SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Technical Document to Support a Water Reservation Rule for the Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Phase 1 Project

July 2013

Executive Summary

This document summarizes technical information that supports a rule to reserve water for the protection of fish and wildlife within the western nearshore portion of central Biscayne Bay. Water is to be reserved consistent with the objectives and information contained within the *Central and Southern Florida Project Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Project Phase 1 Final Integrated Project Implementation Report and Environmental Impact Statement* (USACE and SFWMD 2012), referred to simply as the project implementation report or PIR, with other sources of information for quantifying water to be reserved from use by permit applicants pursuant to Chapter 373.223(4), Florida Statutes (F.S.) for the protection of fish and wildlife in support of the Comprehensive Everglades Restoration Plan (CERP). Water for protection of fish and wildlife means water that is necessary to ensure a healthy and sustainable native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood, and population variation.

The Water Resources Development Act of 2000 (US Congress 2000) requires that water be reserved or allocated as an assurance that each CERP project meets its goals and objectives. A water reservation is a legal mechanism to set aside water from consumptive water use for the protection of fish and wildlife or public health and safety. Under Florida law, Chapter 373.223(4), F.S., the reservation is composed of a quantification of the water to be protected, which may include a seasonal component and a location component. The water quantified for protection of fish and wildlife will be reserved by rule. As part of the rule development process, the PIR for the project, other documents, and results of additional analyses provide the best available information to support the correlation between hydrology and biology to establish a quantity of water needed for the protection of fish and wildlife.

Implementation of the Biscayne Bay Coastal Wetlands Phase 1 Project will impound and redistribute freshwater runoff from the existing canal discharges into the coastal wetlands adjoining Biscayne Bay to provide a more natural and historical overland flow pattern through existing coastal wetlands and tidal creeks. This redistribution of freshwater runoff will improve the temporal and spatial distribution of inflows to Biscayne Bay.

To protect fish and wildlife, the South Florida Water Management District (SFWMD) will reserve water that currently discharges to Biscayne Bay from the C-100, C-1, C-102, Homestead Air Reserve Base (Military Canal), and C-103 basins independent of whether it is anticipated to be diverted into the project features, or is discharged via the existing coastal structures (USACE and SFWMD 2012, Annex C). The SFWMD will protect the water made available for the natural system by the project, which is the water that will be diverted or pumped by project features, and is identified as the "Total Diverted Canal Flow" in the PIR. In addition, the SFWMD has further committed to reserve all canal discharges up to the specified target flow described in the PIR ("Total Available Canal Flow") under the state's reservation authority.

The determination of the amount of water needed for the protection of fish and wildlife is based on meeting a year-round salinity target for the nearshore area of Biscayne Bay of 20 (practical salinity scale) given in the PIR. Annex C of the PIR describes the amount of water needed to meet the salinity target for the entire project area, and provides annual summations of the quantities. Because these annual quantities are summarized and are representative of the planning-level information contained in the PIR, more detailed analyses were required to identify specific bodies of water that need protection. This detailed analysis involved adding five additional years of data to the 20-year period of record to obtain the best available information.

During this evaluation process, the estimated quantity of water or target flow needed to achieve a nearshore salinity target of 20 is slightly different (higher) than the amount given in the PIR. Although the quantity of water is different, it is consistent with the intent of the PIR and the project performance measures. Since the project area includes five major canals, the amount contributed by each canal toward the quantity targeted by the project was determined. Secondly, each canal outfall is fed by more than one tributary, so statistical and graphical analyses were performed to determine which tributaries are important in contributing water to meet the targeted quantities of water to Biscayne Bay. The results of these analyses form the basis for the specific quantities of water and reaches of canals to be protected.

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Section 1. Introduction and Overview

1.1 Purpose of Document

This document summarizes technical information that supports a rule to reserve water for the protection of fish and wildlife within the western nearshore portion of central Biscayne Bay. For the purposes of this document, the nearshore zone of central Biscayne Bay is defined as the western shoreline of Biscayne Bay extending offshore (east) up to 500 meters (1,640 feet) beginning at the northern boundary of the Deering Estate park and extending southward to the Florida Power and Light access channel near Turkey Point including the embayments and canals reaches downstream of the coastal water control structures. Certain quantities of fresh water were identified in the *Central and Southern Florida Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Phase 1 Final Integrated Project Implementation Report and Environmental Impact Statement* (PIR) (USACE and SFWMD 2012) to ensure that the Biscayne Bay Coastal Wetlands (BBCW) Phase 1 Project is effective in achieving its objectives. It included existing surface water flows up to a restoration target flow as needed for fish and wildlife in nearshore central Biscayne Bay. The South Florida Water Management District (SFWMD) will reserve the water by rule so that it cannot be allocated for consumptive use.

A summary of the BBCW Phase 1 Project major components and features is provided within this document. In addition, the information about how the project will benefit fish and wildlife and the linkages to freshwater inflows is summarized. For more details, and to become familiar with the project, readers are referred to source documents:

- *Central and Southern Florida Project Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Phase 1 Final Integrated Project Implementation Report and Environmental Impact Statement* (USACE and SFWMD 2012): http://www.evergladesplan.org/pm/projects/docs_28_biscayne_bay_pir.aspx.
- Memorandum for Commander, U.S. Army Corps of Engineers District, Jacksonville, which is a memorandum for record that consists of a report detailing the findings of the preliminary scenario runs for the BBCW Phase 1 Project produced by the Coastal and Hydraulics Laboratory, U.S. Army Engineer Research and Development Center in Vicksburg, Mississippi (also provided in **Appendix B**) (Richardson 2003): http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/biscayne_bay_model_memo_2003.pdf.

The PIR provides a summed total of the existing surface water inflows that are needed for the protection of nearshore fish and wildlife in central Biscayne Bay. However, an additional level of analyses is provided within this document to determine the distribution of the total flows among the individual contributing watersheds and associated canal reaches. This additional evaluation was necessary to identify the canal segments and associated flow ranges to be specified in the water reservation rule.

1.2 Need for a Water Reservation

The SFWMD is developing this water reservation to meet federal and state project assurance requirements for the implementation of Comprehensive Everglades Restoration Plan (CERP) projects. The commitments are contained in (1) Section 601(h) of the Water Resource Development Act of 2000 (WRDA 2000; US Congress 2000); (2) Sections 385.26-27 of the *Programmatic Regulations for the Comprehensive Everglades Restoration Plan; Final Rule*

(DOD 2003), referred to as simply the Programmatic Regulations; and (3) Section 373.470(3)(c), Florida Statutes (F.S.). The purpose of this process is to provide assurance that each CERP project provides its intended benefits for the natural system by protecting the water identified by the PIR. These authorizations include identification of water for the natural system to be reserved or allocated under state law. This identification includes water available to the natural system prior to project implementation (i.e. water that the State has agreed to protect but is not mandated to protect by Section 601(h) of WRDA 2000), and water made available for the natural system as a result of the project (i.e. water that is required to be protected by Section 601(h) of WRDA 2000; Sections 385.26 and 385.27 of the Programmatic Regulations, and 373.470(3)(c), F.S.).

1.3 Affected Water Bodies

The water bodies affected by the proposed water reservation include canals within the watershed of the project area and the nearshore zone of central Biscayne Bay as defined below. The project area includes the BBCW Phase 1 Project components as described in the PIR, i.e. Deering Estate, Cutler Wetlands, and L-31E Flow Way. Fish and wildlife that is the subject of the reservation rulemaking are located in the nearshore area of Biscayne Bay. The proposed rule will include integrated inland surface water canals that convey surface water in quantities and during the time of year that are identified within this document for the protection of fish and wildlife in the nearshore zone. These canals include the C-100, C-1, C-102, C-103, and Military, along with identified hydraulically connected secondary drainage canals. Additional detail regarding the water bodies to be affected by the proposed rule is included in Section 2.

1.4 Basis of the Water Reservation

A water reservation is a legal mechanism to set aside water from consumptive water use for the protection of fish and wildlife or public health and safety. The reservation is composed of a quantification of the water to be protected, which may include a seasonal component and a location component.

The SFWMD has elected to use its water reservation authority (Section 373.223(4), F.S.) to protect both the water made available to the natural system prior to project implementation and water made available by the project, and will undertake this protection in a single rulemaking process.

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

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

When water is reserved under this statute, it is not available to be allocated for use by permit applicants, and is protected for the natural system. For purposes of this document, water for protection of fish and wildlife means water that contributes to “ensuring a healthy and sustainable, native fish and wildlife community; one that can remain healthy and viable through natural cycles of drought, flood and population variation."[1] In quantifying water to be reserved, existing legal uses of water are protected so long as such uses are not contrary to the public interest. An existing legal use is a water use that is authorized under a consumptive use permit under Part II of Chapter 373, F.S. or is exempt from the consumptive use permit requirements.

It is also important to understand what a water reservation does not do. Part II, Chapter 373, F.S. covers authorizations related to consumptive use of water and includes the authority to establish reservations. The SFWMD's authority to act as local sponsor of a CERP project is found in Part I at Chapter 373.1501, F.S. The provisions of Part II do not authorize the SFWMD to establish criteria for operations of a CERP project by rule. For CERP projects, Section 385.28 of the Programmatic Regulations requires that the operating plans for projects be consistent with an established water reservation or allocation. While the CERP project operational criteria and the water reservation are related, they derive from distinct federal and state authorities.

The proposed reservation rule will benefit the nearshore zone of central Biscayne Bay by preventing existing fresh surface water inflow needed to meet desirable salinity concentrations associated with a more productive nearshore nursery habitat for a variety of fish and wildlife from being allocated to new uses. The technical information and recommendations within this document will serve as the basis for the quantification of water for the protection of these fish and wildlife species and will be adopted through rulemaking.

The terms "target(s)" or "performance measure(s)" in this document are used in the context of the PIR for the purpose of evaluating and comparing various project alternatives as part of the assessment and selection process. These terms should not be construed or interpreted as applying to the SFMWD's definition to define "harm", "significant harm", or "serious harm" found in Chapter 40E-8, Florida Administrative Code. Also, these values should not be construed as a regulatory threshold for the purpose of evaluating compliance of existing legal users with conditions in their permits.

1.5 Water Reservation Process

Figure 1 summarizes the general steps of the rule development process. The SFWMD's Governing Board authorized publication of a notice of rule development on December 9, 2010. This document has been created in support of Chapter 120, F.S. and Sections 373.044 and 373.113, F.S. rule development authorities, and fulfills the second step of the process.

The SFWMD's public rule development process encourages stakeholders and interested persons to participate by providing input before and after drafting of rule language, including a suggested alternative rule. Once draft rule language is finalized, it is presented to the SFWMD Governing Board for consideration to authorize the notice of rulemaking and subsequently hold a public hearing to adopt the final rule.

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[1] Association of Florida Community Developers, et al. versus Department of Environmental Protection, et. al., Division of Administrative Hearings (DOAH) Case Number 04-0880RP, Final Order February 24, 2006, added 943 So. 2d 989 (Florida Fourth District Court of Appeals 2006)

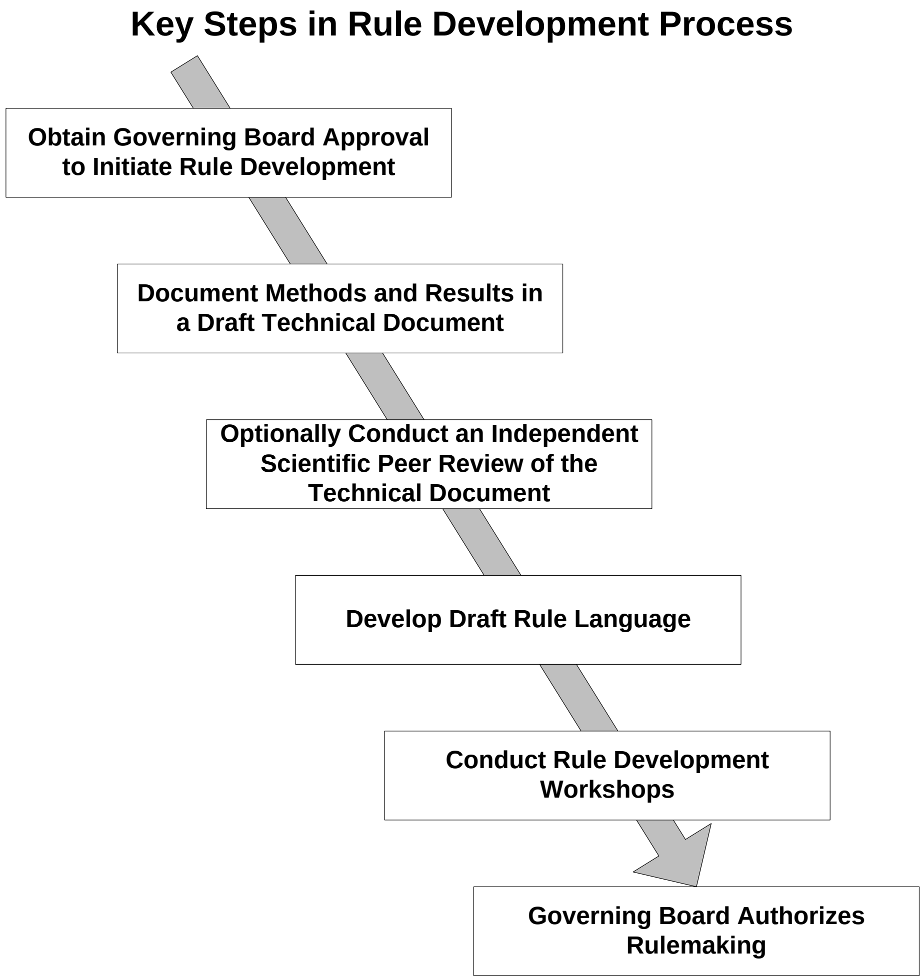

Figure 1. Process steps of water reservation rulemaking.

An additional independent scientific peer review of this technical document is not planned as the United States Army Corps of Engineers (USACE) performed the required (Section 2034 of the Water Resources Development Act of 2007 [US Congress 2007]) independent external peer review of the draft PIR, which was completed on December 1, 2009 in accordance with USACE Engineer Circular 1165-2-209 requirements (USACE 2010). In addition, SFWMD encourages stakeholder review and comment of the technical document. SFWMD provides multiple opportunities for stakeholders to provide feedback prior to final rule adoption.

Section 2. Identification of the Water Reservation Water Bodies

2.1 General Description of Biscayne Bay

Biscayne Bay proper and adjacent water bodies make up a shallow estuarine lagoonal system extending the entire length of Miami-Dade County and part of Monroe County in southeastern Florida (**Figure 2**). The Biscayne Bay ecosystem includes more than 500 species of fish, extensive seagrass meadows, and endangered species such as the Florida manatee (*Trichechus manatus latirostris*) and American crocodile (*Crocodylus acutus*). The longest stretch of mangrove forest remaining on Florida's eastern coastline occurs within Biscayne Bay. The system is a nursery for many ecologically and commercially important species, such as shrimp, crabs, lobster, and the reef fish community. Large areas of hard bottom habitat support sponges and corals.

In recognition of the importance of the Biscayne Bay system, various areas have been protected by inclusion in parks, sanctuaries and by law. The bay can generally be divided into three major regions: north, central, and south (**Figure 2**). The central region of the bay extends from Rickenbacker Causeway south to Card Sound. Much of the southern portion of the central region of Biscayne Bay is contained within Biscayne National Park. The south region is included within the Florida Keys National Marine Sanctuary and the Crocodile Lakes National Wildlife Refuge. The remaining portions have been declared an Aquatic Preserve and the entire system has been declared an Outstanding Florida Water by State law.

The numerous freshwater inflow sources along Biscayne Bay's western shore include canals, tidal creeks, overland flow, and groundwater. A regional network of canals drains fresh water into the bay from developed areas of the watershed (**Figures 2** and **3**). The canal network is managed for flood control and, in some cases, water supply through operation of water control structures. The BBCW Phase 1 Project depends on water from a series of canals. Four primary canals, C-100, C-1, C-102, and C-103, drain the project area. The C-100 canal system drains the northern portion of the project area in the vicinity of the Deering Estate, and outfalls at the S-123 structure (**Figure 3**). The C-1 canal system extends from the L-31N borrow canal in southwest Miami-Dade County east to Black Point where the S-21 structure controls discharge to the bay from this basin. The C-102 canal extends from the L-31N borrow canal basin in southwestern Miami-Dade County east to Biscayne Bay at the northern end of the L-31E coastal wetlands, and outfalls at the S-21A structure. The C-103 canal basin, which includes Florida City and North canals, connects the southern portion of the BBCW Phase 1 Project with Biscayne Bay, and outfalls at the S-20F structure. An additional conveyance canal, Military Canal, drains the former Homestead Air Reserve Base and outfalls at the S-20G structure. Water within certain reaches of these canals is identified for protection as part of the BBCW Phase 1 Project water reservation.

The focus of the evaluations for this water reservation process is the nearshore zone in the central region of Biscayne Bay. The general location of the BBCW Phase 1 Project is in the central region between Shoal Point and Turkey Point. This nearshore habitat is a mix of hard and soft bottom areas consisting of extensive seagrass and macroalgal beds. Salinity in this nearshore zone is largely a function of fresh water discharged from canals, and varies between about 10 and 40 throughout the year.

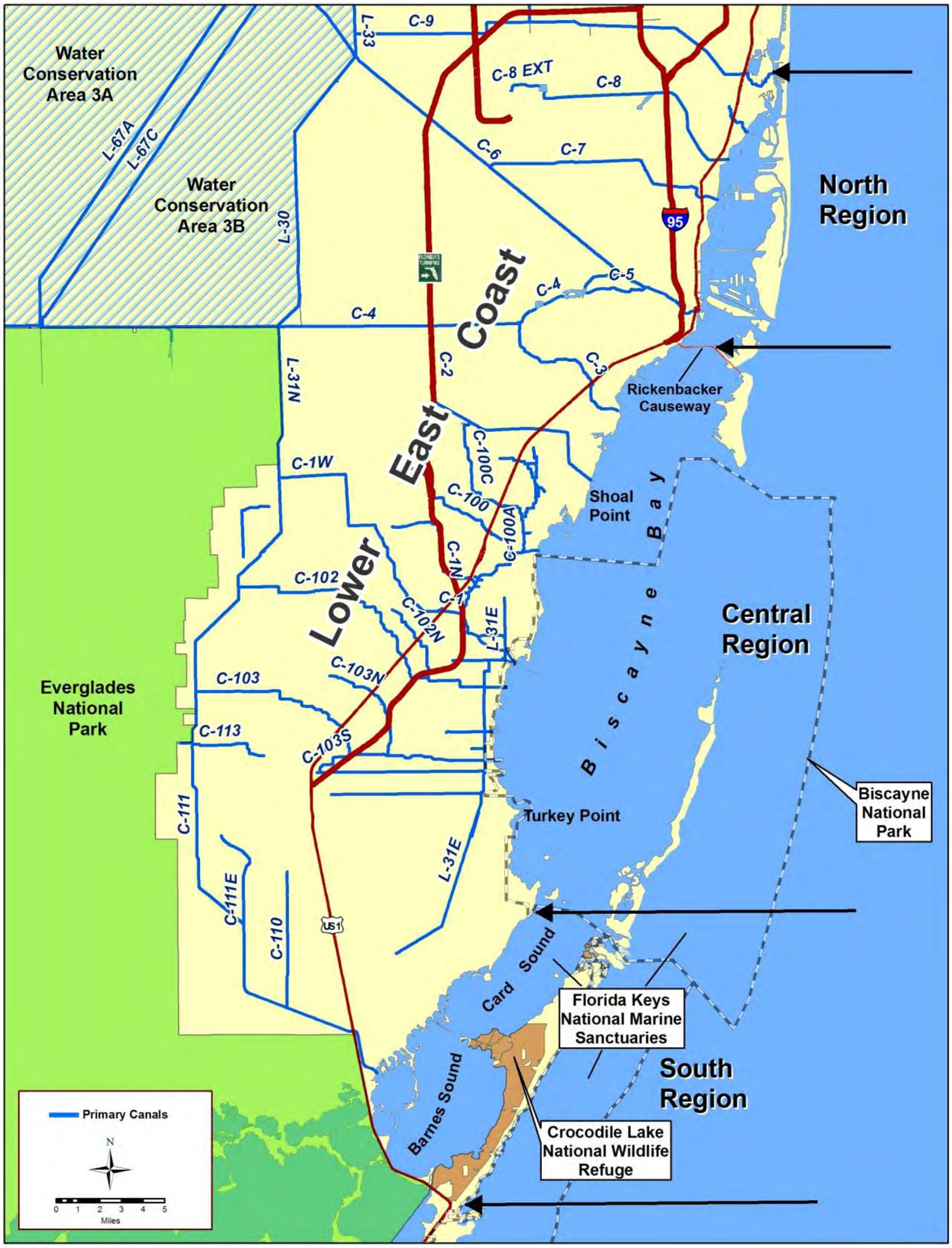

Figure 2. Map of Biscayne Bay and its watershed.

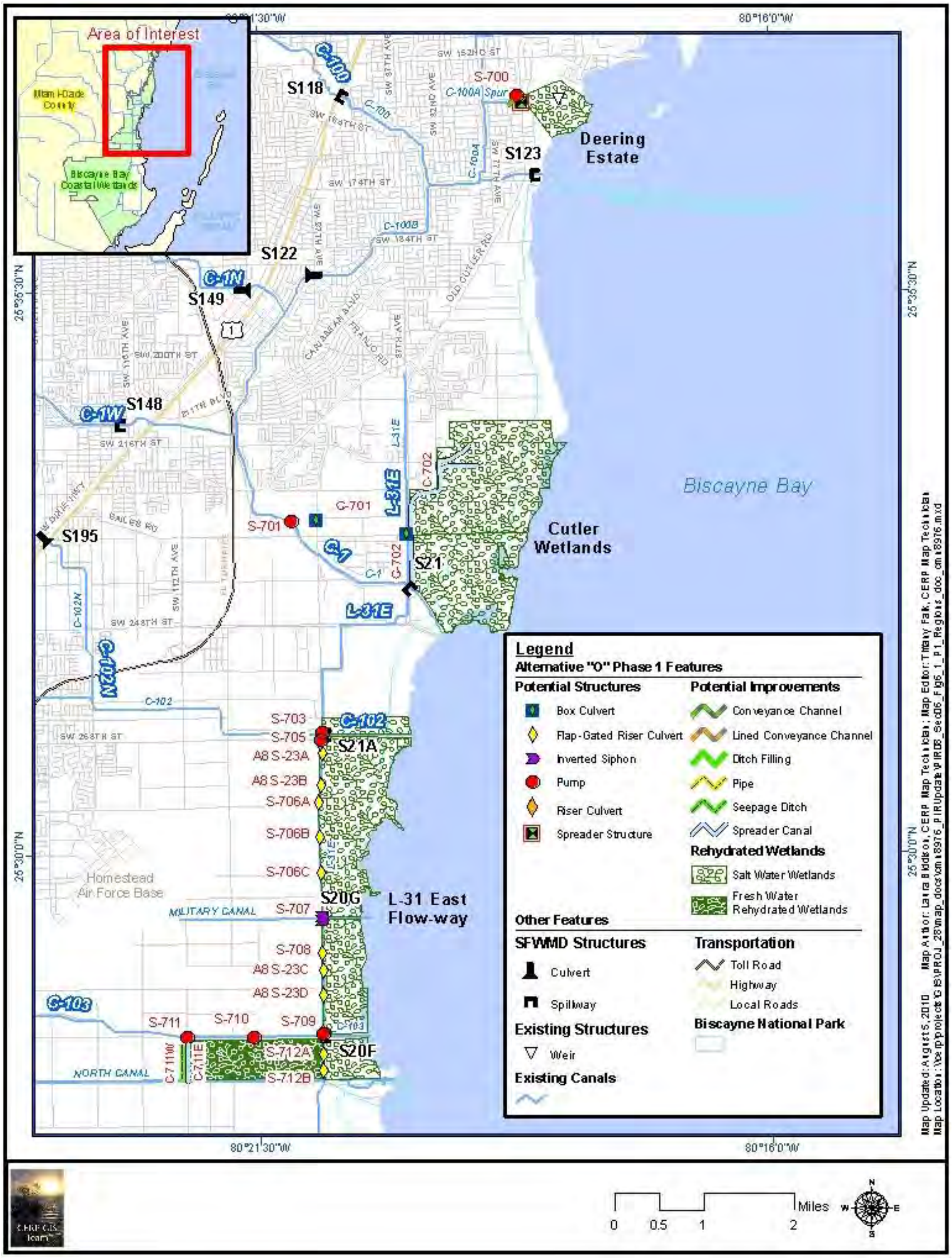

Figure 3. The BBCW Phase 1 Project and surrounding areas.

2.2 Biscayne Bay Coastal Wetlands Project Phase 1 Features

One of the BBCW Phase 1 Project's primary purposes is to benefit the nearshore zone of the bay, by improving the probability that the water in this zone will meet a desired salinity concentration of 20 or less, and thus provide a more productive nearshore nursery habitat for a variety of fish and wildlife (PIR pages 3–22; Appendix C, Attachment 1; and Annex C, Figure C-22). The principal benefits will be realized from changes to the spatial distribution of freshwater flows into the bay as a result of redirecting freshwater runoff. Project features have been designed to redirect fresh water currently discharged directly into Biscayne Bay through man-made canals into wetlands adjacent to the bay restoring a more natural water flow pattern into the bay.

The BBCW Phase 1 Project consists of three project components: Deering Estate, Cutler Wetlands, and L-31 East Flow Way (**Figure 3**) (PIR, Section 3.1). The selected alternative plan (Alternative O Phase 1) was chosen because it provides a cost-effective means of providing the greatest ecological benefits. Overall, the plan encompasses about 1,578 hectares (3,899 acres) of land. The project features include seven pump stations, ten culverts that reconnect wetlands, and three miles of spreader canals. The project may also include plugging up to 762 meters (2,500 feet) of mosquito ditches. The project features associated with each of the three components are briefly described in the subsections below. Additional detail regarding these features can be found in Section 7 of the BBCW Phase 1 Project PIR.

2.2.1 Deering Estate Component

The Deering Estate component includes a 152-meter (498-foot) extension of the C-100A spur canal, 164 linear meters (538 linear feet) of discharge pipe, and a 100-cubic feet per second (cfs, or 2.8 cubic meters per second [m^3/s]) pump station. These features will redistribute fresh water that would otherwise be discharged to Biscayne Bay via the S-123 structure to Cutler Creek and associated coastal wetlands located within the Deering Estate. The S-700 pump station has been constructed by the SFWMD's expedited process, and began regular operation on December 20, 2012. This pump station facility (S-700) is now in the implementation phase.

2.2.2 Cutler Wetlands Component

Features in the Cutler Wetlands component include a 400 cfs (11.3 m^3/s) pump station, a conveyance canal, a spreader canal, culverts, and potential mosquito control ditch plugs. The pump station, located on the C-1 canal, will deliver water to a lined conveyance canal (2,234 linear meters [7,329 linear feet]) and adjacent wetlands. This conveyance canal will run beneath two roadway crossings (SW 97th and SW 87th avenues) and across the L-31E borrow canal via concrete box culverts, and deliver water to a spreader canal (4,011 linear meters [13,159 linear feet]) located east of the levee. The diverted water, which would otherwise be discharged as a point source to Biscayne Bay via the S-21 structure, will rehydrate freshwater and saltwater wetlands. Portions of existing mosquito ditches may also be plugged, if necessary, to ensure a proper distribution of water within the wetlands.

2.2.3 L-31 East Flow Way Component

Features in this component will be fed by water from two major canals (C-102 and C-103), and convey fresh water into saltwater wetlands east of the L-31E levee. It includes two pump stations, S-705 (100 cfs, 2.8 m^3/s) and S-709 (40 cfs, 1.1 m^3/s), that withdraw water from the C-102 and C-103 canals, respectively, and discharge the water into the L-31E borrow canal. A new inverted siphon (S-707) will isolate the L-31E borrow canal from the Military Canal, and add flexibility for water level control within this reach of the L-31E borrow canal. A total of 10 flap gated culverts are planned to be placed within the levee so that fresh water can gravity discharge into the coastal wetlands east of L-31E, and ultimately into Biscayne Bay. The pump stations are designed to maintain higher average water levels within the L-31E borrow canal to improve flow rates within the culverts. Two existing culverts were constructed in 1999 and four additional culverts as part of the SFWMD's expedited process. The S-703 pump station (50 cfs, 1.4 m^3/s) will also withdraw water from the C-102 canal, and discharge directly into the coastal wetlands north of the C-102 canal.

When sufficient water is available, two additional 40 cfs (1.1 m^3/s) pump stations, S-710 and S-711, will withdraw water from the C-103 canal and discharge into a 162-hectare (400-acre) wetland impoundment between the C-103 and North canals. Water that flows out of the impoundment into the L-31E borrow canal will be conveyed into the coastal wetlands east of the levee via two flap gated culverts.

Section 3. Hydrologic and Hydrodynamic Characteristics of the Region

3.1 Description of Southern Miami-Dade County Hydrology

Annual rainfall over the central and southern Biscayne Bay watershed averages about 145 centimeters (57 inches), providing about 80 percent of the water input. The balance of water originates from groundwater seepage and surface water flows from outside the watershed. Rainfall flows by gravity on the ground surface and through the soil to canals where it is temporarily held or conveyed to tide. The topography is flat and the underlying aquifer is highly transmissive. The canal-based surface water management systems in the watershed of the south and central regions function primarily as aquifer drains (Langevin 2001), and the primary canals have been cut into some of the most permeable layers of the underlying aquifer. In the absence of rainfall, groundwater stored in the soil usually continues to seep into the primary canals due to differences in water levels.

Prior to development, surface flow to central Biscayne Bay followed the general topographic gradient from west to east. Water levels were higher in the past, and runoff from the Everglades drained through the coastal ridge via sloughs called transverse glades. In some cases, water collected into streams or creeks that flowed into the bay. East of the coastal ridge, freshwater wetlands extended to a narrow fringe of mangroves along the bay's western shoreline where fresh water was detained by a coastal berm. Groundwater seepage into the bay was prolific. In some cases, fresh water discharged from the floor of the bay through springs (Parker et. al. 1955). Over the years, the characteristics of freshwater inflow to the bay changed. The pre-development, sporadic, short bursts of rainy season flow through the transverse glades and prolonged dry season groundwater discharges have been replaced by regulated releases through drainage canals along with a reduction of groundwater discharge (Buchanan and Klein 1976).

Drainage improvements have effectively lowered the groundwater table about 1.5 or 2.0 meters (about 5.0 to 6.5 feet) in the watershed west of the coastal ridge. Today, surface water flows into the central bay originate primarily in the C-100 (Cutler Drain), C-1 (Black Creek), C-102 (Princeton Canal), and C-103 (Mowry Canal) basins. Secondary basins include those drained by the North, Florida City, and Military canals. Goulds Canal is a major secondary canal within the C-102 basin. A small amount of water flows overland directly to the bay from the small coastal basins east of Old Cutler Road and the L-31E levee.

Each primary canal basin is divided operationally into western and eastern subbasins by control structures near the coastal ridge. Surface flow follows the historical pattern with flow from western subbasins through coastal ridge structures to the eastern subbasins. Water management in each subbasin involves balancing conflicting objectives and needs of stakeholders. The basins have limited capacity to store water, primarily in lakes, drainage conveyances, and soil. During periods of rainfall, this capacity is typically exceeded, and surface water is released to prevent flooding. During periods of little rainfall, basin storage is depleted, primarily via evaporation and seepage, and surface water control structures are kept closed to limit the rate of groundwater lost and prevent saltwater intrusion until it can be improved by rainfall. The preferred stage elevations for the control of water management structures are set to balance these seasonal objectives. Water to maintain these preferred stage elevations can come from Lake Okeechobee and the Water Conservation Areas.

For the primary area of interest, water levels along the coast are controlled within the four primary drainage basins by water control structures that outfall directly into the bay. The C-100 canal system drains the northern portion of the BBCW Phase 1 Project area in the vicinity of the Deering Estate, and outfalls at the S-123 structure. The C-1 canal system extends from the L-31N borrow canal in southwestern Miami-Dade County east to Black Point where the S-21 structure controls discharge to the bay from this basin. The C-102 canal system extends from the L-31N borrow canal east to Biscayne Bay at the northern end of the L-31E Flow Way component, and outfalls at the S-21A structure. The C-103 canal basin, which includes the Florida City and North canals, connects the southern portion of the project area with Biscayne Bay, and outfalls at the S-20F structure. An additional canal (Military Canal) drains stormwater runoff from the former Homestead Air Force Base and outfalls at the S-20G structure. The coastal structures are operated according to established water level criteria, and in some cases, include seasonal criteria.

3.2 Description of Central Biscayne Bay Hydrodynamics and Salinity

The central region of Biscayne Bay (**Figure 2**) is about 360 square kilometers (about 140 square miles) in size, and natural depth ranges up to about four meters (13 feet). The nearshore zone along the western margin out to 500 meters (1,640 feet) is about one meter or less in depth. It is bounded to the east by the southern portion of the Safety Valve shoals, and a series of barrier islands, the largest of which is Elliott Key. The southern boundary is the southern edge of Cutter Bank. Tidal exchange with the Florida Straits occurs largely via the Safety Valve, and to a small extent through Caesar's Creek and over Cutter Bank. Tidal range averages about 60 centimeters (24 inches). In general, net tidal flow is toward the north due to tidal and wind-driven currents.

