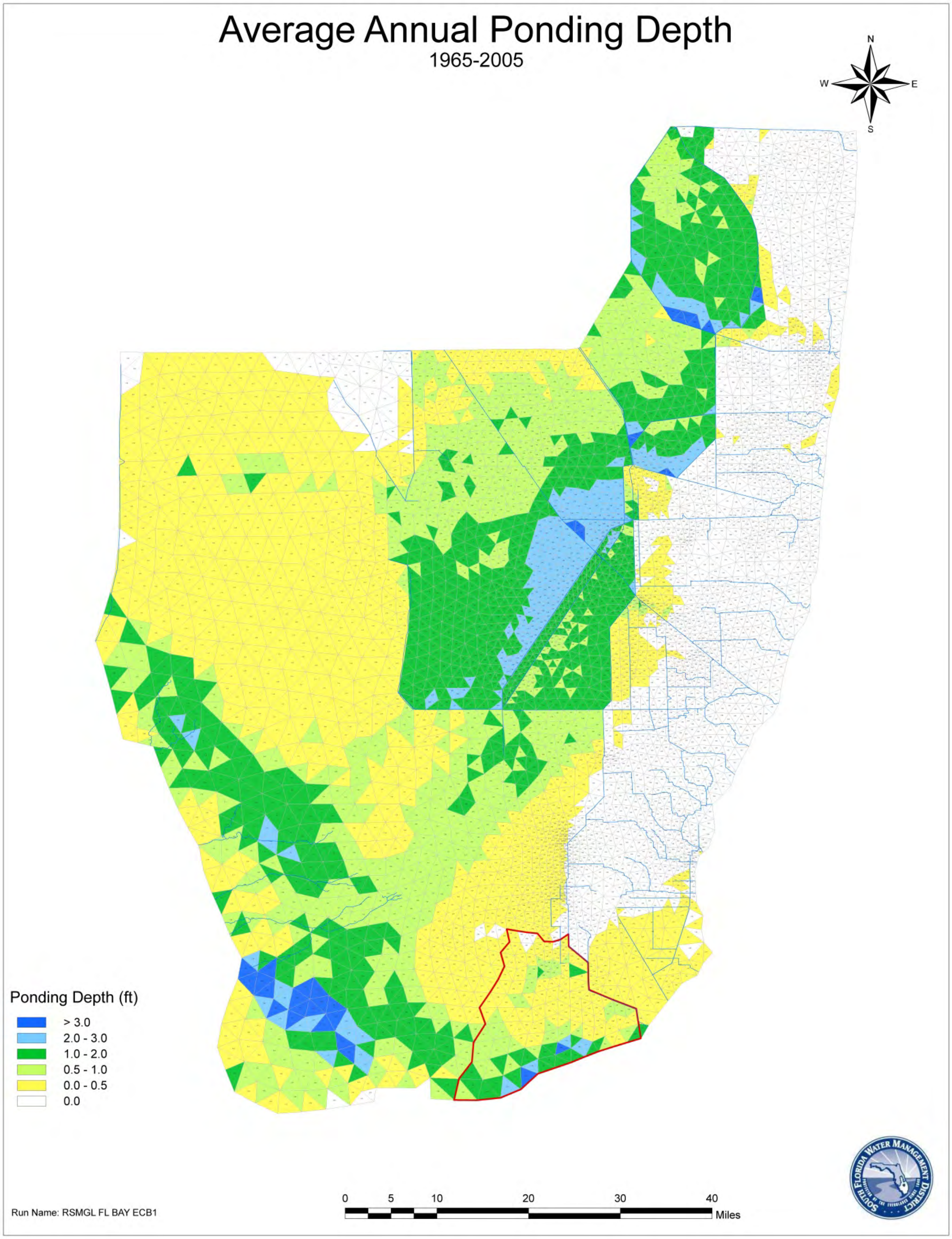


Figure A-13A-1: 41-Year Annual Average Ponding Depths for ECB1

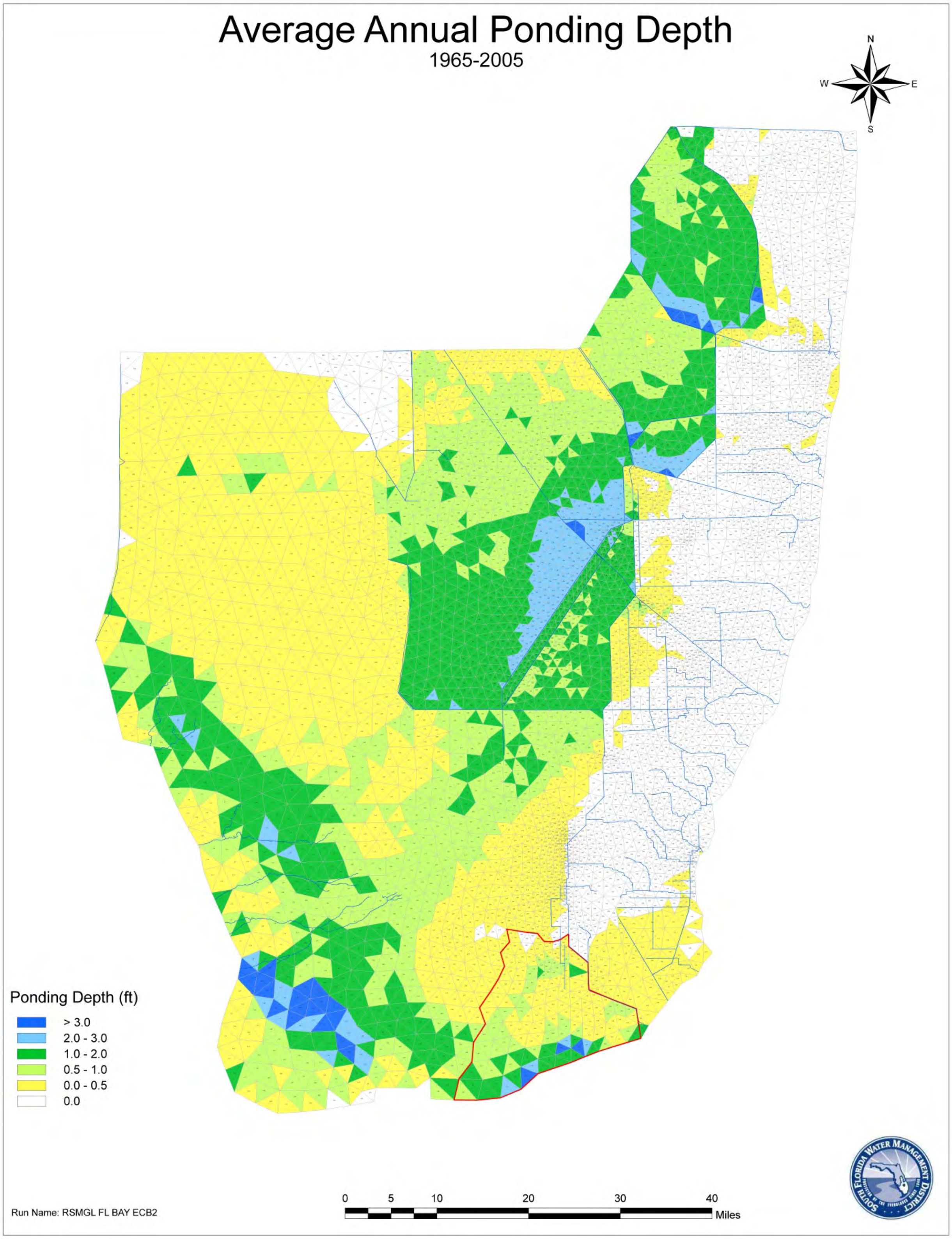


Figure A-13A-2: 41-Year Annual Average Ponding Depths for ECB2

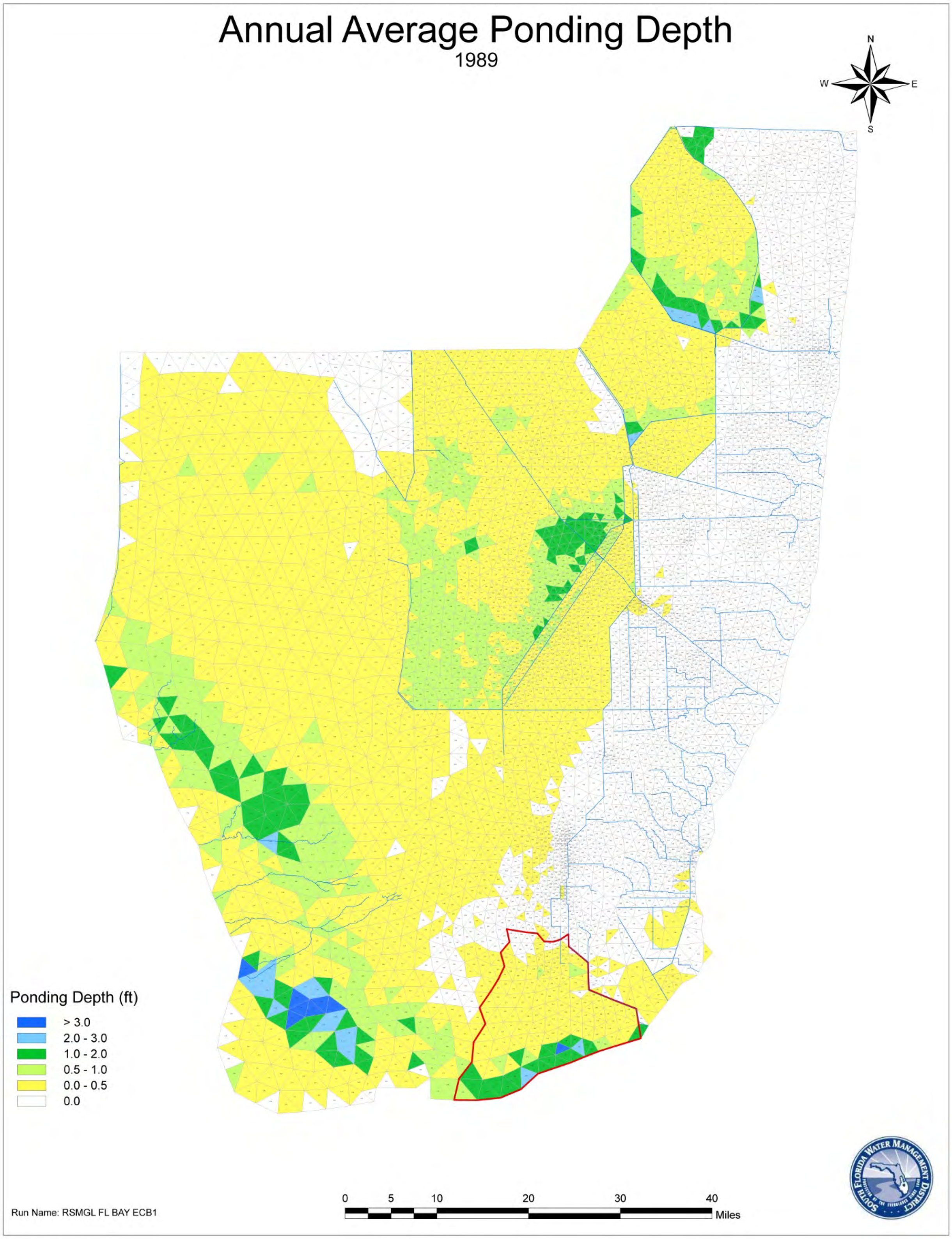


Figure A-13B-1: Dry Year (1989) Average Ponding Depths for ECB1

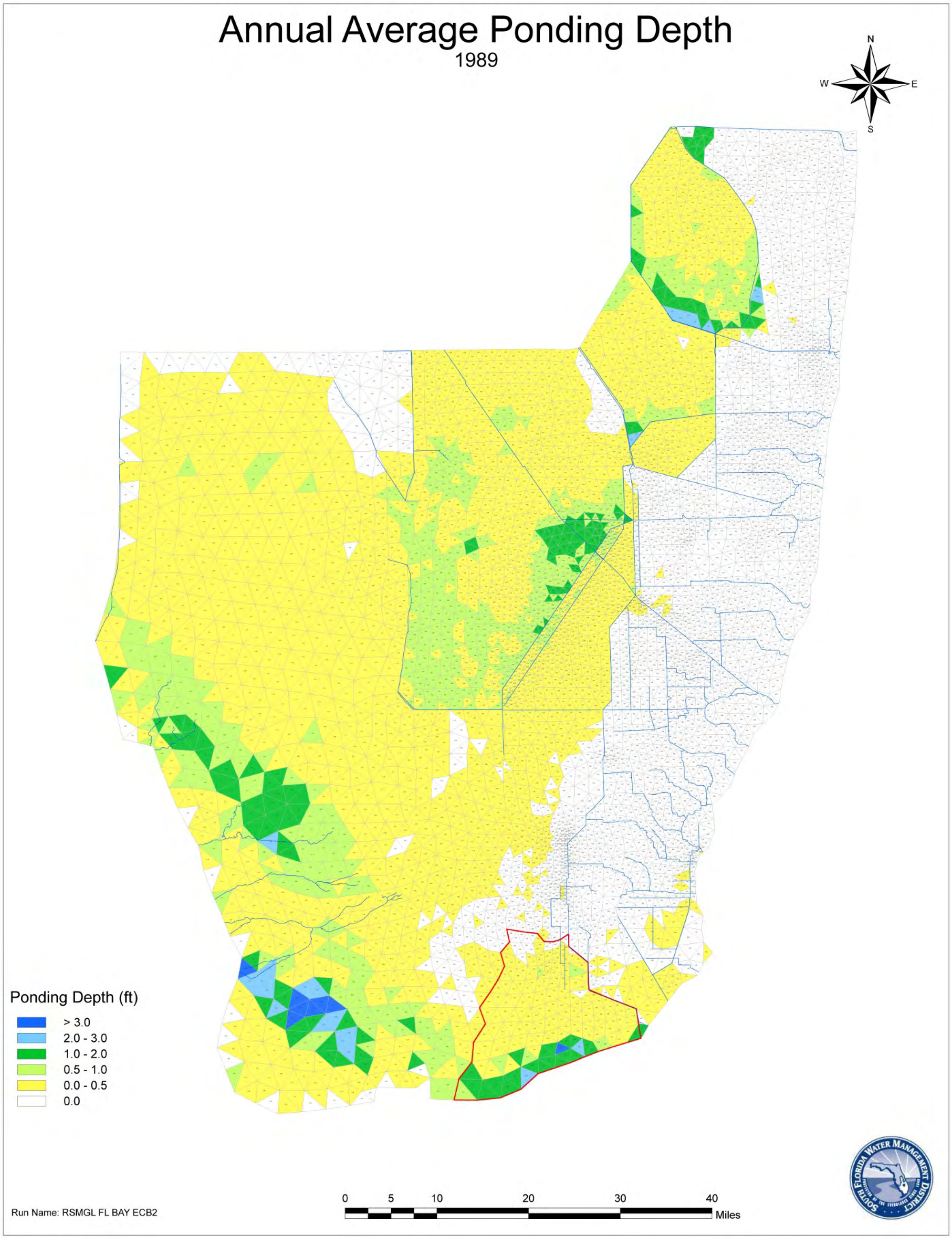


Figure A-13B-2: Dry Year (1989) Average Ponding Depths for ECB2

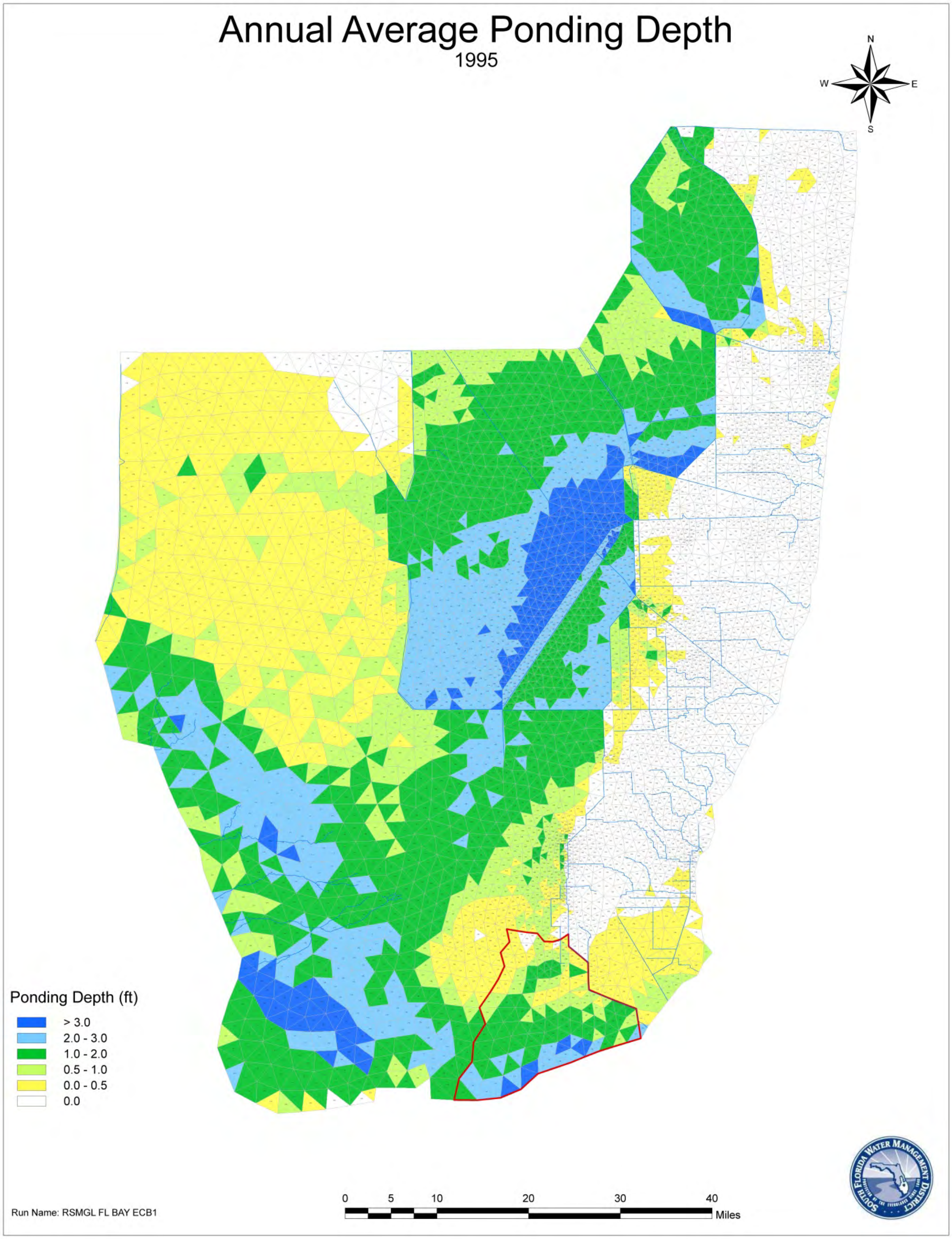


Figure A-13C-1: Wet Year (1995) Average Ponding Depths for ECB1

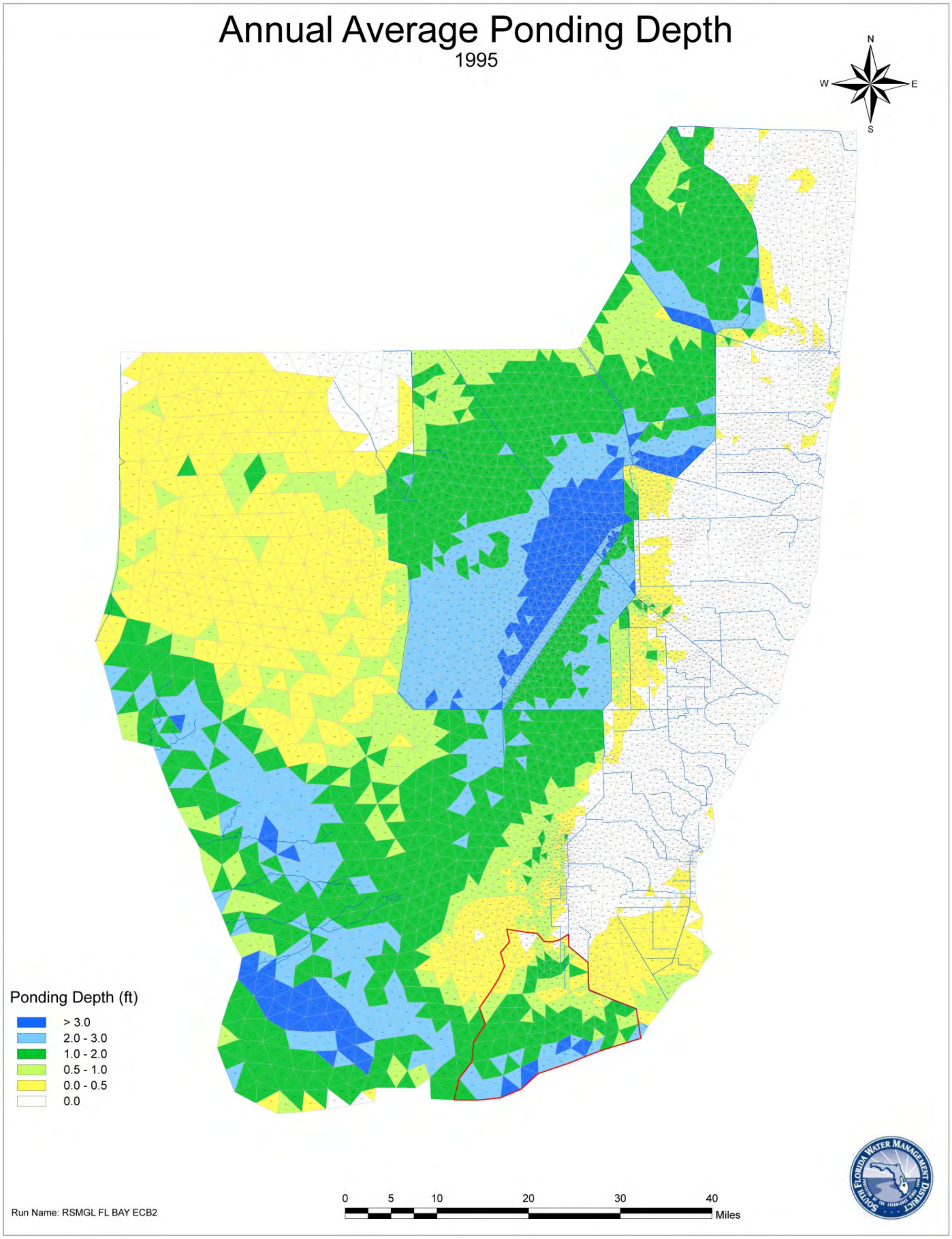


Figure A-13C-2: Wet Year (1995) Average Ponding Depths for ECB2