Net rainfall inputs are relatively small due to evaporation. Therefore, salinity patterns reflect major freshwater inputs from the watershed. The historical, natural freshwater inputs produced a distinctive salinity gradient that supported diverse habitats characteristic of Biscayne Bay (seagrass and algal meadows, oyster reefs, sponge beds, mangrove forest, and marshes). Simulations of the pre-development hydrologic inputs to the bay with models such as the SFWMD's Natural Systems Model produce freshwater inputs that are more damped and less variable than currently, and inflows more constant (SFWMD 2012). It is likely that historical salinity patterns were more stable in the past, exhibiting fewer extremes.

The primary influence of salinity patterns in central Biscayne Bay today is the freshwater inputs from the major canals. Salinity patterns reflect the locations and patterns of canal flow rates. These freshwater inputs are sufficient to affect salinity primarily within the western half of the central region. During 1986 through 2011, canal discharges totaled about 82,000 to 747,000 acre-feet (ac-ft) per year (10,115–92,141 hectare meters per year). Salinity along the eastern boundary of the region near Elliott Key is frequently greater than 35 due to evaporation and very little fresh water running off the island. In general, bay waters are well mixed vertically, so stratification is limited. Despite the historical changes in the way fresh water enters the bay from the watershed, these inputs still directly support a salinity gradient that ranges from about 15 near the mangrove shoreline to 35 in the center of the bay during the wet season. Average annual salinity is generally less than 30 in the nearshore zone. As freshwater inputs decline and evaporation increases throughout the dry season, however, salinity in the nearshore zone increases. It is not unusual for salinity nearshore to exceed 35 near the end of the dry season due to lack of canal discharge and high evaporation rates. Nevertheless, the nearshore salinity pattern is sufficient to support various habitats for several estuarine species.

Section 4. Hydrologic and Salinity Conditions Interaction with Biological Responses

4.1 Fish and Wildlife Species to Be Protected

The freshwater-influenced condition considered to be most strongly correlated with the distribution and abundance of estuarine biota in time and space is salinity (Whitfield et al. 2012, Bulger et al. 1993, Remane and Shlieper 1972, Kinne 1966, Gunter 1961, Emery et al. 1957). The mechanisms underlying this correlation may be physiological, related to tolerance or specific requirements for development (Patillo et al. 1995, Bulger et al. 1993), as well as ecologically related to refugia from predation, food supply, or preferred habitat (Peterson 2003, Day et al. 1989). While the existing pattern and distribution of freshwater inflows to Biscayne Bay is not ideal, and the spatial extent of the areas that are within the target salinity is limited, several existing estuarine animal species utilize the lower salinity nearshore habitat, and it supports diverse submersed aquatic vegetation. Some examples are given below.

4.1.1 Invertebrates

Juvenile pink shrimp (*Farfantepenaeus duorarum*) seek refuge in the lower salinity nearshore habitat where shoal grass is most abundant. Optimal salinity for juvenile growth is around 30 (Browder et al. 2002). As pink shrimp mature they move seaward into more marine habitats. The abundance of pink shrimp in Biscayne Bay supports a commercial and recreational fishery.

Blue crab (*Callinectes sapidus*), another commercial fishery in Biscayne Bay, is dependent on a low salinity habitat for part of its life cycle. For example, optimum blue crab egg hatching occurs at salinity between 23 and 28, and juveniles prefer a seagrass habitat with salinity between two and 21 (Pattillo et al. 1997).

The eastern oyster (*Crassostrea virginica*) is not currently harvested in central Biscayne Bay, but is present nearshore in small numbers where conditions are right. Growth rates of oysters are reported to be optimal from 14 to 28 salinity (Shumway 1996), but are common in salinity from 10 to 30. This species is important ecologically because (1) the accumulation of shells provides physical habitat structure for a variety of other species, (2) their organic-rich deposits are a food source for benthic feeders, and (3) they filter particulates from the water improving water quality (Pattillo et al. 1997).

4.1.2 Vertebrates

The common snook (*Centropomus undecimalis*) is a highly prized recreational fish that is relatively abundant in central Biscayne Bay. The common snook is listed as a species of special concern by the Florida Fish and Wildlife Conservation Commission. Although snook can live in fresh water and have been observed in such areas (e.g., Lake Okeechobee), they are primarily an estuarine species and are closely associated with mangrove vegetated shorelines and seagrass beds. Juveniles particularly prefer habitats with lower salinity (Pattillo et al. 1997).

The largest concentration of American crocodiles in the United States lies in the south region of Biscayne Bay, although a 1996–1998 study also documented the presence of this endangered species in the central area of the bay (Mazzotti and Cherkiss 1998). This species once ranged throughout Biscayne Bay, but is now primarily limited to southern Biscayne Bay and northeastern Florida Bay. The population in the Biscayne Bay is the fastest growing in Florida. Most of the crocodiles observed in this area are juveniles and subadults, favoring a habitat with intermediate salinity (i.e., less than 20), a shoreline with vegetation, and shelter from wind and waves. Salinity affects the distribution, growth, and survival of crocodiles (Moler 1991, Kushlan and Mazzotti 1989, Dunson and Mazzotti 1989, Mazzotti et. al. 1986, Mazzotti and Dunson 1984). For example, Mazzotti et al. (1986) reported that hatchlings grew best at a salinity of nine. Young crocodiles in this area require moderate salinity generally through the month of December each year, with a seasonal rainfall-driven pattern.

4.2 Desired Hydrologic and Salinity Conditions to Support Fish and Wildlife

The BBCW Phase 1 Project has six planning objectives that address the desirable conditions for the ecosystem:

1. Reestablish productive nursery habitat along the shoreline.
2. Redistribute freshwater flow to minimize point source discharges to improve freshwater and estuarine habitat.
3. Restore and improve quantity, quality, timing, distribution of freshwater to the bay, including Biscayne National Park.
4. Preserve and restore spatial extent of natural coastal glades habitat.
5. Reestablish connectivity between Biscayne coastal wetlands, C-111 Basin, Model Land Basin, and adjacent basins.
6. Restore nearshore and saltwater wetland salinity regimes.

The BBCW Phase 1 Project is estimated to intercept and redistribute between 44 and 85 percent of the water currently discharged at the canal outfalls per year based on historical canal flow rates. The intercepted water will be diverted to a mix of freshwater and saltwater wetlands. Water will be detained within the wetlands for a period of hours to days depending on location before making its way into Biscayne Bay through seepage and overland runoff where it will affect salinity within the nearshore zone. The balance of the water not diverted will continue to be discharged directly into the bay also supporting the nearshore salinity gradient.

The redistributed BBCW Phase 1 Project water will enter the bay via overland flow and through a series of small creeks resembling historical patterns. These flow paths will be more representative of natural, pre-development spatial patterns. The result of this change will be a larger nearshore area with salinity closer to the project salinity target of 20. This pattern will produce a salinity gradient ranging from near zero at the mouths of the creeks to about 25 within one kilometer (about 0.6 miles) of the shoreline when water is available. The gradient provides essential nearshore habitat for a variety of estuarine organisms. The survival of many estuarine organisms depends upon a stable seasonal availability of low salinity environments (Serafy et al. 1997, Montague and Ley 1993, Brook 1982, Kohout and Kolipinski 1967), and the reduction or loss of these environments in Biscayne Bay has resulted in concomitant reduction or loss of species dependent on such conditions. A total of 1,194 hectares (2,949 acres) of restored habitat are conservatively expected in the nearshore zone from the BBCW Phase 1 Project, since the analysis only estimated benefits within 500 meters (1,640 feet) of the shoreline. According to simulations conducted during project planning, benefits will extend into the bay much further than 500 meters (1,640 feet). In addition, the nursery functions that will be restored for several species will ultimately benefit the fish community not only throughout Biscayne Bay, but also within the offshore reef community as a function of "bay to reef" ontogeny (Ault et al. 2001), since many marine species are dependent on the estuarine zone during early life stages.

During the Project's planning process, a mechanistic numerical model was applied to aid in the assessment of the effects of BBCW Phase 1 Project features on Biscayne Bay. Particular emphasis was placed on assessing the impact of changing freshwater inflow patterns on the salinity of the bay. The Biscayne Bay TABS-MDS (multidimensional sediment) model version utilized for determining the quantity of fresh water needed in Biscayne Bay was developed by the United States Army Engineer Research and Development Center's Coastal and Hydraulics Laboratory (Brown et al. 2003). The two dimensional model of the hydrodynamics and salinity was calibrated and verified against a set of hydrodynamic and salinity field data collected in the region.

To estimate how much freshwater inflow may be needed to meet the project salinity target of 20 (spatial average) near the western shoreline of Biscayne Bay, the model was applied such that fresh water was added through a simulation of restored creeks based on historical creek locations to maintain a salinity of 20 continuously nearshore a few hundred meters from the shoreline (Richardson 2003, **Appendix B**). The simulation was run for the model calibration period of 1997–1998, a relatively typical year for climate. Thus it is assumed that results are representative of an average condition. The results include a summation of freshwater inflows for a one-year period by five subregions along the Project shoreline, and provide an estimate of water needed to maintain the target salinity.

4.3 Expected Project Benefits to the Ecosystem

Water redirected by features of the BBCW Phase 1 project will benefit the nearshore zone of central Biscayne Bay by providing a more natural distribution of freshwater inflow. The result of this change will be a larger nearshore area with salinity closer to the Project salinity target of 20. The project will restore 1,194 hectares (2,949 acres) of habitat out of a total possible nearshore area of 3,474 hectares (8,581 acres). The new patterns of freshwater delivery should promote the reestablishment of additional species that were once common in this area of Biscayne Bay such as the spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), black mullet (*Mugil cephalus*), and crevalle jack (*Caranx hippos*). The BBCW Phase 1 Project will not substantially change the existing timing of runoff, however. Water storage will be relatively small. Because the BBCW Phase 1 Project is dependent on the existing patterns of runoff, a desirable salinity range, while improved, will only be achieved some of the time. It is likely that salinity patterns will not reflect the target conditions at times in the dry season.

Water diverted by project features is expected to also benefit freshwater and saltwater wetlands. According to the PIR, the water flow rate needed to maintain a salinity of 20 in the nearshore area will improve habitats in wetlands since some of the available water is redirected into wetlands on its way into the bay. The selected alternative plan (Alternative O Phase 1) will result in an estimated 115 hectares (284 acres) of freshwater wetlands and 2,588 hectares (6,392 acres) of saltwater wetlands restored for a total of 2,703 hectares (6,676 acres) of restored wetlands. The project is expected to increase the hydroperiod in the target freshwater wetlands from about 70 days per year to nearly 200 days per year. This will result in improved functioning graminoid wetlands, which serve as critical habitat to prey fish and wading birds. Restored wetlands should support important forage species such as rainwater killifish (*Lucania parva*) on which wading birds and predatory fish depend. Rehydrating the coastal wetlands and reducing the average salinity of the water in these areas will improve functionality. An example of the benefits of increasing the freshwater input into saltwater wetlands is improved habitat for the endangered American crocodile, which requires mesohaline salinity conditions to maximize juvenile survival.

The selected plan (Alternative O Phase 1) provides the most cost-effective approach to implementing the prescribed changes. Furthermore, it meets the CERP's requirement of all selected plans: it maximizes net environmental and economic benefits on a systemwide basis to the South Florida ecosystem as a whole.

Section 5. Identification of Water to be Reserved

5.1 Analysis of Waters to Be Reserved

The BBCW Phase 1 Project PIR identified an estimate of the overall quantity of water needed to meet the salinity target within the nearshore Biscayne Bay. To determine the locations and quantities of surface water for this reservation, the contribution that each surface water basin makes towards meeting the salinity target needs to be identified along with contributing reaches of the surface water bodies within the watershed. The estimated quantity of water needed to achieve the salinity target of 20 used here is slightly different than the amount identified in the PIR. The PIR used a value of 517,000 ac-ft per year (63,771 hectare meters per year) as the estimated freshwater inflow needed to sustain a salinity of 20; however, the actual value given by the model simulation used during plan formulation was 518,759 ac-ft per year (63,988 hectare meters per year). Annex C of the PIR states that the 517,000 ac-ft per year value is an approximation, and was sufficient for purpose of the document, which was to illustrate how the existing canal discharges related to project performance. The larger number provided by the model result is used to determine the water reservation since it is the best available information. For the State's reservation process, it was necessary to establish the quantity of water that is contributed by each canal toward the water flow rate needed attain the salinity target. Inflows to the bay were divided by basin consistent with the meeting the salinity target in the nearshore adjacent to each basin. Flow rates within the tributaries upstream of the coastal outfalls were further analyzed to determine which tributaries and reaches were contributing water toward the flow targets for each basin. Analyses included comparisons of statistical results and plots of flow such as flow duration curves at each of the water control structures within the water management systems (**Appendix C**).

Water made available by the BBCW Phase 1 Project that will be reserved is represented by the "Total Diverted Canal Flow" line in **Figure 4**. The SFWMD has further committed to reserve the difference between the existing water in the system, identified as the "Total Available Canal Flow" in **Figure 4**, and the "Total Diverted Canal Flow" up to the "Target Flow" (518,759 ac-ft or 63,771 hectare meters per year), because it also contributes to meeting the salinity target and the protection of fish and wildlife.

To identify the quantity, timing, and distribution of water for the natural system, a probabilistic approach was selected during the PIR planning process. This approach utilized volume probability curves based on historical results. It depicts the distribution of annual water quantities that provide natural system benefits as a result of project features through the range of climatic conditions contained within the available period of hydrological record. The data period of record available when the PIR was written was 1986 to 2006, but the SFWMD has updated the data set with additional records available through 2011 to be more robust, and use best available information. Therefore, the updated curves are slightly different than those in Annex C of the PIR.

The PIR analysis assumed no source shifting from existing legal uses of water, and therefore, existing uses within the basins would continue at the same level and locations, or be slightly lower due to authorized allocated water that would be used in the future. To prevent increases to withdrawals of surface water in the future that could reduce the timing and volume of flow-target compatible discharges to central Biscayne Bay, it is necessary to evaluate each basin contributing water to the bay to determine (1) what portion of the total target freshwater flow is generated by each basin or canal, (2) whether a portion of the basin or canal discharge exceeds the target flow and, therefore, would not need to be restricted and, (3) evaluate the risk of future increases in demand for surface water to determine if additional restrictions are needed to insure there will be no future consumptive use-based reductions to flow rates.

Water made available by the BBCW Phase 1 Project was estimated by calculating the quantity of water diverted by all the project features (i.e., water diverted from canals) on a daily basis. This total diverted water is based on the designed pump capacity of each pump station. In general, the project facilities sometimes use just a portion of the total amount of water available on any given day. This is especially true in the wet season when runoff is greatest. The project features are not designed to capture all water available because it would be impractical to install pumps large enough to capture all peak flows. While one operational goal is to maximize the amount of water redirected to wetlands, it will at times be necessary to discharge excess water via the existing coastal structures during peak flow events. Nonetheless, water that is not diverted still provides habitat benefits to the estuary by contributing toward meeting the salinity target in the nearshore area. The quantity of water that can be diverted on a given day was compared to the historical quantity given in the SFWMD's hydrometeorologic database, DBHYDRO, for each day and each canal outfall. The daily results were summed for each year, and are represented by the pink line in **Figure 4**.

Project benefits were calculated based upon both diverted water and water that passed through the canal outfalls into Biscayne Bay or the Total Available Canal Flow. The primary source of the water is from the C-100, C-1, C-102, Military Canal, and C-103 basins (at structures S-123, S-21, S-21A, S20G, and S-20F, respectively). To protect fish and wildlife, the SFWMD will reserve all surface water that is currently discharged into Biscayne Bay from these structures (up to the flow target) independent of whether it is anticipated to be diverted into the project features, or discharged via the existing coastal outfall structures.

To identify the total quantity of water available (Total Available Canal Flow), estimates of the annual flows from these outfalls in DBHYDRO were summed, and are represented by the blue line in **Figure 4**. The total annual flows were ranked for the 25-year period of record to produce a volume probability curve. The volume of water defined as beneficial is the annual flows from these structures or the total quantity of water available as depicted by the blue line in **Figure 4** up to the target flow (brown line). All of the water that is normally discharged from the canals provides project benefits, except for the wettest years, which occur about 20 percent of the time. During the wettest years, some of the available water is in excess of the targeted 518,759 ac-ft (63,771 hectare meters).

Existing water resource protection rules were examined to see how they applied or were complementary for protecting the water identified in the PIR. Identification of specific water bodies to be protected under the state's water reservation process could not be accomplished without performing a more detailed analysis of the data, because the PIR description was generalized, giving only the total available canal flow combined into annual sums for the period of record. A more detailed analysis was performed on a seasonal basis using the best available information. To determine the water bodies that should be protected under the state's water reservation rule, basin-wide analyses of all contributing flows were performed on flow results at 15 additional water control structures located upstream and tributary to the five coastal outfalls. Details are summarized below, and specifics are in the appendices.

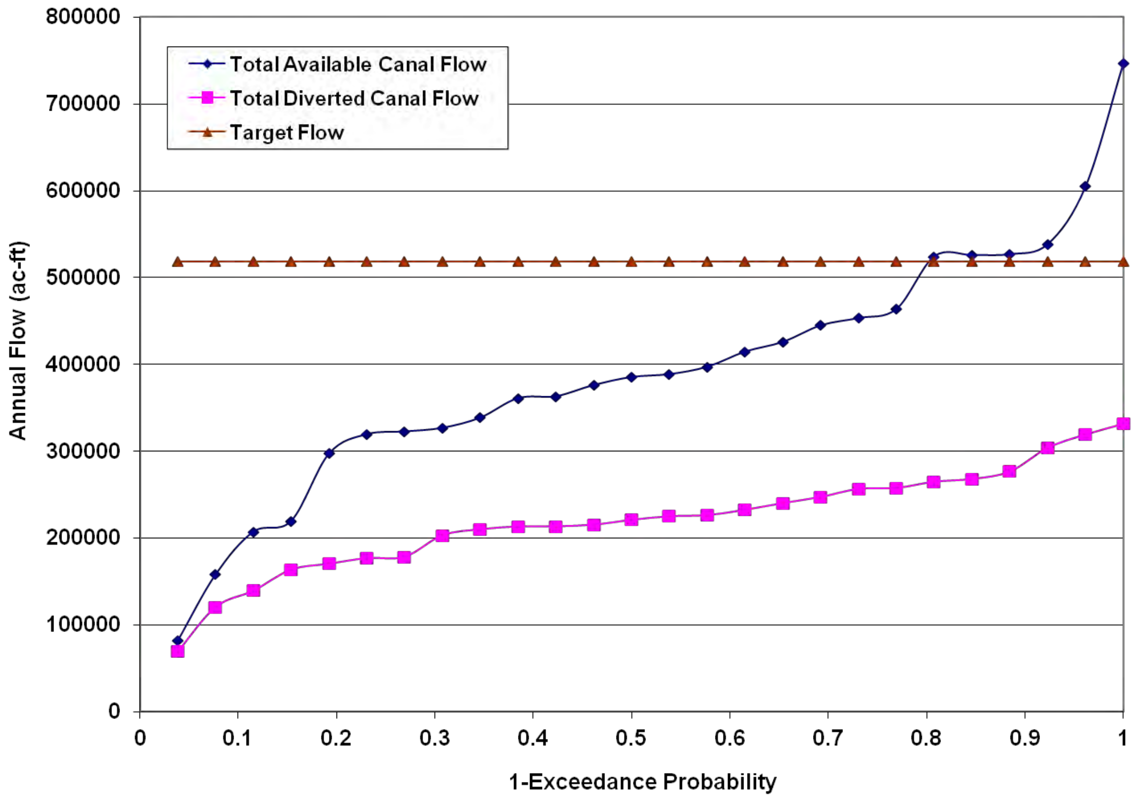

Figure 4. Updated (1986–2011) plot of annual canal discharges and diverted water from the BBCW PIR.

5.1.1 Existing Water Resource Protections

The BBCW Phase 1 Project is designed to utilize surface water flows or discharges to Biscayne Bay, and Annex C of the PIR states that surface water from canal discharges are needed to meet project performance. The Project does not identify groundwater to be protected nor quantify groundwater flows in terms of meeting the surface water flow target identified in the PIR. Accordingly, this project reservation will not address groundwater withdrawals. Existing consumptive use rules provide adequate protection of groundwater from future withdrawals along the coast. These criteria include restrictions on pumpage-based movement of the saltwater interface in the Biscayne aquifer (Section 3.4, *Basis of Review for Water Use Permit Application within the South Florida Water Management District* [SFWMD 2010], referred to as the Basis of Review), harmful changes to wetland hydrology (Section 3.3.1, Basis of Review), and restrictions on the use of surface and groundwater from all conveyance canals that are hydraulically connected to the Everglades. (Section 3.2.1.E, Basis of Review; **Figure 5**).

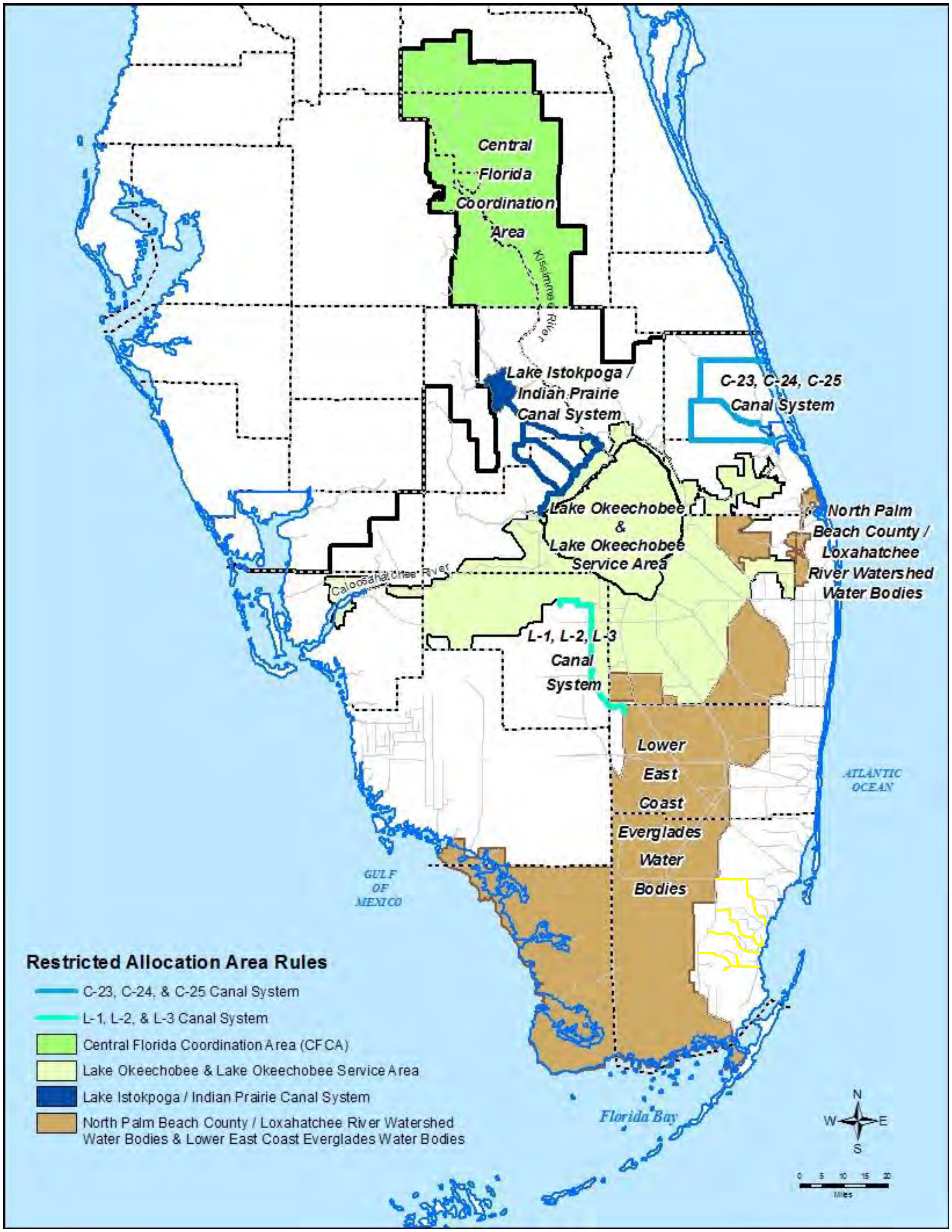

Figure 5. Areas covered by the restricted allocation rules within the SFWMD boundaries. Water within canal reaches highlighted in yellow are within the BBCW Phase 1 Project and included.

The canals that are hydraulically connected to the Everglades in the BBCWP area include the C-100C, C-1, C-102, C-103 and C-103S and a portion of the C-103N up to structure S-166.

These rules have been implemented to limit groundwater withdrawals of southern Miami-Dade water utilities and commercial uses.

Some changes in water use are expected in the future. An analysis of the effects of possible future groundwater withdrawals in southern Miami-Dade County was conducted using the District's South Florida Water Management Model (SFWMM) (SFWMD 2005). The demands for public water supply are assumed to increase by 65.7 million gallons per day (MGD) between current (i.e. 2010) and future (i.e. 2030) demands. Nearly all of these increases have already been authorized by consumptive use permits, and are typically approved with 20 year permit durations. The permittee with the greatest use is the Miami-Dade Water and Sewer Department (MDWSD). MDWSD maintains several wellfields throughout the County. Some of the wellfields with the most assumed future increase in demand are located just north and west of the BBCWP water reservation drainage basins. Other public utilities with smaller uses include the Florida Keys Aqueduct Authority, City of Homestead and Florida City. The effects of these specific differences were examined for the watershed south of the C-4 canal (**Figure 6**).

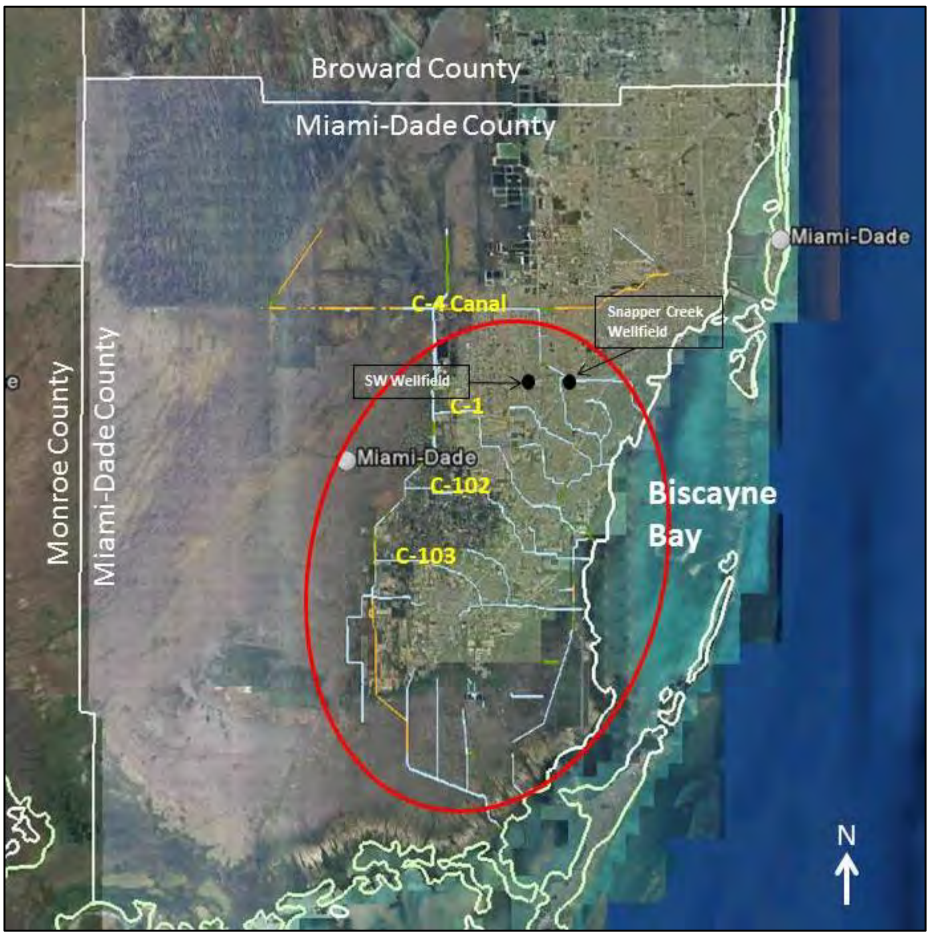

Figure 6. Area circled in red is generally the watershed south of the C-4 canal. Larger wellfields are indicated as black dots.

Canal flow rates were predicted for a 41 year simulation period based on the assumed changes in future demands from the years 2010 to 2030. The 2010 water supply demands in the model simulation represents current demands while the future projected water supply demands are estimated for the year 2030 as described in the model simulation assumptions (**Table 1**). Essentially, the primary difference between the two simulations is a change in demand based on assumed changes in land uses and existing permitted consumptive uses. The changes in canal flow rates associated with the change in demands from 2010 to 2030 were compared and quantified for the canal outfalls included in the proposed reservation rule.

Table 1. Change in volume (million gallons per day [MGD]) due to assumed changes in water demand between the years 2010 and 2030 for areas south of the C-4 canal.

Water Use Category	Change in Volume (MGD)	Percentage Change (%)
Public Water Supply	27.3*	14.9
Golf Courses	0.0	0.0
Industrial & Residential Self Supplied	0.3	8.3
Urban Landscape Irrigation	2.6	3.2
Agricultural Irrigation	-0.3	-0.6
Total Net New Allocations (Unpermitted)	2.6	

*Change is already allocated by existing consumptive use permits.

The largest differences between simulated canal discharge rates occur at S-123 (-8%) and S-21 (-5%) (**Table 2**). To better understand the potential impacts to the BBCW, the mean difference in flow rate at these structures was calculated within the targeted and maximum reserved flow rates for the individual structures (see **Appendix A**). The mean difference within the targeted flow rate at S-123 is -2.7 cfs and at S-21, -5.4 cfs. It is unlikely, assuming that such a difference actually occurred, that it would have a detectable impact to the functionality of the Project features. These results validate the assumption in the PIR that the existing allocated water uses within or adjacent to the project area are unlikely to reduce benefits.

Table 2. Simulated mean flow rates at the BBCWP coastal outfalls.

Outfall	Mean 2010 Flow Rate (cfs)	Mean 2030 Flow Rate (cfs)	Overall Percentage Change (%)	Mean Flow Rate Difference within BBCWP Flow Targets (cfs)
S-123	50.5	46.5	-8	-2.7
S-21	134.5	127.6	-5	-5.4
S-21A	61.0	60.9	-<1	0.0
S-20F	95.3	93.2	-2	-0.1

In addition to the factors listed above, future potential risk of significant new groundwater demands were considered based on the location of existing urban development and the urban development boundary within the affected basins. In some of the basins where canal reaches have not been included for protection within the proposed rule such as the C-100 basin, land use is urban, and essentially built out. New water demands are not projected in the future and are unlikely. In other areas of the western basins where canal reaches have not been included for protection within the proposed rule such as the C-102 and C-103 basins, land use is largely agricultural and rural. If any of these areas convert to urban land uses in the future, water demand will decrease, because most of the water supplied to future urban areas will be derived from existing legal users where the allocations for public water supply have already been permitted. The projected future demand for all other water use categories located south of the C-4 canal is 2.6 MGD (**Table 1**). This increase in demand does not include the projected increases for public water supply which have already been allocated in existing consumptive use permits.

In summary, the risk of significant new impacts to the water available to the Project in the future from groundwater withdrawals is small. Based on these factors, the analysis below is focused on flow within the canals themselves.

5.1.2 Summary of Analyses to Determine Flows for Each Canal

The target BBCW Phase 1 Project water flow into the bay was estimated by application of the Biscayne Bay TABS-MDS simulation model (Brown et al. 2003). The results of the simulation were given for five subregions of the project area in a 2003 memorandum from the United States Army Engineer Research and Development Center's Coastal and Hydraulics Laboratory (Richardson 2003, **Appendix B**). Enough detail is given in the memorandum that the flows can be separated by primary drainage basins since the source of the water is presumed to be water discharged at the major canal outfalls. Inflows can be estimated for the C-100 and C-1 canals, and a subtotal can be estimated for the C-102, Military, and C-103 canals as a group. The latter three canals are lumped together, because the project will include an interconnect within the L-31E borrow canal to facilitate sharing water from the C-102 and C-103 canals. Inflow from Military Canal will pass directly into Biscayne Bay when the project is built, as the water will not be diverted into wetlands, but is included in the reservation. A summary of the calculated inflows are given in **Table 3** by basin. It should be noted that, as with all simulations, the flow target given in the PIR includes some uncertainty, so it is considered an estimate.

Table 3. Summary of annual freshwater inflows (1986-2011) to meet the BBCW Phase 1 Project target by basin.