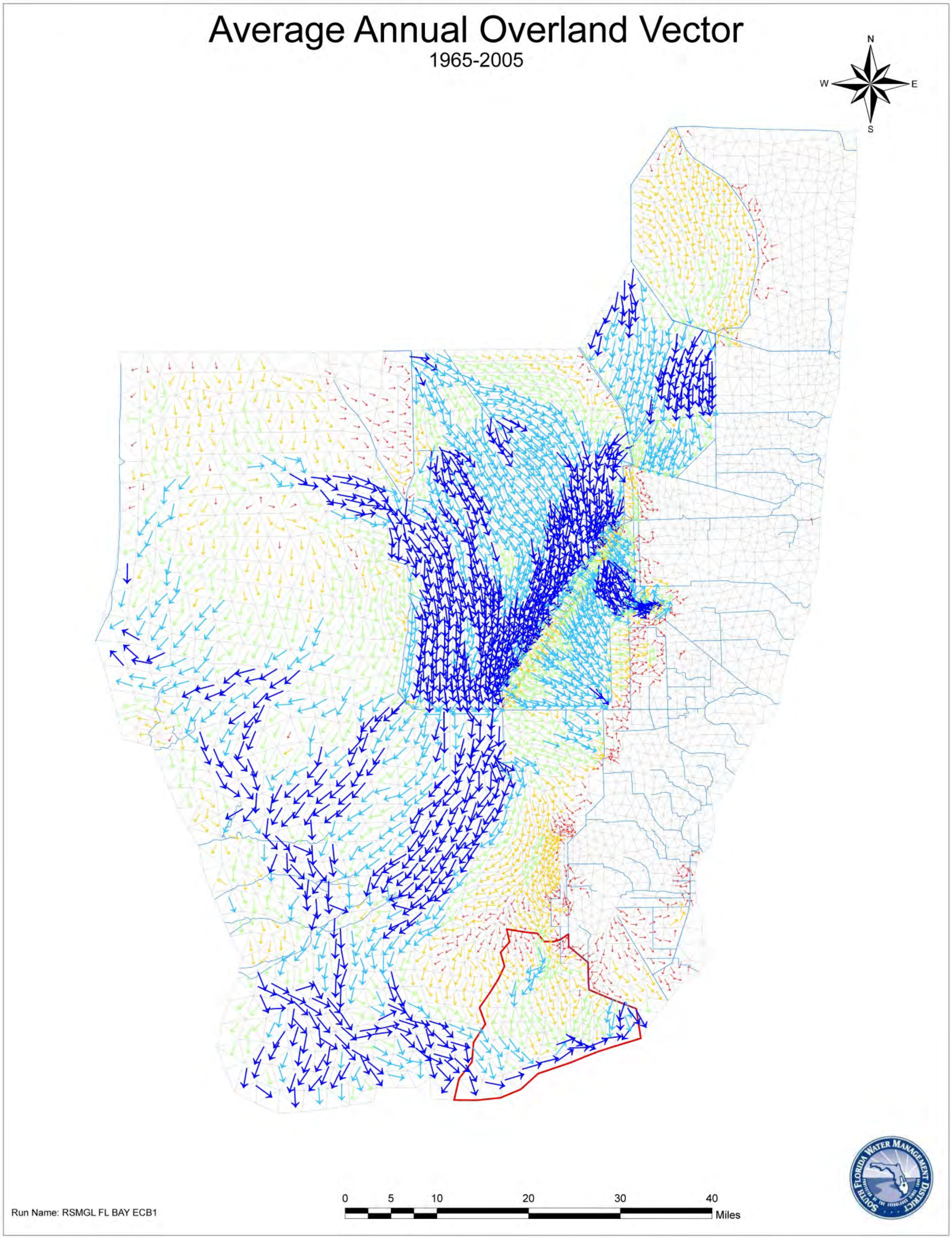


Figure A-14A-1: 41-Year Annual Average Overland Vectors for ECB1

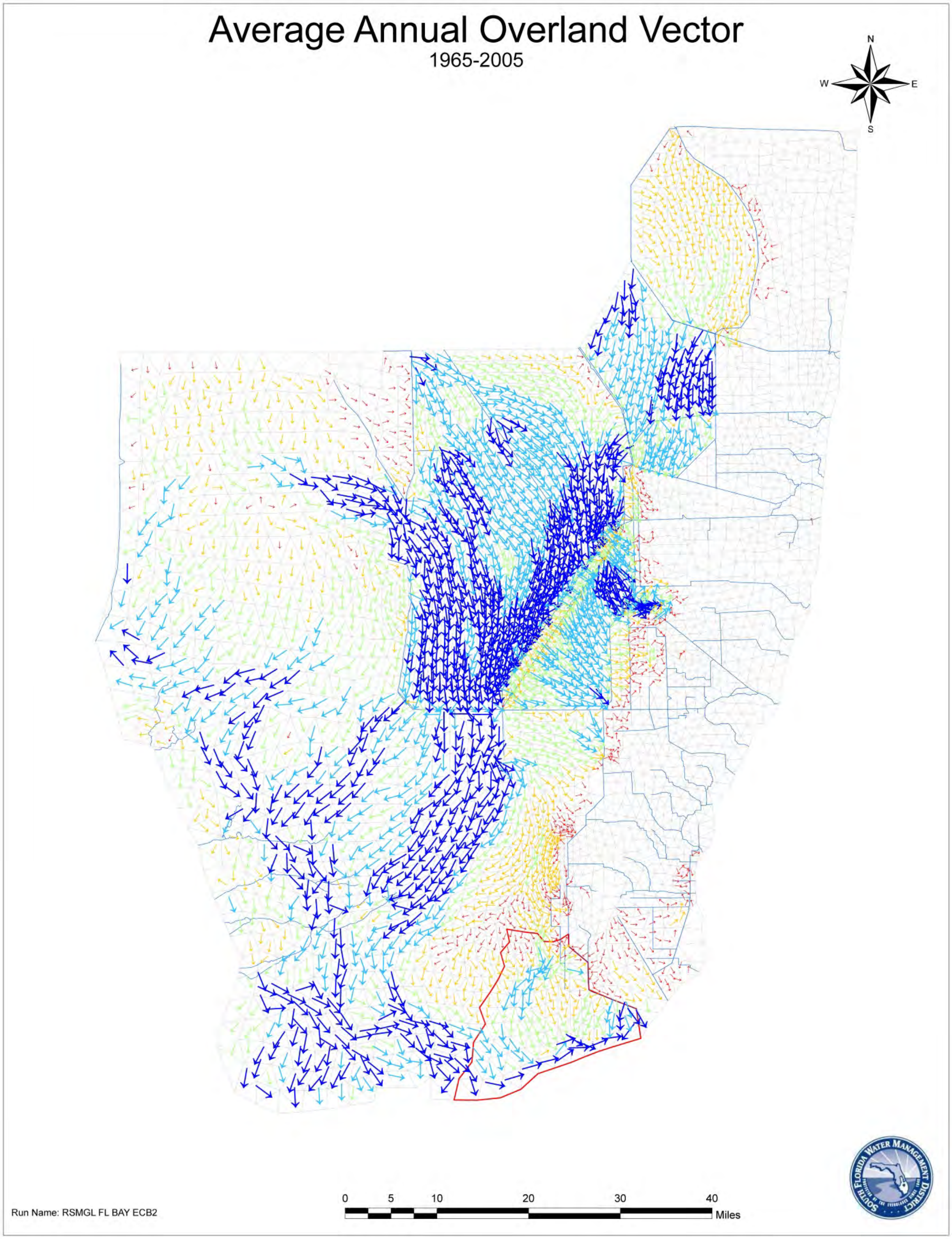


Figure A-14A-2: 41-Year Annual Average Overland Vectors for ECB2

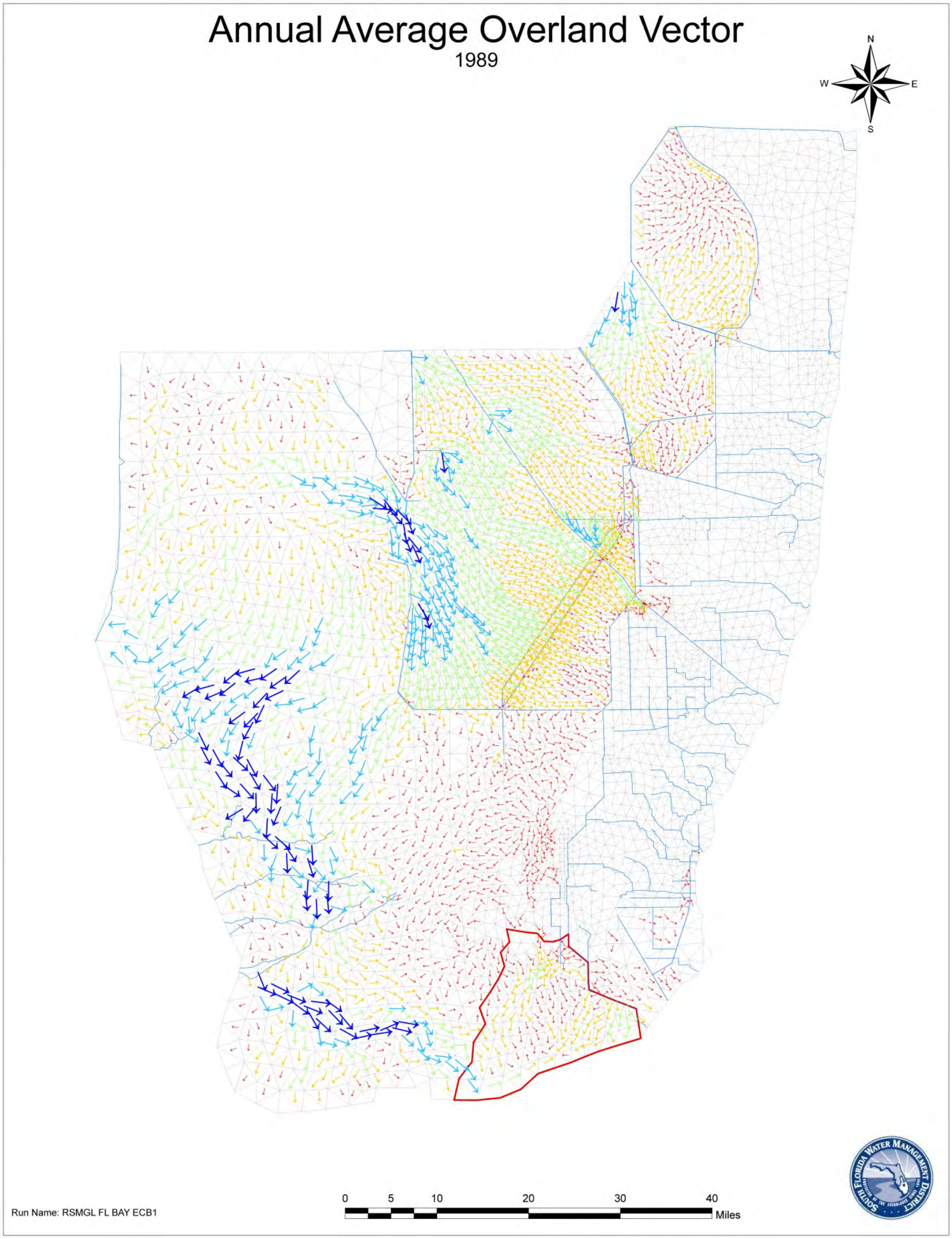


Figure A-14B-1: Dry Year (1989) Overland Vectors for ECB1

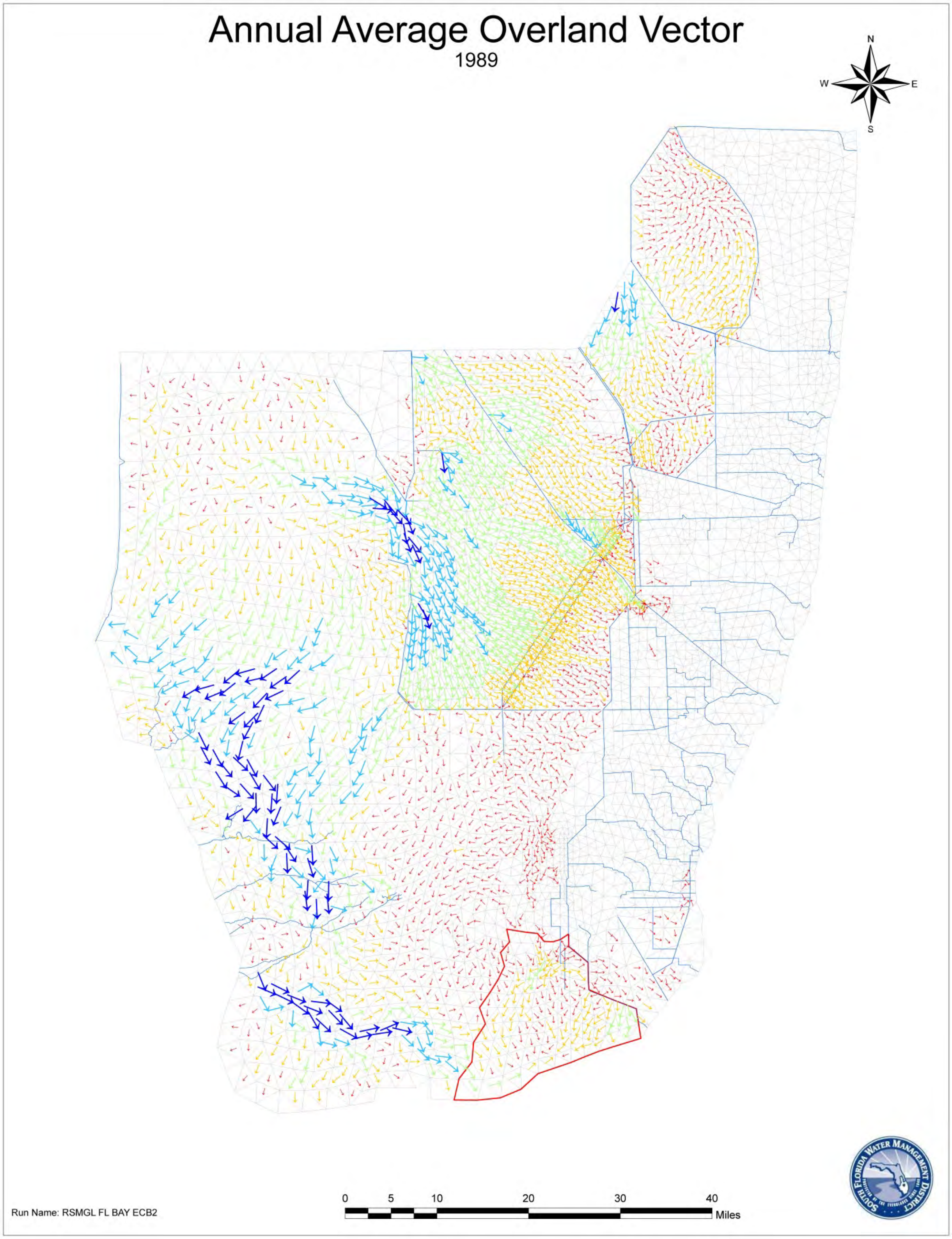


Figure A-14B-2: Dry Year (1989) Overland Vectors for ECB2

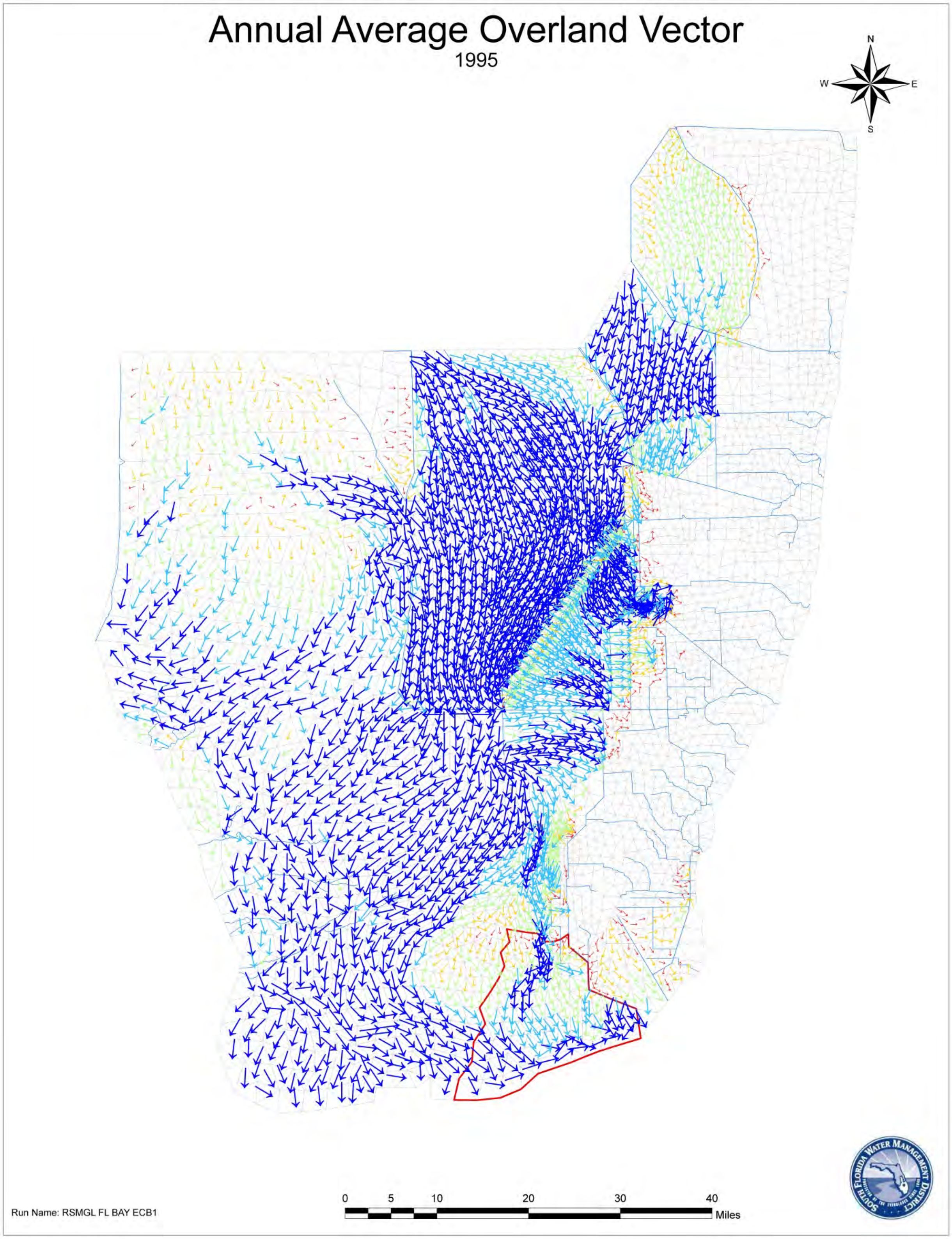


Figure A-14C-1: Wet Year (1995) Overland Vectors for ECB1

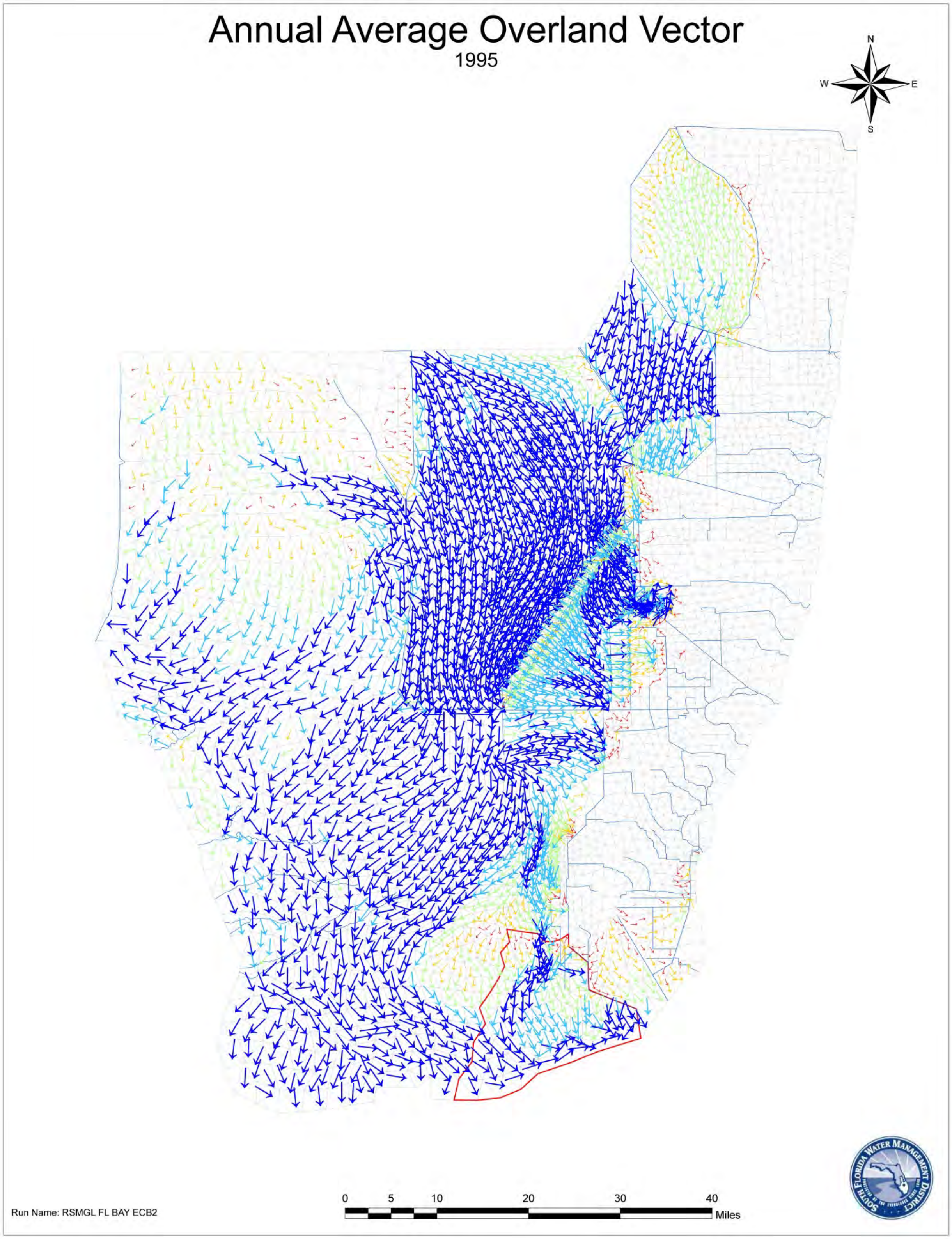