Basin	Annual Inflow		
	ac-ft per year	**ac-ft per day**	**cfs**
C-100	125,714	344.4	174
C-1	208,952	572.5	289
C-102+Military+C-103	184,093	504.4	254
Total	**518,759**	**1421.3**	**716**

Analysis of Tributary Contributions

A second step in the process is to determine the tributaries and reaches upstream of each of the coastal outfalls that contribute significant quantities of water toward meeting the individual targeted flow rates as given in **Table 3**. Daily average surface water flow results were compiled for each of the water control structures within the drainage basins for the January 1986 through December 2011 period of record as available from DBHYDRO. In some cases records have been revised due to quality assurance reviews, so a recompilation of the data is preferred to ensure that the best available information is used. Data sets within DBHYDRO are periodically reviewed for accuracy and precision and updated if necessary.

Flow data were compiled for each of the water control structures within each basin up to the western divide structures near the L-31N levee within the watershed (**Appendix C**) for the period 1986-2011. Flow duration curves and time series were plotted for each of the data sets, and correlations between each of the upstream data sets with the data sets at the coastal outfalls within each basin were calculated. Flow duration and time series plots provide a qualitative look at the magnitudes of water flow at each of the structures, and the pattern of discharges through time. Correlation statistics provide information about how well flows at individual tributary structures relate to flows at the coastal outfalls that actually discharge into the bay. A strong relationship suggests that the tributaries upstream are flowing at the same time as the coastal outfall. A weak relationship suggests that the tributaries upstream are not flowing at the same time as the coastal outfall. The most useful of these statistics are nonparametric (Kendall tau and Spearman), and calculated for data sets when the coastal outfall is actually discharging and also equal to or less than targeted flow for each outfall. By limiting the data range, it eliminates the inclusion of zero flow conditions, and very high peak flows, otherwise correlation statistics can indicate stronger relationships than during times that are actually important toward meeting project objectives. Statistics were calculated for all of the data, and by wet and dry seasons.

C-100 Basin Analysis

Fresh water is discharged into Biscayne Bay from the C-100 basin at the S-123 outfall structure, which is fed by the C-100 canal (**Figure 7**). Flow into the C-100 canal is controlled by the S-118 structure upstream, the S-120 structure on the C-100A canal, the S-119 structure on the C-100C canal, and the S-122 structure on the C-100B canal, which acts as a divide between the C-100 basin and the C-1 basin to the south. One additional structure (S-121) acts as a divide between the C-100 and C-2 basins to the north on the C-100C canal. Flow through both divide structures into the C-100 canal is insignificant as they were almost never operated within the period of record. Therefore, only contributions through S-118, S-120, and S-119 need to be examined. Summary statistics associated with the flow rates through these water control structures from 1986-2011 are summarized in **Table 4** (See **Appendix C** for detailed information).

Overall, freshwater flows discharged into Biscayne Bay through S-123 17.1 percent of the time, and contributed toward the flow targeted quantity (i.e., greater than zero and less than 173.66 cfs [4.92 m^3/s]) 10.5 percent of the time. During the time that water was flowing through S-123 within the target flow rate, some relationship existed with flows at upstream water control structures, especially at S-118 and S-119, according to the correlation coefficients. The maximum mean percentage of target flow contributed by these structures has been 0.8 percent at S-118, 0.5 percent at S-119, and 1.7 percent at S-120 (**Figure 8** and **Appendix C**). Given the small amount of time that water flow contributed toward meeting the targeted discharge into the bay, it is concluded that most of the water is captured in the reaches of canals downstream of these structures.

The key reaches of canals that contribute water include the C-100 canal from S-123 up to S-118, the C-100A canal up to S-120, the C-100C canal up to S-119, and surface water bodies connected directly to these reaches.

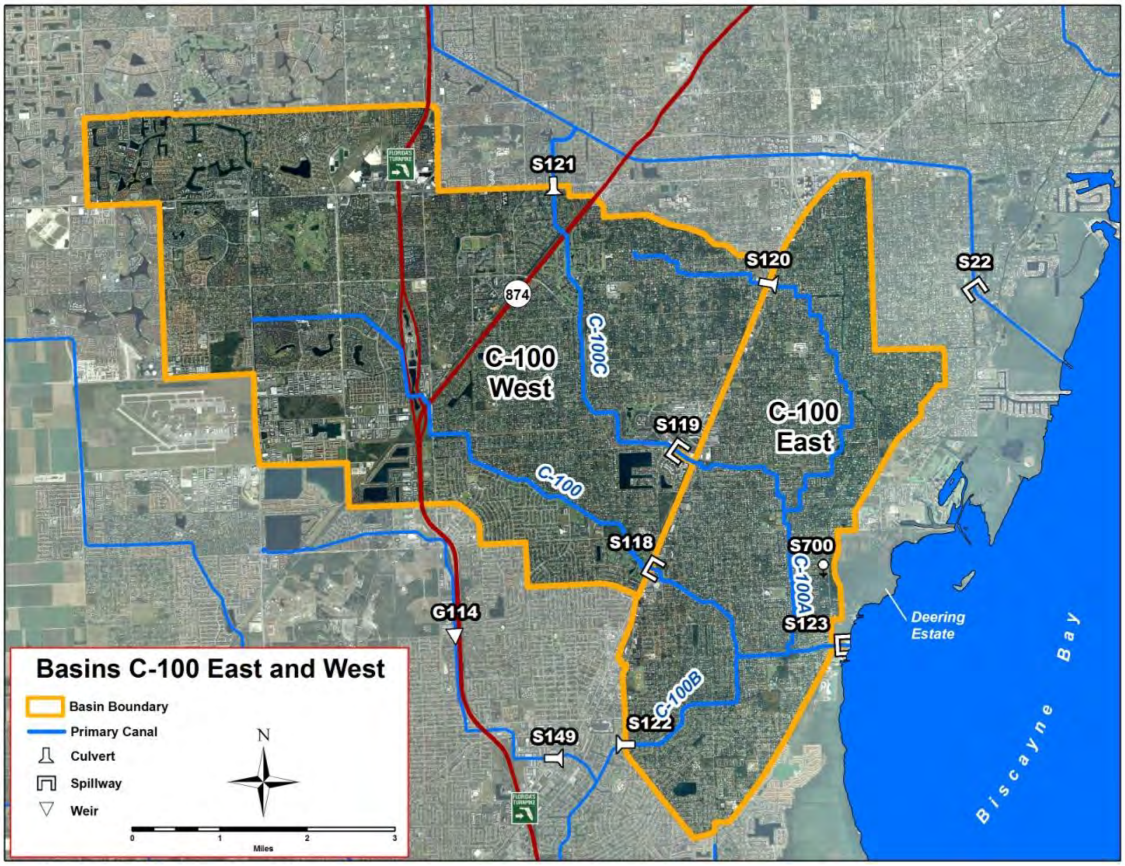

Figure 7. Map of the C-100 basin (shaded area) with associated primary canals.

Table 4. Selected water flow statistics for water control structures in the C-100 (Cutler Drain) basin from 1986-2011. Correlations are with S-123 daily flows.

Structure	Mean (cfs)	Median (cfs)	Kendall Tau-b Correlation Coefficient		Spearman Correlation Coefficient	
			Wet Season	Dry Season	Wet Season	Dry Season
S-123	53	0	-	-	-	-
S-118	12	0	0.53	0.49	0.70	0.65
S-120	12	0	0.26	0.15	0.34	0.19
S-119	8	0	0.47	0.36	0.63	0.48

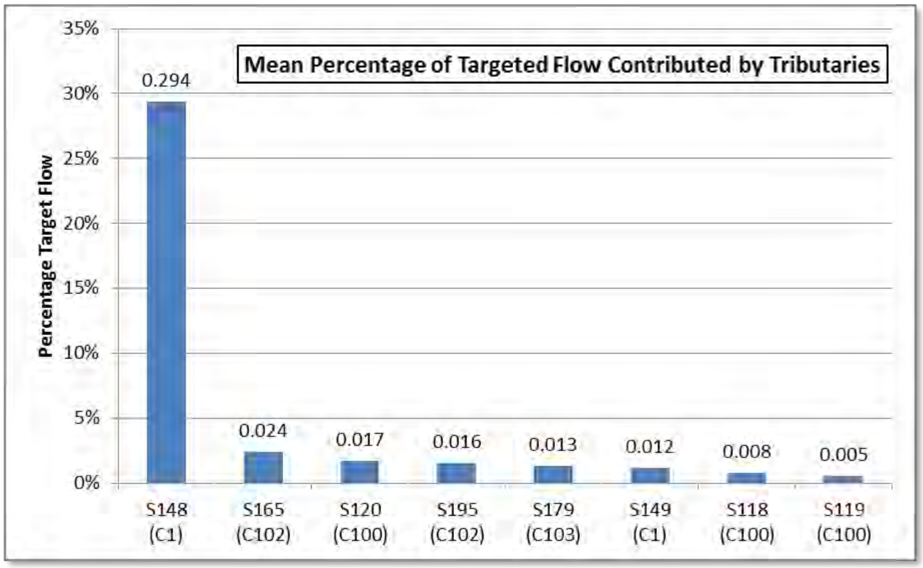

Figure 8. Ranked estimated percentage of maximum mean daily flow passing through tributary structures that contributed toward individual outfall flow targets. Structures are given on the X axis with the basin in parentheses below.

C-1 Basin Analysis

Fresh water is discharged into Biscayne Bay from the C-1 basin at the S-21 outfall structure. Water is delivered by the C-1W canal to maintain specific water levels at S-21 to prevent saltwater intrusion. Tributary to the C-1 canal is the L-31E borrow, C-1N, and C-1W canals (**Figure 9**). Water control structures immediately upstream of S-21 include S-148 (C-1W), S-149 (C-1N), and S-122. S-122 is the divide between the C-1 and C-100 basins. S-122 is almost never operated; therefore, flow into the C-1 basin is insignificant. Flow into the C-1W canal from the L-31N borrow canal can also occur through the watershed divide structure S-338. Some of the statistical results from **Appendix C** are summarized in **Table 5**.

Table 5. Selected water flow statistics for water control structures in the C-1 (Black Creek) basin from 1986-2011. Correlations are with S-21 daily flows.

Structure	Mean (cfs)	Median (cfs)	Kendall Tau-b Correlation Coefficient		Spearman Correlation Coefficient	
			Wet Season	Dry Season	Wet Season	Dry Season
S-21	174	87	-	-	-	-
S-148	140	0	0.39	0.39	0.53	0.51
S-149	11	0	-0.16	0.20	-0.20	0.24
S-338	109	76	0.21	0.23	0.28	0.32

Overall, freshwater flows discharged into Biscayne Bay through the S-21 outfall structure 65.6 percent of the time, and contributed toward the flow targeted quantity (i.e., greater than 0 and less than 288.63 cfs [8.17 m^3/s]) 42.9 percent of the time. During the time that water was flowing through S-21 within the target flow rate, a moderate relationship existed with flows at the upstream water control structure S-148 according to the correlation coefficients. The relationships between S-21 flows and S-149 and S-338 flows are relatively weak, if not negative in the case of S-149. The maximum mean percentage of target flow contributed by S-149 is 1.2 percent, and by S-148, 29.4 percent (**Figure 8**).

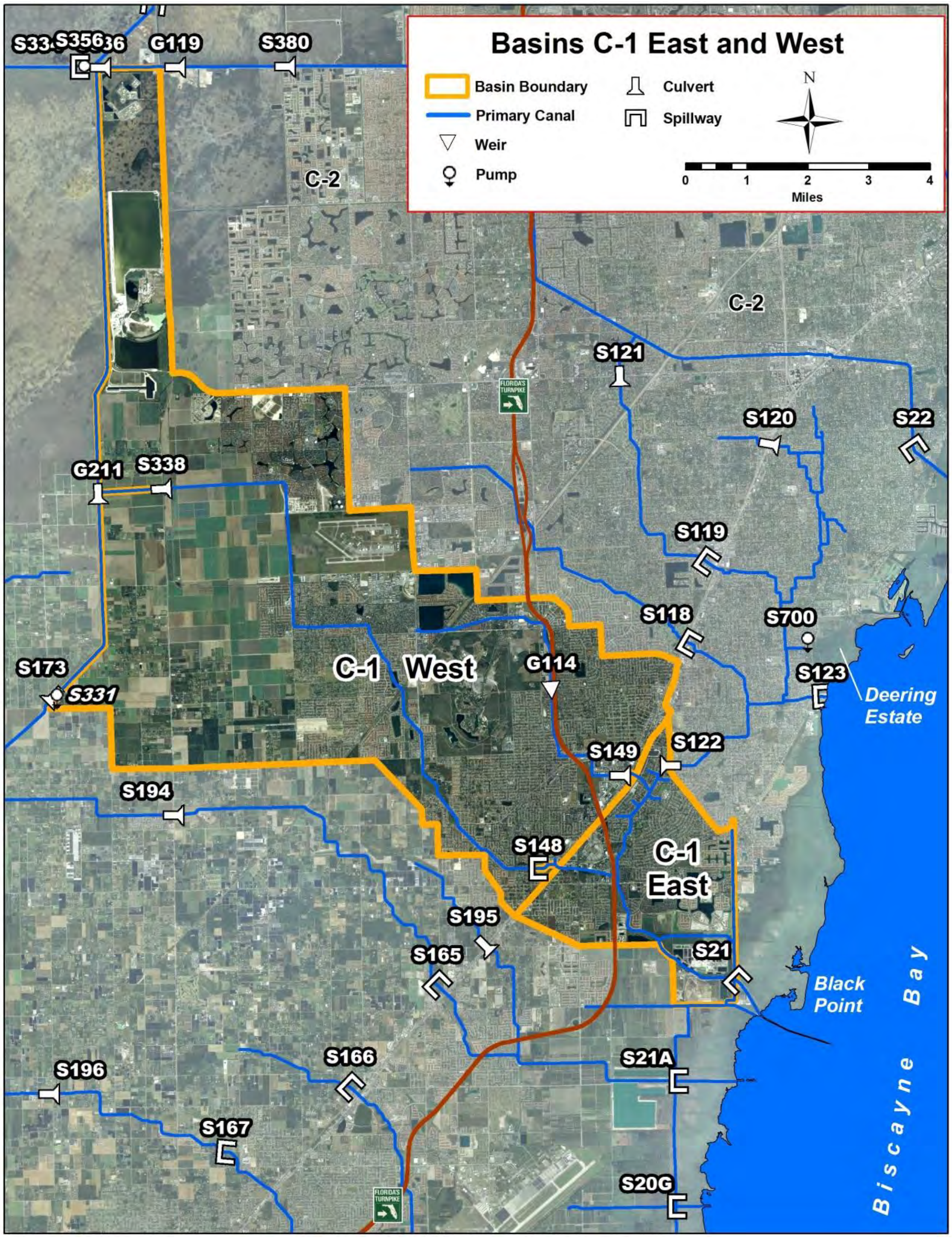

Figure 9. Map of the C-1 basin (shaded area) with associated primary canals.

The key reaches of canals that contribute water include the C-1 canal from S-21 up to S-148, the C-1W canal up to S-338, the L-31 borrow canal north of the C-1 canal, the C-1N canal up to S-149, and surface water bodies connected directly to these reaches.

C-102 Basin Analysis

Fresh water is discharged into Biscayne Bay from the C-102 basin at the S-21A outfall structure, which is fed by the C-102 canal (**Figure 10**). Tributary to the C-102 canal is the L-31E borrow, Goulds, and C-102N canals. Water control structures immediately upstream of S-21A include S-165 (C-102) and S-195 (C-102N). Flow into the C-102 canal from the L-31N borrow canal can also occur through the watershed divide structure S-194. Some of the statistical results from **Appendix C** are summarized in **Table 6**.

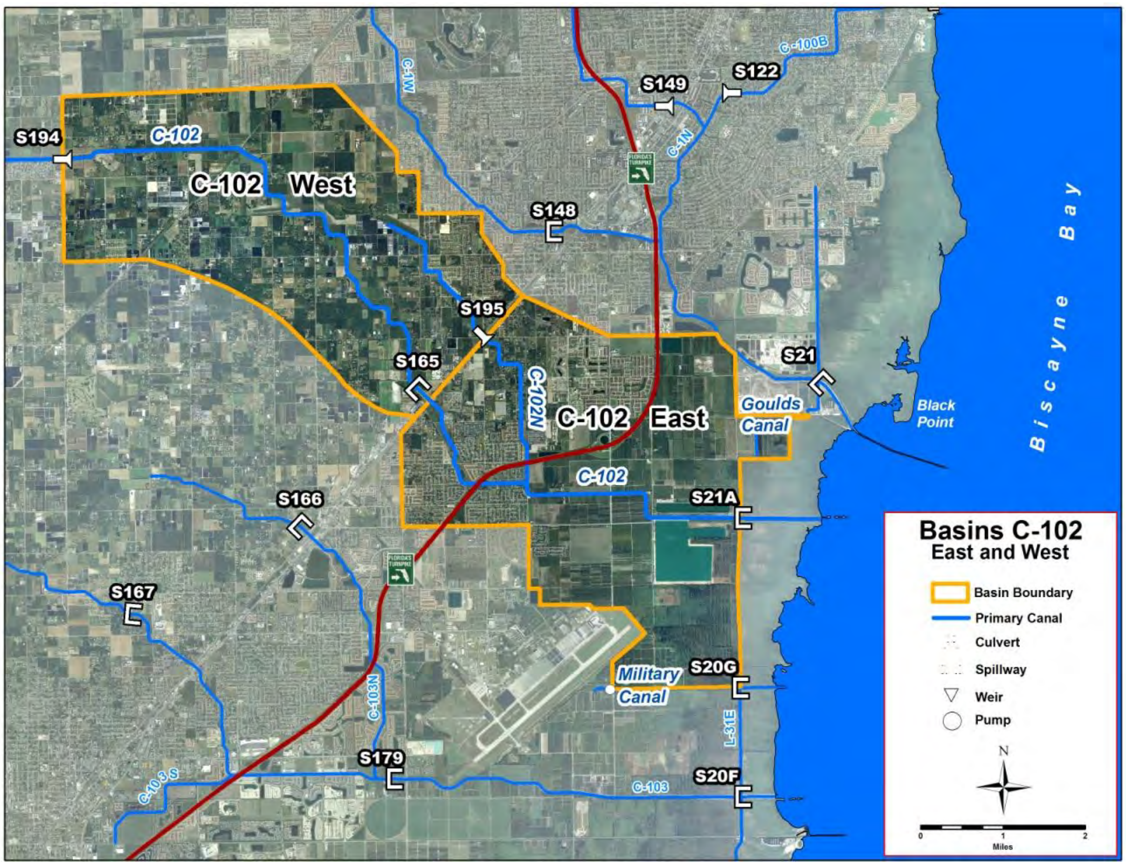

Figure 10. Map of the C-102 basin (shaded area) with associated primary canals.

The BBCW Phase 1 Project will result in a connection between the C-102 and C-103 basins, and therefore, the freshwater discharge target combines the flows from both basins. However, to test for meaningful historical relationships between flows from contributing upstream water control structures and discharges at the coastal outfalls, the basins must be analyzed separately. To facilitate this, the percentage contributions toward the overall target were approximated for each outfall based on the overall historical discharge rates. Since the flow rate at the S-21A structure has been about 51 percent of the flow at the S-20F structure (C-103 canal), it is estimated that the C-102 basin will contribute about 33.8 percent of the water toward the total, and, therefore, the approximate water discharge target would be 85.88 cfs (0.338*254.28 cfs) (2.43 m^3/s [0.338*7.20 m^3/s]).

Overall, freshwater flows discharged into Biscayne Bay through S-21A 82.8 percent of the time, and contributed toward the approximated flow targeted quantity (i.e., greater than zero and less than 85.89 cfs [2.43 m^3/s]) 38.5 percent of the time. During the time that that water was flowing through S-21A within the approximated target flow rate, no relationship existed with flows at the upstream water control structures S-165 and S-195 according to the correlation coefficients. Flows through S-165 and S-195 typically only occur during storm events when discharges into Biscayne Bay at S-21A are in excess of the approximated target. Most of the water discharged into the bay is captured in the canal reaches downstream of S-165 and S-195. The maximum mean percentage of target flow contributed by S-165 is 2.4 percent, and by S-195, 1.6 percent (**Figure 8**).

The key reaches of canals that contribute water include the C-102 canal from S-21A up to S-65, the C-102N canal up to S-195, the L-31E borrow canal between a divide at Military Canal north to Goulds Canal, and Goulds Canal

Table 6. Selected water flow statistics for water control structures in the C-102 (Princeton Canal) basin from 1986-2011. Correlations are with S-21A daily flows.

			Kendall Tau-b Correlation Coefficient		Spearman Correlation Coefficient	
Structure	**Mean (cfs)**	**Median (cfs)**	**Wet Season**	**Dry Season**	**Wet Season**	**Dry Season**
S-21A	108	75	-	-	-	-
S-165	14	0	0.02	0.06	0.03	0.07
S-195	11	0	0.00	0.05	0.00	0.06
S-194	51	0	0.05	0.09	0.07	0.10

Homestead Air Reserve Base Basin Analysis

Fresh water is discharged into Biscayne Bay from the Homestead Air Reserve Base (formerly Homestead Air Force Base) basin at the S-20G outfall structure, which is fed by Military Canal (**Figure 11**). The canal is separated hydrologically from the primary surface water systems to the north and south. Divide structures separate Military Canal from the L-31E borrow canal. A 668-cfs (19-m^3/s) pump station and manual screw gates are maintained by the Homestead Air Reserve Base located at a reservoir at the eastern edge of the Base. The pump station and water control gates drain the areas that were once part of the larger Homestead Air Force Base via a stormwater management system. The pump station is used on occasion to mitigate flooding of the runway and flight line area, pumping into Military Canal. Some of the statistical results from **Appendix C** are summarized in **Table 7**. No correlations with tributary flows were calculated for the Military Canal system, because no major tributaries are associated with it.

Freshwater discharges through S-20G affect salinity within Biscayne Bay, and therefore are important ecologically. A specific targeted flow range has not been defined for the discharges at S-20G since these are relatively small compared to discharges from the C-103 and C-102 basins, but the water discharged is considered important for meeting the salinity target nearshore.

The key reaches of canal that contribute water include Military Canal from S-20G up to the Homestead Air Reserve Base pump station.

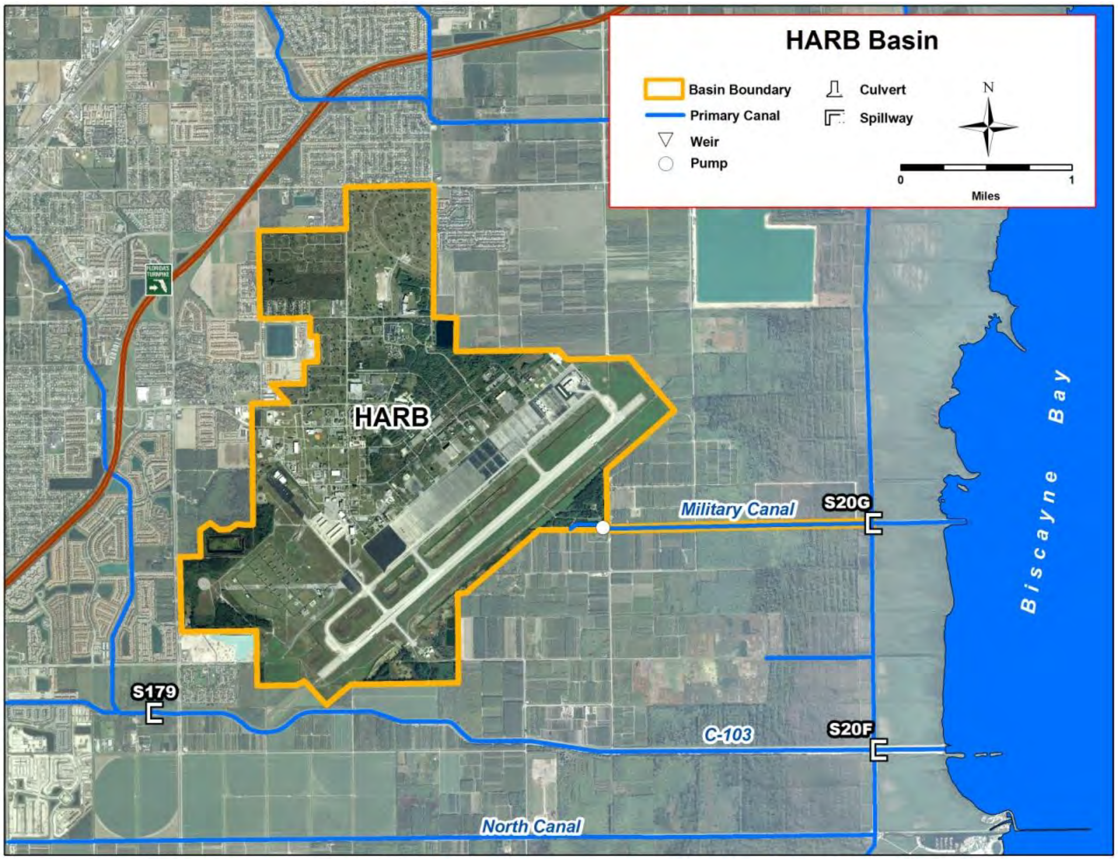

Figure 11. Map of the Homestead Air Reserve Base basin (shaded area) with associated canal.

Table 7. Selected water flow statistics for water control structures in the Homestead Air Reserve Base (Military Canal) basin from 1986-2011.

Structure	Mean (cfs)	Median (cfs)
S-20G	19	0

C-103 Basin Analysis

Fresh water is discharged into Biscayne Bay from the C-103, North and Florida City basins at the S-20F outfall structure, which is fed by the C-103 canal (**Figure 12**). Tributary to the C-103 canal is the L-31E borrow, North, Florida City, C-103N, and C-103S canals. A water control structure immediately upstream of S-20F is S-179. Divide structures limit water flow in the L-31E borrow canal to the reach between the Military and Florida City canals. A divide structure is to be placed in the Florida City Canal at Southwest 107th Avenue in 2013 by Miami-Dade County. It is assumed that the future Florida City structure will result in some groundwater recharge into the Model Land basin to the south, restoring water levels and wetlands to some extent. Since this is part of the original objectives of the BBCW Phase 1 Project, and is consistent with the full conceptual build-out of the Project (Alternative O), it is not considered detrimental to the Project objectives. Water control structures immediately upstream of S-179 include S-167 (C-103) and S-166 (C-103N). Flow into the C-103 canal from the L-31N borrow canal can also occur through the watershed divide structure S-196. Some of the statistical results from **Appendix C** are summarized in **Table 8**.

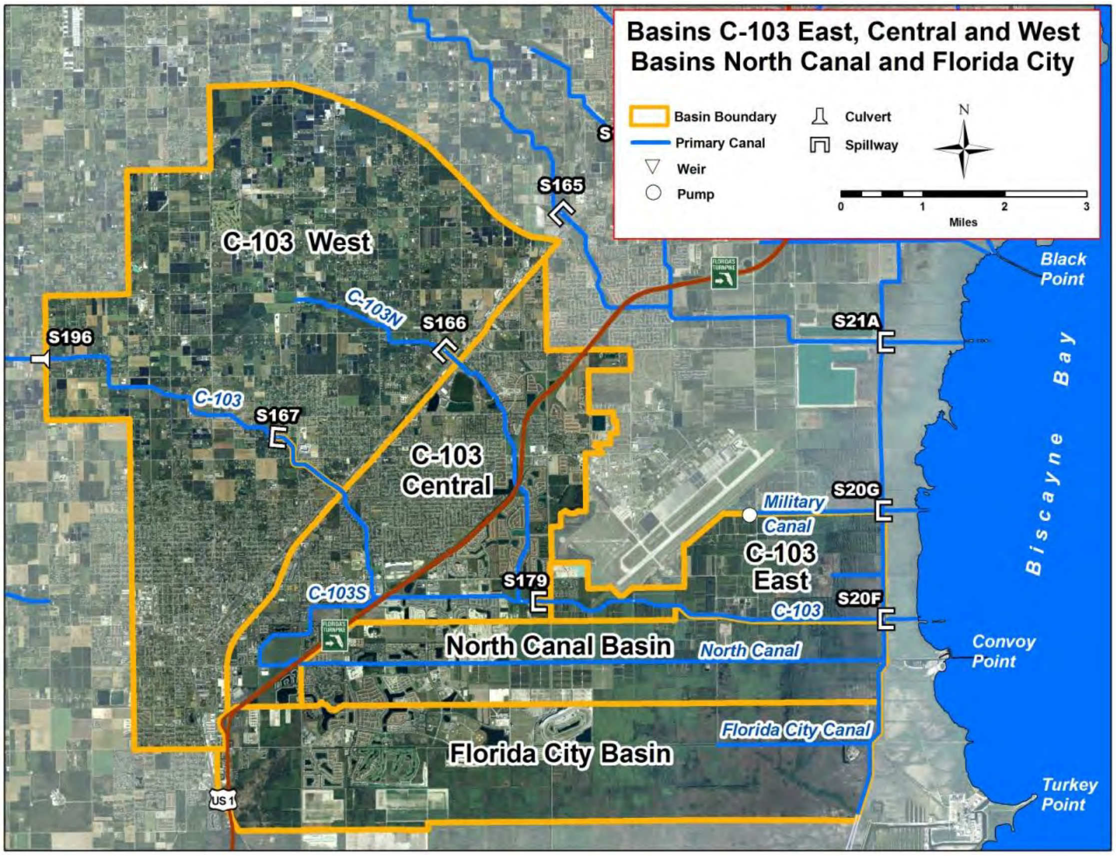

Figure 12. Map of the C-103 basin (shaded area) with associated primary canals.

As described above, the BBCW Phase 1 Project will result in a connection between the C-102 and C-103 basins, and therefore, the freshwater discharge target combines the flows from both basins. However, to test for meaningful historical relationships between flows from contributing upstream water control structures and discharges at the coastal outfalls, the basins must be analyzed separately. To facilitate this, the percentage contributions toward the overall target were approximated for each outfall based on the overall historical quantities discharged. It is estimated that the C-103 basin will contribute about 66.2 percent of the water needed toward the BBCW Phase 1 Project target flow and therefore, the approximate water discharge target would be 168.33 cfs (0.662*254.28 cfs) (4.77 m^3/s [0.662*7.20 m^3/s]).

Overall, freshwater flows discharged into Biscayne Bay through S-20F 83.5 percent of the time, and contributed toward the approximated flow targeted rate (i.e., greater than zero and less than 166.34 cfs [4.71 m^3/s]) 41.4 percent of the time. During the time that water was flowing through S-20F within the approximated target flow rate, no relationship existed with flows at the upstream water control structure S-179, or structures upstream of S-179 according to the correlation coefficients. Flows through these structures typically only occur during storm events when discharges into Biscayne Bay at S-20F are in excess of the approximated target. Most of the water discharged into the bay is captured in the canal reaches downstream of S-179. The maximum mean percentage of target flow contributed by S-179 is 1.3 percent (**Figure 6**).

The key reaches of canals that contribute water include the C-103 canal from S-20F up to the S-179, the North Canal, the Florida City Canal up to new structure at Southwest 107th Avenue, and the L-31E borrow canal between the divide at Military Canal south to the divide near the Florida City Canal. The C-103 canal is protected by the restricted allocation rule.

Table 8. Selected water flow statistics for water control structures in the C-103 (Mowry Canal) basin from 1986-2011. Correlations are with S-20F daily flows.

Structure	Mean (cfs)	Median (cfs)	Kendall Tau-b Correlation Coefficient		Spearman Correlation Coefficient	
			Wet Season	Dry Season	Wet Season	Dry Season
S-20F	194	137	-	-	-	-
S-179	39	0	0.09	-0.10	0.12	-0.12
S-167	10	0	0.02	0.03	0.03	0.04
S-166	6	0	0.04	0.06	0.05	0.07
S-196	20	0	-0.06	0.09	-0.08	0.12

5.1.3 Canal Reaches Identified for Protection

The portions of the following drainage canals that contribute to the total available canal flow into Biscayne Bay are proposed for protection by the reservation rule below.

All surface water contained within the nearshore zone of central Biscayne Bay from the Deering Estate park south to the Turkey Point channel is to be reserved from allocation. Surface water flowing into the nearshore zone of central Biscayne Bay as identified below is to be reserved from allocation. **Figure 13** shows the nearshore zone of central Biscayne Bay and locations of water within the canal reaches that will be reserved for the protection of fish and wildlife.

Surface water flowing into the nearshore zone of central Biscayne Bay as identified below is to be reserved from allocation as depicted on **Figure 13**.

Surface water flows through S-123 contributed by the following:

a. The reach of the C-100A canal upstream of S-123 to S-120 and contributed by all integrated conveyance canals.

b. The reach of the C-100C canal upstream of S-123 to S-119 and contributed by all integrated conveyance canals.

c. The reach of the C-100 canal upstream of S-123 to S-118 and contributed by all integrated conveyance canals.

d. The reach of the C-100B canal upstream of S-123 to S-122 and contributed by all integrated conveyance canals.