Figure A-14C-2: Wet Year (1995) Overland Vectors for ECB2

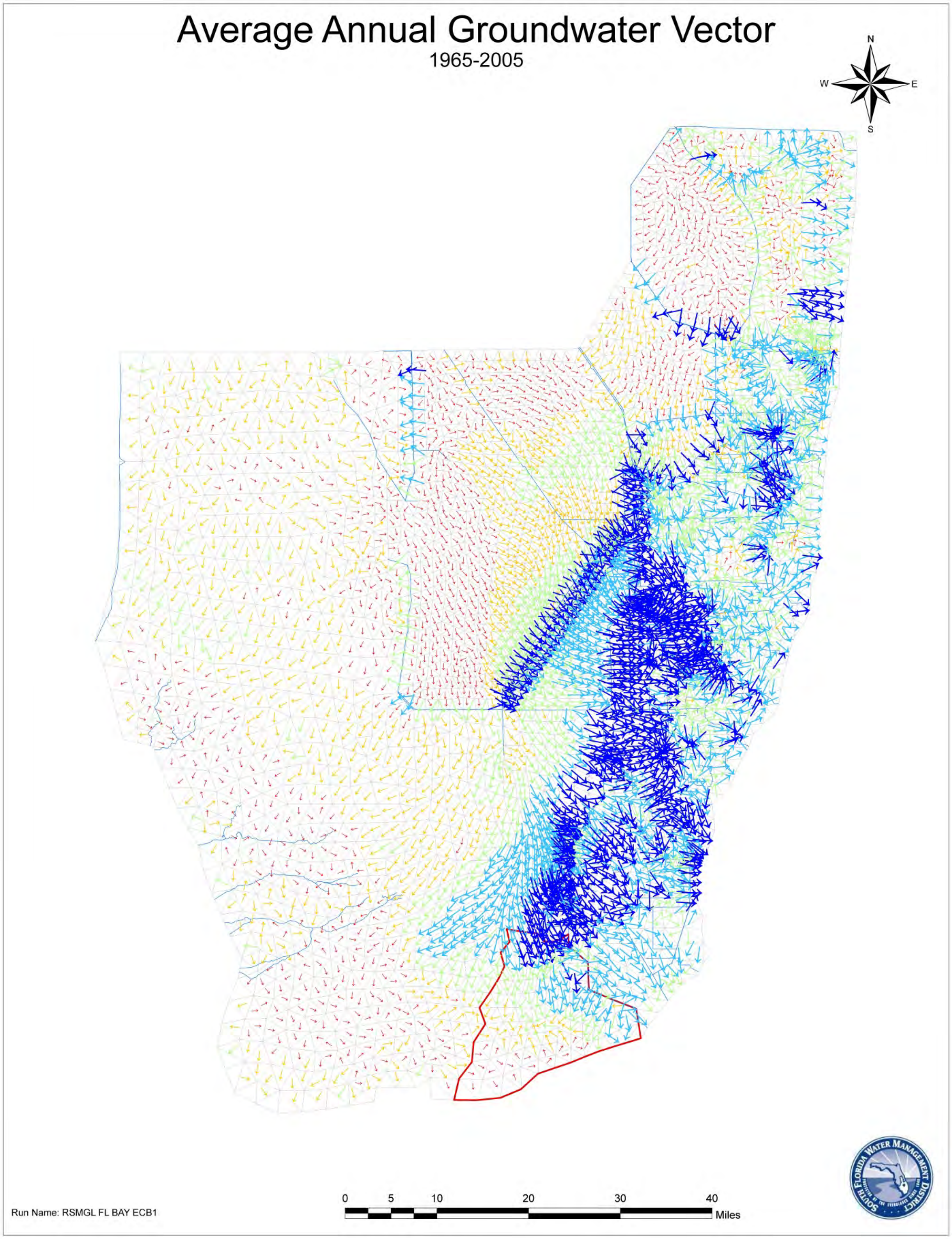


Figure A-15A-1: 41-Year Annual Average Ground Water Vectors for ECB1

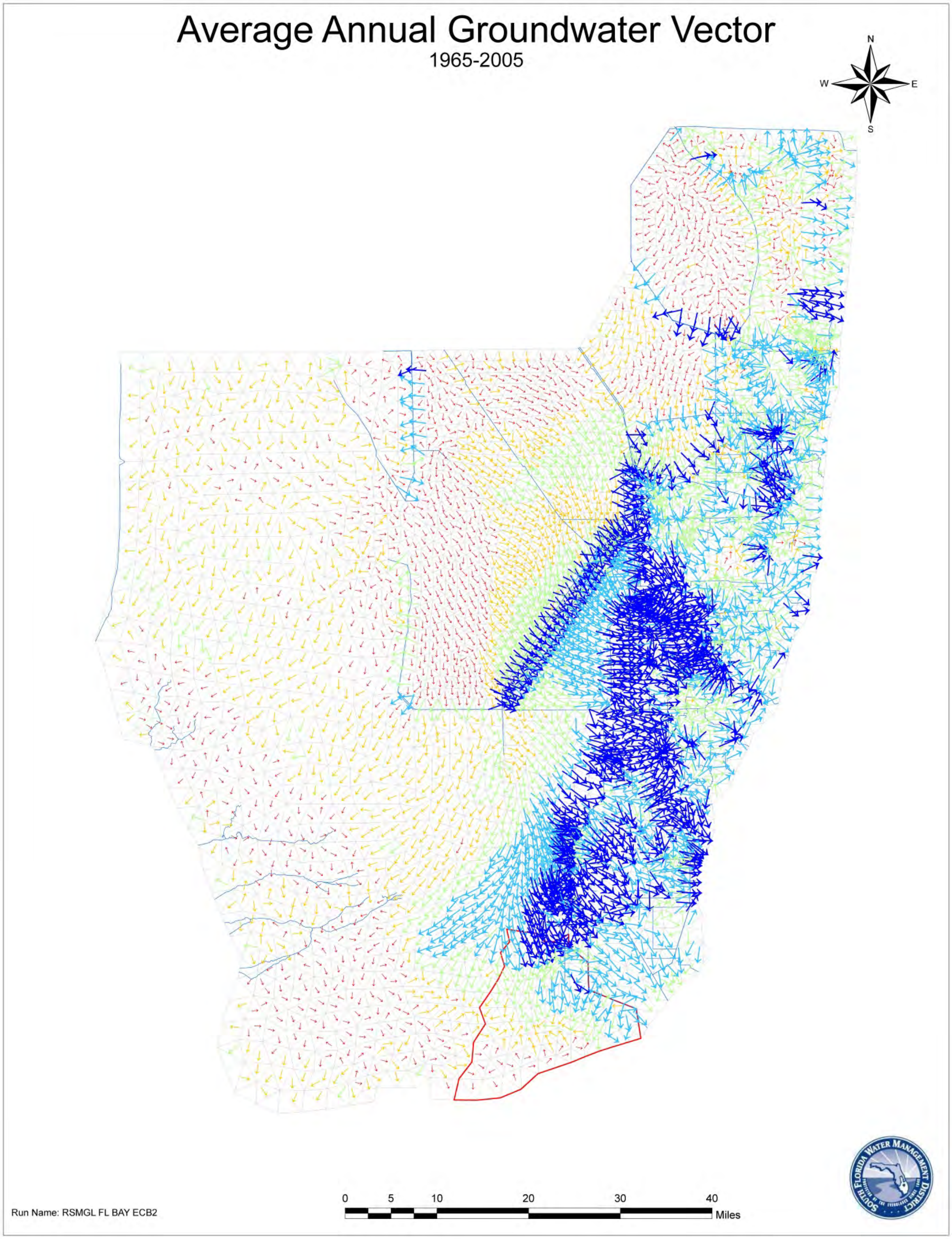


Figure A-15A-2: 41-Year Annual Average Ground Water Vectors for ECB2

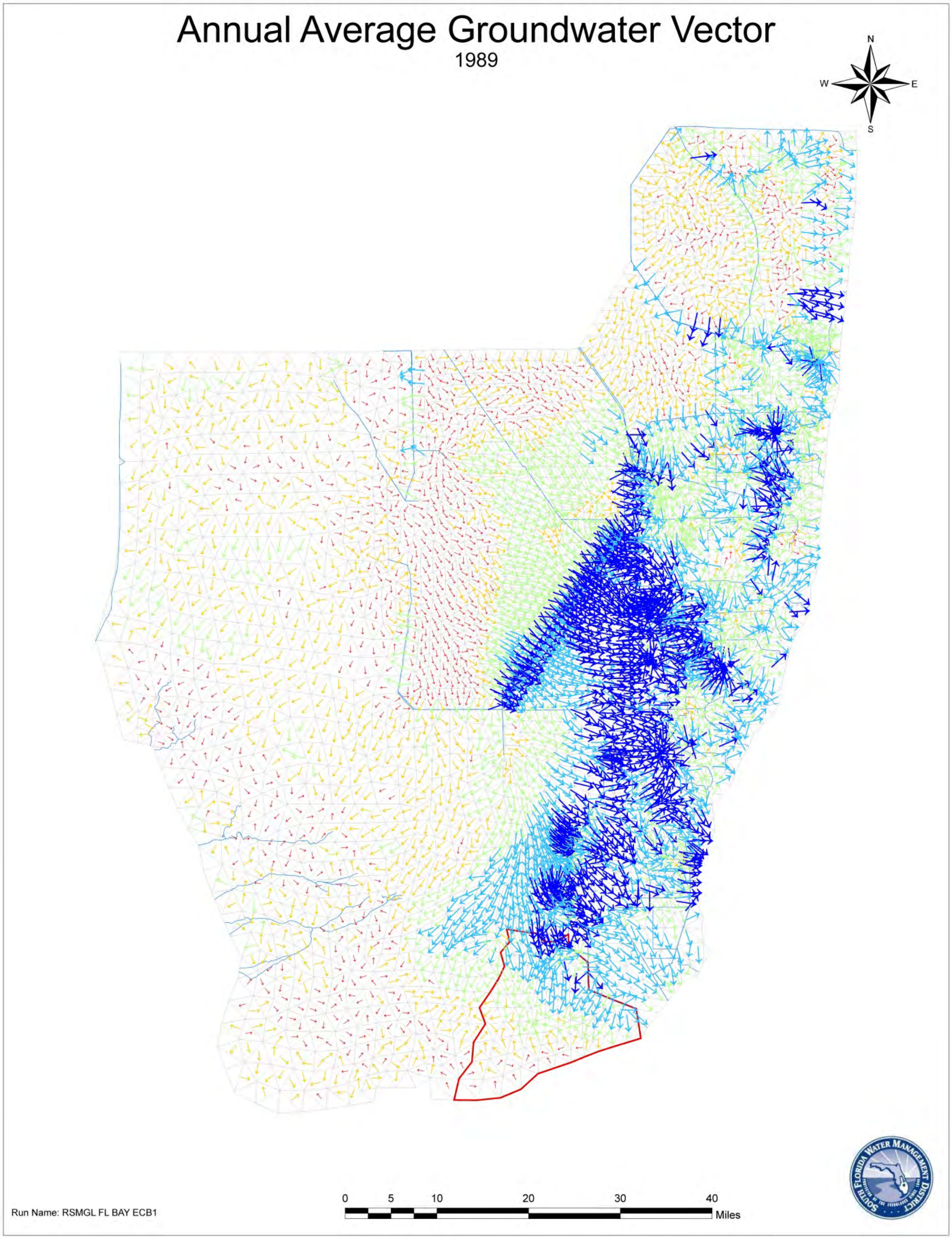


Figure A-15B-1: Dry Year (1989) Ground Water Vectors for ECB1

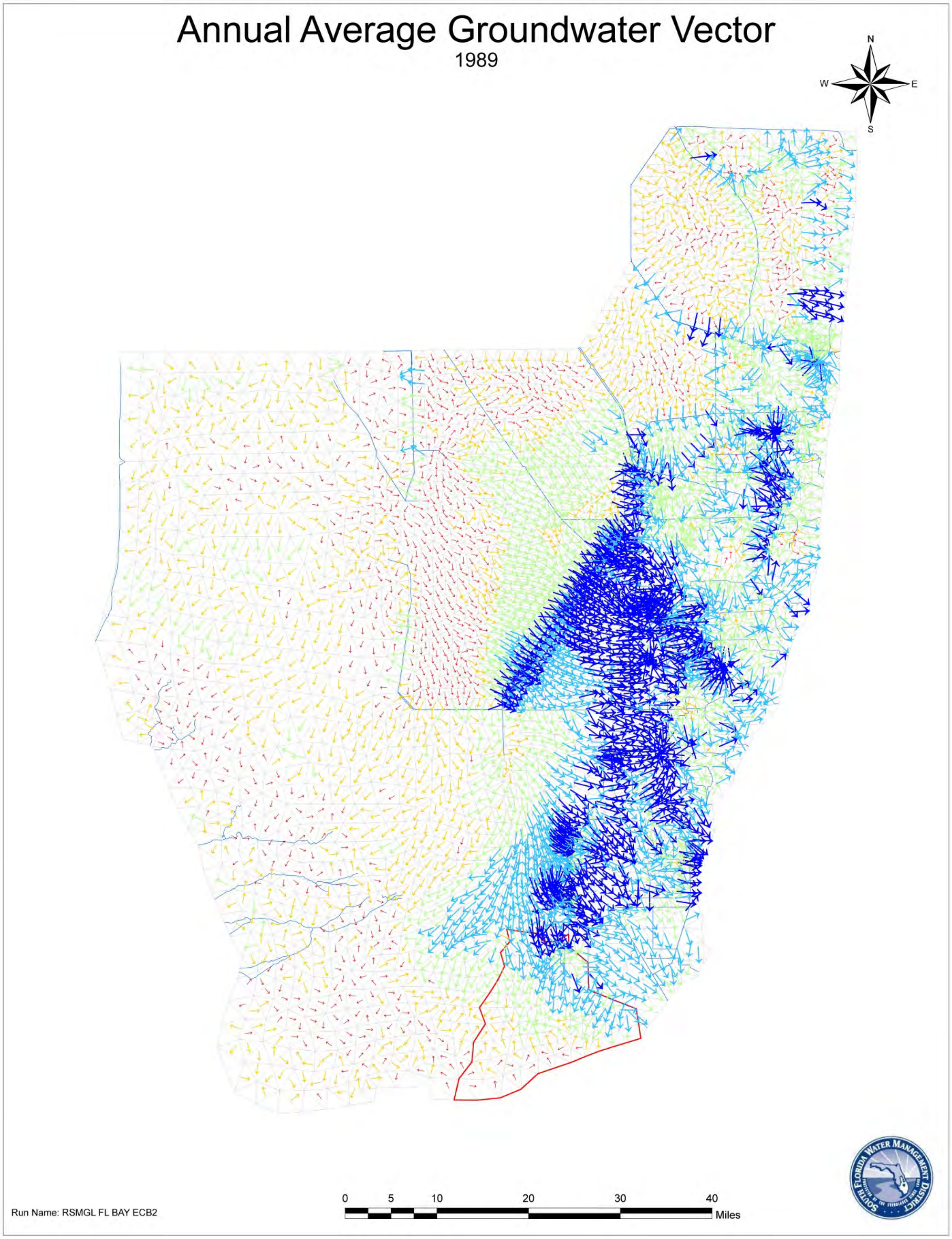


Figure A-15B-2: Dry Year (1989) Ground Water Vectors for ECB2

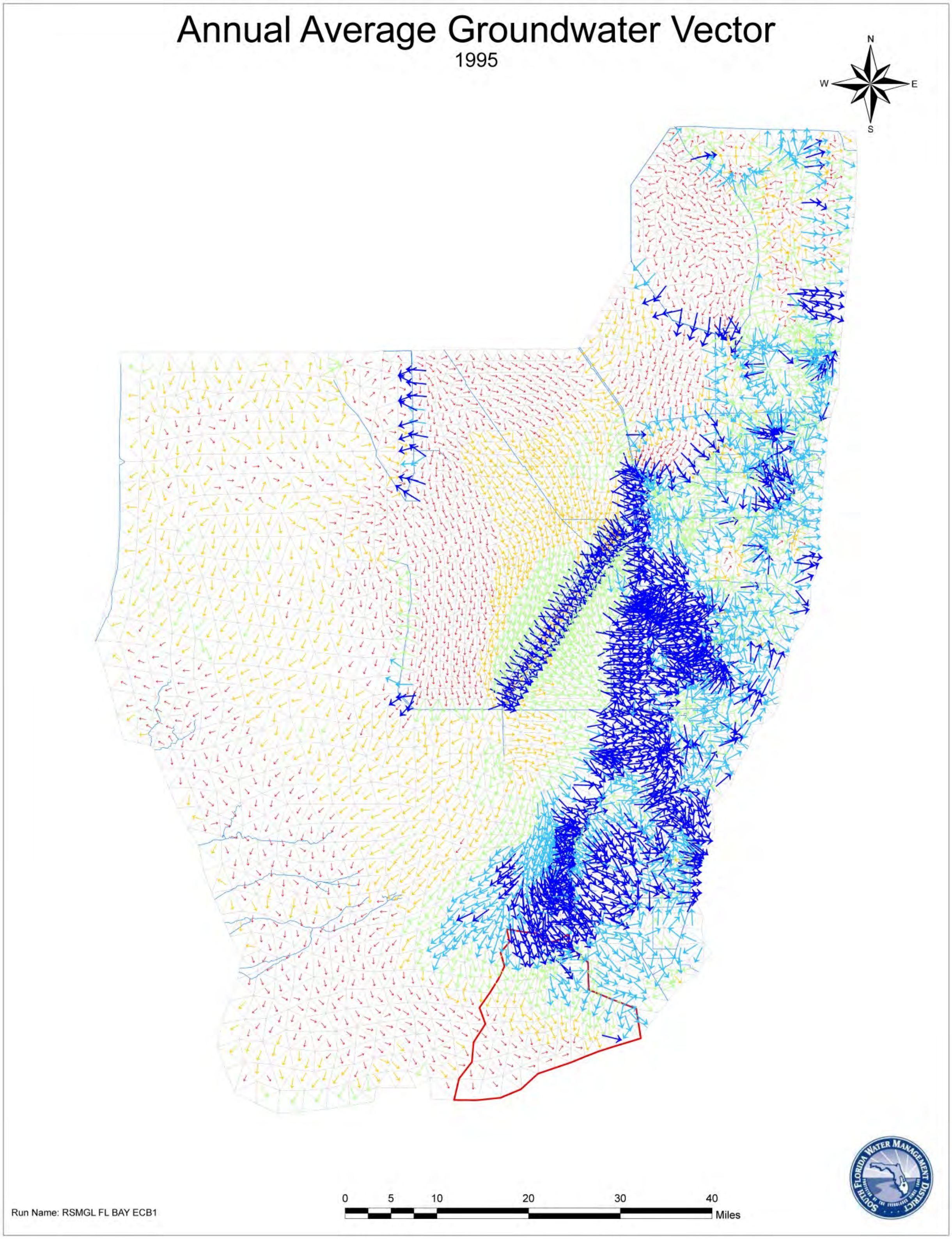


Figure A-15C-1: Wet Year (1995) Ground Water Vectors for ECB1

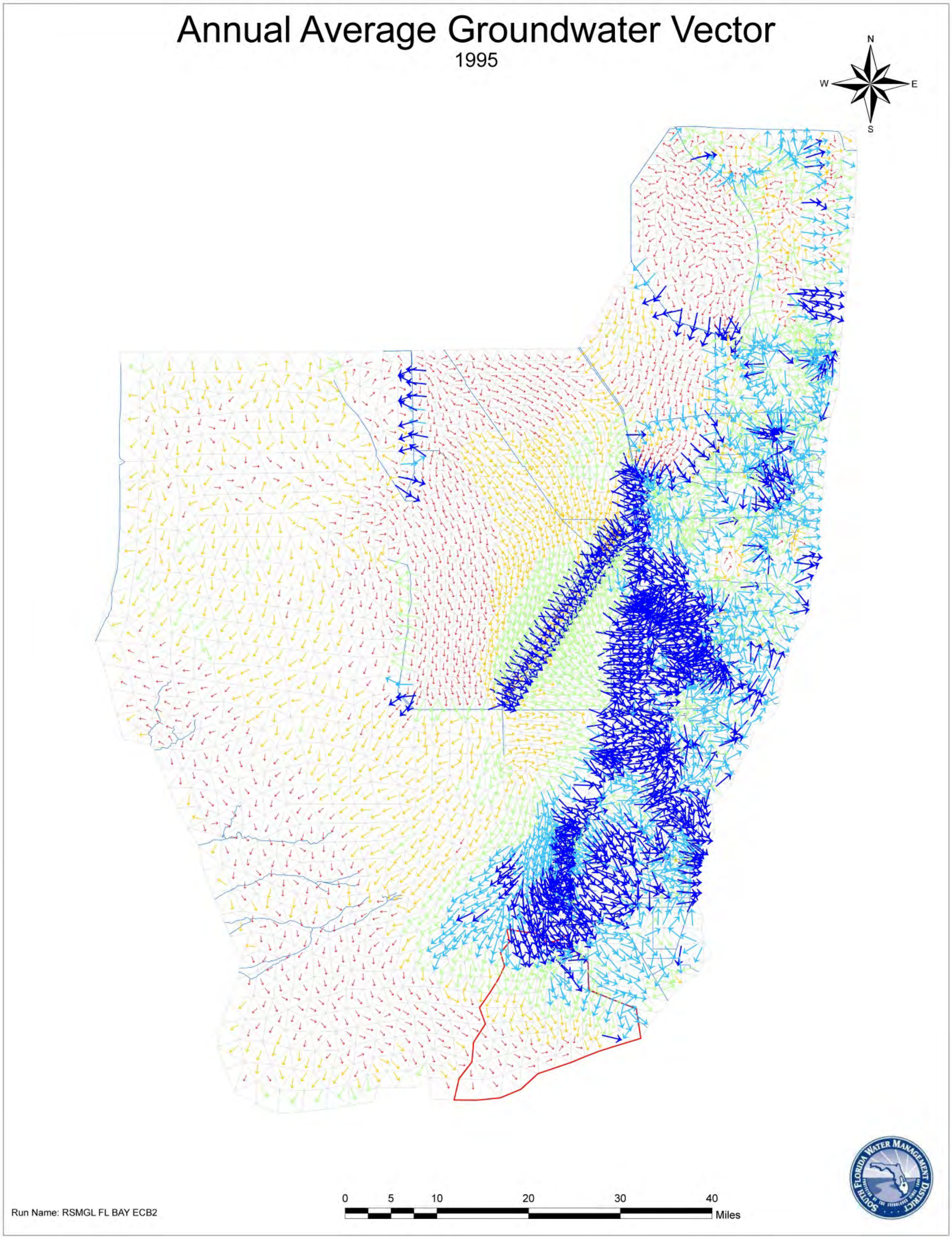


Figure A-15C-2: Wet Year (1995) Ground Water Vectors for ECB2

Transects

Figure A-7A shows a map with location of all overland flow transects in RSMGL. Transects T17, T18, T-21, T22 and T27 are located south of Tamiami Trail within ENP. Flows through these transects show the difference in regional scale due to implementation of ERTP and Tamiami Trail One-Mile Bridge.

Transect 17 (Figure A-16A): Southward flows south of Tamiami Trail and west of L-67 extension increased in ECB2 compared to ECB1 as a consequence of ERTP.

Transect 18 (Figure A-16B): The existence of the Tamiami Trail One-Mile Bridge increased southward flows slightly south of Tamiami Trail in wet season and east of L-67 extension increased in ECB2 compared to ECB1, but dry season flows are slightly less. Since L-29 maximum stage is not increased from 7.5 to 8.5 feet, desired objective to increase more southern flows was not met.

Transect 21, Transect 22 and Transect 27 (Figures A-16C through A-16E): Westward flows in western and northwestern Shark River Slough increased in ECB2 compared to ERTP since flows across T17 increased due to change in WCA 3A schedule from IOP to ERTP. Southwestward flows in central Shark River Slough shows a similar trend.