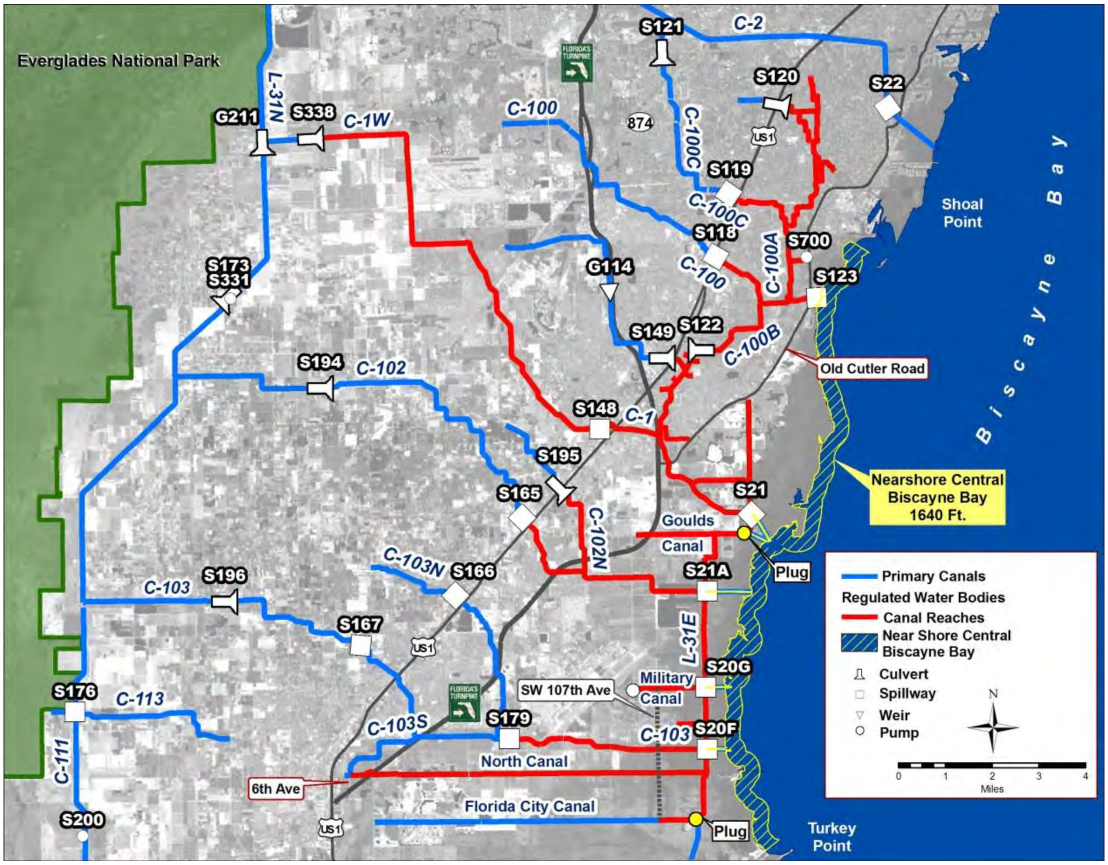

Figure 13. Proposed surface water bodies to be protected under a CERP BBCW (Phase 1) reservation rule.

Surface water flows through S-21 contributed by the following:

a. The reach of the L-31E borrow canal upstream of S-21 to the canal terminus.

b. The reaches of the C-1 canal upstream of S-21 to S-122 and S-149 and contributed by all integrated conveyance canals.

c. The reaches of the C-1 canal upstream of S-21 to the C-1W canal and S-338 and contributed by all integrated conveyance canals.

Surface water flows through S-21A contributed by the following:

a. The reaches of the C-102 canal connecting to the C-102N canal upstream of S-21A to S-195.

b. The reach of the C-102 canal upstream of S-21A to S-165.

c. The reach of the L-31E borrow canal upstream of S-21A to its terminus near S-21 including the Gould's Canal.

d. The reach of the L-31E borrow canal upstream of S-21A south to S-20G.

e. All integrated conveyance canals connected to the canal reaches identified in (a)–(d) above.

Surface water flows through S-20G contributed by the following:

a. The reach of Military Canal upstream of S-20G to the Homestead Air Reserve Base pump station.

Surface water flows through S-20F contributed by the following:

a. The reach of the C-103 canal upstream of S-20F to S-179.

b. The reach of the L-31E borrow canal upstream of S-20F to S-20G and contributed by all integrated conveyance canals.

c. The reach of the L-31E borrow canal from S-20F south to the North Canal and the reach of the North Canal to the C-103S.

d. The reach of the L-31E borrow canal from S-20F south to the Florida City Canal and the reach of the Florida City Canal up to Southwest 107^{th} Avenue.

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Appendix A: Estimate of Inflows by Canal to Meet the Biscayne Bay Coastal Wetlands Phase 1 Project Performance Target

Richard Alleman

The *Central and Southern Florida Project Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Project Phase 1 Final Integrated Project Implementation Report and Environmental Impact Statement* (USACE and SFWMD 2012), referred as “the PIR” in the remainder of this appendix, describes a project performance measure for nearshore salinity. According to Annex C of the PIR, 517,000 acre-feet (ac-ft) of water per year is estimated to be needed to meet a salinity target of about 20 nearshore in the Biscayne Bay Coastal Wetlands (BBCW) Phase 1 Project area. The estimate was derived from application of the Biscayne Bay TAB-MDS model (Richardson 2003), which is discussed in more detail in **Appendix B**. The total annual inflow from the modeling results was actually 518,759 ac-ft. The difference between the PIR value of 517,000 ac-ft and the actual value is likely due to estimates taken from Figure 21 in the memorandum (Richardson 2003) rather than the model output, but nonetheless well within the certainty of the approach used to determine the target and response in Biscayne Bay.

The results of the simulation were given for five subregions of the project area in the memorandum (see Figure 21, Appendix B). The five subregions do not coincide exactly with the canal basins that supply the water. To obtain the level of detail needed for creating a reservation rule, flows contributed by each canal toward the target must be determined. These estimates can be based on Figures 8 through 12 in the memorandum, the number of creeks in each group, and the quantity supplied by each creek to meet the target. Since the source of water into the creeks is presumed to be from the nearby canals, the flows can be regrouped by canal basin (**Figure A-1**) and the quantity of freshwater inflow to meet the salinity target can be estimated for each canal.

Inflows are estimated for the C-100 and C-1 canals. Also a subtotal is estimated for the C-102, Military, and C-103 canals as a group. These three canals are lumped together because the BBCW Phase 1 Project will include an interconnect within the L-31E borrow canal to facilitate sharing water from the C-102 and C-103 canals. Inflow from the Military Canal will pass directly into Biscayne Bay when the project is built, as the water will not be diverted into wetlands. Nevertheless, the inflow from Military Canal reduces salinity in the nearshore environment, so the flows contribute toward meeting the salinity target. A summary of the inflows are given in **Table A-1** by canal or canal group.

The quantity of water supplied by each primary canal was calculated using creeks associated with the water supplied by a specific canal or canal group (**Table A-2**). This worked out cleanly except for one creek. Creek 33 was shared evenly by both the C-1 and C-102 canals since input from both of these canals influence salinity at this location. Therefore, 50 percent of the inflows of Creek 33 were added to the C-1 canal, and 50 percent were added to the group containing the C-102, Military, and C-103 canals.

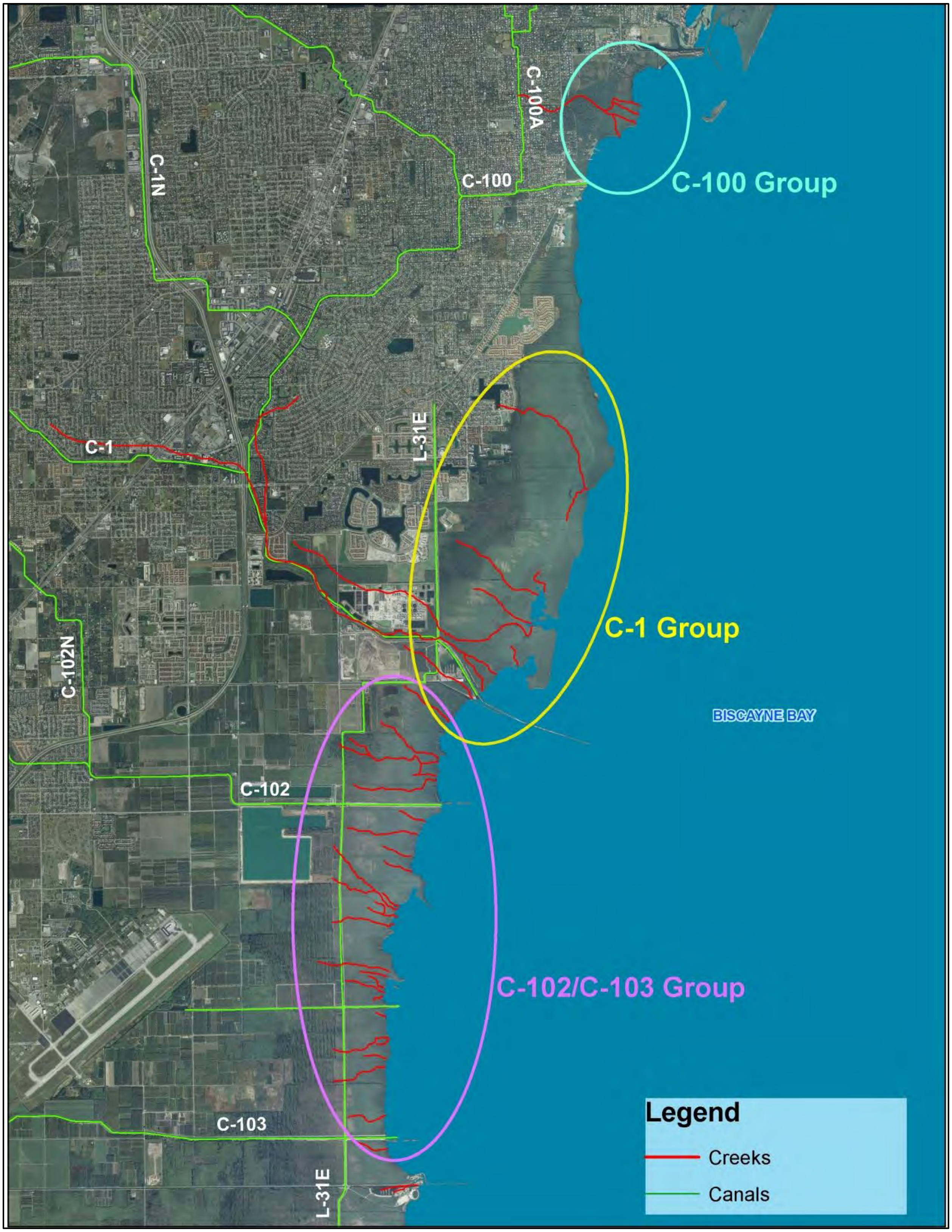

Figure A-1. Creeks (red lines) were grouped by basins associated with primary canals.

Table A-1. Summary of annual freshwater inflows to meet the BBCW Phase 1 Project target by canal.

Canal(s)	Annual Inflow (ac-ft)
C-100	125,714
C-1	208,952
C-102 + Military + C-103	184,093
Total	**518,759**

Table A-2. Target inflows to Biscayne Bay based on individual creeks by canal (in ac-ft).

Canal	Creek Number	Group Number	Daily Flow per Creek	Note	Daily Inflow per Canal	Annual Inflow per Canal
C-100	47	5	172.21		344.42	125,713.68
	48	5	172.21			
C-1	33	2	16.86	½ of flow	572.47	208,952.52
	36	3	13.71			
	41a	4	180.63			
	41b	4	180.63			
	43	4	180.63			
C-102+ Military+ C-103	1	1	36.28		504.36	184,092.82
	2	1	36.28			
	3	1	36.28			
	6	1	36.28			
	8	1	36.28			
	13	1	36.28			
	16	2	33.73			
	17b	2	33.73			
	18	2	33.73			
	22	2	33.73			
	23	2	33.73			
	25	2	33.73			
	26	2	33.73			
	30	2	33.73			
	33	2	16.86	½ of flow		

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Richardson, T. 2003. Memorandum to the Commander, U. S. Army Corps of Engineers District, Jacksonville. Memorandum for record that consists of a report detailing the findings of the preliminary scenario runs for the Biscayne Bay Coastal Wetlands Project. From Thomas Richardson, Director, Coastal and Hydraulics Laboratory, United States Army Engineer Research and Development Center, Vicksburg, MS. Dated December 20, 2003.

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Appendix B: Memorandum for Commander, U. S. Army Engineer District, Jacksonville

Following is the entire content of a memorandum sent by Thomas Richardson, the Director of the United States Army Engineer Research and Development Center's Coastal and Hydraulics Laboratory in Vicksburg, Mississippi, to the Commander of the United States Army Corps of Engineers Jacksonville, District on December 20, 2003 describing results from application of a hydrodynamic model for Biscayne Bay. Some reformatting was necessary so the content could fit into this document, but none of the content has been altered.

CEERD-HC-ES 20 Dec 2003

MEMORANDUM FOR Commander, U. S. Army Engineer District, Jacksonville,
ATTN: CESAJ-EN-HI (Mr. Mitch Granat), (Prudential Building)
701 San Marco Blvd.**,** Jacksonville, FL 32207

SUBJECT: Report on the results of preliminary scenario runs for the Biscayne Bay Coastal Wetlands project. These runs are intended to yield rough estimates of the relationship between freshwater discharge distribution and volume, and the near-shore salinity regime of Biscayne Bay in the Coastal Wetlands study area.

1. Enclosed please find the Memorandum for Record that consists of a report detailing the findings of the preliminary scenario runs for the Biscayne Bay Coastal Wetlands project.

2. If you have questions concerning the information provided, please contact Mr. Gary Brown at 601-634-4417.

Encl

THOMAS RICHARDSON
Director
Coastal and Hydraulics Laboratory

Background

1. The purpose of the preliminary scenario runs is to ascertain some general information about the relationships between freshwater inflows to Biscayne Bay, and the near-shore salinity regime in the Biscayne Bay Coastal Wetlands project area (see Figure 1). These preliminary scenario runs were done using an existing hydrodynamic/salinity model and model mesh that had been developed for a previous study of the entire Bay (see Brown, et. al. 2003)). Although this existing mesh is not appropriate for use in the final scenario analyses for the Biscayne Bay Coastal Wetlands project, it can be used to ascertain some general information about the system, which in turn could be used as guidance for selecting final design alternatives to be simulated in the final scenario runs. These final scenario runs will be run with a modified model and model mesh that are appropriate for use in this study.

2. The computer code used in this study is the TABS-MDS finite element numerical model. It is an ERDC modified version of the RMA10 numerical model (King, 1988). It has been used extensively in previous studies of multiple estuaries.

Preliminary Scenario Runs Boundary Conditions and Specifications

A. Simulation period

3. The model simulation period extends from August, 1997- July, 1998. July, 1997 is used as spin-up, i.e. the model is allowed to run for this month so that the hydrodynamics and salinity can circulate long enough for the system to achieve dynamic equilibrium.

B. Boundary Conditions

4. The model boundary conditions and the sources of the boundary condition data are given as follows:

- Flows at 16 coastal structures: taken from the South Florida Water Management District (SFWMD) DBHYDRO database, recently updated by Dr. Matahel Ansar to account for the influence of the tide on the discharge equations at the structures.
- Tide: taken from Coastal and Hydraulics Laboratory (CHL)/Biscayne National Park (BNP) data gathered at CTD 9 (located in the Safety Valve). The data was missing for Jul 98, so data taken from the NOAA gage at Virginia Key was used to replace this missing data.
- Ocean Salinity: taken from measured monthly averaged ocean salinity at Alina's Reef.
- Wind: Taken from CHL/BNP data gathered at Convoy Point. This was then corrected for wind gage elevation and for shoreline effects on the wind.
- Rainfall: taken from CHL/BNP data gathered at Convoy Point. The data was missing for July 98, so data taken by the SFWMD at S-21 was used to replace this missing data.
- Evaporation: taken from SFWMD data collected at Hialeah, Florida.
- Groundwater Inflow: estimated values supplied by Dr. Chris Langevin at USGS (Langevin, 2000).

C. Preliminary Scenario Run Configurations

5. There are a total of 10 preliminary scenario runs that were conducted. Preliminary scenario runs 1- 9 were designed to determine the impacts on the near-shore salinity regime of making

various independent adjustments to the spatial and temporal distribution of fresh water inflow to the Bay, as well as adjustments to the total volume of inflow to the Bay. The 10th preliminary scenario run represents an inverse modeling approach. That is, the spatial and temporal distribution of the inflow is regulated such that the target near-shore salinity is always achieved. This approach is designed to estimate the both the total volume and the temporal and spatial distribution of inflow required to maintain the desired salinity regime in the near-shore.

6. Table 1 shows a matrix of the various adjustment parameters investigated in preliminary scenario runs 1-9. The following discussion gives definitions and descriptions of these parameters.

Table 1: Preliminary Scenario Run Matrix

Scenario	Flow in existing canals	Flow in 21 tidal creeks	Flow in 8 primary tidal creeks	15K Ac-ft of additional storage	120K Ac-ft of available water	15K Ac-ft of additional storage and 120K ac-ft of available water
Ps1	X					
Ps2		X				
Ps3			X			
Ps4		X		X		
Ps5			X	X		
Ps6		X			X	
Ps7			X		X	
Ps8		X				X
Ps9			X			X

Figures 2 – 6 depict the existing coastal canals, the 21 tidal creeks, and the 8 primary tidal creeks discussed below.

Flow in Existing Canals: the inflows are directed to the Bay via the existing coastal canals. These canals are C-100, C-1, C-102, Military Canal, and C-103. The corresponding discharge control structures at each of these canals are: S-123, S-21, S-21A, S20G, S20F.

Flow in 21 Tidal Creeks: the inflows in the canals in the study area are directed to the Bay via 21 historic tidal creeks. The inflows are distributed as follows: The flow from C-102, Military Canal, and C-103 is combined and distributed evenly among 15 creeks located between Convoy Point (just south of C-103) and Black Point (located at the C-1 outfall) (see Figures 2-4). The flow from the C-1 canal is distributed evenly among 4 creeks located just north of the C-1 Canal (see Figures 4 and 5). The flow from C-100 is distributed evenly between 2 creeks located to the north of C-100 (see Figure 6).

Flow in 8 Primary Tidal Creeks: the inflows in the canals in the study area are directed to the Bay via 8 historic tidal creeks. These creeks were selected from among a set of creeks identified by Dr. Jack Meeder of the Southeastern Environmental Research Center as creeks that show evidence of relatively high historical discharges. The inflows are distributed as follows: The flow from C-102, Military Canal, and C-103 is combined and distributed evenly among the 5 primary creeks located between Convoy Point (just south of C-103) and Black Point (located at the C-1 outfall) (see Figures 2-4). The flow from the C-1 canal is distributed evenly between 2 primary creeks located just north of the C-1 Canal (see Figures 4 and 5). The flow from C-100 is routed to 1 primary creek located to the north of C-100 (see Figure 6).

<u>15K Ac-Ft of Additional Storage</u>: the inflows in the canals in the study area are routed through a storage basin with 15K Acre-feet of capacity. The storage basin is regulated as follows:

If the storage basin is less than half full, the total discharge from the storage basin to the Bay is set at 420 ac-ft/day. This figure is based on estimates given by Dr. Jack Meeder of the required volume of water to maintain the desired near-shore habitat in the study area (Meeder, et. al. 2003). This total volume corresponds to 20 ac-ft/day/creek for the 21 creek simulations, and 52.5 ac-ft/day/creek for the 8 creek simulations.

If the storage basin is more than half full, the discharge increases linearly from 420 ac-ft/day at half the basin capacity, to 1260 ac-ft/day at full basin capacity. If the basin exceeds capacity, then the water is routed directly into the coastal creeks without any attenuation in the storage basin.

Note that all of the water at the 5 coastal structures is routed through the basin, and the outflow from the basin to the Bay is distributed evenly among all of the coastal creeks (i.e. 21 tidal creeks, or 8 primary tidal creeks, depending on the scenario).

<u>120K Ac-Ft of Available Water</u>: the inflows in the canals in the study area are routed through the coastal creeks. The flows are routed according to the rules established for each set of creeks (see <u>Flow in 21 Tidal Creeks</u> and <u>Flow in 8 Primary Tidal Creeks</u> above). If the discharge to the Bay is high, then the inflow hydrograph is unaltered: the flow is merely redistributed to the Bay according to the groupings described above. However, if the discharge falls below a specified minimum threshold, then water is taken from the available 120K ac-ft of storage and is used to maintain the discharge at the specified minimum threshold until the incoming discharge increases above the threshold again.

This specified minimum threshold is the same as the minimum flow established above for the 15K ac-ft of additional storage, i.e. 20 ac-ft/day/creek for the 21 creek simulations, and 52.5 ac-ft/day/creek for the 8 creek simulations.

<u>15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water</u>: this configuration functions very much like the 15K ac-ft of additional storage configuration. The difference is that the supplemental water is used to maintain the minimum discharge threshold if the water in the storage basin is completely exhausted. Hence, the outflow is never allowed to drop below the specified minimum threshold value.

Since the storage basin stores the water from all 5 coastal canals, the outflow from the basin to the Bay is distributed evenly among all of the coastal creeks (i.e. 21 tidal creeks, or 8 primary tidal creeks, depending on the scenario).

Figure 7 shows the cumulative inflow hydrographs that result from each of these configurations. Note that the 120K Ac-Ft of available water actually adds to the total volume of inflow, whereas the 15K Ac-Ft of storage merely redistributes the timing of the inflow, storing water during the wet season and releasing it during the dry.

7. The 10th preliminary scenario run is designed to force the model to supply whatever amount of freshwater is needed to maintain a stable mesohaline environment in the Coastal Wetlands study area. The following describes how this was implemented in the model.

Based on conservation of mass principles, an equation has been developed that can be used to prescribe the inflow to Biscayne Bay. The equation is as follows:

$$q_{IN} = \frac{q_{BAY}}{C_{TARGET}}\left(C - C_{TARGET}\right) \qquad (1)$$

Where:

q_{IN} = The freshwater inflow, per unit shoreline length (ft2/sec)
q_{BAY} = The net contribution of water from the Bay, per unit shoreline length (ft2/sec)
C_{TARGET}= The target salinity concentration at a selected near-shore location (ppt)
C = The salinity concentration measured in the model at the selected near-shore location (ppt)

This equation is used to prescribe the inflows to the Bay. The C values are measured values at a distance of 100 to 200m from the shoreline. The shoreline is broken into segments that correspond to natural groupings of the coastal creeks. For this scenario, the 21 tidal creek configuration is used. The creeks are divided into 5 separate groups. Each group is assigned a unique location in the near-shore where the salinity is measured. The total inflow for that group is then adjusted to drive the measured salinity towards the target salinity (using Equation 1). The inflow is evenly divided among the all the creeks associated with that group. Figures 8-12 show the groupings and the corresponding near-shore salinity measurement locations.

In order to solve Equation 1, an estimate of the average flux of water from the Bay to the near-shore is required. The following approximate values were obtained by examining model results and field data from the Biscayne Bay Phase 1 study:

Average net velocity towards the near-shore (v)= 0.2 ft/sec

Average depth (d)= 3 ft

q_{BAY} = vd = 0.6 ft^2/sec

Note that this is merely a gross approximation of this flux. It is not necessary to know the exact value of this flux, because the model will be continuously adjusting the inflows to drive the measured salinity toward the target salinity value.

Results

8. Figure 13 is useful for showing the effect of distributing the fresh water inflow amongst 21 tidal creeks and 8 primary tidal creeks. The figure depicts the average Bay salinity from August 97 – October 97 for flow distributed via 3 different mechanisms: the existing canals, the 21 creek configuration, and the 8 creek configuration. Note that distributing the flow to the creeks does indeed tend to spread the fresh water longitudinally along the shoreline. Specifically, the high flow observed in the existing configuration at C-103 is effectively distributed along the shoreline.

This results in a more efficient use of the available fresh water, with respect to nearshore habitat restoration goals.

9. The 21 creek configuration is somewhat more efficient at distributing the flow along the shoreline. In most locations the difference is negligible; diffusion in the Bay tends to obscure the difference in salinity impacts at a given location between 1 large creek and several closely spaced smaller creeks. However, there are some locations, such as at the C-103 canal and in the embayment just north of the C-1 canal, where there is no creek in the 8 creek configuration discharging to the Bay. In these locations, the differences between the 2 distribution configurations are the most pronounced.

10. Figures 14-19 are given in order to determine the impacts of the various preliminary scenario inflow configurations on the salinity of the Bay. Figures 14-16 show average salinity plots over 3 separate time intervals: August 97 – October 97, November 97 – May 98, and June 98 – July 98. The analysis was divided up this way because the 97 –98 flow year was atypical with respect to seasonal rainfall and runoff. Specifically, the dry season months (November 97 – May 98) were actually relatively wet, and the later wet season months (June 98 – July 98) were exceptionally dry.

11. Figure 17 shows the percent of time (over the course of 1 year) that the model salinity falls outside of the mesohaline range (here defined as 5 – 20 ppt). Figure 18 shows the maximum continuous time that the salinity is outside of the mesohaline range. The contour interval is from 0 to 28 days, (28 days is an estimate given by Greg Graves, Florida Department of Environmental Protection, of the maximum continuous time that the salinity can be outside of the mesohaline range in a viable estuarine habitat).

12. In Figures 14-18 there are 5 images. They represent values computed for each of 5 preliminary scenario configurations. In each of these figures, the 21 creek configuration simulations have been chosen for demonstration purposes; however, the 8 creek configuration simulations show the same trends as do the 21 creek configuration simulations, and could have been used instead. (see, for example, Figure 19, which shows the similarity of the impacts observed in the 8 creek and 21 creek scenarios for a given fresh water discharge configuration)

13. The 5 preliminary scenario configuration simulations shown in Figures 14 –18 are as follows:

- Existing flows [Ps2]
- 15K ac-ft of additional storage [Ps4]
- 120K ac-ft of available water (85 K is actually utilized) [Ps6]
- 15 ac-ft of additional storage and 120K ac-ft of available water (7K is actually utilized) [Ps8]
- Target nearshore environment [Ps10]

14. For each of these configurations, the preliminary scenario number that corresponds to the run shown is given in brackets. Also, note that, although 120K Ac-Ft of water is available for use in scenarios Ps6 and Ps8, the total volume is not used in the either simulation, due to the rules of operation that govern the simulations. The actual amount utilized in each simulation is given in parenthesis.

15. By examining these images, it can be seen that the scenarios where additional water is supplied to the Bay show the most promise in yielding a viable estuarine habitat. This tendency

can be most readily observed in Figure 18. The reason for this is that the additional water is supplied during the dry season, when it is needed most. If this water is not available, the salinity quickly exceeds the mesohaline limit of 20 ppt.

16. The scenarios with 15K ac-ft of available storage do permit some fresh water to be stored during the wet season and released during the dry. However, the storage volume alone is not sufficient to store the amount of water needed to maintain mesohaline salinity levels throughout the dry months. At least some supplemental water is necessary to maintain these levels.

17. Figure 20 is identical to Figure 7, except that the cumulative inflow hydrograph resulting from preliminary scenario 10 has been added to the plot. This plot represents an estimate of the minimum volume of fresh water inflow required to maintain mesohaline conditions in the coastal wetlands study area for 1 year. There are several things to note about this plot. First, note that the total volume of water required (517 K ac-ft) exceeds the volume of water available from the original inflow hydrograph (400 K ac-ft) by about 120 K ac-ft. Hence, this additional volume of water is required to maintain mesohaline conditions throughout the study area. Also note that the rate of release that is required is relatively constant. This is due partly to the fact that the Bay tends to buffer the variability of the inflow, and hence the rate at which water is required to maintain the desired conditions is mostly a function of such slowly varying trends as seasonally averaged ocean salinity concentrations and seasonally averaged wind speed and direction.

18. Figure 21 is useful for investigating the variability of the fresh water requirements for each of the 5 natural groupings of creeks that are investigated in preliminary scenario 10. The figure shows the average daily volume of fresh water required for each group, given as the total volume required for that group and as the volume required per creek. The most significant trend observed in this figure is that the volume of water required for each group is inversely proportional to the degree of physical confinement at each group location, as dictated by the shoreline morphology. So, for example, the volume of water required for group 3, which is 1 creek discharging into a well-confined embayment, is only about 13 ac-ft/day. However, the volume of water required for group 4, which discharges to a region of the shoreline directly influenced by currents in the Bay, is about 545 ac-ft/day.

19. Another way to state this phenomenon is that the volume of fresh water required for a given location is inversely proportional to the residence time for that location. Hence, if the required volume of water needed for restoration of the entire coastal wetlands study area is unavailable, a targeted restoration effort could be designed to focus on regions that require the least volume of water to achieve restoration. Alternatively, the nearshore residence time of the more exposed regions of the study area could be increased by the construction of groins and other structures.

Conclusions

20. The following general conclusions can be stated for this study. Note again that these runs are intended to be preliminary, and hence the exact quantities required to achieve the desired goals for the Biscayne Bay Coastal Wetlands project should not be taken from this report. Rather, these runs are intended for use as guidance for the selection of the final alternatives to be examined in future final scenario runs.

- The 21 creek configuration is slightly more efficient at distributing the flow along the shoreline than is the 8 creek configuration, but the observed salinity trends are the same for both configurations. The most pronounced differences are observed in confined locations where the 21 creek configuration has a discharge location and the 8 creek configuration does not.

- Scenarios where additional water is supplied to the Bay show the most promise in yielding a viable estuarine habitat.

- The scenarios with 15K ac-ft of available storage do permit some fresh water to be stored during the wet season and released during the dry. However, the storage volume alone is not sufficient to store the amount of water needed to maintain mesohaline salinity levels throughout the dry months. At least some supplemental water is necessary to maintain these levels.

- Approximately 120K ac-ft/yr of additional fresh water is required to maintain mesohaline conditions throughout the study area.

- The required rate of fresh water release is relatively constant. This is due partly to the fact that the Bay tends to buffer the variability of the inflow, and hence the rate at which water is required to maintain the desired conditions is mostly a function of such slowly varying trends as seasonally averaged ocean salinity concentrations and seasonally averaged wind speed and direction.

- The volume of fresh water required for a given location is inversely proportional to the residence time for that location.

- If the required volume of water needed for restoration of the entire coastal wetlands study area is unavailable, a targeted restoration effort could be designed to focus on regions that require the least volume of water to achieve restoration. Alternatively, the nearshore residence time of the more exposed regions of the study area could be modified by the construction of groins and other structures.

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King, I.P. (1988) "A Finite Element Model for Three-Dimensional Hydrodynamic Systems" report prepared by Resource Management Associates, Lafayette California, for U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Langevin, C. D. (2000). "Simulation of Ground-Water Discharge to Biscayne Bay, Southeastern Florida" Draft Report, United States Geological Survey, 2000.

Meeder, J., Harlem, P. and Renshaw, A. "Paleoecological Determination of the Western Biscayne Bay Coastal Zone Salinity Regime Prior to Anthropogenic Alterations to the System and Estimates of Freshwater Discharge Required to Reproduce an Estuarine Condition" (2003) Power Point Presentation, Southeastern Environmental Research Center, Florida International University, Miami, FL

Figure 1: Location Maps

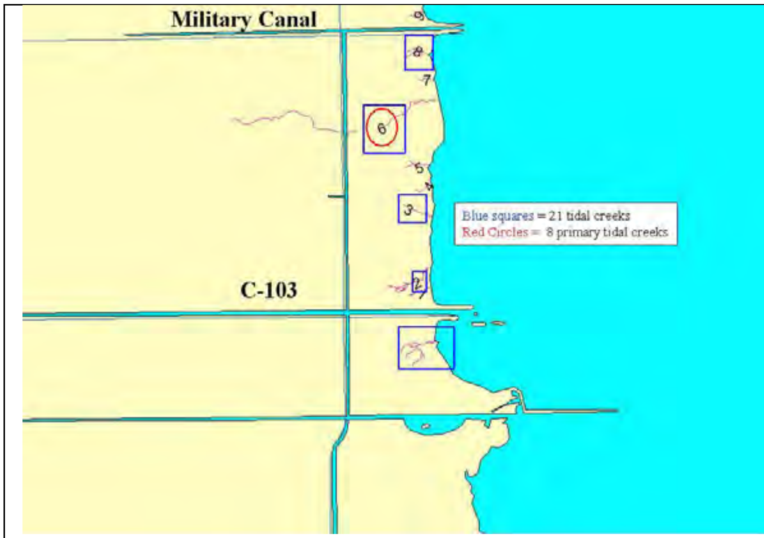


Figure 2: Creek Location Map #1

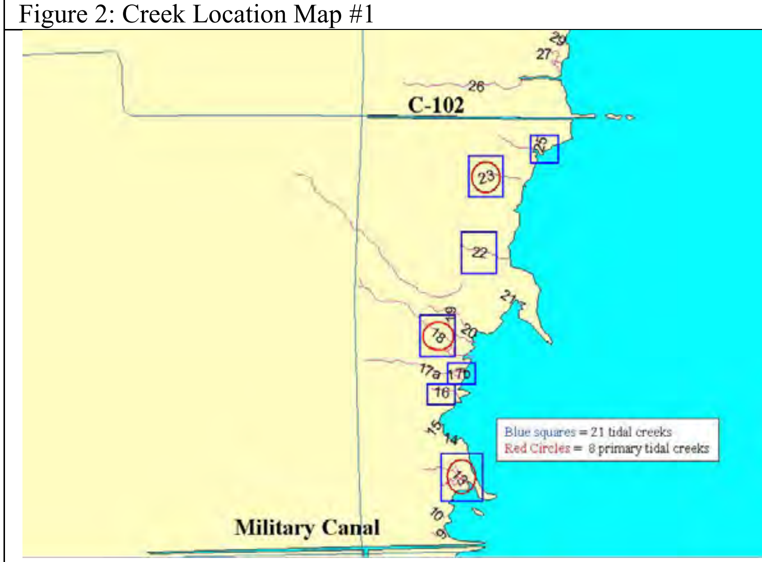


Figure 3: Creek Location Map #2

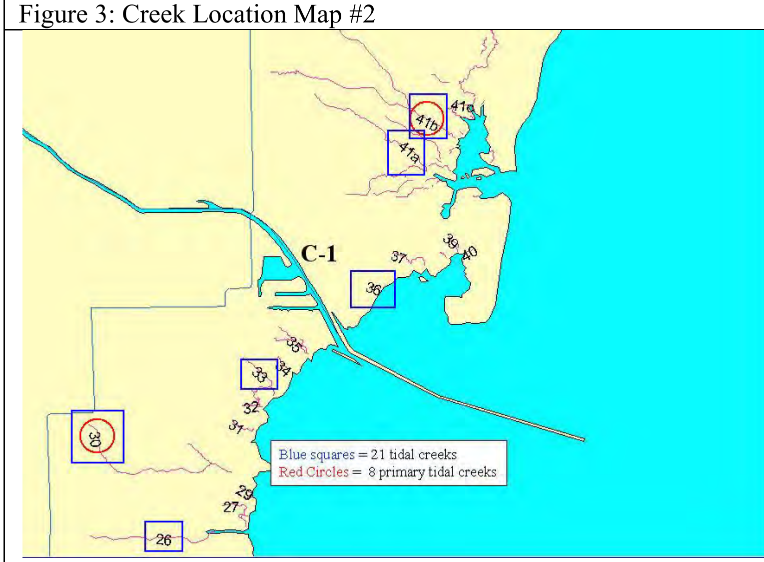


Figure 4: Creek Location Map #3

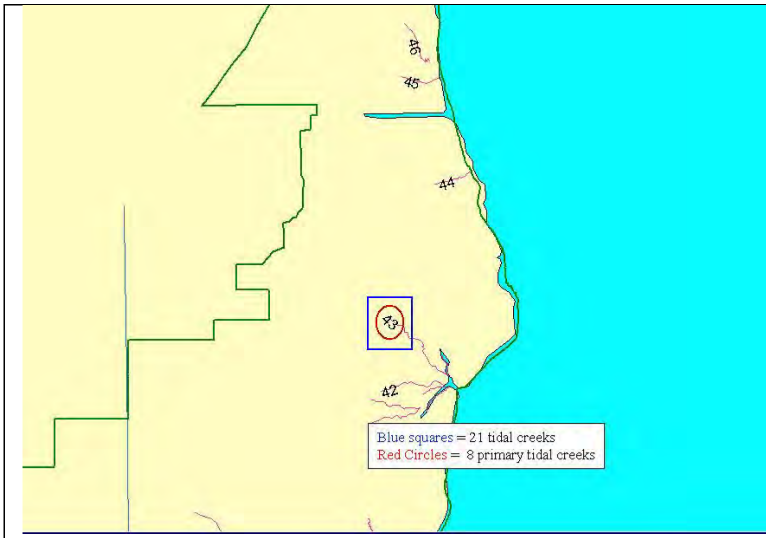


Figure 5: Creek Location Map #4

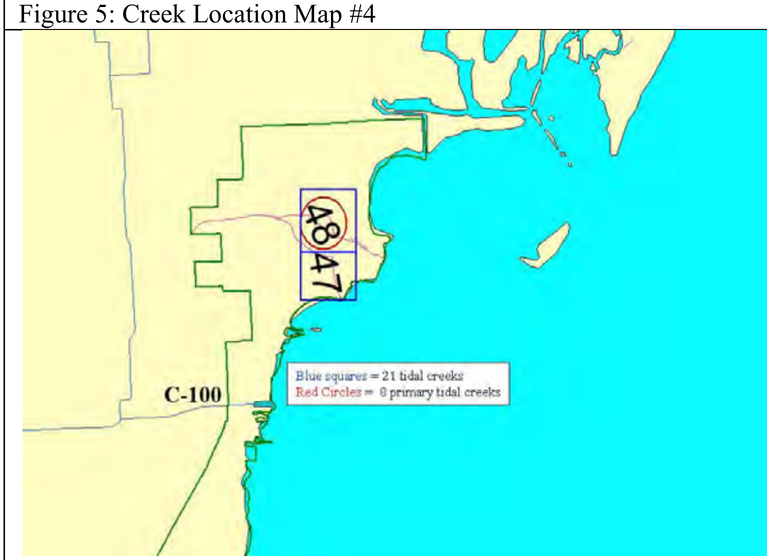


Figure 6: Creek Location Map #5

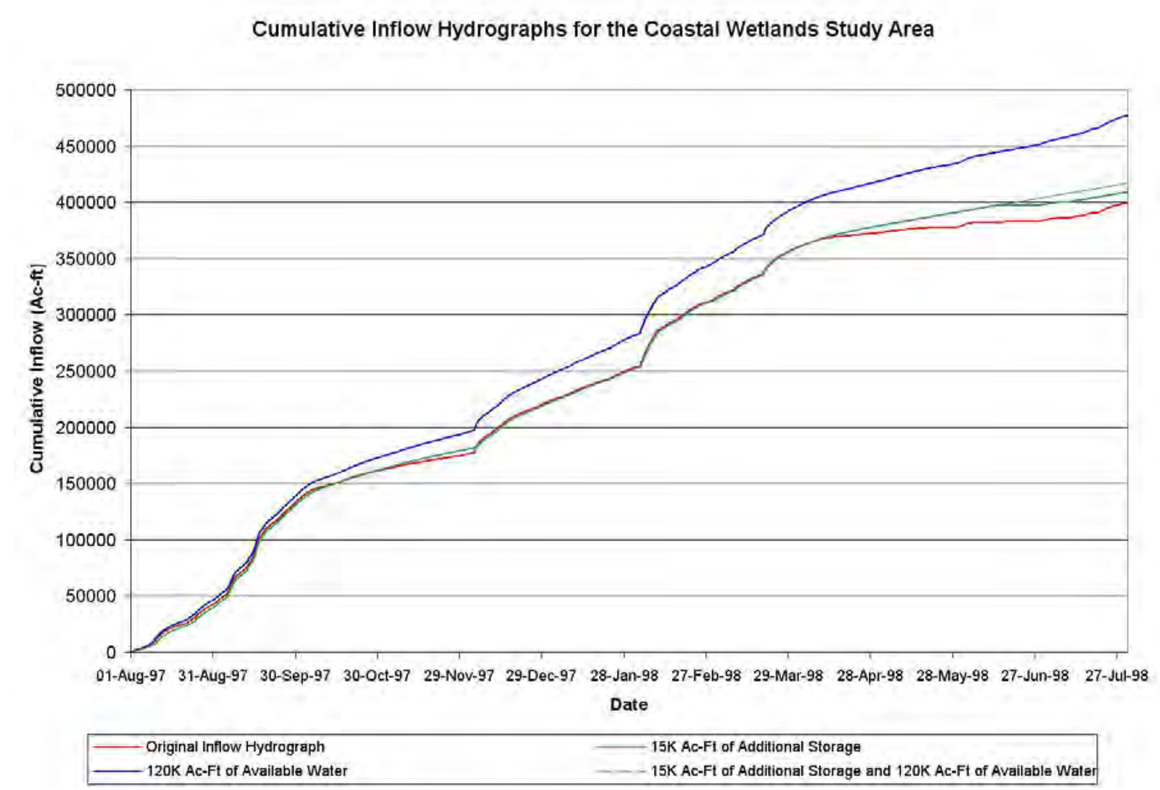


Figure 7: Cumulative Inflow Hydrographs for the Coastal Wetlands Study Area

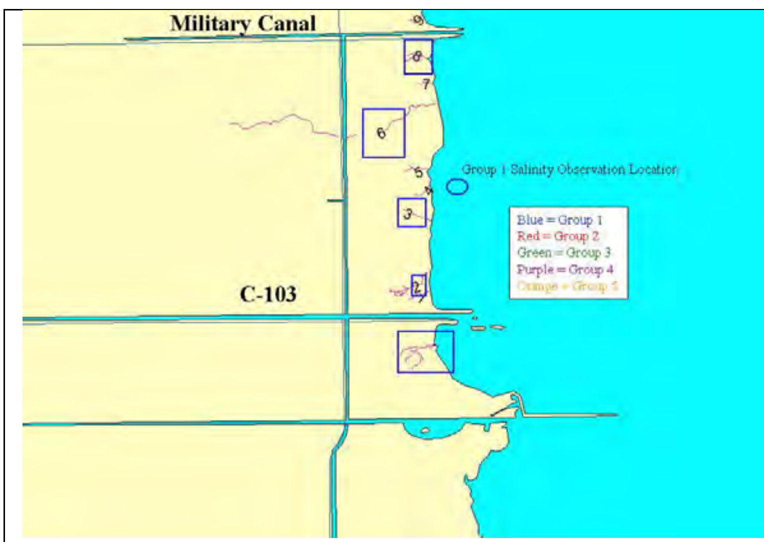


Figure 8: Preliminary Scenario 10 Grouping Map #1

Figure 9: Preliminary Scenario 10 Grouping Map #2

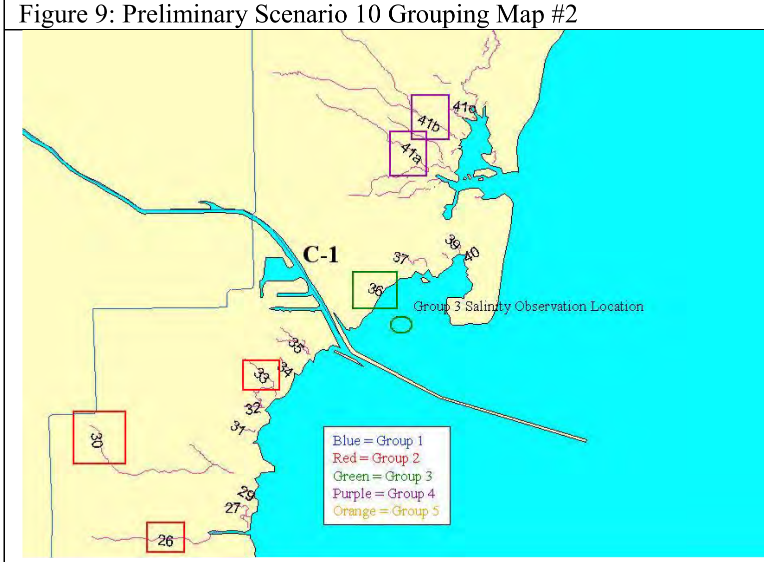


Figure 10: Preliminary Scenario 10 Grouping Map #3

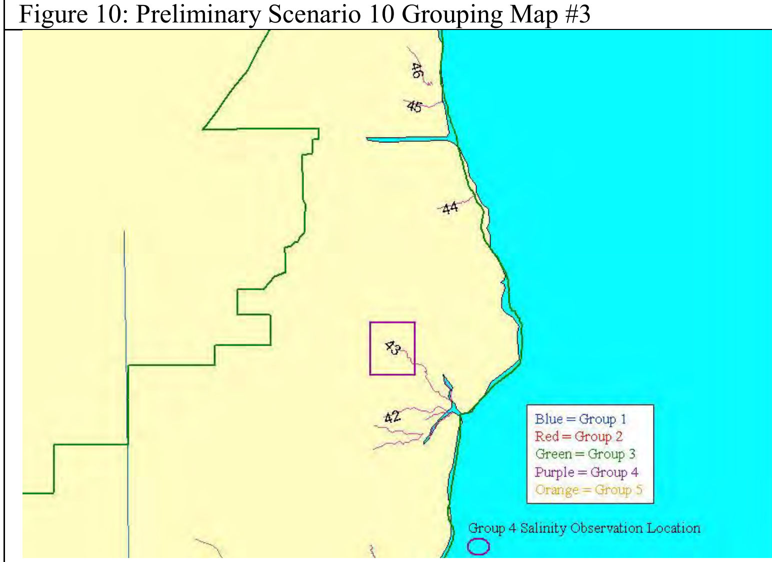


Figure 11: Preliminary Scenario 10 Grouping Map #4

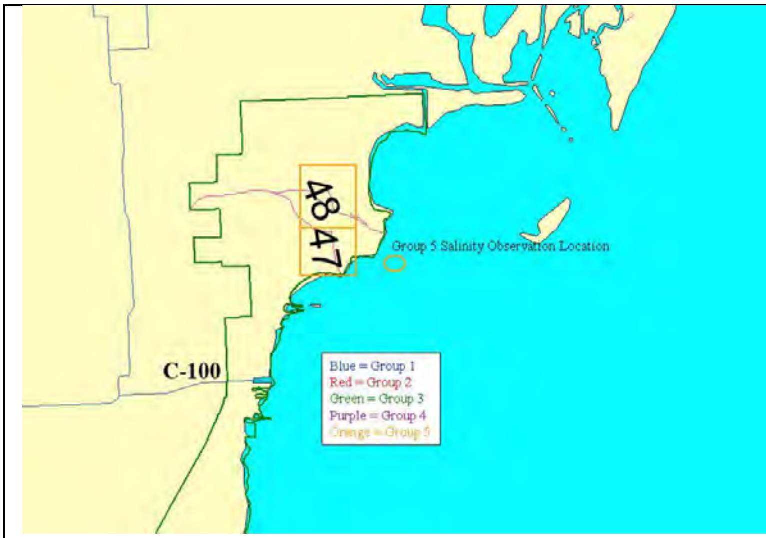
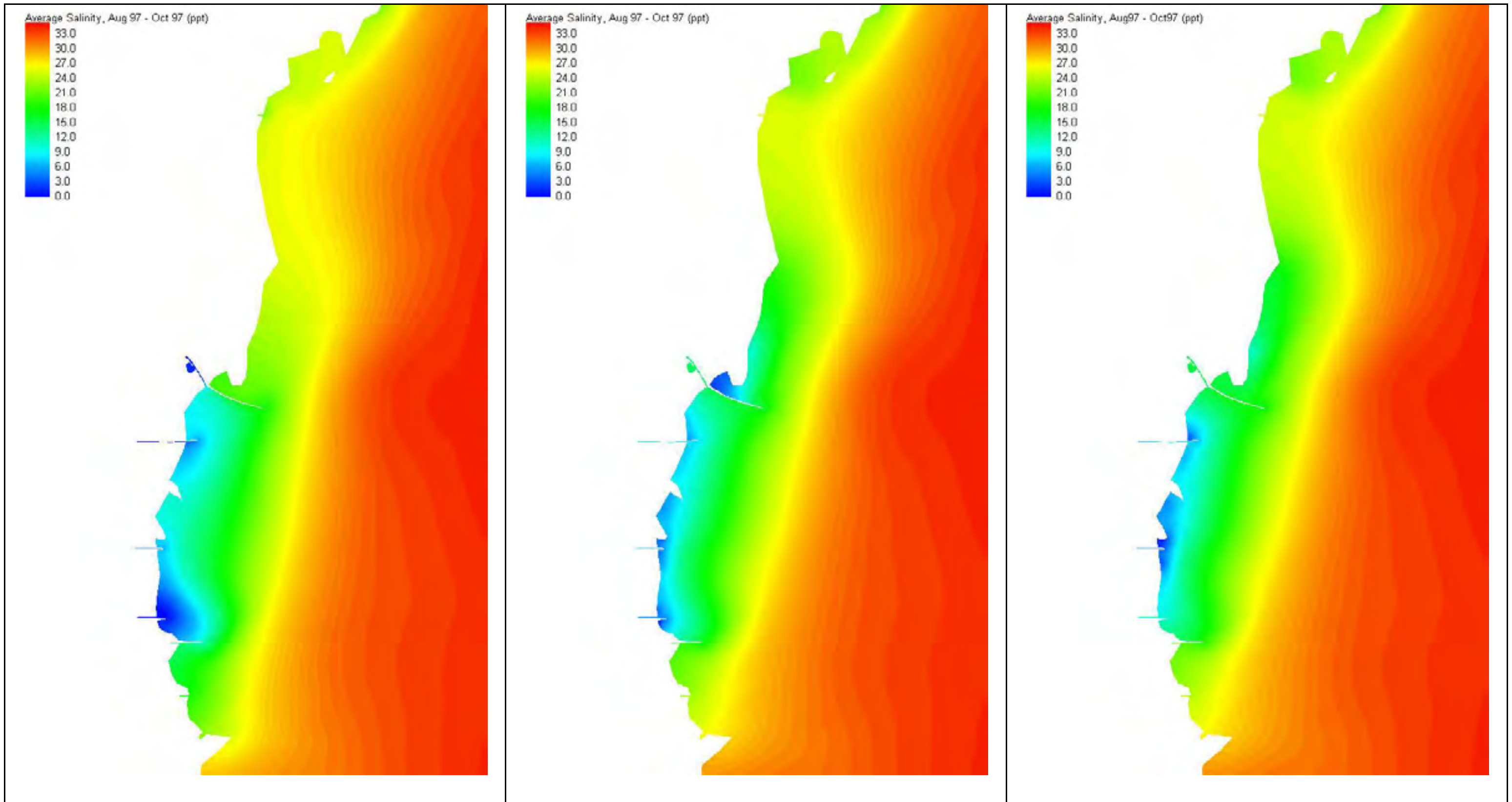
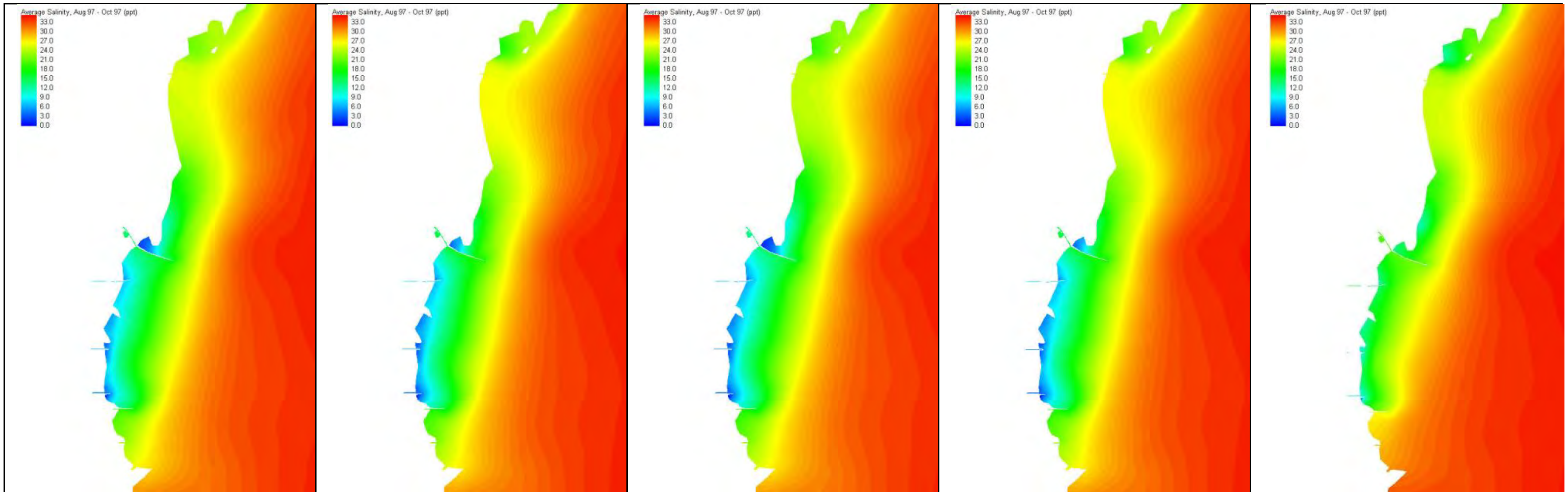


Figure 12: Preliminary Scenario 10 Grouping Map #5



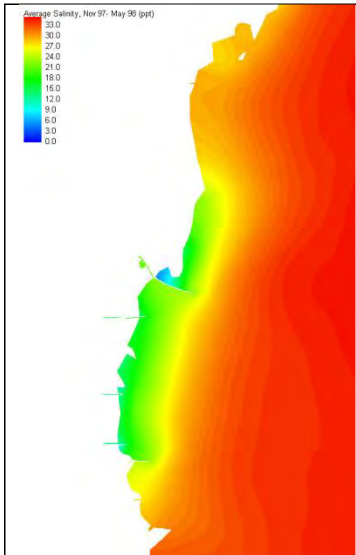
Existing Configuration	21 Creek Configuration	8 Creek Configuration

Figure 13: Inflow Distribution Configuration Comparison: Average Salinity, August 97 – October 97

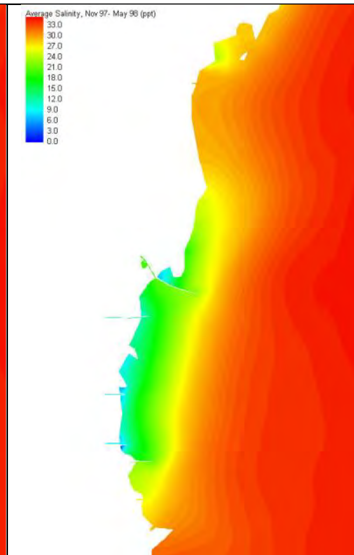


Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

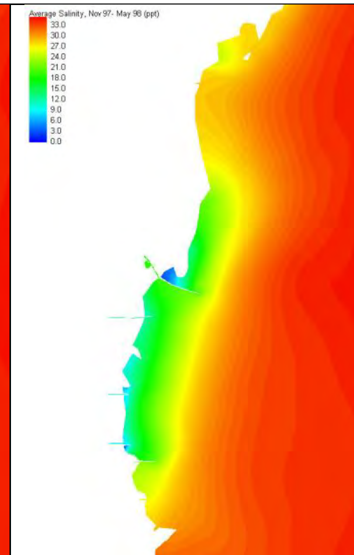
Figure 14: 21 Creek Simulation Comparison: Average Salinity, August 97 – October 97



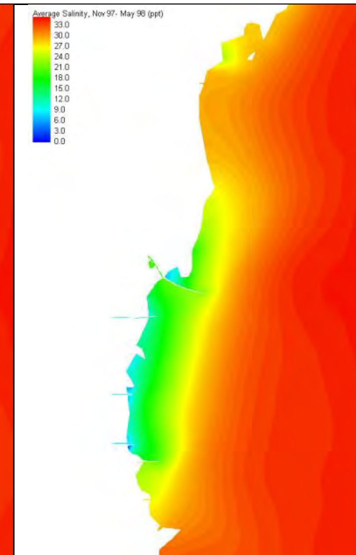
Existing Flows



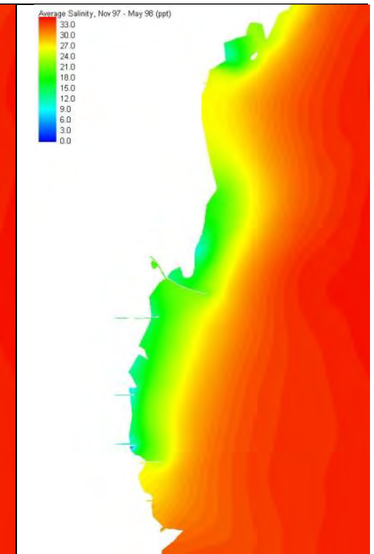
15K Ac-Ft of Additional Storage



120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)



15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)



Target Nearshore Environment (Preliminary Scenario 10)

Figure 15: 21 Creek Simulation Comparison: Average Salinity, November 97 – May 98

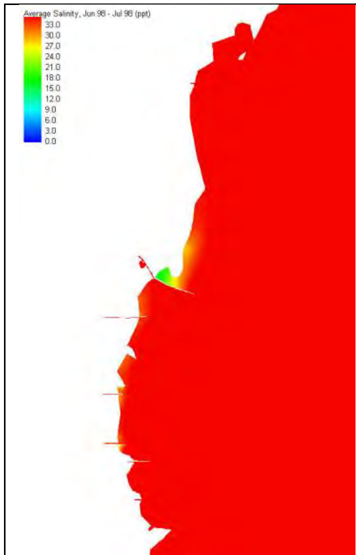
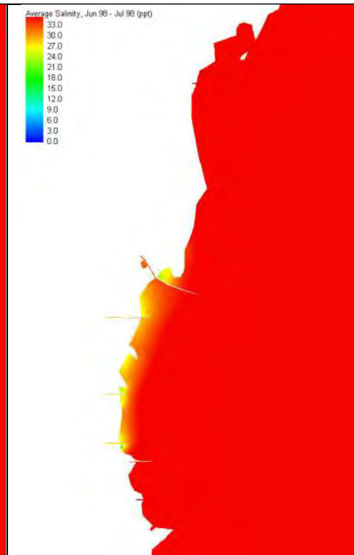
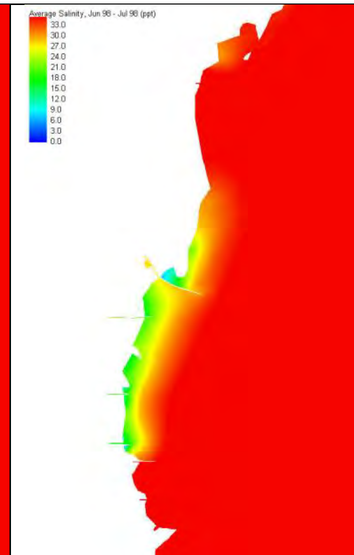
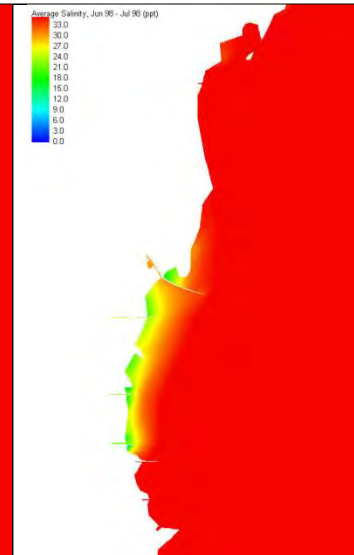
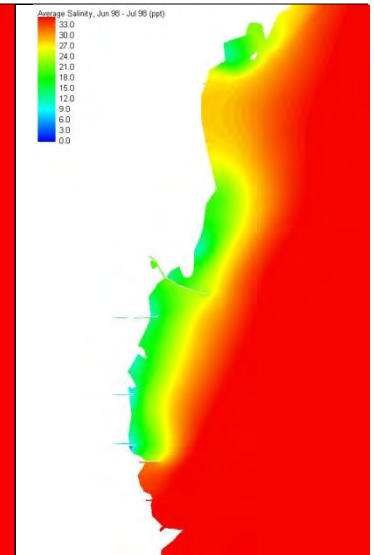
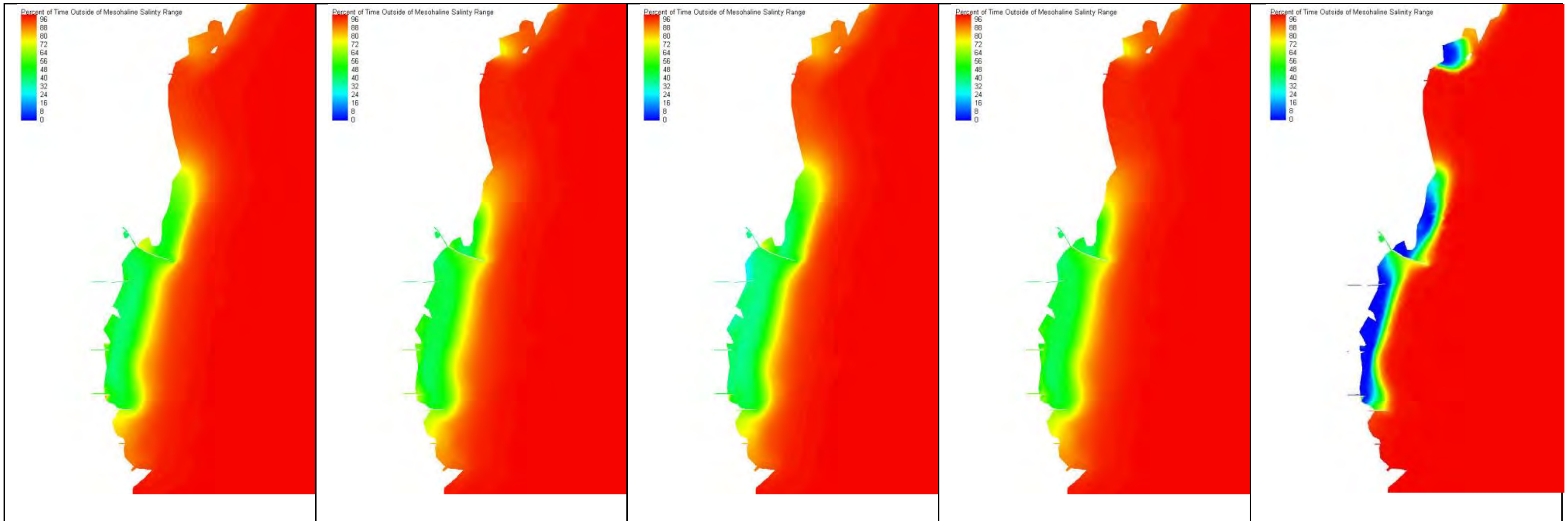
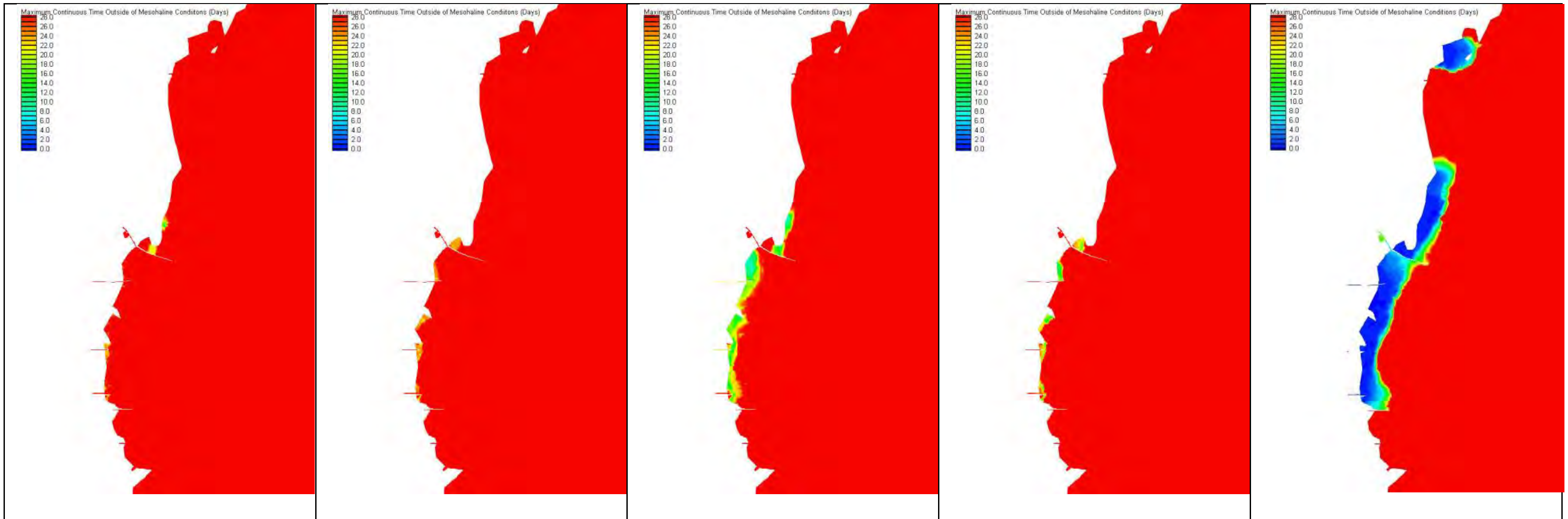
				
Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 16: 21 Creek Simulation Comparison: Average Salinity, June 98 – July 98



Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 17: 21 Creek Simulation Comparison: Percent of Time Outside of Mesohaline Range



Existing Flows	15K Ac-Ft of Additional Storage	120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	15K Ac-Ft of Additional Storage and 120K Ac-Ft of Available Water (7K Ac-Ft is actually utilized)	Target Nearshore Environment (Preliminary Scenario 10)

Figure 18: 21 Creek Simulation Comparison: Maximum Continuous Time Outside of Mesohaline Range (Days)