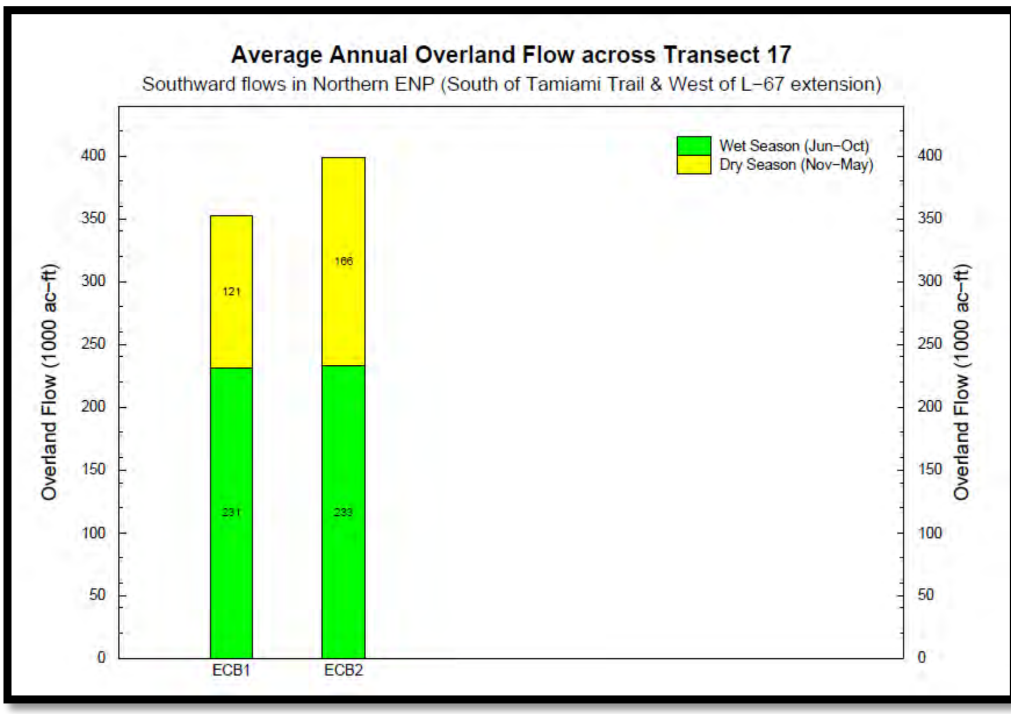


Figure A-16A: Overland Transect Flows across T17

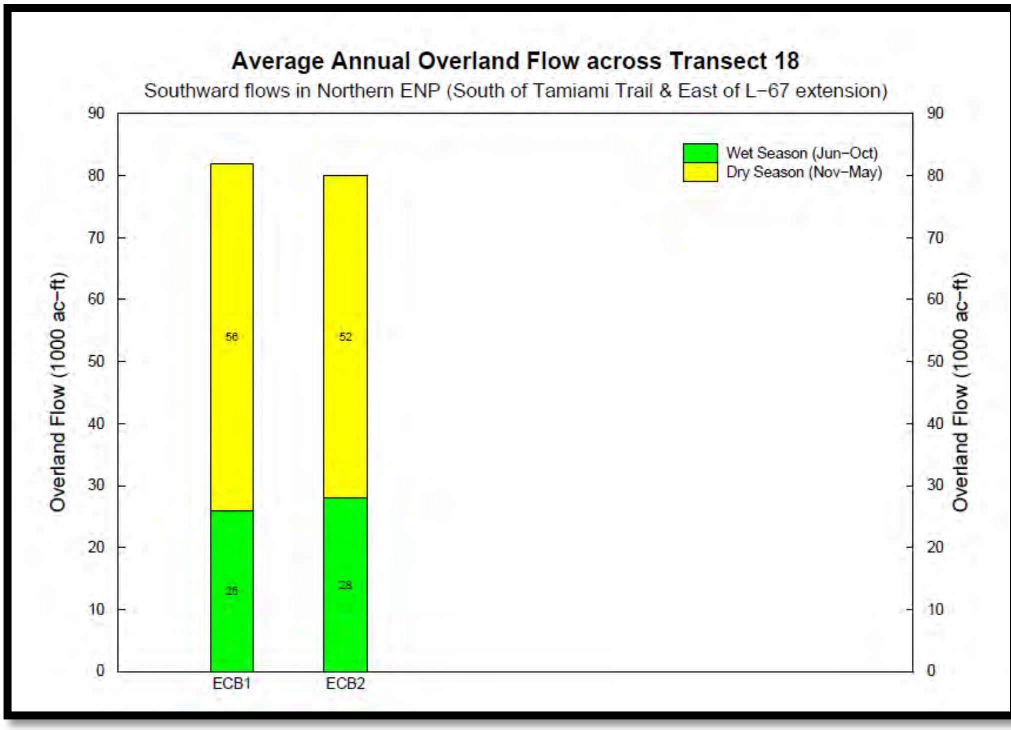


Figure A-16B: Overland Transect Flows across T18

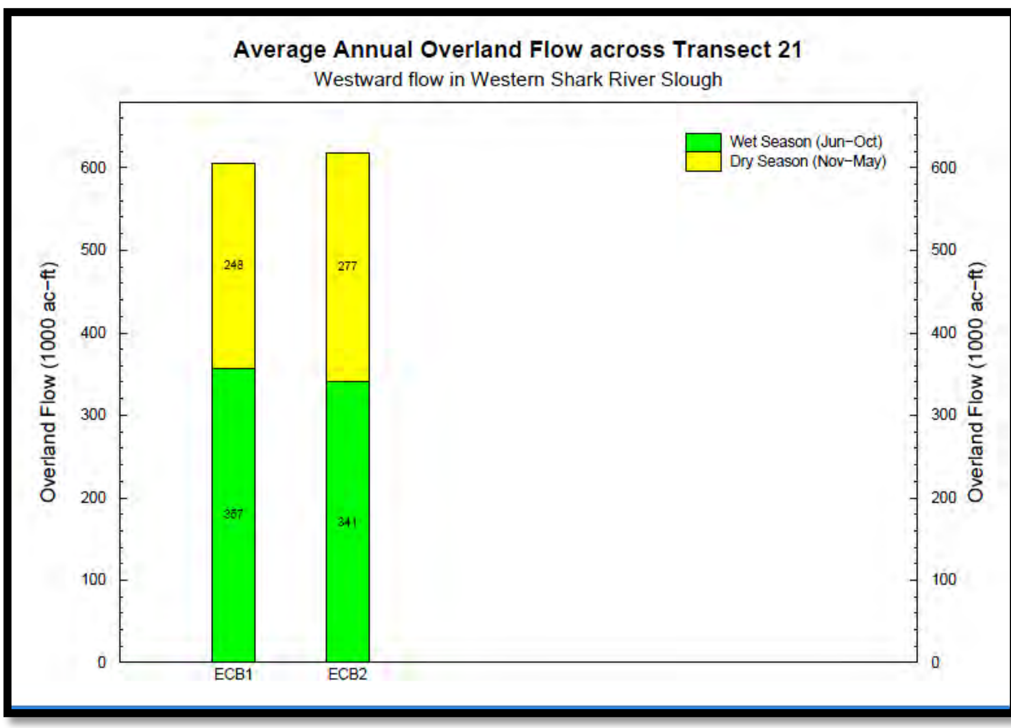


Figure A-16C: Overland Transect Flows across T21

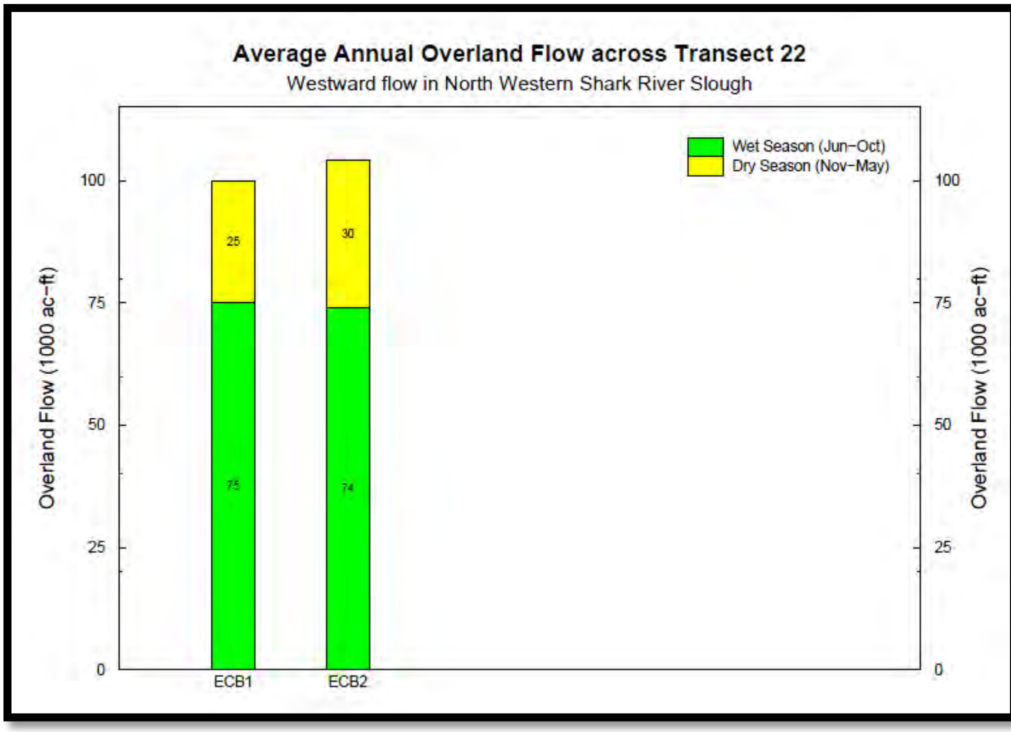


Figure A-16D: Overland Transect Flows across T22

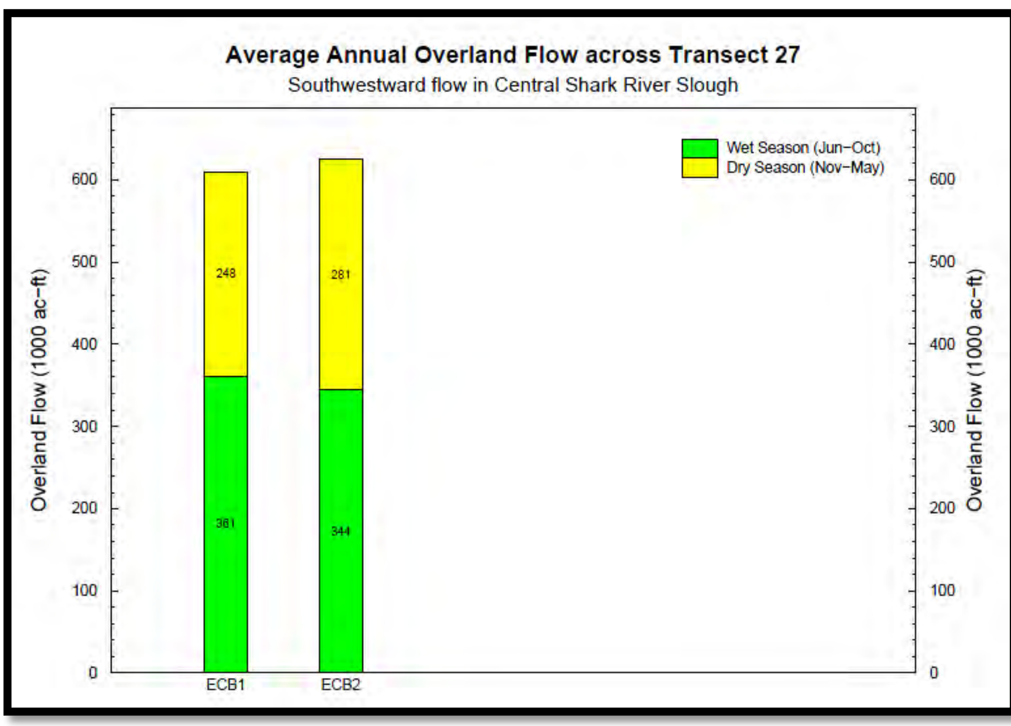


Figure A-16E: Overland Transect Flows across T27

5.0 Conclusions

Florida Bay MFL Update Project is using RSMGL model to evaluate the effect (in terms of flow) of three projects (Tamiami Trail One-Mile Bridge Project, ERTP and C-111 Spreader Canal Western Project) within Florida Bay Drainage Basin Area. Among these three projects, C-111 Spreader Canal Western Project and ERTP show increase in flows in the Florida Bay drainage basin. Flows toward Taylor Slough increased by 13.6% and toward eastern panhandle decreased by 3%. As a result, the combined flows toward Taylor Slough and eastern panhandle show a net increase of 1.7%. Due to the implementation of ERTP, the increased design capacity of S-332D pump during CSSS breeding season causing diversion in flows from the L-31N canal to the headwaters of Taylor Slough. In addition, due to the implementation of the C-111 Spreader Canal Western Project, the diversion of flows from the C-111 canal to ENP produces a hydraulic ridge at the headwater of the Taylor Slough causing increased overland flows in Taylor Slough and reduced overland flows in the ENP eastern panhandle. Eventually, tidal outflow from Florida Bay drainage basin area to Florida Bay increased slightly (by 2.1 kac-ft or 0.41%) in ECB2 compared to ECB1.

Tamiami Trail One-Mile Bridge is located further north of the Florida Bay drainage basin and consequently no significant change in flow pattern was observed. Tamiami Trail One-Mile Bridge likely increased peak flows toward the south in the wet season, but did not increase the total average annual flows since L-29 maximum canal stage is not raised to allow more S-333 flows into L-29 and through the bridge.

6.0 References

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Lake Worth Drainage District, Palm Beach County, Broward County and South Florida Water Management District (February, 2013) C-51 Reservoir –Preliminary Design and Cost Estimate – Final Report, South Florida Water Management District, West Palm Beach, FL.

South Florida Water Management District (October, 2013) 2013 Lower East Coast Water Supply Plan Update, South Florida Water Management District, West Palm Beach, FL.