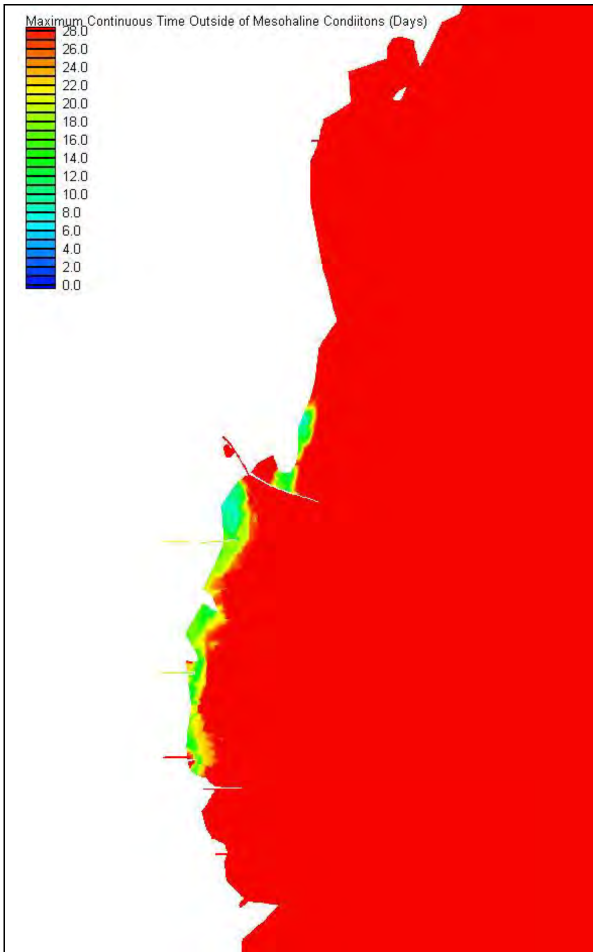
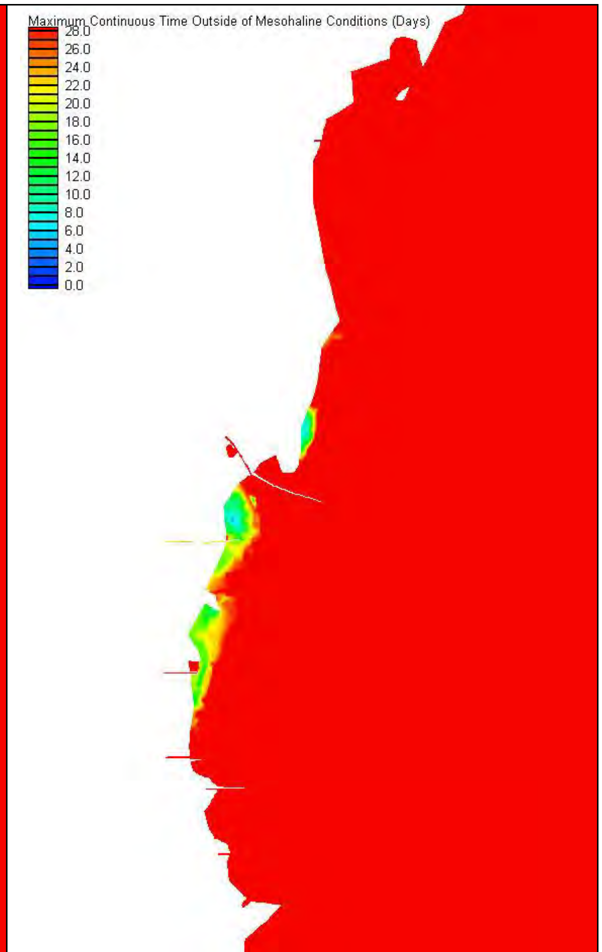
	
21 Creek Configuration, 120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)	8 Creek Configuration, 120K Ac-Ft of Available Water (85K Ac-Ft is actually utilized)

Figure 19: Comparison of 21 Creek Configuration and 8 Creek Configuration: Maximum Continuous Time Outside of Mesohaline Range (Days)

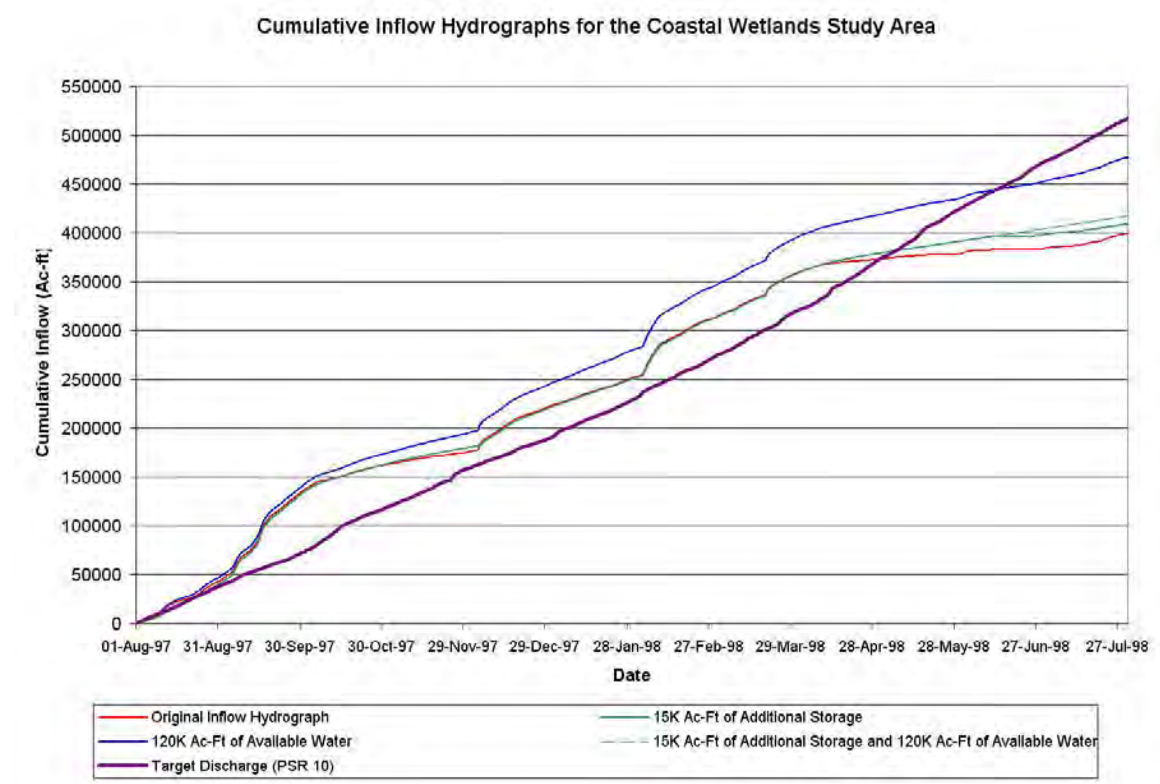


Figure 20: Cumulative Inflow Hydrographs for the Coastal Wetlands Study Area With Target Discharge Shown

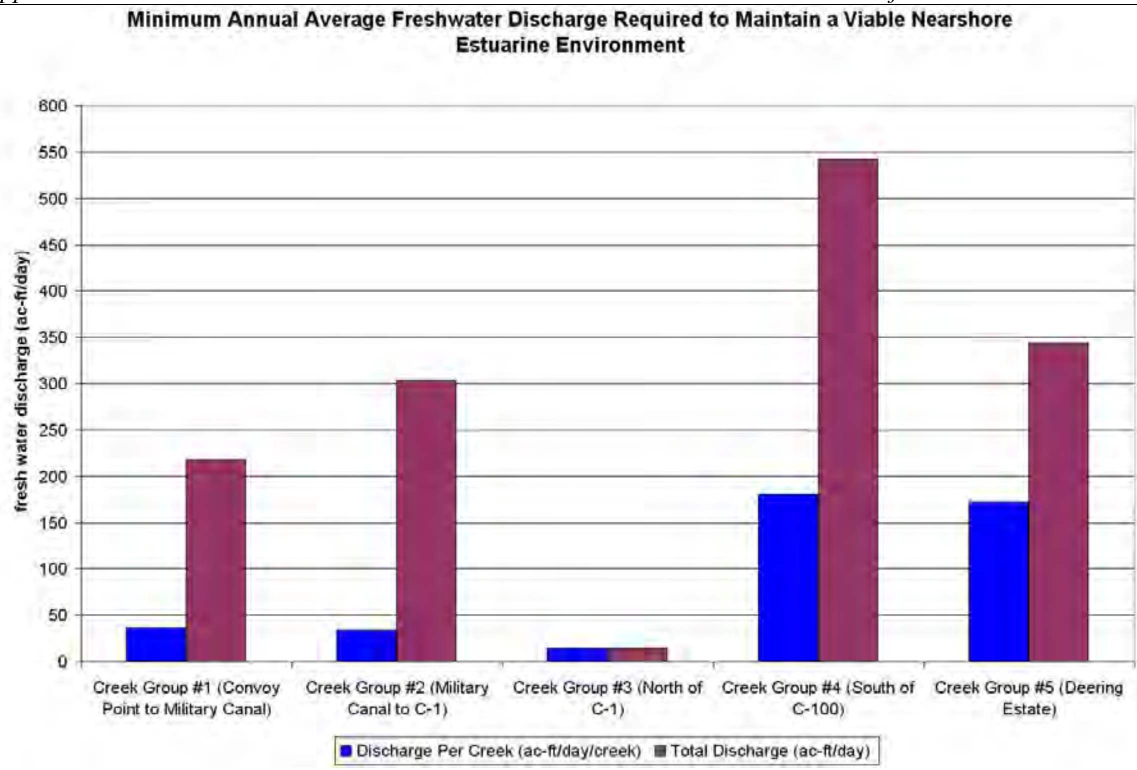


Figure 21: Minimum Annual Average Freshwater Discharge Required to Maintain a Viable Nearshore Estuarine Environment for Each of the 5 Creek Groupings in Preliminary Scenario #10

Appendix C: Flow Statistics and Plots

In this appendix, water flow statistical results are given for each water control structure within the Biscayne Bay Coastal Wetlands Phase 1 Project area, and volume probability or flow duration plots and time series plots by basin that are based on daily averages (means). Data were obtained from the South Florida Water Management District's DBHYDRO database for the January 1, 1986 through December 31, 2011 period as available. Water flow results are estimated in cubic feet per second (cfs) using rating curves that depend on the physical dimensions of the structure, length of time a gate or gates are open, the height of the gate(s), and the stage elevation of the head and tail water. A complete record of water flow data is not available for every water control structure within the period of record.

Correlation coefficients were calculated based on available paired data sets from each of the important water control structures within each basin and the coastal outfall structure from the basin. Pearson product-moment, Kendall tau-b rank, and Spearman rank coefficients are given. Since the data set distributions are skewed and nonnormal, the Kendall tau-b and Spearman results are most useful for evaluating relationships. Whereas the Pearson approach tests for a linear relationship between variables, the Kendall tau approach can indicate that the observed data are in the same order without regard to magnitude, and the Spearman approach accounts for the proportion of variability. The Kendall tau coefficients tend to be smaller in magnitude than the Spearman or Pearson coefficients given the same relationship.

Time series plots are given for interior water control structures to indicate when flow through the structures were contributing water to meet the target flow downstream at the associated basin coastal outfall structure. Results are shown for two cases. The first case occurred when flow at the outfall structure was at or below the specific water flow target ("contributes to target flow"). In this case, it is clear that water flowing through an upstream structure was contributing some quantity toward meeting the target flow into Biscayne Bay at the outfall. A second case occurred when flow into the bay at the outfall was greater than the target quantity, but would not have met the target flow without contributions from structures upstream. It is not possible to ascertain the importance of contribution from individual water control structures in the second case for multiple tributaries, as the water is comingled from all contributing structures upon reaching the coastal outfall. All that can be concluded is that water contributions from one or more of the structures were important in meeting the target flow. Because of this uncertainty, these points on the time series plots are labeled as "possible contribution to target flow".

Most of the flow rate units are given in cfs since data are stored in the DBHYDRO database in this unit. The exceptions are the volume probability or flow duration curves. These are given in acre-feet per day since a comparison is made on most plots to the Biscayne Bay inflow target, which has been described in the *Central and Southern Florida Project Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Phase 1 Final Integrated Project Implementation Report and Environmental Impact Statement* (USACE and SFWMD 2012) as acre-feet. In addition, these plots include only positive flow results, meaning flow through the structure toward the coast rather than backflow.

C-100 Basin (Cutler Drain)

Table C-1. C-100 basin statistics of flow rate (cfs) at water control structures for all seasons.

Statistic	S-123	S-118	S-119	S-120
Number of Cases	9,313	8,239	8,037	7,604
Maximum	5,710.54	1,505.67	478.87	457.42
Median	0.00	0.00	0.00	0.00
Arithmetic Mean	53.17	11.90	7.75	12.36
Standard Error	2.67	0.76	0.38	0.58
Standard Deviation	257.57	69.20	33.85	50.94
25^{th} percentile	0.00	0.00	0.00	0.00
75^{th} percentile	0.00	0.00	0.00	0.00

Table C-2. C-100 basin statistics of flow rate (cfs) at water control structures for the wet season.

Statistic	S-123	S-118	S-119	S-120
Number of Cases	3,910	3,457	3,430	3,195
Maximum	5,710.54	1,505.67	478.87	337.26
Median	0.00	0.00	0.00	0.00
Arithmetic Mean	108.77	25.19	15.06	25.55
Standard Error	5.81	1.74	0.82	1.26
Standard Deviation	363.38	102.01	48.04	71.33
25^{th} percentile	0.00	0.00	0.00	0.00
75^{th} percentile	64.44	0.00	0.00	0.00

Table C-3. C-100 basin statistics of flow rate (cfs) at water control structures for the dry season.

Statistic	S-123	S-118	S-119	S-120
Number of Cases	5,403	4,782	4,607	4,409
Maximum	2,800.80	616.91	336.63	457.42
Median	0.00	0.00	0.00	0.00
Arithmetic Mean	12.93	2.28	2.30	2.81
Standard Error	1.66	0.33	0.21	0.36
Standard Deviation	122.28	22.54	14.53	23.92
25^{th} percentile	0.00	0.00	0.00	0.00
75^{th} percentile	0.00	0.00	0.00	0.00

Table C-4. C-100 Basin correlation coefficients.

Structure	Pearson	Kendall tau-b	Spearman
All Data			
S-118	0.765	0.386	0.409
S-119	0.765	0.407	0.432
S-120	0.385	0.342	0.364
All Seasons when S-123 Flow > 0			
S-118	0.760	0.492	0.622
S-119	0.753	0.502	0.633
S-120	0.391	0.315	0.400
Wet Season when S-123 Flow > 0			
S-118	0.776	0.523	0.659
S-119	0.776	0.524	0.664
S-120	0.479	0.412	0.484
Dry Season when S-123 Flow > 0			
S-118	0.803	0.512	0.548
S-119	0.561	0.331	0.416
S-120	0.384	0.244	0.303
All Seasons when S-123 Flow > 0 and < 173.66			
S-118	0.708	0.512	0.687
S-119	0.667	0.451	0.600
S-120	0.326	0.250	0.335
Wet Season when S-123 Flow > 0 and < 173.66			
S-118	0.736	0.527	0.702
S-119	0.710	0.469	0.627
S-120	0.334	0.263	0.358
Dry Season when S-123 Flow > 0 and < 173.66			
S-118	0.523	0.488	0.654
S-119	0.366	0.358	0.481
S-120	0.314	0.154	0.186

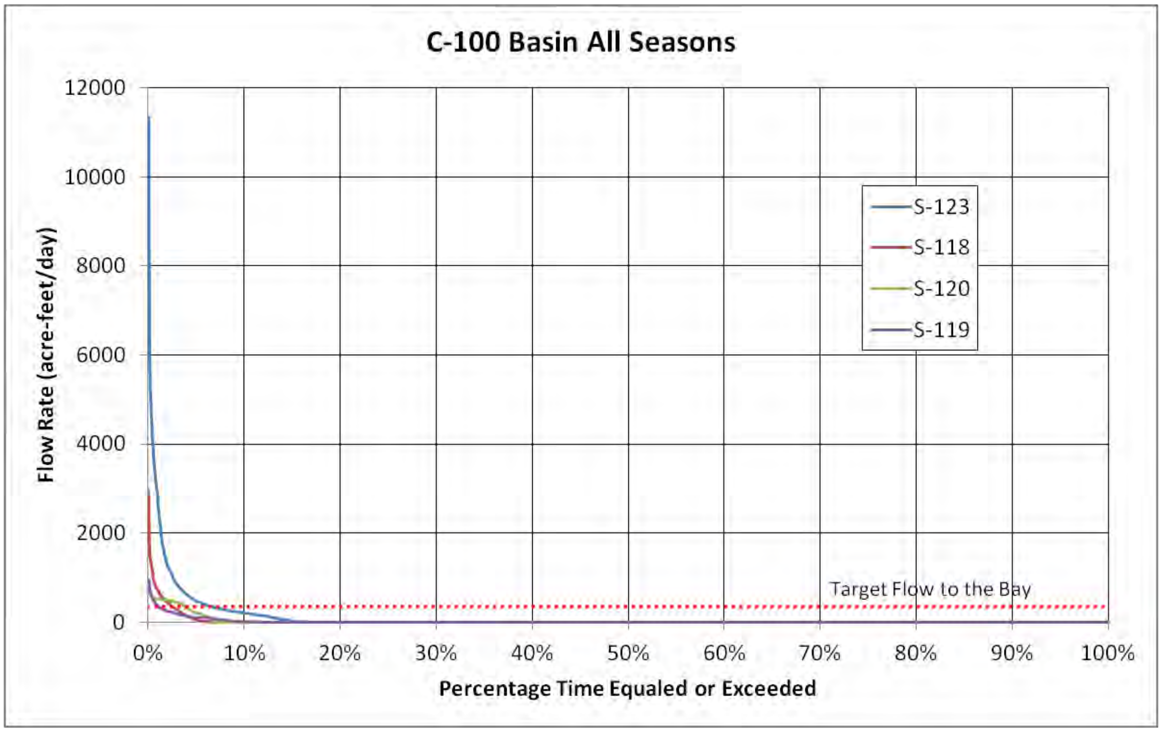


Figure C-1. Flow duration curves for the C-100 basin water control structures during all seasons.

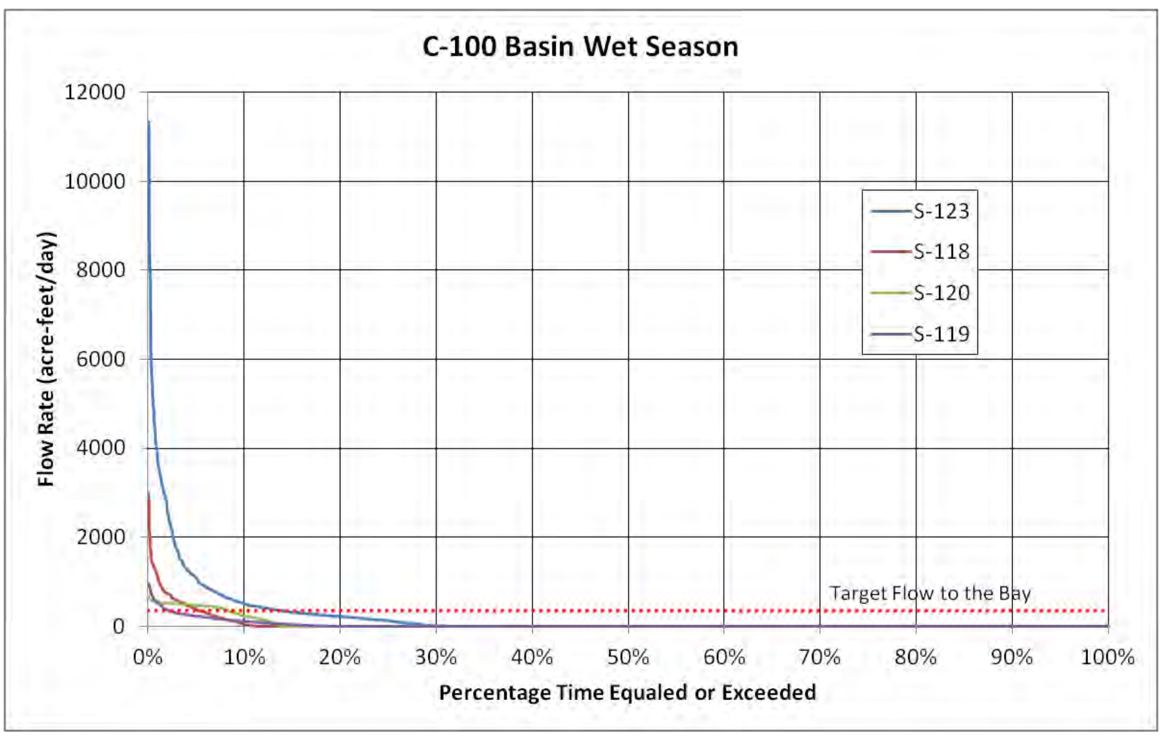


Figure C-2. Flow duration curves for C-100 basin water control structures during the wet season.

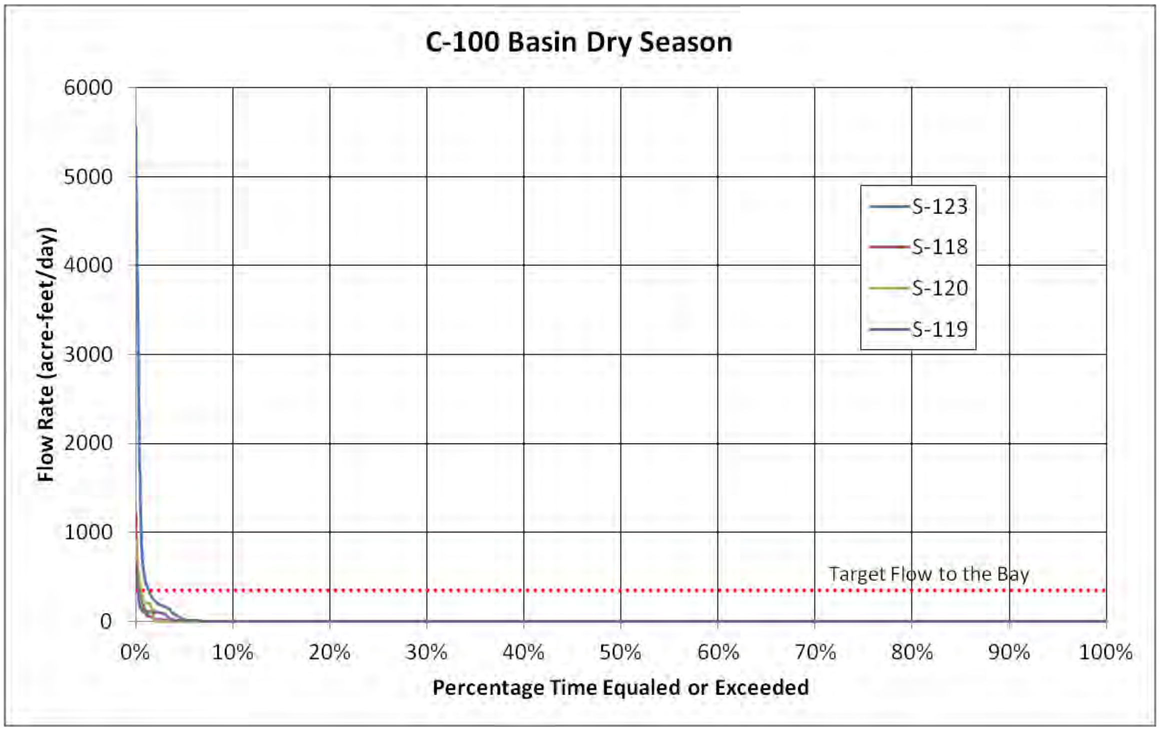


Figure C-3. Flow duration curves for C-100 basin water control structures during the dry season.

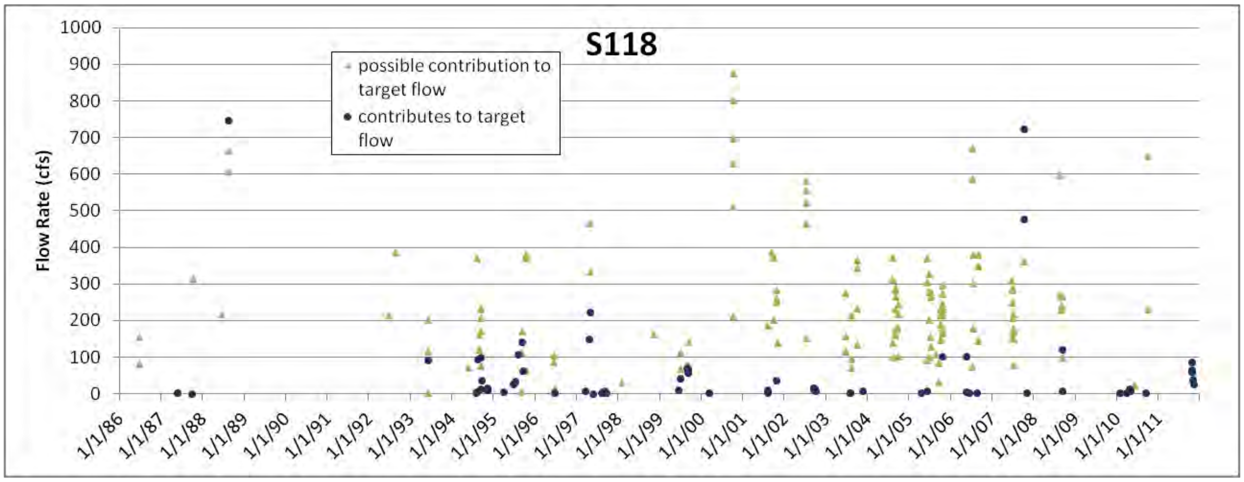


Figure C-4. S-118 water flow contributions toward target flow at S-123.

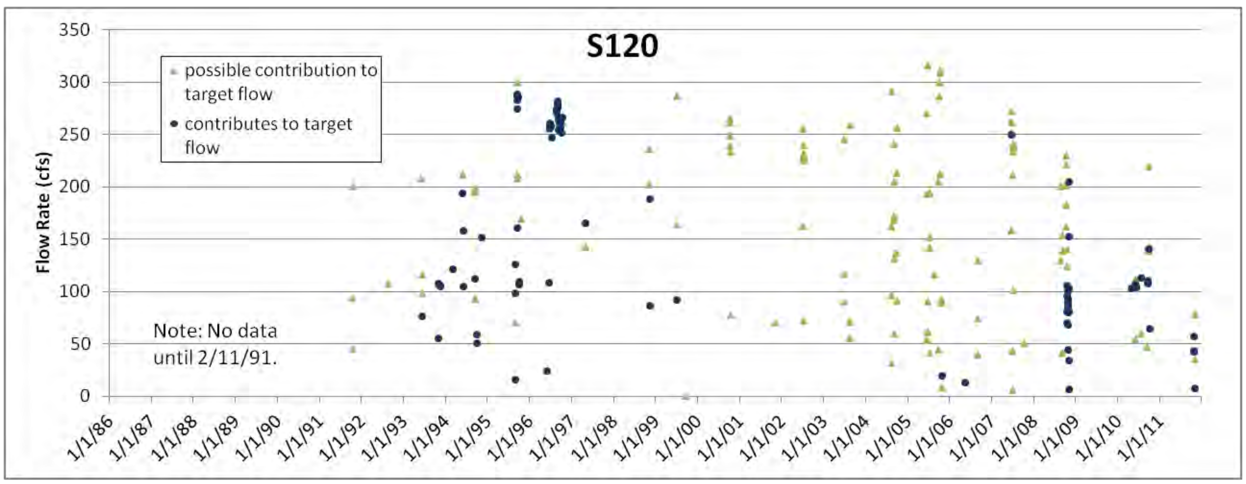


Figure C-5. S-120 water flow contributions toward target flow at S-123.

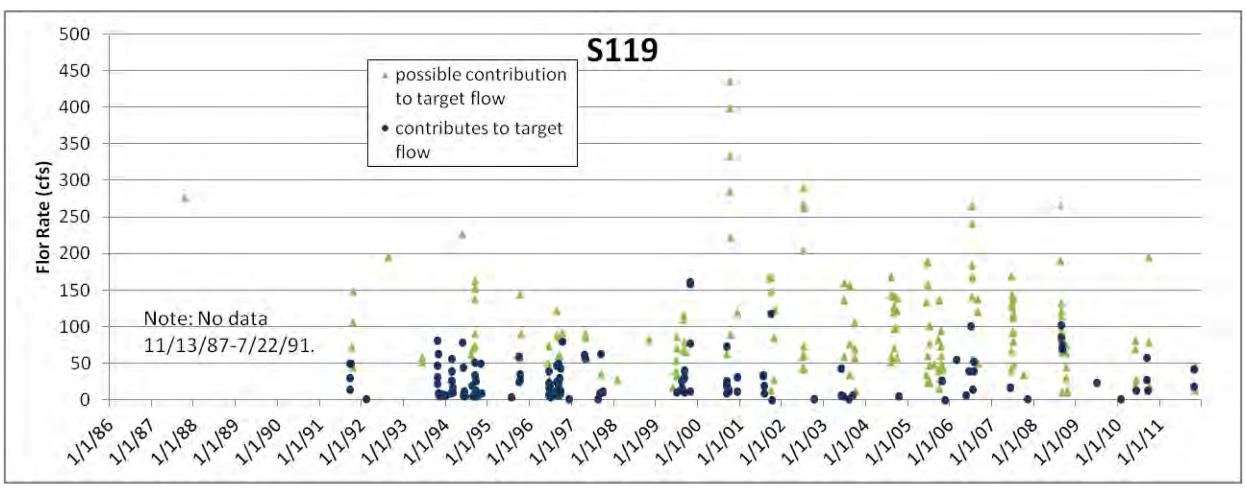


Figure C-6. S-119 water flow contributions toward target flow at S-123.

C-1 Basin (Black Creek)

Table C-5. C-1 basin statistics of flow rate (cfs) at water control structures for all seasons.

Statistics	S-21	S-149	S-148	S-338
Number of Cases	9,496	1,092	7,301	9,496
Maximum	2,594.97	325.73	1,478.34	409.67
Median	86.61	0.00	0.29	76.10
Arithmetic Mean	173.72	10.84	139.50	108.87
Standard Error	2.45	1.25	2.611	1.21
Standard Deviation	238.71	41.25	223.08	118.12
25th percentile	0.00	0.00	0.00	0.00
75th percentile	254.00	0.00	235.23	211.02

Table C-6. C-1 basin statistics of flow rate (cfs) at water control structures for the wet season.

Statistic	S-21	S-149	S-148	S-338
Number of Cases	3,978	470	3,050	3,978
Maximum	2,029.77	325.73	1,478.34	409.67
Median	213.43	0.00	208.22	158.86
Arithmetic Mean	299.25	8.35	258.10	146.08
Standard Error	4.46	2.051	4.84	2.01
Standard Deviation	281.61	44.47	267.05	126.87
25th percentile	83.98	0.00	0.00	0.00
75th percentile	472.55	0.00	468.11	253.16

Table C-7. C-1 basin statistics of flow rate (cfs) at water control structures for the dry season.

Statistic	S-21	S-149	S-148	S-338
Number of Cases	5,518	622	4,251	5,518
Maximum	2,594.97	155.03	1,043.33	406.77
Median	0.00	0.00	0.00	0.00
Arithmetic Mean	83.22	12.71	54.40	82.05
Standard Error	1.97	1.55	2.00	1.39
Standard Deviation	146.11	38.56	130.30	103.39
25th percentile	0.00	0.00	0.00	0.00
75th percentile	109.02	0.00	12.16	172.54

Table C-8. C-1 Basin correlation coefficients.