South Florida Water Management District (November, 2011) Expedited C-111 Spreader Canal Western Project, Preliminary Project Operating Manual http://dcluster2/viewvc/svnroot/trunk/CentEver/rsmgl/doc/FWO/C-111-SC/C-111SC_Final_Preliminary_Project_Operating_Manual_11_8_11.docx?view=log

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VanZee, R. (February, 2013) Implementation of the Regional Simulation Model for the Central Everglades Project, Documentation and User Manual, South Florida Water Management District, West Palm Beach, FL.
http://dcluster2/viewvc/svnroot/trunk/rsm_imp/rsmbn/docs/usersGuide_RSMBN.pdf?revision=9053&view=co

Attachment A

Table of Assumptions for ECB1

Feature	Details
Meteorological Data	• Rainfall file used: rain_v3.0_beta_tin_14_05.bin. • Reference evapotranspiration file used: RET_48_05_MULTIQUAD_v1.0.bin (ARCADIS, 2008).
Topography	• Same as calibration topographic data set except where reservoirs are introduced (Stormwater Treatment Area [STA] 1 East [1E], C4 Impoundment and C-111 reservoirs). • United States Geological Survey High-Accuracy Elevation Data Collection for Water Conservation Areas (WCAs) 1, 2A, 2B, 3A, and 3B, Big Cypress National Preserve and ENP.
Tidal Data	• Tidal data from two primary (Naples and Virginia Key) and five secondary (Flamingo, Everglades, Palm Beach, Delray Beach and Hollywood Beach) National Oceanic and Atmospheric Administration stations were used to generate a historic record to be used as sea level boundary conditions for the entire simulation period.
Land Use and Land Cover	• Land use and land cover classification for the LEC urban areas (east of the LEC Flood Protection Levee) use 2008–2009 land use coverage as prepared by SFWMD. Consumptive use permits as of 2011 were used to update the land use in areas where it did not reflect the permit information. • Land use and land cover classification for the natural areas (west of the LEC Flood Protection Levee) is the same as the calibration land use and land cover classification for that area. • Modified at locations where reservoirs are introduced (STA1-E, C4 Impoundment, Lakebelt lakes and C-111 reservoirs).
Water Control Districts	• Water control districts in Palm Beach and Broward counties and in the Western Basins assumed.
Lake Belt Lakes	• Based on 2005 Lake Belt lake coverage obtained from the United States Army Corps of Engineers (USACE).
Water Conservation Areas 2A & 2B	• Current C&SF Project regulation schedule including regulatory releases to tide through LEC canals. • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control), if water levels in WCA 2A are less than minimum operating criteria of 10.5 feet. Any water supply releases below the floor will be matched by an equivalent volume of inflow.

Feature	Details
Water Conservation Areas 3A & 3B	• Current C&SF Project regulation schedule for WCA 3A, as per Water Control Plan – IOP for protection of the CSSS – C&SF Project for Flood Control and Other Purposes (USACE, December 2006). • Includes regulatory releases to tide through LEC canals. Documented in the Water Control Plan (USACE, December 2006). • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control), if water levels are less than minimum operating criteria of 7.5 feet in WCA 3A. Any water supply releases below the floor will be matched by an equivalent volume of inflow.
Everglades Construction Project Stormwater Treatment Areas	• STA 1E: 5,132 acres total treatment area. • A uniform bottom elevation equal to the spatial average over the extent of STA 1E is assumed.
Everglades National Park	• Water deliveries to ENP are based upon IOP. • L-29 stage constraint for operation of S-333 assumed to be 7.5 feet NGVD. • G-3273 constraint for operation of S-333 assumed to be 6.8 feet NGVD. • Tamiami Trail culverts east of the L-67 Extension are simulated. • 5.5 miles remain of the L-67 Extension Levee. • S-355A and S-355B are operated. • S-356 is not operated. • Partial construction of C-111 project reservoirs consistent with the 2009 as-built information from USACE (does not include contract 8 or contract 9). A uniform bottom elevation equal to the spatial average over the extent of each reservoir is assumed. • S-332, S-332DX1, and S-175 are not operated. • 8.5 Square Mile Area project feature as per federally authorized Alternative 6D of the Modwaters/8.5 Square Meter Area Project (USACE, 2000 GRR). Operations per 2011 IOP criteria (USACE, June 2011) including S-331 trigger shifted from Angel's Well to Las Palmas Groundwater Gage-2. Special operations for S-357 (S-357 operation based on S-357 headwater and Las Palmas Canal Gage-1 stage) per 2011 IOP criteria (USACE, June 2011) is too detail to capture in current resolution of RSMGL. Under normal conditions, it is intended to limit the pumping capacity of S-357 to 250 ac-ft per day (126 cfs) although the design capacity is 575 cfs. So, design capacity of S-357 is limited to 126 cfs in RSMGL to assume normal condition operations.
Other Natural Areas	• Flows to Biscayne Bay are simulated through Snake Creek, North Bay, Miami River, Central Bay and South Bay.

Feature	Details
Pumpage and Irrigation	• PWS pumpage for the LEC was updated using 2010 consumptive use permit information as documented in the C-51 Reservoir Feasibility Study (Lake Worth Drainage District et al., February 2013). Permits under 0.1 MGD were not included. • Residential self -supported pumpage are based on 2030 projections from the SFWMD Water Supply Bureau. • Industrial pumpage are based on 2030 projections from the SFWMD Water Supply Bureau. • Irrigation demands for the six irrigation land use types are calculated internally by the model. • Seminole Hollywood Reservation demands are set forth under VI. C of the Tribal Rights Compact, which is available at (*www.semtribe.com/services/water/compact.doc*). Tribal sources of water supply include various bulk sale agreements with municipal service suppliers.

Canal Operations	• C&SF Project system and operating rules in effect in 2010.
	• Includes operations to meet control elevations in the primary coastal canals for the prevention of saltwater intrusion.
	• Includes existing secondary drainage/water supply system.
	• C-4 Flood Mitigation Project.
	• Western C-4, S-380 structure retained open.
	• C-11 Water Quality Treatment Critical Project (S-381 and S-9A).
	  o S-9/S-9A operations modified for performance consistency with SFWMM ECB.
	• S-25B and S-26 pumps are not modeled since they are used very rarely during high tide conditions and the model uses a long-term average daily tidal boundary.
	• Northwest Dade Lake Belt area assumes that the conditions caused by currently permitted mining exist and that the effects of any future mining are fully mitigated by industry.
	• ACME Basin A flood control discharges are sent to C-51, west of the S-155A structure, to be pumped into STA 1E. ACME Basin B flood control discharges are sent to STA 1E through the S-319 structure.
	• Releases from WCA 3A to ENP and the South Dade Conveyance System (SDCS) will follow IOP:
	  o Structures S-343A, S-343B, S-344 and S-12A are closed November 1 to July 15.
	  o Structure S-12B is closed January 1 to July 15.
	  o Structure S-12C is closed February 1 to July 15.
	  o Structure S-12D is operated throughout the year. Only structure S-12D is operated between February 1 and July 15 to meet the total flow target.
	• SDCS operations will follow IOP for protection of CSSS.

Canal Configuration	• Canal configuration same as calibration except only 5.5 miles remain of the L-67 Extension Canal.

Feature	Details
Lower East Coast Service Area Water Shortage Management	• LEC water restriction zones and trigger cell locations are equivalent to SFWMM ECB implementation. An attempt was made to tie trigger cells with associated groundwater level gages to the extent possible. The Lower East Coast Subregional (LECsR) model is the source of this data. • Periods where the LEC is under water restriction due to low Lake Okeechobee stages were extracted from the corresponding RSMBN ECB simulation.

References

ARCADIS (2008) Generation of the Expanded Coverage Reference Evapotranspiration Dataset for Hydrologic Modeling.

United States Army Corps of Engineers (June, 2011) Review Plan for Interim Operating Criteria for 8.5 Square Mile Area Project and Environmental Assessment. United States Army Corps of Engineers, Jacksonville, FL.

United States Army Corps of Engineers (December, 2006) Final Supplemental Environmental Impact Statement, Interim Operational Plan (IOP) for Protection of the Cape Sable Seaside Sparrow. United State Army Corps of Engineers, Jacksonville, FL.

United States Army Corps of Engineers (2000) Final General Reevaluation Report, 8.5 Square Mile Area. United States Army Corps of Engineers, Jacksonville, FL.

Lake Worth Drainage District, Palm Beach County, Broward County and South Florida Water Management District (February, 2013) C-51 Reservoir –Preliminary Design and Cost Estimate – Final Report. South Florida Water Management District, West Palm Beach, FL.

Water Rights Compact (Private) Among the Seminole Tribe of Florida, the State of Florida and the South Florida Water Management District. Available at *www.sem**tribe**.com/ser**vic**es/water/**compact**.doc.*

Attachment B

Table of Assumptions for ECB2

Feature	Details
Meteorological Data	• Rainfall file used: rain_v3.0_beta_tin_14_05.bin. • Reference evapotranspiration file used: RET_48_05_MULTIQUAD_v1.0.bin (ARCADIS, 2008).
Topography	• Same as calibration topographic data set except where reservoirs are introduced (Stormwater Treatment Area [STA] 1East [1E], C4 Impoundment and C-111 reservoirs). • United States Geological Survey High-Accuracy Elevation Data Collection for the Water Conservation Areas (WCAs) 1, 2A, 2B, 3A, and 3B, the Big Cypress National Preserve and ENP.
Tidal Data	• Tidal data from two primary (Naples and Virginia Key) and five secondary (Flamingo, Everglades, Palm Beach, Delray Beach and Hollywood Beach) National Oceanic and Atmospheric Administration stations were used to generate a historic record to be used as sea level boundary conditions for the entire simulation period.
Land Use and Land Cover	• Land use and land cover classification for the LEC urban areas (east of the LEC Flood Protection Levee) use 2008–2009 land use coverage as prepared by SFWMD. Consumptive use permits as of 2011 were used to update the land use in areas where it did not reflect the permit information. • Land use and land cover classification for the natural areas (west of the LEC Flood Protection Levee) is the same as the calibration land use and land cover classification for that area. • Modified at locations where reservoirs are introduced (STA1-E, C4 Impoundment, Lakebelt lakes and C-111 reservoirs).
Water Control Districts	• Water control districts in Palm Beach and Broward counties and in the Western Basins assumed.
Lake Belt Lakes	• Based on 2005 Lake Belt Lake coverage obtained from United States Army Corps of Engineers (USACE).
Water Conservation Area 1 (Arthur R. Marshall Loxahatchee National Wildlife Refuge)	• Current C&SF Project regulation schedule including regulatory releases to tide through LEC canals. • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control), if water levels are less than minimum operating criteria of 14 feet. The bottom floor of the schedule (Zone C) is the area below 14 feet. Any water supply releases below the floor will be matched by an equivalent volume of inflow. • Structure S10E connecting WCA 1 to the northeastern portion of WCA 2A is no longer considered part of the simulated regional system.

Feature	Details
Water Conservation Areas 2A & 2B	• Current C&SF Project regulation schedule including regulatory releases to tide through LEC canals. • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control), if water levels in WCA 2A are less than minimum operating criteria of 10.5 feet. Any water supply releases below the floor will be matched by an equivalent volume of inflow.
Water Conservation Areas 3A & 3B	• ERTP regulation schedule for WCA 3A, as per SFWMM modeled alternative 9E1 (USACE, 2011). • Includes regulatory releases to tide through LEC canals. Documented in the Water Control Plan (USACE, December 2006) • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control) if water levels are less than minimum operating criteria of 7.5 feet in WCA 3A. Any water supply releases below the floor will be matched by an equivalent volume of inflow.
Everglades Construction Project Stormwater Treatment Areas	• STA 1E: 5,132 acres total treatment area. • A uniform bottom elevation equal to the spatial average over the extent of STA 1E is assumed.
Everglades National Park	• Water deliveries to ENP are based upon ERTP, with the WCA 3A regulation schedule including the lowered Zone A (compared to IOP) and extended Zones D and E1. • L-29 stage constraint for operation of S-333 assumed to be 7.5 feet NGVD. • G-3273 constraint for operation of S-333 assumed to be 6.8 feet NGVD. • The Tamiami Trail One-Mile Bridge as per the 2008 Tamiami Trail Limited Reevaluation Report (USACE, June 2008) is modeled as a one-mile weir. Located east of the L67 extension and west of the S-334 structure. • Tamiami Trail culverts east of the L-67 Extension are simulated where the bridge is not located. • 5.5 miles remain of the L-67 Extension Levee. • S-355A & S-355B are operated. • S-356 is not operated. • Partial construction of C-111 project reservoirs consistent with the 2009 as-built information from USACE (does not include contract 8 or contract 9). A uniform bottom elevation equal to the spatial average over the extent of each reservoir is assumed. • S-332, S-332DX1, S175 are not operated. • 8.5 Square Mile Area project feature as per federally authorized Alternative 6D of the Modwaters/8.5 Square Mile Area Project (USACE, 2000 GRR). Operations per 2011 IOP criteria (USACE, June 2011) including S-331 trigger shifted from Angel's Well to Las Palmas Groundwater Gage-2. Special operations for S-357 (S-357 operation based on S-357 headwater and Las Palmas Canal Gage 1

Feature	Details
	stage) per 2011 IOP criteria is too detail to capture in current resolution of RSMGL. Under normal conditions, it is intended to limit the pumping capacity of S-357 to 250 ac-ft per day (126 cfs) although the design capacity is 575 cfs. So, design capacity of S-357 is limited to 126 cfs in RSMGL to assume normal condition operations.
CERP Projects	• C-111 Spreader Canal Western Project includes the Frog Pond Detention Area, which is modeled as an above ground impoundment. • S-200A, B, and C are 3 pumps feeding Frog Pond Detention Area each with a capacity of 75 cfs. The pumps have a tailwater OFF trigger of 8.5 feet NGVD in the impoundment and a CSSS Population Site C remote OFF trigger of 10 centimeters above ground elevation for the period of March 15 to June 30. • S-199A, B, and C are 3 pumps feeding Aerojet Canal each with a capacity of 75 cfs. The pumps have a tailwater OFF trigger of 8.0 feet NGVD and a CSSS Population Site D remote OFF trigger of 10 centimeters above ground elevation for the period of March 15 to June 30.
Other Natural Areas	• Flows to Biscayne Bay are simulated through Snake Creek, North Bay, the Miami River, Central Bay and South Bay
Pumpage and Irrigation	• PWS pumpage for the LEC was updated using 2010 consumptive use permit information as documented in the C-51 Reservoir Feasibility Study (Lake Worth Drainage District et al., February 2013). Permits under 0.1 million gallons per day (MGD) were not included. • Residential self-supported pumpage are based on 2030 projections from the SFWMD Water Supply Bureau. • Industrial pumpage are based on 2030 projections from the SFWMD Water Supply Bureau. • Irrigation demands for the six irrigation land use types are calculated internally by the model. • Seminole Hollywood Reservation demands are set forth under VI. C of the Tribal Rights Compact , which is available at (*www.semtribe.com/services/water/compact.doc*). Tribal sources of water supply include various bulk sale agreements with municipal service suppliers.
Canal Operations	• C&SF Project system and operating rules in effect in 2012. • Includes operations to meet control elevations in the primary coastal canals for the prevention of saltwater intrusion. • Includes existing secondary drainage/water supply system. • C-4 Flood Mitigation Project. • Western C-4, S-380 structure retained open. • C-11 Water Quality Treatment Critical Project (S-381 and S-9A). o S-9/S-9A operations modified for performance consistency with SFWMM ECB.