Structure	Pearson	Kendall tau-b	Spearman
All Data			
S-149	0.132	-0.003	-0.003
S-148	0.809	0.647	0.779
S-338	0.602	0.506	0.650
All Seasons when S-21 Flow > 0			
S-149	0.218	0.081	0.100
S-148	0.770	0.653	0.821
S-338	0.505	0.420	0.596
Wet Season when S-21 Flow > 0			
S-149	0.332	0.182	0.226
S-148	0.742	0.652	0.820
S-338	0.524	0.446	0.633
Dry Season when S-21 Flow > 0			
S-149	0.048	0.087	0.109
S-148	0.704	0.566	0.722
S-338	0.638	0.580	0.720
All Seasons when S-21 Flow > 0 and < 288.63			
S-149	0.133	0.074	0.092
S-148	0.564	0.397	0.525
S-338	0.306	0.193	0.271
Wet Season when S-21 Flow > 0 and < 288.63			
S-149	-0.172	-0.165	-0.202
S-148	0.500	0.393	0.527
S-338	0.316	0.207	0.284
Dry Season when S-21 Flow > 0 and < 288.63			
S-149	0.253	0.195	0.244
S-148	0.619	0.393	0.513
S-338	0.343	0.226	0.318

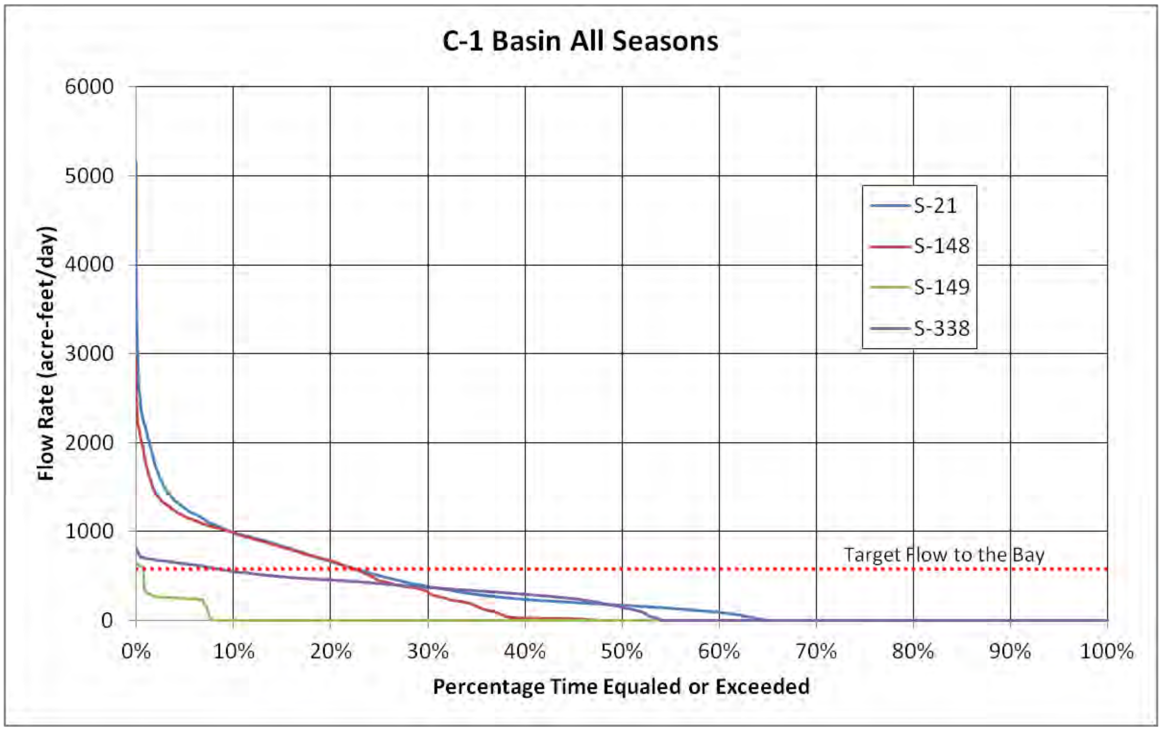


Figure C-7. Flow duration curves for the C-1 basin water control structures during all seasons.

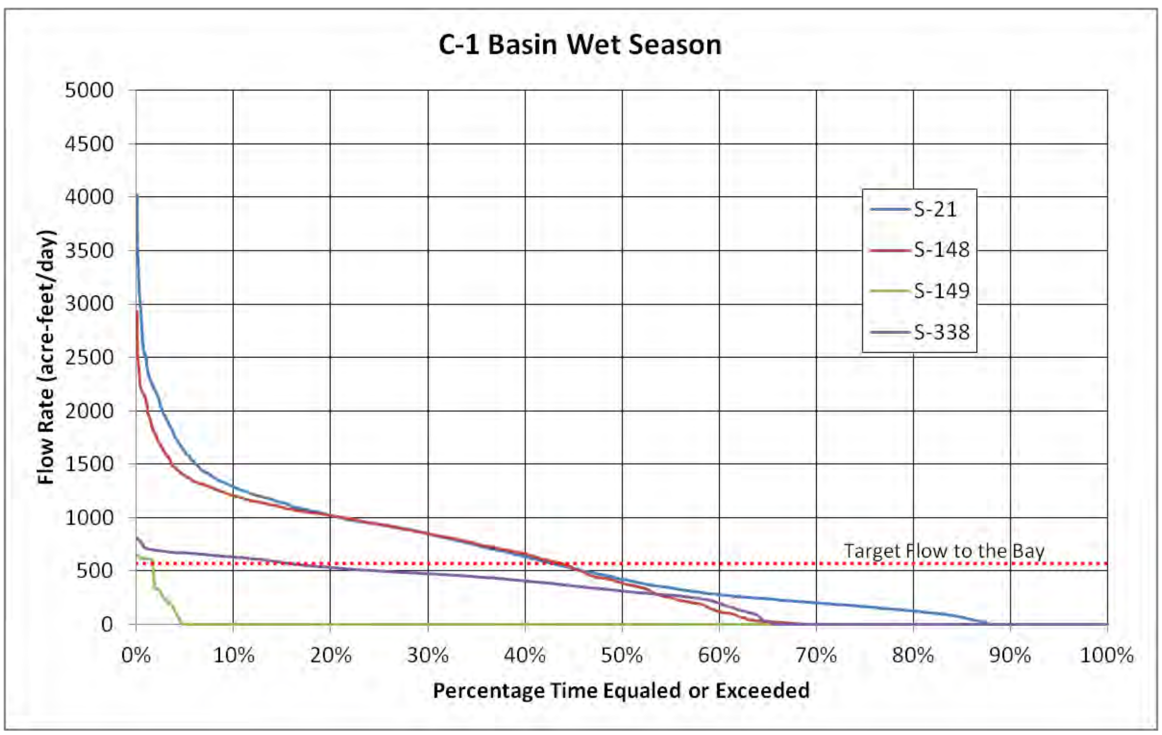


Figure C-8. Flow duration curves for the C-1 basin water control structures during the wet season.

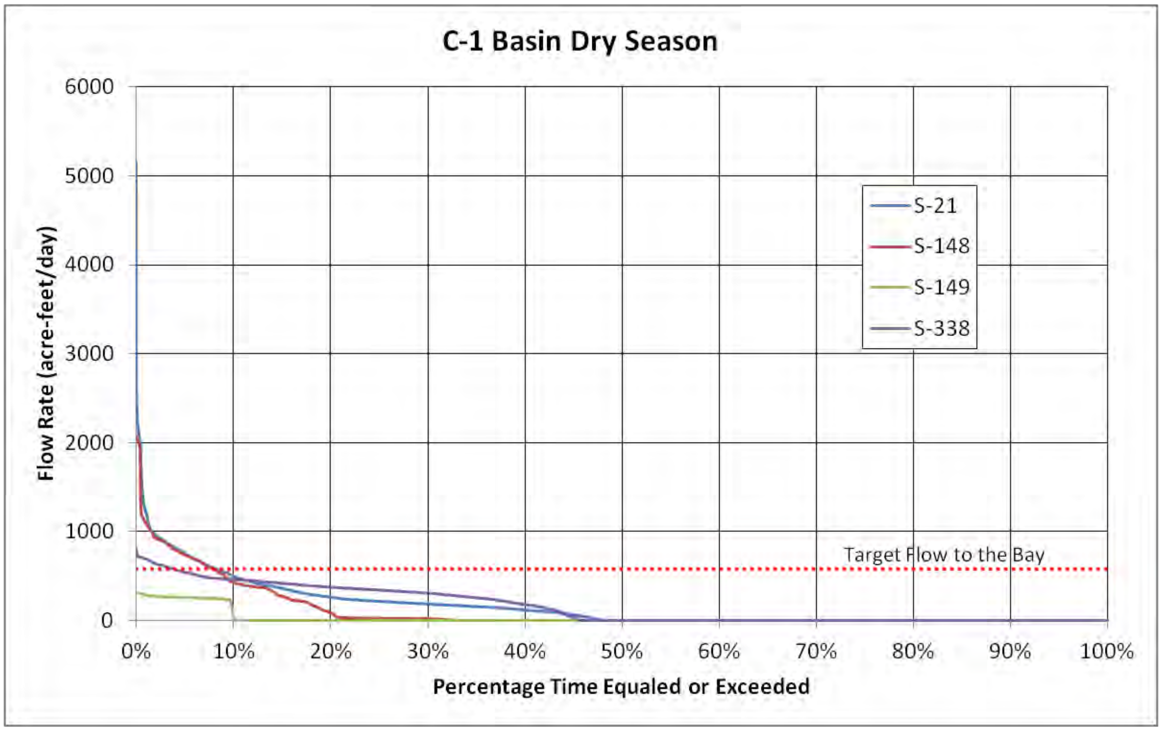


Figure C-9. Flow duration curves for the C-1 basin water control structures during the dry season.

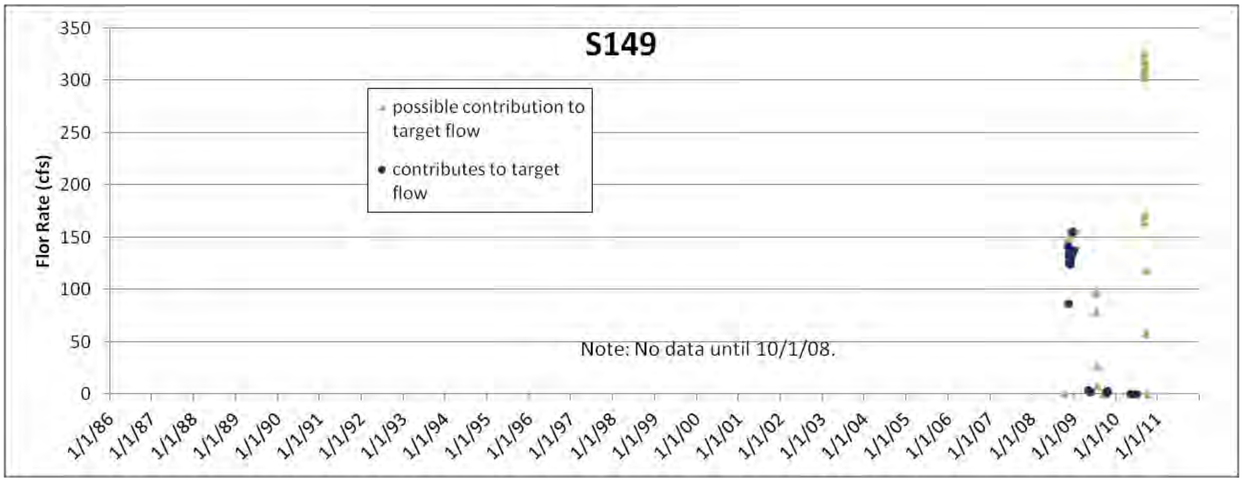


Figure C-10. S-149 water flow contributions toward target flow at S-21.

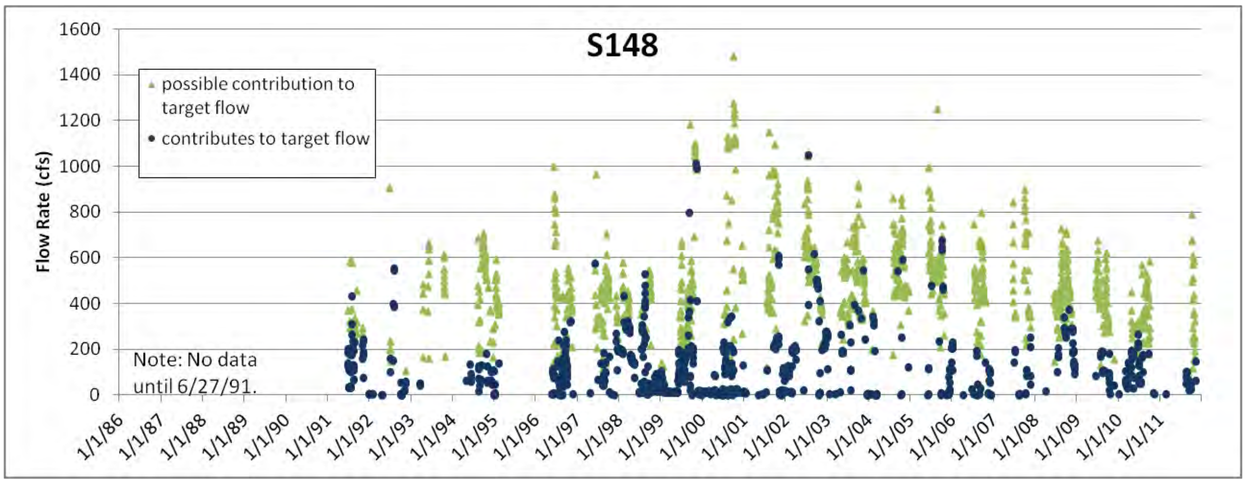


Figure C-11. S-148 water flow contributions toward target flow at S-21.

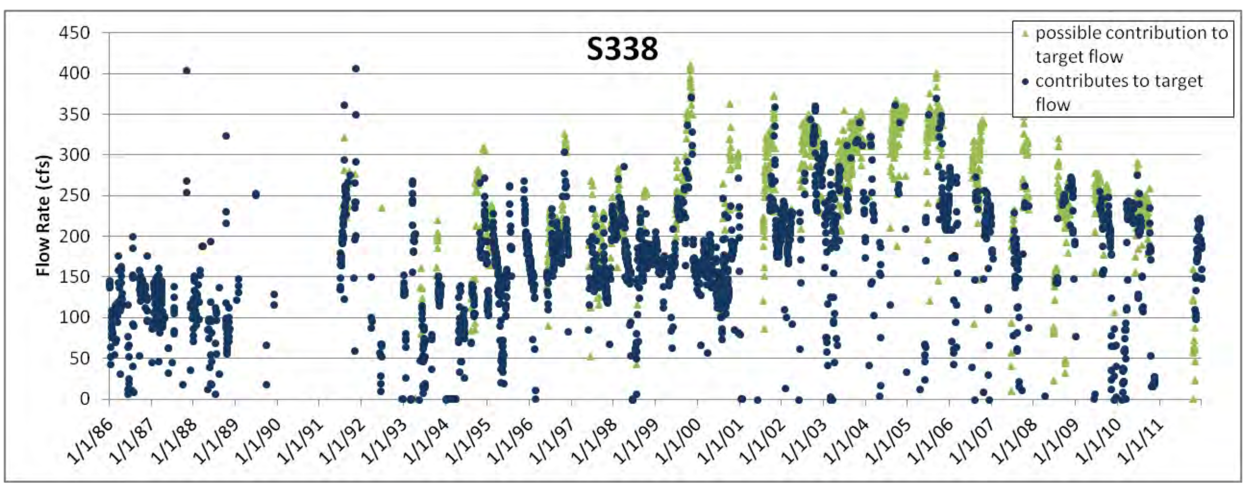


Figure C-12. S-338 water flow contributions toward target flow at S-21.

C-102 Basin (Princeton Canal)

Table C-9. C-102 basin statistics of flow rate (cfs) at water control structures for all seasons.

Statistic	S-21A	S-195	S-165	S-194
Number of Cases	9,201	8,570	9,364	9,496
Maximum	2,472.13	565.90	686.67	427.11
Median	74.75	0.00	0.00	0.00
Arithmetic Mean	107.65	10.67	14.41	51.07
Standard Error	1.59	0.50	0.57	0.64
Standard Deviation	152.17	46.00	55.55	62.23
25th percentile	25.93	0.00	0.00	0.00
75th percentile	128.34	0.00	0.00	105.42

Table C-10. C-102 basin statistics of flow rate (cfs) at water control structures for the wet season.

Statistic	S-21A	S-195	S-165	S-194
Number of Cases	3,792	3,627	3,894	3,978
Maximum	2,472.13	565.90	686.67	390.99
Median	110.80	0.00	0.00	59.42
Arithmetic Mean	162.57	22.25	31.22	59.13
Standard Error	3.23	1.10	1.28	1.02
Standard Deviation	198.60	66.08	80.01	64.07
25th percentile	59.92	0.00	0.00	0.00
75th percentile	187.70	0.00	0.00	109.65

Table C-11. C-102 basin statistics of flow rate (cfs) at water control structures for the dry season.

Statistic	S-21A	S-195	S-165	S-194
Number of Cases	5,409	4,943	5,470	5,518
Maximum	1,369.51	309.95	359.39	427.11
Median	52.74	0.00	0.00	0.00
Arithmetic Mean	69.15	2.17	2.44	45.25
Standard Error	1.23	0.24	0.26	0.81
Standard Deviation	90.25	17.11	19.54	60.24
25th percentile	2.00	0.00	0.00	0.00
75th percentile	98.06	0.00	0.00	97.81

Table C-12. C-102 Basin correlation coefficients.

Structure	Pearson	Kendall tau-b	Spearman
All Data			
S-195	0.667	0.278	0.340
S-165	0.751	0.290	0.354
S-194	0.145	0.144	0.196
All Seasons when S-21A Flow > 0			
S-195	0.681	0.303	0.374
S-165	0.758	0.299	0.372
S-194	0.120	0.118	0.163
Wet Season when S-21A Flow > 0			
S-195	0.712	0.401	0.499
S-165	0.792	0.456	0.565
S-194	0.712	0.401	0.499
Dry Season when S-21A Flow > 0			
S-195	0.397	0.103	0.127
S-165	0.486	0.039	0.048
S-194	0.144	0.118	0.162
All Seasons when S-21A Flow > 0 and < 85.89			
S-195	0.043	0.035	0.043
S-165	0.043	0.042	0.051
S-194	0.014	0.017	0.022
Wet Season when S-21A Flow > 0 and < 85.89			
S-195	0.014	0.003	0.003
S-165	0.010	0.024	0.030
S-194	0.063	0.047	0.066
Dry Season when S-21A Flow > 0 and < 85.89			
S-195	0.063	0.049	0.061
S-165	0.071	0.056	0.068
S-194	0.168	0.094	0.103

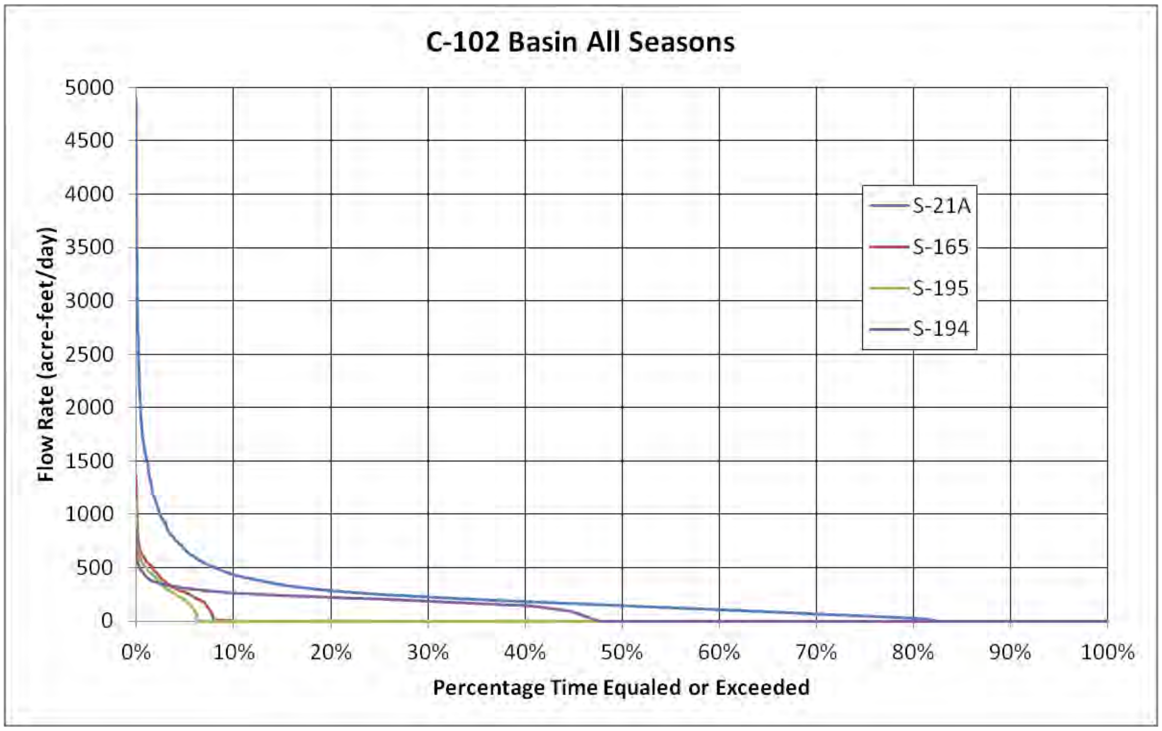


Figure C-13. Flow duration curves for the C-102 basin water control structures during all seasons.

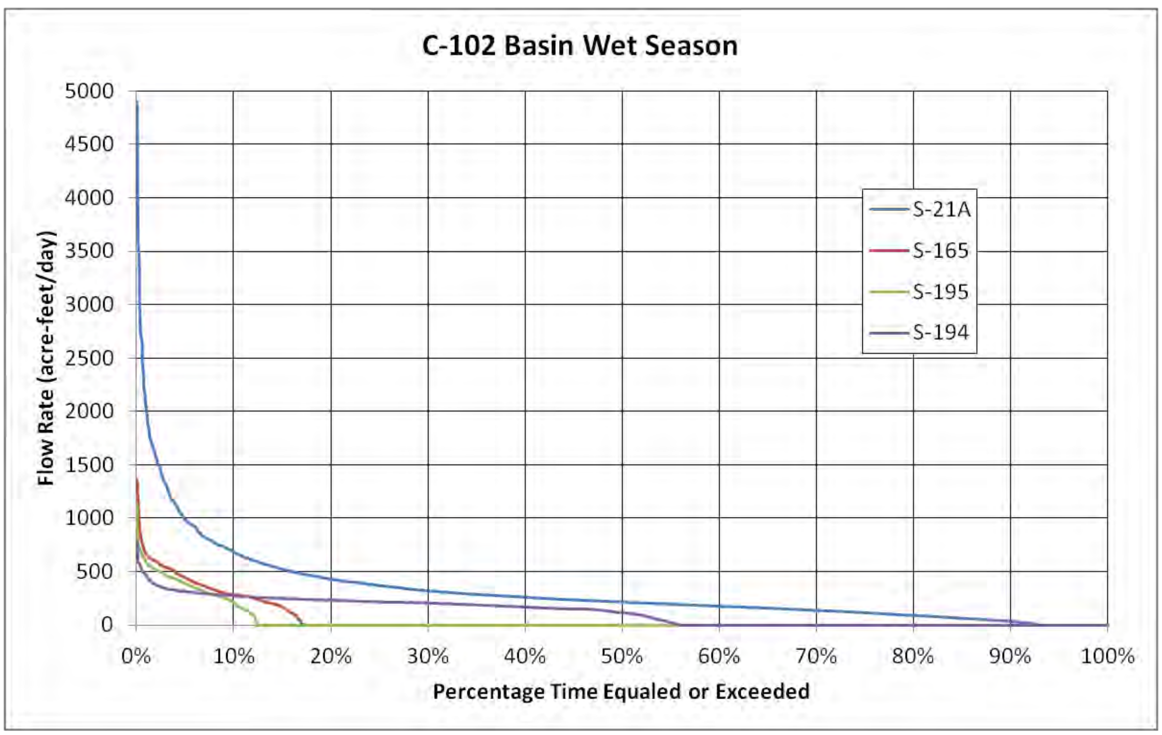


Figure C-14. Flow duration curves for the C-102 basin water control structures during the wet season.

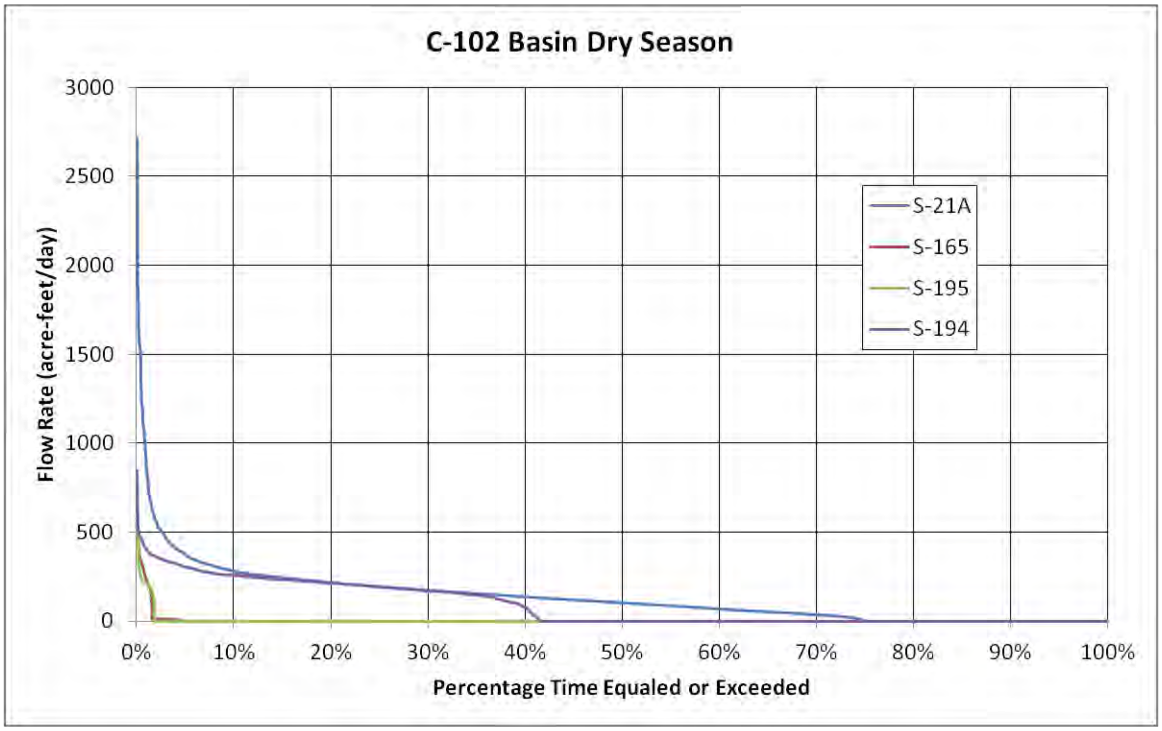


Figure C-15. Flow duration curves for the C-102 basin water control structures during the dry season.

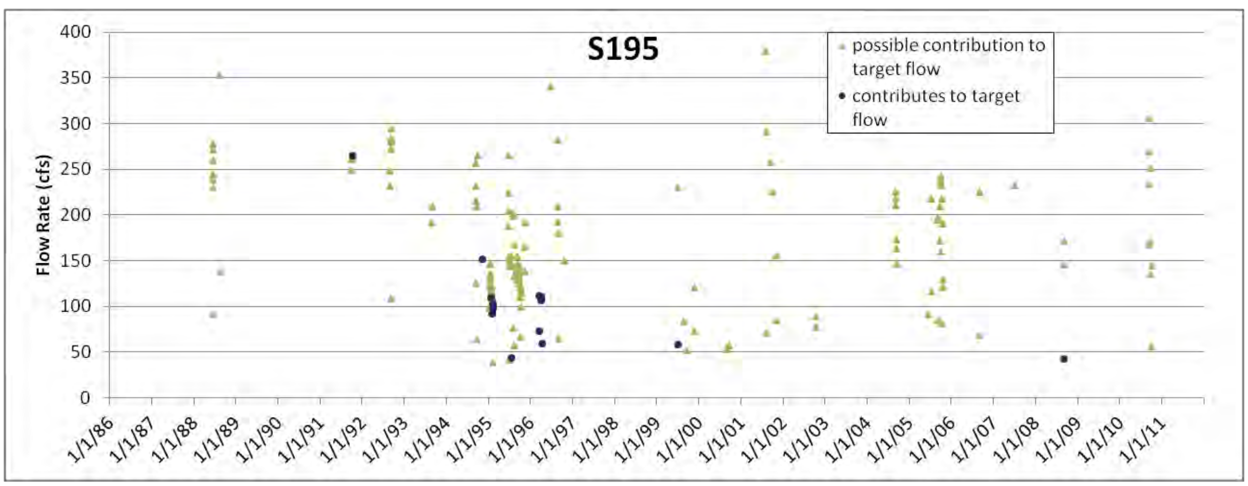


Figure C-16. S-195 water flow contributions toward an approximated target flow at S-21A.

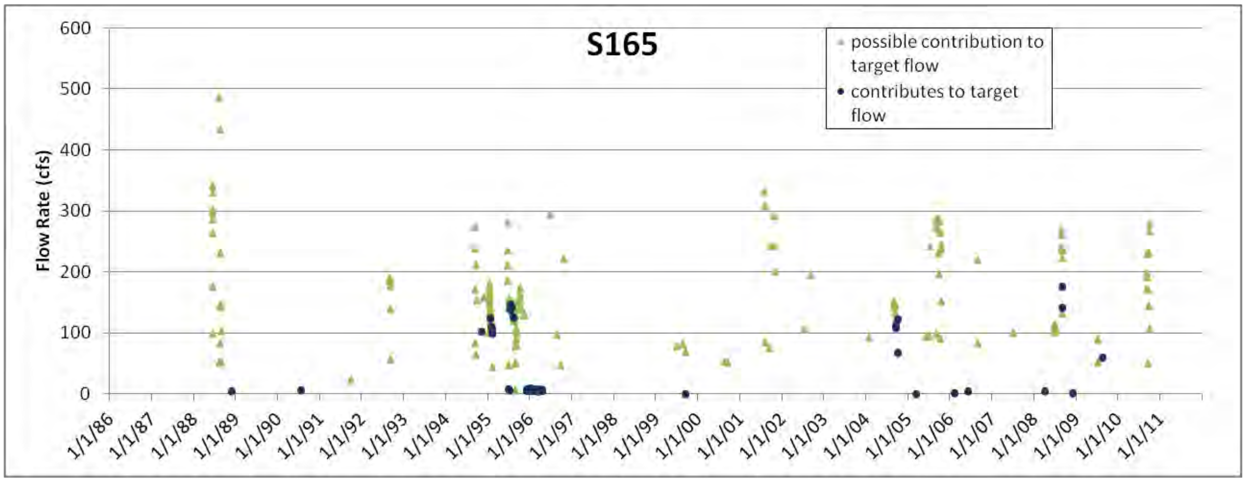


Figure C-17. S-165 water flow contributions toward an approximated target flow at S-21A.

Homestead Air Reserve Base Basin (Military Canal)

Table C-13. Homestead Air Reserve Base (HARB) basin statistics of flow rate (cfs) at S-20G for all seasons.

Statistic	S-20G
Number of Cases	9,496
Maximum	632.68
Median	0.00
Arithmetic Mean	19.13
Standard Error	0.49
Standard Deviation	48.09
25^{th} percentile	0.00
75^{th} percentile	18.21

Table C-14. HARB basin statistics of flow rate (cfs) at S-20G for the wet season.

Statistic	S-20G
Number of Cases	3,978
Maximum	632.68
Median	10.66
Arithmetic Mean	32.82
Standard Error	0.98
Standard Deviation	61.64
25^{th} percentile	0.00
75^{th} percentile	39.69

Table C-15. HARB basin statistics of flow rate (cfs) at S-20G for the dry season.

Statistic	S-20G
Number of Cases	5,518
Maximum	480.06
Median	0.00
Arithmetic Mean	9.26
Standard Error	0.43
Standard Deviation	31.76
25^{th} percentile	0.00
75^{th} percentile	3.82

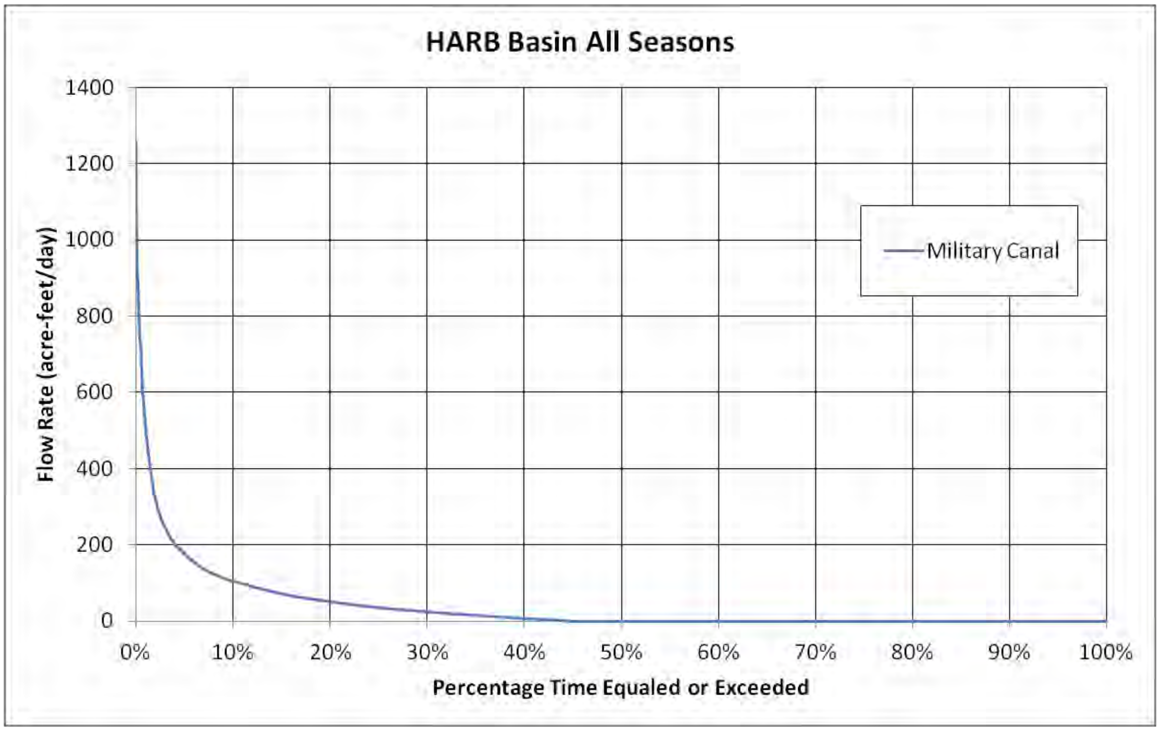


Figure C-18. Flow duration curve for the HARB basin at S-20G during all seasons.