Feature	Details
	• S-25B and S-26 pumps are not modeled since they are used very rarely during high tide conditions and the model uses a long-term average daily tidal boundary • Northwest Dade Lake Belt area assumes that the conditions caused by currently permitted mining exist and that the effects of any future mining are fully mitigated by industry. • ACME Basin A flood control discharges are sent to C-51, west of the S-155A structure, to be pumped into STA 1E. ACME Basin B flood control discharges are sent to STA 1E through the S-319 structure. • Releases from WCA 3A to ENP and the South Dade Conveyance System (SDCS) will follow the ERTP regulation schedule for WCA 3A, as per SFWMM modeled alternative 9E1: o Structures S-343A, S-343B, S-344 and S-12A are closed November 1 to July 15. o Structure S-12B is closed January 1 to July 15. o Both structures S-12C and S-12D are operated throughout the year. • SDCS operations will follow ERTP for protection of CSSS.
Canal Configuration	• Canal configuration same as calibration except only 5.5 miles remain of the L-67 Extension Canal.
Lower East Coast Service Area Water Shortage Management	• LEC water restriction zones and trigger cell locations are equivalent to SFWMM ECB implementation. An attempt was made to tie trigger cells with associated groundwater level gages to the extent possible. The Lower East Coast Subregional (LECsR) model is the source of this data. • Periods where the LEC is under water restriction due to low Lake Okeechobee stages were extracted from the corresponding RSMBN ECB simulation.

References

ARCADIS (2008) Generation of the Expanded Coverage Reference Evapotranspiration Dataset for Hydrologic Modeling.

United States Army Corps of Engineers (December, 2011) Review Plan for Interim Operating Criteria for 8.5 Square Mile Area Project and Environmental Assessment. United States Army Corps of Engineers, Jacksonville, FL.

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United States Army Corps of Engineers (December, 2006) Final Supplemental Environmental Impact Statement, Interim Operational Plan (IOP) for Protection of the Cape Sable Seaside Sparrow. United State Army Corps of Engineers, Jacksonville, FL.

United States Army Corps of Engineers (2000) Final General Reevaluation Report, 8.5 Square Mile Area. United States Army Corps of Engineers, Jacksonville, FL.

Lake Worth Drainage District, Palm Beach County, Broward County and South Florida Water Management District (February, 2013) C-51 Reservoir – Preliminary Design and Cost Estimate – Final Report. South Florida Water Management District, West Palm Beach, FL.

Water Rights Compact (Private) Among the Seminole Tribe of Florida, the State of Florida and the South Florida Water Management District. Available at *www.sem**tribe**.com/ser**vic**es/water/**compact**.doc.*

Attachment C

Comparison of Assumptions (ECB1 versus ECB2)

Feature	ECB1	ECB2
Meteorological Data	• Rainfall file used: rain_v3.0_beta_tin_14_05.bin. • Reference evapotranspiration file used: RET_48_05_MULTIQUAD_v1.0.bin (ARCADIS, 2008).	Same as ECB1.
Topography	• Same as calibration topographic data set except where reservoirs are introduced (Stormwater Treatment Area [STA] 1 East [1E], C4 Impoundment and C-111 reservoirs). • United States Geological Survey High-Accuracy Elevation Data Collection for the Water Conservation Areas (WCAs) 1, 2A, 2B, 3A, and 3B, the Big Cypress National Preserve and ENP.	Same as ECB1.
Tidal Data	• Tidal data from two primary (Naples and Virginia Key) and five secondary (Flamingo, Everglades, Palm Beach, Delray Beach and Hollywood Beach) National Oceanic and Atmospheric Agency stations were used to generate a historic record to be used as sea level boundary conditions for the entire simulation period.	Same as ECB1.
Land Use and Land Cover	• Land use and land cover classification for the LEC urban areas (east of the LEC Flood Protection Levee) use 2008–2009 land use coverage as prepared by SFWMD. Consumptive use permits as of 2011 were used to update the land use in areas where it did not reflect the permit information. • Land use and land cover classification for the natural areas (west of the LEC Flood Protection Levee) is the same as the calibration land use and land cover classification for that area. • Modified at locations where reservoirs are introduced (STA 1E, C4 Impoundment, Lakebelt lakes and C-111 reservoirs).	Same as ECB1.
Water Control Districts	• Water control districts in Palm Beach and Broward counties and in the Western Basins assumed.	Same as ECB1.

Feature	ECB1	ECB2
Lake Belt Lakes	• Based on 2005 Lake Belt lake coverage obtained from USACE.	Same as ECB1.
Water Conservation Area 1 (Arthur R. Marshall Loxahatchee National Wildlife Refuge)	• Current C&SF Project regulation schedule including regulatory releases to tide through LEC canals. • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control), if water levels are less than minimum operating criteria of 14 feet. The bottom floor of the schedule (Zone C) is the area below 14 feet. Any water supply releases below the floor will be matched by an equivalent volume of inflow. • Structure S10E connecting WCA 1 to the northeastern portion of WCA 2A is no longer considered part of the simulated regional system.	Same as ECB1.
Water Conservation Area 2A & 2B	• Current C&SF Project regulation schedule including regulatory releases to tide through LEC canals. • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control), if water levels in WCA 2A are less than minimum operating criteria of 10.5 feet. Any water supply releases below the floor will be matched by an equivalent volume of inflow.	Same as ECB1.
Water Conservation Area 3A & 3B	• Current C&SF Project regulation schedule for WCA 3A, as per the Water Control Plan – IOP for protection of CSSS – C&SF Project for Flood Control and Other Purposes (USACE, December 2006). • Includes regulatory releases to tide through LEC canals. Documented in the Water Control Plan (USACE, December 2006). • No net outflow to maintain minimum stages in the LEC Service Area canals (salinity control) if water levels are less than minimum operating criteria of 7.5 feet in WCA 3A. Any water supply releases below the floor will be matched by an equivalent volume of inflow.	Same as ECB1 except for the following: • ERTP regulation schedule for WCA 3A instead of IOP, as per SFWMM modeled alternative 9E1 (USACE, 2012).
Everglades Construction Project Stormwater Treatment Areas	• STA 1E: 5,132 acres total treatment area. • A uniform bottom elevation equal to the spatial average over the extent of STA 1E is assumed.	Same as ECB1.

Feature	ECB1	ECB2
Everglades National Park	• Water deliveries to ENP are based upon IOP. • L-29 stage constraint for operation of S-333 assumed to be 7.5 feet NGVD. • G-3273 constraint for operation of S-333 assumed to be 6.8 feet NGVD. • Tamiami Trail culverts east of the L-67 Extension are simulated. • 5.5 miles remain of the L-67 Extension Levee. • S-355A & S-355B are operated. • S-356 is not operated. • Partial construction of C-111 project reservoirs consistent with the 2009 as-built information from USACE (does not include contract 8 or contract 9). A uniform bottom elevation equal to the spatial average over the extent of each reservoir is assumed. • S-332, S-332DX1, S175 are not operated. • 8.5 SMA Project feature as per federally authorized Alternative 6D of the MWD/8.5 SMA Project (USACE, 2000 GRR); operations per 2011 Interim Operating Criteria (USACE, June 2011 EA) including S-331 trigger shifted from Angel's well to Las Palmas Groundwater Gage-2. Special operations for S-357 (S-357 operation based on S-357 HW and Las Palmas Canal Gage-1 stage) per 2011 Interim Operating Criteria (USACE, June 2011 EA) is too detail to capture in current resolution of RSMGL. Under normal conditions, it is intended to limit the pumping capacity of S-357 to 250 ACFT/day (126 cfs) although the design capacity is 575 cfs. So, design capacity of S-357 is limited to 126 cfs in RSMGL to assume normal condition operations.	Same as ECB1 except for the following: • Water deliveries to ENP are based upon ERTP, with the WCA 3A regulation schedule including the lowered Zone A (compared to IOP) and extended Zones D and E1. • The Tamiami Trail One-Mile Bridge as per the 2008 Tamiami Trail Limited Reevaluation Report (US Army Corps of Engineers, June 2008) is modeled as a one mile weir. Located east of the L-67 extension and west of the S-334 structure. • Tamiami Trail culverts east of the L-67 Extension are simulated where the bridge is not located.
CERP Projects	• None.	• C-111 Spreader Canal Western Project includes the Frog Pond Detention Area, which is modeled as an above ground impoundment. • S-200A, B, and C are 3 pumps feeding Frog Pond Detention Area each with a capacity of 75 cfs. The pumps have tail water OFF trigger of 8.5 feet NGVD in

Feature	ECB1	ECB2
		the impoundment and a CSSS Population Site C remote OFF trigger of 10 centimeters above ground elevation for the period of March 15 to June 30. • S-199A, B, and C are 3 pumps feeding Aerojet Canal each with a capacity of 75 cfs. The pumps have tail water OFF trigger of 8.0 feet NGVD and a CSSS Population Site D remote OFF trigger of 10 centimeters above ground elevation for the period of March 15 to June 30.
Other Natural Areas	• Flows to Biscayne Bay are simulated through Snake Creek, North Bay, the Miami River, Central Bay and South Bay	Same as ECB1.
Pumpage and Irrigation	• PWS pumpage for the LEC was updated using 2010 consumptive use permit information as documented in the C-51 Reservoir Feasibility Study (Lake Worth Drainage District et al., February 2013). Permits under 0.1 million gallons per day were not included. • Residential self-supported pumpage are based on 2030 projections from the SFWMD Water Supply Bureau. • Industrial pumpage are based on 2030 projections from the SFWMD Water Supply Bureau. • Irrigation demands for the six irrigation land use types are calculated internally by the model. Seminole Hollywood Reservation demands are set forth under VI. C of the Tribal Rights Compact, which is available (*www.sem**tribe**.com/ser**vic**es/water/**compact**.doc*). Tribal sources of water supply include various bulk sale agreements with municipal service suppliers.	Same as ECB1.

<table>
<tr><th>Feature</th><th>ECB1</th><th>ECB2</th></tr>
<tr><td>Canal Operations</td><td>
C&SF Project system and operating rules in effect in 2010.
Includes operations to meet control elevations in the primary coastal canals for the prevention of saltwater intrusion.
Includes existing secondary drainage/water supply system.
C-4 Flood Mitigation Project.
Western C-4, S-380 structure retained open.
C-11 Water Quality Treatment Critical Project (S-381 and S-9A).
S-9/S-9A operations modified for performance consistency with SFWMM ECB.
S-25B and S-26 pumps are not modeled since they are used very rarely during high tide conditions and the model uses a long-term average daily tidal boundary.
Northwest Dade Lake Belt area assumes that the conditions caused by currently permitted mining exist and that the effects of any future mining are fully mitigated by industry.
ACME Basin A flood control discharges are sent to C-51, west of the S-155A structure, to be pumped into STA 1E. ACME Basin B flood control discharges are sent to STA 1E through the S-319 structure.
Releases from WCA 3A to ENP and the South Dade Conveyance System (SDCS) will follow IOP:
Structures S-343A, S-343B, S-344 and S-12A are closed November 1 to July 15
Structure S-12B is closed January 1 to July 15
Structure S-12C is closed February 1 to July 15
Structure S-12D is operated throughout the year. Only structure S-12D is operated between February 1 and July 15 to meet the total flow target.

SDCS operations will follow IOP for protection of CSSS
</td><td>Same as ECB1 except for the following:
C&SF system and operating rules in effect in 2012 (instead of 2010).
Releases from WCA 3A to ENP and the SDCS will follow the ERTP regulation schedule for WCA 3A, as per SFWMM modeled alternative 9E1.
Both structures S-12C and S12D are operated throughout the year (no closures for S-12C).
SCDS operations will follow ERTP for protection of the CSSS.
</td></tr>
<tr><td>Canal Configuration</td><td>Canal configuration same as calibration except only 5.5 miles remain of the L-67 Extension Canal.</td><td>Same as ECB1.</td></tr>
</table>

Feature	ECB1	ECB2
Lower East Coast Service Area Water Shortage Management	• LEC water restriction zones and trigger cell locations are equivalent to SFWMM ECB implementation. An attempt was made to tie trigger cells with associated groundwater level gages to the extent possible. The Lower East Coast Subregional (LECsR) model is the source of this data. • Periods where the LEC is under water restriction due to low Lake Okeechobee stages were extracted from the corresponding RSMBN ECB simulation.	Same as ECB1.

References

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United States Army Corps of Engineers (June, 2011) Review Plan For Interim Operating Criteria for 8.5 Square Mile Area Project And Environmental Assessment. United States Army Corps of Engineers, Jacksonville, FL.

United States Army Corps of Engineers (June, 2008) Tamiami Trail One-Mile Bridge: Limited Reevaluation Report and Environmental Assessment. United States Army Corps of Engineers, Jacksonville, FL.

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