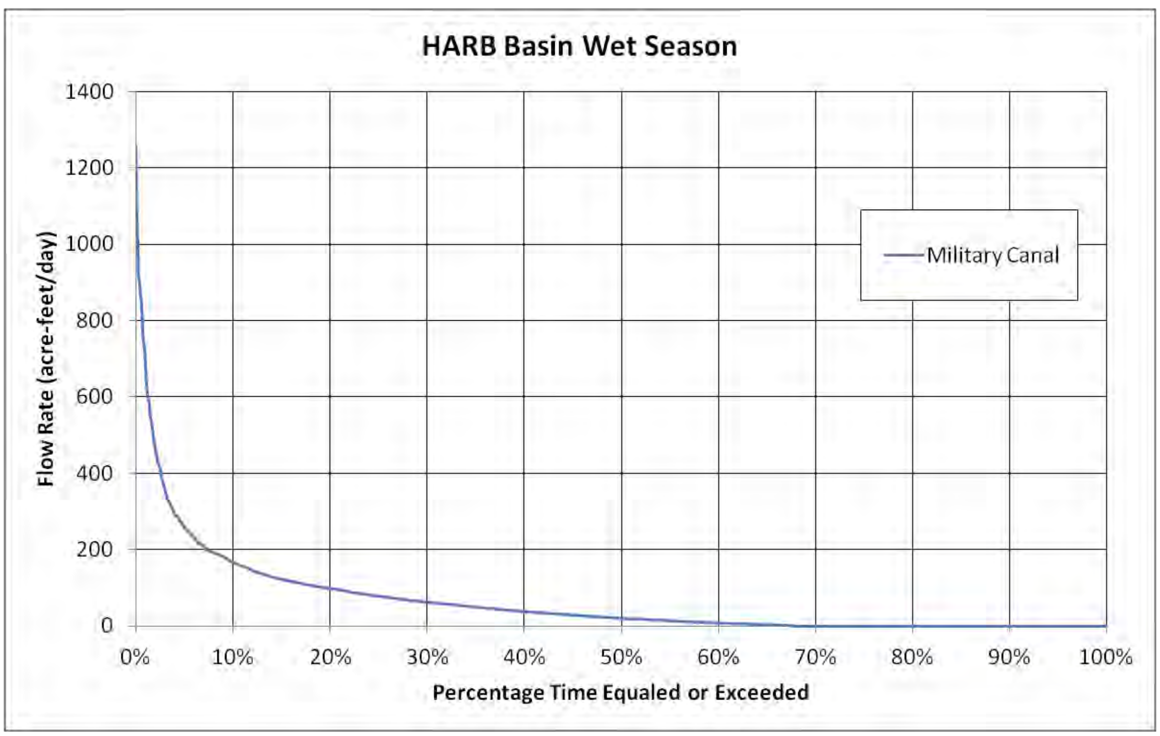


Figure C-19. Flow duration curve for the HARB basin at S-20G during all the wet season.

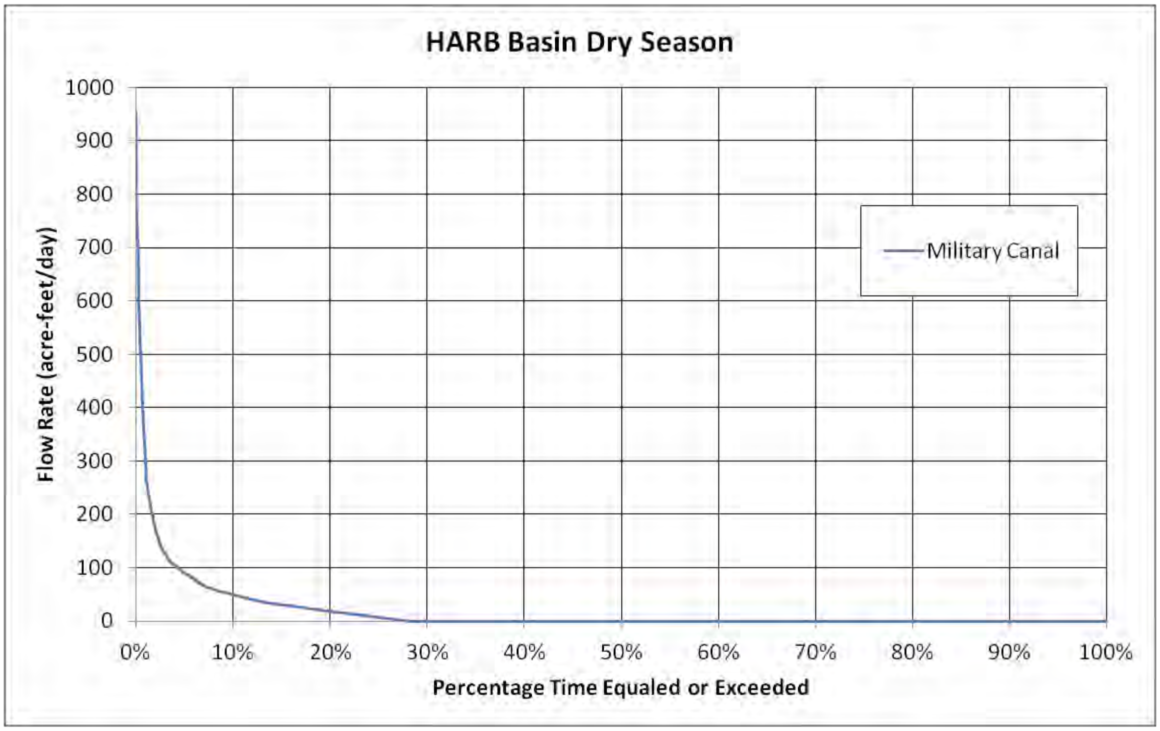


Figure C-20. Flow duration curve for the HARB basin at S-20G during all the dry season.

C-103 Basin (Mowry Canal)

Table C-16. C-103 basin statistics of flow rate (cfs) at water control structures for all seasons.

Statistic	S-20F	S-179	S-166	S-167	S-196
Number of Cases	9,465	9,473	9,496	9,496	9,496
Maximum	2,944.99	2,565.13	657.99	604.58	286.08
Median	136.96	0.00	0.00	0.00	0.00
Arithmetic Mean	193.75	38.55	6.29	10.47	20.06
Standard Error	2.58	1.50	0.35	0.45	0.38
Standard Deviation	251.17	145.69	34.28	43.47	36.86
25th percentile	23.00	0.00	0.00	0.00	0.00
75th percentile	246.40	0.00	0.00	0.00	42.68

Table C-17. C-103 basin statistics of flow rate (cfs) at water control structures for the wet season.

Statistic	S-20F	S-179	S-166	S-167	S-196
Number of Cases	3,978	3,966	3,978	3,978	3,978
Maximum	2,944.99	2,565.13	657.99	604.58	286.08
Median	213.48	0.00	0.00	0.00	0.00
Arithmetic Mean	295.93	79.92	13.62	22.50	24.28
Standard Error	4.99	3.29	0.81	1.00	0.62
Standard Deviation	314.61	207.02	50.85	62.92	39.37
25th percentile	107.64	0.00	0.00	0.00	0.00
75th percentile	359.70	17.20	0.00	0.00	49.16

Table C-18. C-103 basin statistics of flow rate (cfs) at water control structures for the dry season.

Statistic	S-20F	S-179	S-166	S-167	S-196
Number of Cases	5,487	5,507	5,518	5,518	5,518
Maximum	2,013.01	1,202.15	210.56	273.38	274.92
Median	86.00	0.00	0.00	0.00	0.00
Arithmetic Mean	119.68	8.75	1.00	1.81	17.02
Standard Error	2.09	0.80	0.13	0.20	0.47
Standard Deviation	154.98	59.45	9.57	14.82	34.62
25th percentile	1.40	0.00	0.00	0.00	0.00
75th percentile	177.73	0.00	0.00	0.00	37.52

Table C-19. C-103 Basin correlation coefficients.

Structure	Pearson	Kendall tau-b	Spearman
All Data			
S-179	0.795	0.400	0.486
S-166	0.580	0.260	0.317
S-167	0.687	0.314	0.384
S-196	0.257	0.191	0.258
All Seasons when S-20F Flow > 0			
S-179	0.811	0.421	0.518
S-166	0.599	0.276	0.341
S-167	0.696	0.328	0.406
S-196	0.223	0.127	0.175
Wet Season when S-20F Flow > 0			
S-179	0.842	0.559	0.682
S-166	0.629	0.359	0.446
S-167	0.747	0.430	0.536
S-196	0.246	0.109	0.157
Dry Season when S-20F Flow > 0			
S-179	0.646	0.179	0.224
S-166	0.307	0.118	0.145
S-167	0.336	0.114	0.140
S-196	0.218	0.143	0.163
All Seasons when S-20F Flow > 0 and < 168.34			
S-179	0.036	-0.036	-0.044
S-166	0.010	0.053	0.065
S-167	0.057	0.030	0.037
S-196	0.093	0.053	0.072
Wet Season when S-20F Flow > 0 and < 168.34			
S-179	0.090	0.092	0.115
S-166	-0.019	0.038	0.046
S-167	0.024	0.023	0.028
S-196	-0.049	-0.056	-0.076
Dry Season when S-20F Flow > 0 and < 168.34			
S-179	0.019	-0.097	-0.120
S-166	0.077	0.060	0.073
S-167	0.071	0.031	0.038
S-196	0.144	0.090	0.119

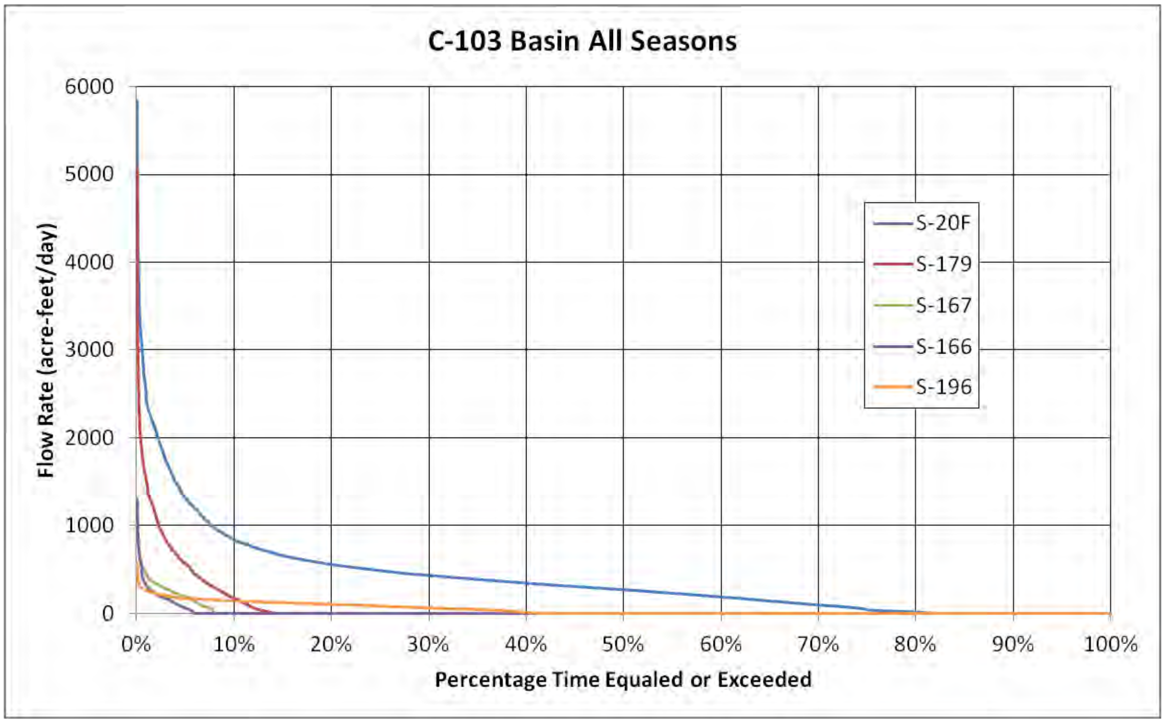


Figure C-21. Flow duration curves for the C-103 basin water control structures during all seasons.

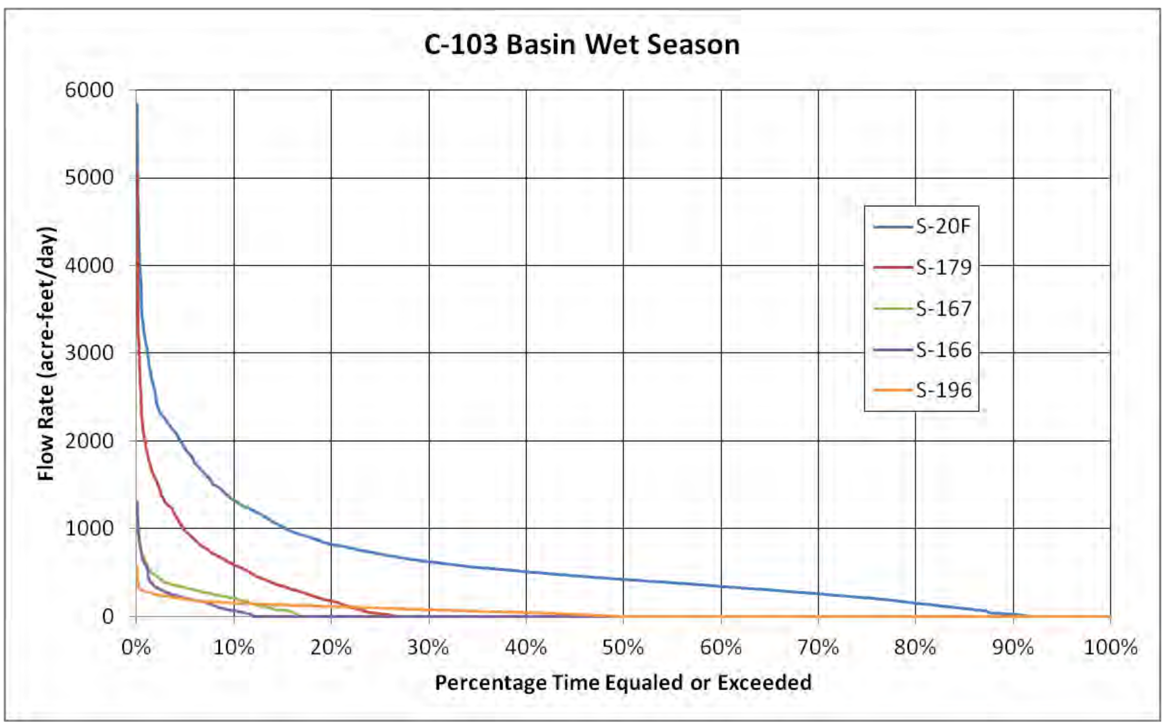


Figure C-22. Flow duration curves for the C-103 basin water control structures during the wet season.

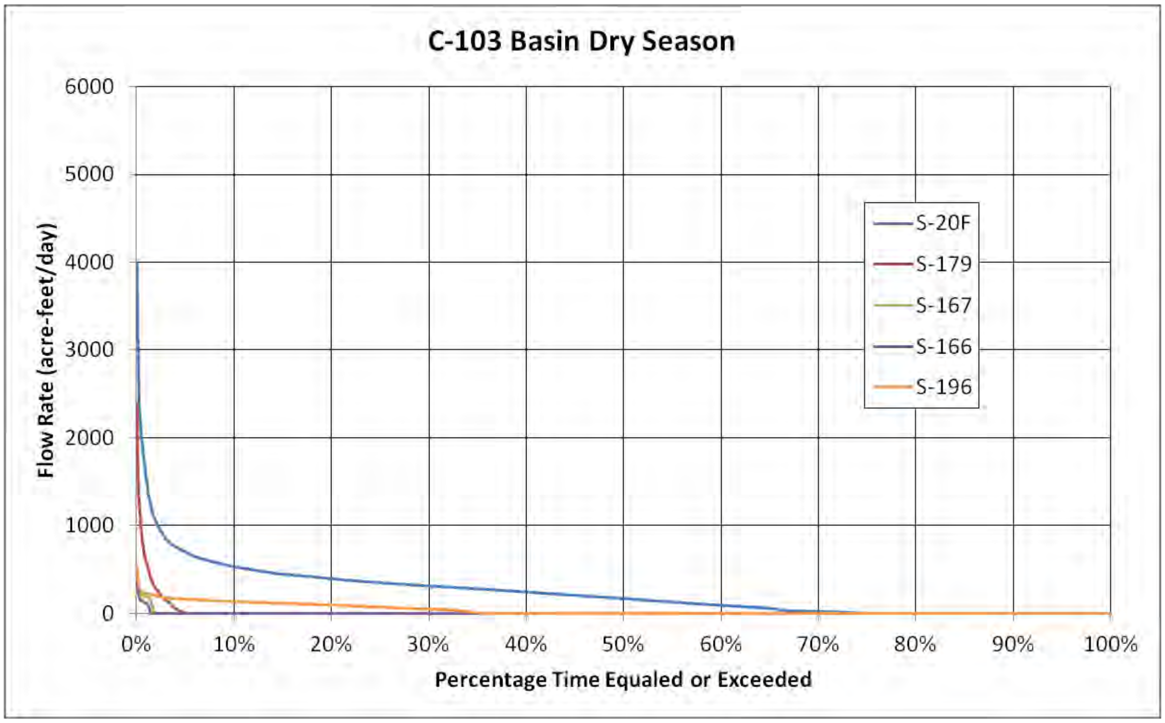


Figure C-23. Flow duration curves for the C-103 basin water control structures during the dry season.

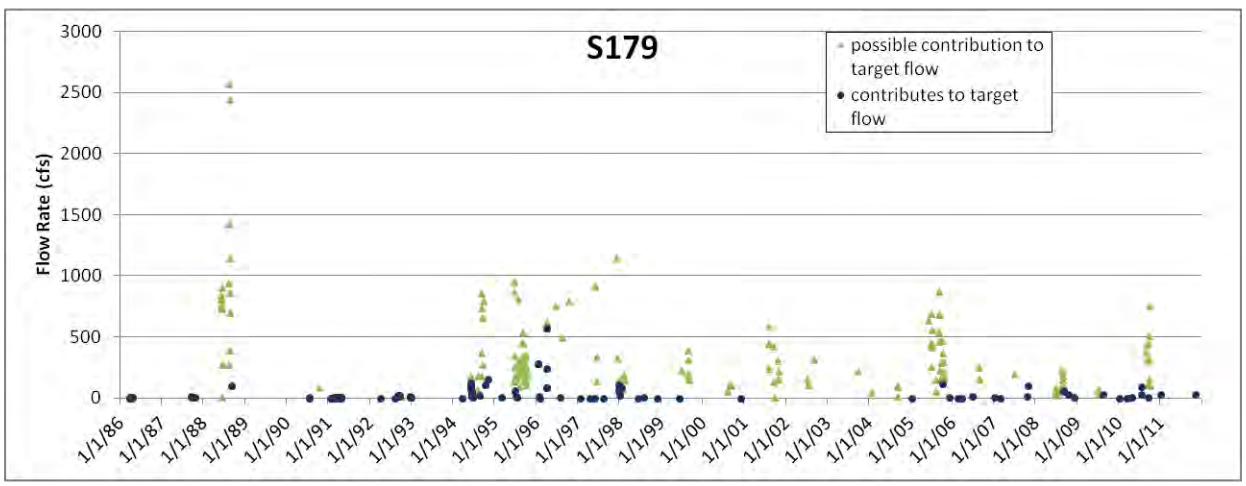


Figure C-24. S-179 water flow contributions toward an approximated target flow at S-20F.

Combined C-102, Homestead Air Reserve Base, and C-103 Basins

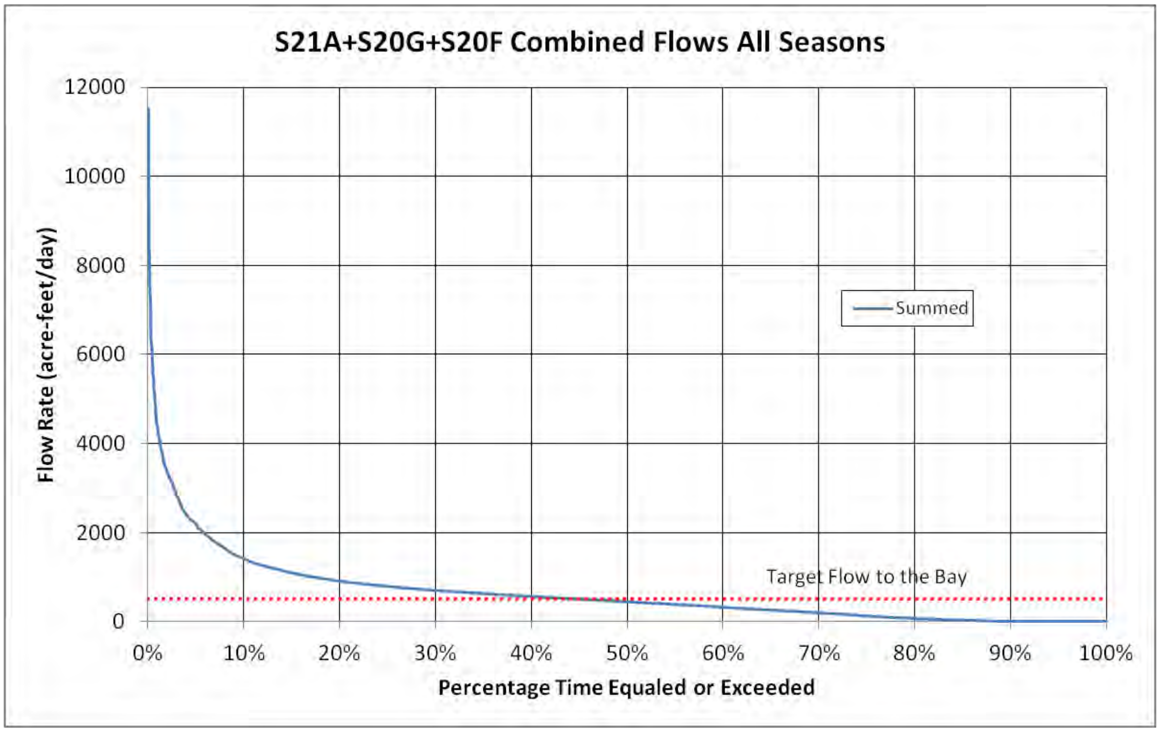


Figure C-25. Summed flows to the bay from the C-102, HARB, and C-103 basins for all seasons.

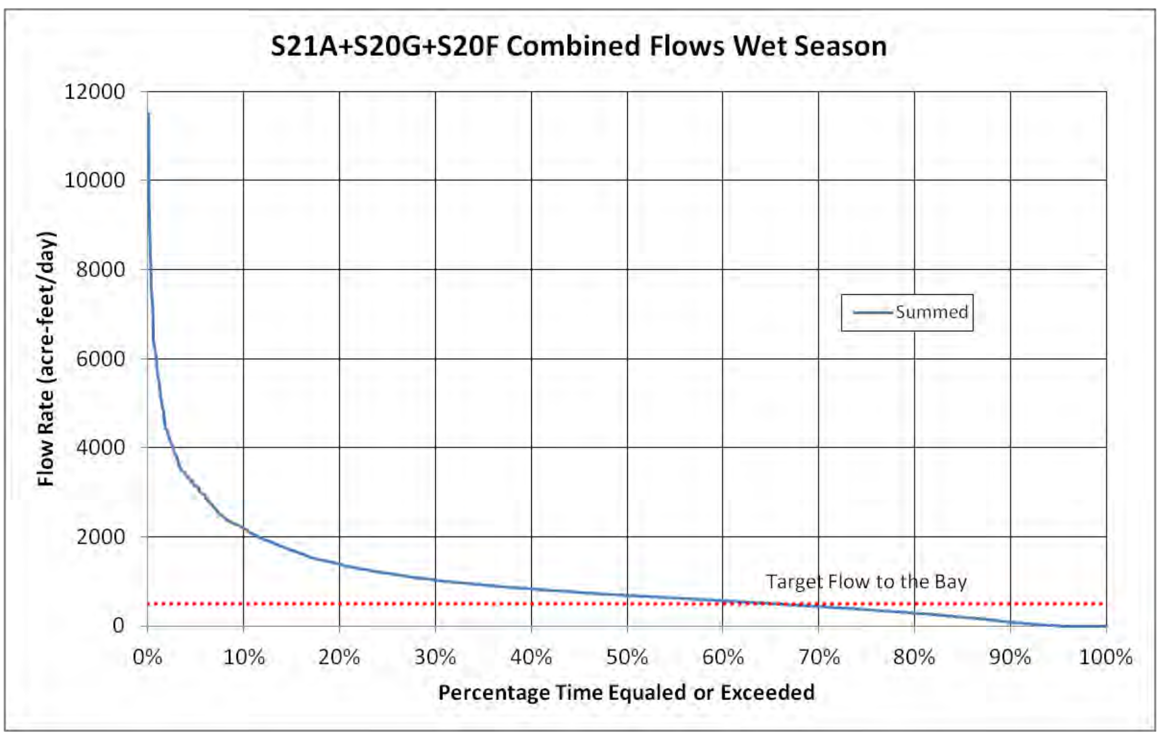


Figure C-26. Summed flows to the bay from the C-102, HARB, and C-103 basins for the wet season.

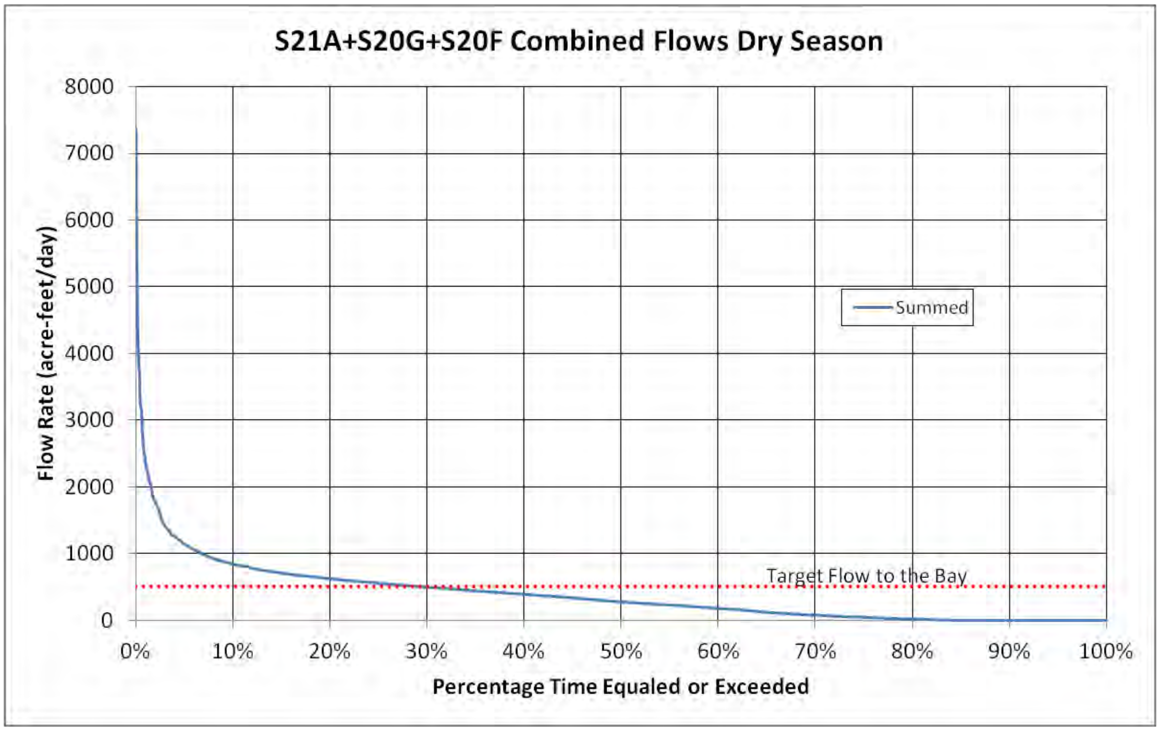


Figure C-27. Summed flows to the bay from the C-102, HARB, and C-103 basins for the dry season.

Summarized Contributions from Upstream Structures

Some of the flow results for the various tributaries described above can be summarized into a single plot to illustrate the relative importance of flow from each upstream tributary toward meeting the target flows at each coastal outfall. This was calculated by compiling the daily mean flow rates at each upstream water control structure when the respective coastal outfalls for the basin were greater than zero. If the outflow at the coastal structure was less than the target flow, or would have been less than the target flow without upstream contributions, it was assumed that the flow through the upstream structure contributed a proportion of the water to meet the target flow. A percentage of contributing flow for each day was calculated relative to the total target flow, ranging from 0 to 100. Even though, in many cases more than one tributary contributed water, each one was evaluated independently as if it were the only tributary. It was not possible to determine if flow from one tributary within a basin was more important than another in contributing water. Therefore, the percentages represent the maximum possible contributions and are overestimates when combined with other sources. Percentages given in Figure C-28 are averaged over the available period records for each water control structure (% per day), and ranked according to magnitude.

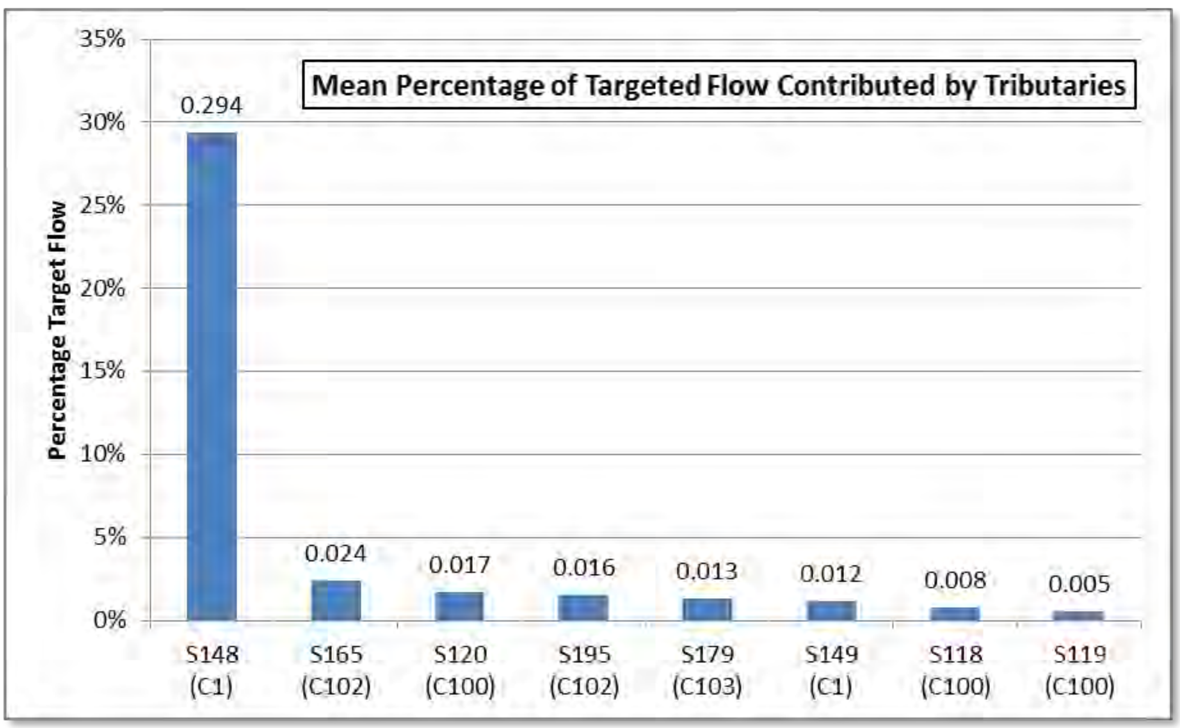


Figure C-28. Ranked estimated percentage of maximum mean daily flow passing through tributary structures that contributed toward individual outfall flow targets. Structures are given on the X axis with the basin in parentheses below.

Literature Cited

USACE and SFWMD. 2012. *Central and Southern Florida Project Comprehensive Everglades Restoration Plan Biscayne Bay Coastal Wetlands Phase 1 Final Integrated Project Implementation Report and Environmental Impact Statement*. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL. South Florida Water Management District, West Palm Beach, FL.